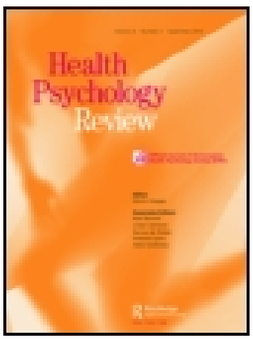

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Self-directed interventions to promote weight loss: a systematic review and meta-analysis

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Abstract

Many self-directed weight-loss interventions have been developed using a variety of delivery formats (e.g. internet, smartphone) and change techniques. Yet, little research has examined whether self-directed interventions can exclusively promote weight loss. MEDLINE, Embase, PsycINFO, CINAHL, and the Cochrane Library were systematically reviewed for randomised controlled trials evaluating self-directed interventions in relation to weight loss outcomes in adults. Standard mean differences (SMD) and 95% confidence intervals (CI) were calculated using a random effects model. Twenty-seven trials incorporating 36 comparisons met our inclusion criteria. Participants using self-directed interventions lost significantly more weight (*MD* = -1.56 kg, CI -2.25, -0.86 ranging from 0.6 to 5.3 kg) compared to those in the minimal-intervention or no-treatment groups (3.1-month follow-up median). The majority of interventions were internet-based (18 evaluations) and these were effective at 3 months (*MD* = -1.74 kg, CI -2.65, -0.82 ranging from 0.6 to 4.8 kg) (*SMD* = -0.48, 95% CI -0.72, -0.24, I^2 = 82%; $p < .0001$; 16 evaluations) and 6 months follow-up (*MD* = -2.71 kg, CI -4.03, -1.39 ranging from 2.2 to 5.3 kg) (*SMD* = -0.59, 95% CI -0.99, -0.19, I^2 = 76%; $p = .004$; 4 evaluations). Self-directed weight-loss interventions can generate modest weight loss for up to 6 months but may need to be supplemented by other interventions to achieve sustained and clinically meaningful weight loss.

Keywords: Weight loss; self-delivered intervention; eHealth; systematic review; meta-analysis; obesity

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Introduction

Being overweight or obese is associated with multiple health risks including cardiovascular disease and a range of cancers, which account for many premature deaths (Allender, Peto, Scarborough, Boxer, & Rayner, 2006; Whitlock et al., 2009). Yet the prevalence of obesity worldwide has more than doubled since 1980, increasing ill health, mortality and healthcare costs. In the United States (US), for example, 68% of adults are overweight or obese, accounting for more than 20% of health care costs (Flegal, Carroll, Ogden, & Curtin, 2010) while in the United Kingdom (UK), 62% of adults are overweight or obese (Health and Social Care Information Centre, 2015), and it has been predicted that by 2050, 40% of the population could be obese, resulting in health and social costs of £49.9 billion (US$76.1 billion) per annum (Butland et al., 2007). Weight control is, therefore, a global public health priority (Finucane et al., 2011; World Health Organisation [WHO], 2014).

Obesity-related health risks can be reduced substantially with weight loss of as little as 5% of body weight (Jensen et al., 2014) and this may generate psychological benefits including improved health-related quality of life, body image and depression (Blaine, Rodman, & Newman, 2007; Busch et al., 2013; Lasikiewicz, Myrissa, Hoyland, & Lawton, 2014). In the US, the Centers for Disease Control and Prevention have developed clear policies promoting weight loss and prevention of weight-related illness (e.g. Leeman et al., 2012). Similarly, UK public health policy advocates weight loss through individual lifestyle change (Department of Health [DoH], 2013; National Institute of Health and Care Excellence [NICE], 2014). Self-directed interventions may facilitate economical implementation of these policies, because, if effective, they are more likely to be cost-effective and have much wider reach than, for example, face-to-face individual or group interventions.

By “self-directed interventions”, we mean those requiring no professional contact or no contact beyond an introductory face-to-face session. Such interventions require users to self-regulate and generate change without professional assistance. They can be implemented with existing infrastructure and staffing and embedded in users’ everyday lives. Many such interventions have been developed (Arem & Irwin, 2011). Attrition rates can be high (Eysenbach, 2005)—for example, in one study, only 30% of subscribed participants reported use of a website program after 52 weeks (Neve, Collins and Morgan (2010)—but evidence suggests that such interventions can promote weight-loss and can augment face-to-face weight-loss interventions (Tang, Abraham, Greaves, & Yates, 2014; Wieland et al., 2012). In a review of reviews, Tang et al. (2014) found that self-directed interventions employ particular change techniques including individualised feedback and online social support to enhance effectiveness. These authors concluded that further reviews of primary level studies should clearly categorise interventions by mode of delivery and investigate features associated with increased effectiveness.

Information technology advances have allowed development of interactive systems, which can be adapted to individual users’ needs and preferences. These have been incorporated in a wide range of electronic interventions using various digital platforms (e.g. smartphones, tablets, and tracker bracelets). Delivered online and offline, these interventions can emulate elements of face-to-face interactions by, for example, prompting goal-setting, instructing progress monitoring and providing timely goal-related feedback (McEwan et al., 2016). By scaffolding self-regulation, such interventions may facilitate cognitive and affective change that underpins changes in weight-gain behaviour patterns (Kessler, 2009). Social support and social comparison can also be provided through message boards and online chat sessions. The use of self-regulatory prompts and social support provision are

associated with weight loss effectiveness in face-to-face weight loss programmes (Greaves et al., 2011) but it is unclear if they have a similar effect in self-directed interventions.

Self-directed interventions are likely to be less costly than face-to-face services and could have greater public health impact, but evidence for their effectiveness remains unclear (Harris et al., 2011; Manzoni, Pagnini, Corti, Molinari, & Castelnuovo, 2011; Turk et al., 2009). A recent review of reviews synthesised the findings on effectiveness of self-directed interventions (Tang et al., 2014). Twenty relevant reviews provided mixed but promising findings, for example, one review found a significant average increase of up to 1.5kg in weight loss over evaluation periods when internet-based interventions were delivered in conjunction with standard weight loss treatment (Reed, Schifferdecker, Rezaee, O'Connor, & Larson, 2012). Another review found evidence that computer-based interventions were effective in promoting weight loss and reduced weight regain (Wieland et al., 2012). Weight loss across all evaluations reviewed ranged from 0.8-7.8kg but most reviews advised caution in interpretation of findings because of variability in intervention content and delivery. Most narrative reviews and meta-analyses have combined self-directed interventions with those including face-to-face, online and group sessions. For example, Hutchesson et al. (2015) found that eHealth weight-loss interventions could generate significantly greater weight loss than minimal interventions. This is encouraging but the 183 interventions considered in this review included a variety of delivery formats including self-directed interventions and those that involve regular online professional contact (e.g. via emails). Further review work is needed to clarify whether self-directed interventions, without professional contact, can promote weight loss.

Hartmann-Boyce, Jebb, Fletcher, and Aveyard (2015) undertook meta-analyses to assess weight loss generated by “self-help” interventions compared to minimal controls. They concluded, encouragingly, that self-help interventions can effectively promote weight loss

(*MD* = -1.85 kg) and called for further progress to understand and improve such interventions. Hartmann-Boyce et al. (2015) focused on overweight and obese populations and evaluated weight loss (kg) at between 6 to 12 months follow up. They also included "self-help" interventions involving ongoing online professional contact.

The Present Study

Our focus is on interventions that do not involve ongoing professional contact. We include interventions that involve one face-to-face introductory session but no further contact. We are interested in the capacity of such interventions to promote weight loss, not only among those who are already overweight, but also, preventatively, among normal weight and sedentary populations. While focusing primarily on weight loss, we are also interested in weight-related outcomes such as BMI and waist circumference and on short, medium and longer term effects. In addition, we are interested to discover if different delivery modes (e.g., online versus paper-based) and inclusion of particular commonly-used change techniques differentiate between more or less effective self-directed interventions.

Research Questions

This review addressed three research questions:

(1) How effective are self-directed interventions (without ongoing professional contact) in promoting short, medium and long-term weight loss in adults?

(2) Are particular modes of delivery of self-directed weight-loss interventions more or less effective?

(3) Do particular, frequently employed change techniques enhance effectiveness?

Methods

Inclusion criteria

We included articles published in English before and during July 2014 that reported randomised controlled trials (RCT) of self-directed weight-loss or weight-control interventions.

Intervention Characteristics

Included trials evaluated interventions that:

1. targeted either physical activity, diet or both,
2. were self-directed with no more than one face-to-face contact (e.g. an introductory or instructional session lasting no longer than 90 minutes),
3. included at least one interactive component involving engaging users with the interface (e.g. entering personal data in response to prompts),
4. included at least one self-regulatory element involving users reflecting on their thoughts or behaviour patterns (such as diary keeping, goal-setting or goal-review).

Outcome Measures

Trials included one or more of the following outcome measures:

1. body weight (kilograms or pounds)
2. body mass index (BMI) kg/m^2
3. waist circumference (inches or centimetres)

Comparison groups

Trials were included if they compared self-directed weight loss interventions to a no intervention or minimal intervention control group including:

1. usual care
2. minimal interventions (e.g. provision of information)
3. educational materials (both online and paper)
4. no intervention (wait-list control)

Participant characteristics

Trials were included if they were conducted with:

1. healthy adults (18 years or over) including those at risk of diabetes (but not diagnosed with diabetes or other long-term illnesses) who were not taking medications which could affect weight,
2. people who were of normal weight, overweight or obese

Search strategy

We used the Cochrane PICOS (participant, intervention, comparison and outcome, study design) method to formulate our search criteria. Details of the search strategy are available in Supplementary Table 1. Searches were conducted in MEDLINE (Ovid), Embase (Ovid), PsycINFO (Ovid), CINAHL, and the Cochrane Library. We also searched the references of included articles to identify further trials. All titles and abstracts retrieved from electronic searches were exported into reference management Endnote X4 software before the removal of duplicate articles.

The first author examined the titles and abstracts of articles identified by our search against the above inclusion criteria. A second researcher checked the quality and accuracy of study selection by screening (a randomly selected) 10% of available titles and abstracts. Full text copies of the selected relevant articles were obtained and checked against the inclusion criteria by the first author and by two additional researchers. Disagreements were resolved through discussion and reasons for exclusion were recorded for each article (See Supplementary Table 2).

Quality assessment of Included Studies

We used the Cochrane Collaboration Risk of Bias Tool (Higgins et al., 2011) to assess risk of bias in the included articles. Judgements were made on the following seven items to assess selection, performance, detection, attrition, and reporting bias, namely: (1) Was the random sequence adequately generated? (2) Was the allocation adequately concealed? (3) Was

knowledge of trial arm allocation blinded from participants and personnel during the study? (4) Was knowledge of trial arm allocation blinded from outcome assessors? (5) Were any issues of incomplete outcome data adequately addressed? (6) Were reports of the study free of suggestion of selective outcome reporting? (7) Was the study apparently free of other problems that could put it at a high risk of bias? Each article was judged to have 'unclear', 'low' or 'high' risk of bias in relation to each of these questions. A second researcher checked a random selection of 50% of articles for risk of bias and discrepancies were discussed and resolved.

Data extraction

From each article, we extracted basic information concerning: Setting and methods (e.g. country, year, context, blinding, study design, bias); participants (e.g. total number of participants, missing participants, inclusion criteria, exclusion criteria); participant characteristics (e.g. mean age, sex); comparison groups (e.g., usual care or no-intervention); outcome measures (e.g. primary outcome measure, secondary measure, method of assessing outcomes, duration of follow up); main findings; (e.g. type of cognitive, emotional, behavioural or physiological changes targeted and or assessed in process evaluations) and mode of delivery (e.g. internet, smartphone, leaflets, multicomponent, DVD). In addition, we coded intervention descriptions for inclusion of specific change techniques. We identified 12 previously defined change techniques that were included in at least one of the evaluated interventions (Abraham & Kools, 2012; Abraham & Michie, 2008; Albarracín et al., 2005; Michie, Abraham, Whittington, McAteer, & Gupta, 2009). These were (1) highlighting affective consequences of behavioural choices, (2) instruction to enhance decision-making skills, (3) prompting goal setting, (4) self-monitoring (5) providing feedback, (6) teaching use of reminders, (7) identification of behavioural cues and prompts, (8) modelling behaviours, (9) providing instructions to enhance behavioural skills, (10) providing social comparison

opportunities, (11) prompting social support or social network formation, and (12) prompting group identity formation. When a technique was identified in an intervention description, a further judgement was made as to whether it was tailored to the participant or participant's group or delivered in a generic manner. A second researcher checked a random selection of the interventions (50% of interventions included in meta-analysis) for change techniques and discrepancies were discussed and resolved. The kappa and AC1 statistic were used to assess inter-rater agreement (Gwet, 2002).

We also extracted outcome data for meta-analyses and for methodological quality assessment (using Cochrane Risk of Bias Tool) (see Supplementary Table 3 for full data extraction form).

Analyses

We followed the quality criteria specified by the PRISMA checklist for reporting of systematic review and meta-analyses (Higgins & Green, 2011). All meta-analyses and forest plots were generated using RevMan (version 5.3). Effect sizes were reported as standardised mean differences (*SMD*), the equivalent of Hedge's *g*, that is, the mean difference in weight loss between the control and intervention group divided by the pooled standard deviation, averaged across studies, along with 95% confidence intervals. These were calculated using random effects models to account for the assumption that different studies estimate different or heterogeneous true intervention effects. As a sensitivity analysis, we investigated the underlying effects sizes under a fixed effect model that assumes that all studies included in the meta-analyses are estimating the same, but unknown, intervention effect. When SMDs were found to be significant, we reported the weighted average additional weight lost in the intervention groups, per participant, over and above that lost in the control groups (i.e. the MD between intervention and control group), and the range of average additional loss across interventions. To avoid double-counting of participants and to account for the correlation of

multiple evaluations in studies, where two or more interventions were compared to the same control group from the same population, we computed a single effect size as the average for multiple evaluations and a variance that takes into account the correlation between multiple evaluations (Borenstein, Hedges, Higgins, & Rothstein, 2009; Higgins & Green, 2011). These included five articles containing two evaluations (Brindal et al., 2012; Collins et al., 2012; Lally, Chipperfield, & Wardle, 2008; Morgan et al., 2013; Napolitano, Hayes, Bennett, Ives, & Foster, 2013), and one study containing three evaluations (Gow, Trace, & Mazzeo, 2010).

All weight-related outcomes were converted into the same unit of measurement for meta-analysis (e.g. lbs to kg or inches to cm). In articles where standard deviations were not available, using formulas recommended by Cochrane Collaboration guidelines (Higgins & Green, 2011), confidence intervals (CI) and standard errors (SE) were converted into standard deviations for change in weight from baseline to follow-up (SD). We ensured that heterogeneity of variance was minimised by combining only studies using similar modes of delivery and outcomes. Inspections of funnel plots generated by RevMan were used to examine possible publication bias. Following Wieland et al. (2012), we examined outcomes at the following time points: 4 months or less; greater than 4 but less than 12 months; 12 months or more.

Meta-analyses were performed to assess the effectiveness of included self-directed interventions in promoting weight loss (kg), reducing Body Mass Index (BMI) and decreasing waist circumference (cm). To assess overall effectiveness we pooled weight-related outcomes at final follow-up. We then performed subgroup analyses to assess effectiveness at defined follow-up points to examine effectiveness over time. Meta-analyses were also performed to examine the effectiveness of interventions including change

techniques compared to those without change techniques. Sensitivity analyses were conducted to assess the impact of outlier studies.

Results

Our search identified 3884 references for title and abstract screening, excluding duplicates. This generated 232 potentially eligible articles for full text examination of which 25 satisfied our inclusion criteria. Two additional eligible articles were identified by searching references of included articles, resulting in a final sample of 27 [1](see Figure 1).

Second coding of articles for study selection showed good reliability with 100% agreement on title and abstract (n = 368) and full-text article (n = 23) selection. Most excluded articles did not evaluate self-directed interventions and many did not have an appropriate comparison group (see Supplementary Table 2 for a list of excluded articles).

[Figure 1 near here]

Study characteristics

Supplementary Table 4 presents study characteristics for the 27 included articles reporting 36 RCT evaluations of self-directed interventions. Two interventions included introductory face-to-face sessions lasting no up to 75 minutes (Morgan, Lubans, Collins, Warren, & Callister, 2011a; Morgan et al., 2011b).

The majority of studies were conducted in the US, Australia and the Netherlands. A variety of samples were used, but most recruited community participants while others

[1] In the course of analyses and publication, an updated search up to November (2015) identified two further studies that would have been included in our review appeared in the literature. These are: (1) Blomfield, R. L., Collins, C. E., Hutchesson, M. J., Young, M. D., Jensen, M. E., Callister, R., & Morgan, P. J. (2014). Impact of self-help weight loss resources with or without online support on the dietary intake of overweight and obese men: The SHED-IT randomised controlled trial. *Obesity Research & Clinical Practice*, *8*(5), e476–e487, and, (2) O'Brien, K. M., Hutchesson, M. J., Jensen, M., Morgan, P., Callister, R., & Collins, C. E. (2014). Participants in an online weight loss program can improve diet quality during weight loss: a randomized controlled trial. Nutrition Journal, 13(1), 82. The former reported weight loss results found in Morgan et al. (2013), which we included in our meta-analysis, and the latter reported an effect size well-within the range reported in the studies included in our meta analyses. Thus while it will be interesting to update this review as the literature grows, the findings are current to July 2014.

recruited from work places and universities. The total number of participants randomised included across all trials was 28,500, of which 71% were female with a mean age of 41. Four articles comprising six relevant evaluations included exclusively female samples (Jacobi et al., 2007; Levine et al., 2007; Low et al., 2006; Mouttapa et al., 2011) and four articles containing five evaluations were exclusively male (Morgan, Lubans, Collins, Warren, & Callister, 2011a; Morgan et al., 2011b; Morgan et al., 2013; Veverka et al., 2003).

Eleven articles including 17 evaluations targeted overweight and obese participants and five articles recruited sedentary participants. Twenty-three articles focused on weight loss, while three articles targeted weight maintenance (Kelders, van Gemert-Pijnen, Werkman, & Seydel, 2010; Gow et al., 2010; Johnson et al., 2008) and only one study assessed weight loss and weight maintenance (van Genugten et al., 2012). Seven articles included two interventions arms and a minimal intervention or no treatment control (Brindal et al., 2012; Collins et al., 2012; Lally et al., 2008; Levine et al., 2007; Morgan et al., 2013; Napolitano et al., 2013; Schroder, 2010), two articles had three intervention arms and a minimal intervention or no treatment control (Gow et al., 2010; Low et al., 2006) and 18 articles compared one intervention to a minimal intervention or no treatment control.

Twenty articles including 26 evaluations reported weight loss as an outcome. Fifteen articles comprising 19 evaluations assessed BMI and eleven articles containing 13 evaluations reported waist circumference. Twenty-six evaluations assessed outcomes at 1-4 months, 17 evaluations assessed outcomes between 4 months and 12 months and seven assessed outcomes between 12 and 36 months, with some studies reporting outcomes at more than one follow-up point. Comparison groups included 9 no-treatment, 10 wait-list controls, 7 provision of information or minimal interventions and 1 usual care comparison. Three articles described physical activity interventions (Carr et al., 2008; Carr, Karvinen, Peavler, Smith, &

Cangelosi, 2013; Hansen et al., 2012), and 24 included interventions targeting both diet and physical activity.

The majority of the interventions (29 of the 36) were delivered primarily through internet use. Three were multi-component programmes (Carr et al., 2013; Morgan et al., 2013; Werkman et al., 2010) by which we mean that they employed more than one mode of delivery, for example, Morgan et al. (2013) employed a DVD-based programme and a pedometer. Two used mobile phones to deliver text messages (Haapala, Barengo, Biggs, Surakka, & Manninen, 2009; Shapiro et al., 2012) and one used leaflets (Lally et al., 2008).

Supplementary Table 5 presents a list of change techniques reported in at least five of the 36 self-directed interventions. Self-monitoring was included in 30 (of 36) interventions (and was personalised in 26). Many interventions reported the use of feedback (26 interventions), goal-setting (19 interventions), social support/networks (19 interventions) and behavioural skill instruction (25 interventions). The least used techniques (of those observed) were group identity promotion and decision-making skills instruction of which both were identified in seven interventions. Interestingly, one intervention included 11 of the 12 techniques in an internet-based format including weekly weight change visual feedback in the form of a graph and a social discussion forum (Gow et al., 2010). Based on 50% of the interventions included in the meta-analysis, the inter-rater agreement was high with kappa and AC1 values of 0.91 and 0.84, respectively.

Risk of bias of included studies

The inter-rater reliability between two reviewers was high with 100% agreement on all risk of bias domains after discussion. Overall, study quality was low, with only three of the 27 studies having a low risk of bias in at least five of the seven main categories (Collins et al., 2012; Morgan, Lubans, Collins, Warren, & Callister, 2011a; Morgan et al., 2013). The quality of reporting was also low with only two studies reporting sufficient detail to fully assess risks

of bias (Morgan et al., 2013; Morgan, Lubans, Collins, Warren, & Callister, 2011a) (see Supplementary Figure 1 & 2). The main risks of bias identified from study descriptions were failure to blind assessors (21 of 27 articles), failure to blind participants and personnel (20), not providing sufficient detail on allocation concealment (18), and inadequate reporting of randomisation procedures (11).

Effectiveness of self-directed interventions

Weight loss

Required data could be extracted for 25 evaluations of weight loss. Figure 2 shows the mean and standard deviations for weight loss in the intervention and control groups for each included trial as well as the standard mean difference and corresponding forest plot. Similar supplementary tables are available for all meta-analyses reported below. The results show that those using self-directed interventions lost significantly more weight than those receiving minimal intervention or no treatment (*MD* = -1.56 kg, CI -2.25, -0.86) (*SMD* = -0.41, 95% CI -0.60, -0.23, I^2 = 79%; $p < .00001$). Additional average weight loss per participant in the intervention group ranged from 0.6 to 5.3 kg. The median follow-up time for this whole-sample analysis was 3.1 months. Subgroup analyses (Suppl. Figure 3) revealed similar weight loss at 0-4 months (3-month median) follow-up (*MD* = -1.65 kg, CI -2.40, -0.89) (*SMD* = -0.48, 95% CI -0.69, -0.27, I^2 = 79%; $p < .0001$; 20 evaluations with additional average weight lost ranging from 0.6 to 4.8 kg per participant across interventions) and at 4-12 months (6-month median) (*MD* = -2.26 kg, CI -3.35, -1.18) (*SMD* = -0.48, 95% CI -0.76, -0.21, I^2 = 67%; $p = .0005$; six evaluations with additional average weight lost ranging from 1.7 to 5.3 kg), but considerably less weight loss at 12 months or more (12-month median) follow-up (*SMD* = -0.14, 95% CI -0.38, 0.10, I^2 = 55%; $p = 0.24$; five evaluations).

[Figure 2 near here]

Body mass index outcomes

In the 16 evaluations assessing body mass index, participants receiving self-directed interventions showed significantly greater reduction in BMI levels than those receiving minimal intervention or no treatment (*MD* = -0.41 kg/m², CI -0.70, -0.11) (*SMD* = -0.28, 95% CI -0.53, -0.04, I^2 = 88%; *p* = 0.02). Additional average loss of BMI points per participant in the intervention group ranged from 0.08 to 1.7 kg/m² (Suppl. Figure 4). The median follow-up time for this whole-sample analysis was 3.1 months. Subgroup analyses (Suppl. Figure 5) revealed somewhat greater BMI reduction at 0-4 months (3-month median) (*MD* = -0.54 kg/m², CI -0.88, -0.19) (*SMD* = -0.43, 95% CI -0.72, -0.13, I^2 = 87%; *p* = .004; 12 evaluations with additional average BMI loss ranging from 0.1 to 1.5 kg/m² per participant across interventions) than at 4-12 months (6-month median) (*SMD* = -0.20, 95% CI -0.83, 0.43, I^2 = 91%; *p* = 0.53; six evaluations) where BMI differences were non-significant. Insufficient data (only two evaluations) prevented subgroup analyses for BMI reduction at 12 months or more.

Waist circumference outcomes

Twelve evaluations reported waist circumference and the meta-analysis showed somewhat greater decreases in the self-directed intervention group than those receiving minimal intervention or no treatment (*MD* = -2.37 cm, CI -4.12, -0.61) (*SMD* = -0.66, 95% CI -1.05, -0.26, I^2 = 94%; *p* = .001). Additional average loss of waist circumference per participant in the intervention group ranged from 0.1 to 6.3 cm (Suppl. Figure 6). The median follow-up time for this whole-sample analysis was 5 months. Subgroup analyses (Suppl. Figure 7) showed a significant reduction in waist circumference at 0-4 months (3-month median) (*MD* = -2.81 cm, CI -4.25, -1.37) (*SMD* = -0.98, 95% CI -1.56, -0.39, I^2 = 95%; *p* = .001; nine evaluations with additional average waist circumference loss ranging from 0.1 to 5.2 cm across interventions), but not at 4-12 months (6-month median) (*SMD* = -0.24, 95% CI -1.07, 0.59, I^2 = 94%; *p* = 0.57; four evaluations). Insufficient data (only two evaluations) prevented subgroup analyses for waist circumference reduction at 12 months or more.

Effectiveness of internet-based self-directed interventions

The majority of interventions (18 of 25, 72%) included in the above meta-analyses were internet-based. Participants receiving internet-based self-directed interventions lost significantly more weight than those receiving minimal intervention or no treatment (*MD* = -1.72 kg, CI -2.60, -0.84) (*SMD* = -0.45, 95% CI -0.67, -0.23, I^2 = 80%; $p < .0001$). Additional average weight loss per participant in the intervention group ranged from 0.59 to 5.3 kg (Suppl. Figure 8). The median follow-up time for this whole-sample analysis was 3 months. Subgroup analyses (Suppl. Figure 9) showed significant weight loss results at 0-4 months (3-month median) (*MD* = -1.74 kg, CI -2.65, -0.82) (*SMD* = -0.48, 95% CI -0.72, -0.24, I^2 = 82%; $p < .0001$; 16 evaluations with additional average weight lost ranging from 0.6 kg to 4.8 kg per participant across interventions) and at 4-12 months (6-month median) (*MD* = -2.71 kg, CI -4.03, -1.39) (*SMD* = -0.59, 95% CI -0.99, -0.19, I^2 = 76%; $p = .004$; four evaluations with additional average weight lost ranging from 2.2 kg to 5.3 kg). Insufficient data (only two evaluations) prevented subgroup analyses for follow-up at 12 months or longer.

Similarly, participants receiving internet-based self-directed interventions achieved a significantly greater reduction in BMI levels than those receiving no treatment or minimal intervention (*MD* = -0.47 kg/m², CI -0.81, -0.14) (*SMD* = -0.32, 95% CI -0.61, -0.03, I^2 = 90%; $p = 0.03$; 13 evaluations). Additional average loss of BMI points in the intervention group ranged from 0.08 to 1.7 kg/m² (Suppl. Figure 10). The median follow-up time for this whole-sample analysis was 3.1 months. Subgroup analyses (Suppl. Figure 11) revealed a greater reduction of BMI at 0-4 months (3-month median) (*MD* = -0.58 kg/m², CI -0.98, -0.19) (*SMD* = -0.46, 95% CI -0.79, -0.13, I^2 = 89%; $p = .006$; 10 evaluations with additional average BMI loss ranging from 0.1 to 1.5 kg/m² per participant across interventions) than at 4-12 months (6-month median) (*SMD* = -0.23, 95% CI -0.88, 0.42, I^2 = 91%; $p = 0.49$; five

evaluations) where BMI differences were non-significant. Insufficient data (only one evaluation) prevented subgroup analyses for BMI reduction at 12 months or more.

Eight internet-based evaluations reported waist circumference and found greater decreases in the internet-based self-directed intervention group than those receiving no treatment or minimal intervention (*MD* = -2.69 cm, CI -5.01, -0.37) (*SMD* = -0.85, 95% CI -1.40, -0.29, I^2 = 96%; *p* = .003). Additional average loss of waist circumference per participant in the intervention group ranged from 0.1 to 5.8 cm (Suppl. Figure 12). The median follow-up time for this whole-sample analysis was 4 months. Insufficient data (only one evaluation) precluded longer-term sub-analyses for waist circumference outcomes.

Sensitivity Analyses

We omitted Veverka et al. (2003) as its effect size was much larger than other evaluations but found that this did not change the magnitude or direction of the overall findings. Funnel plots of analyses containing five or more studies were inspected and these appeared to be symmetrical suggesting a small possibility of publication bias in studies. Due to the low overall quality of the studies included, it was not possible to perform a sensitivity analysis including only high quality studies.

Change Technique Inclusion and Effectiveness of Self-Directed Interventions

It was possible to compare interventions that did or did not include five of the 12 identified change techniques, namely, goal setting, self-monitoring, provision of feedback, instructions to enhance behavioural skills and provision of social support. For each of these techniques, at least four studies described interventions that did and did not include the technique. Insufficient data was available for other change techniques. Interventions describing inclusion of each of these techniques were not found to be more effective, in terms of mean weight loss, than those that did not report inclusion. Detailed results are presented in Supplementary Table 5 and Figure 13–17.

Interventions including goal setting (*SMD* = -0.46, 95% CI -0.68, -0.25, I^2 = 79%; p < .0001; 15 evaluations) were not significantly more effective that those not including goal setting (*SMD*= -0.31, 95% CI -0.67, 0.04, I^2 = 75%; p = 0.08; 10 evaluations) (p = 0.48).

Interventions including self-monitoring (*SMD* = -0.43, 95% CI -0.63, -0.24, I^2 = 78%; p < .0001; 21 evaluations) were not significantly more effective that those not including self-monitoring (*SMD* = -0.22, 95% CI -0.62, 0.18, I^2 = 66%; p = 0.29; four evaluations) (p = 0.35).

Interventions including feedback resulted in slightly more weight loss (*SMD* = -0.42, 95% CI -0.62, -0.21, I^2 = 79%; p < .0001; 17 evaluations) than those not including feedback (*SMD* = -0.52, 95% CI -0.89, -0.16, I^2 = 82%; p = .005; eight evaluations) but this difference was not statistically significant (p = 0.62).

Interventions including instructions to enhance behavioural skills (*SMD* = -0.48, 95% CI -0.71, -0.25, I^2 = 77%; p < .0001; 16 evaluations) were not significantly more effective that those not including instructions to enhance behavioural skills (*SMD* = -0.27, 95% CI -0.55, 0.01, I^2 = 76%; p = .06; nine evaluations) (p = 0.26).

Finally, interventions including social support resulted in slightly more weight loss (*SMD* = -0.42, 95% CI -0.68, -0.17, I^2 = 82%; p = .001; 15 evaluations) than those not including social support (*SMD* = -0.36, 95% CI -0.62, -0.10, I^2 = 72%; p = .006; 10 evaluations) but this difference was not statistically significant (p = 0.74).

Discussion

This is the first systematic review of randomised controlled trials of self-directed, interactive, weight-loss interventions, involving no professional contact apart from an introductory session. Our findings show that these interventions are, in general, effective in promoting weight loss at three and six months follow-up compared to no treatment, minimal interventions or usual care. On average, across interventions, those in self-directed

intervention groups lost an additional 1.56 kg when compared to those in the minimal intervention or no treatment groups. Similar results were found for reduced BMI at up to 6 months compared to the comparison groups. The majority of the interventions were delivered using the internet and this subset showed very similar results to the overall study sample with additional weight loss per participant in internet-based, self-directed interventions of 1.72 kg. We conclude that self-directed weight-loss interventions, including internet-delivered interventions, are effective for supporting weight loss up to 6 months.

The average magnitude of observed weight loss just falls short of what is regarded as clinically meaningful (approximately 2-3 kg) (Greaves et al., 2011) suggesting that these interventions have potential as clinically-relevant standalone services. In addition, since they are likely to be cost-effective, when effective, they may also augment clinic services. They can provide 24-hour (on-the-go) access to multiple self-regulatory weight-loss techniques such as self-monitoring, feedback and social support to help with weight maintenance. More importantly, with only one initial face-to-face professional contact, they can prolong client and professional contact engagement without further professional contact. Only one of the trials (McConnon et al., 2007) considered here included an economic evaluation and they found that a self-directed internet-based intervention cost £716.28 more per person per year compared to usual care. However, they advised caution in the interpretation of results because of high attrition and low compliance. Further economic evaluations are required to assess the value of the observed magnitude of weight loss in relation to the cost of providing such interventions in community and clinical contexts.

We did not find evidence of effectiveness of self-directed, weight-loss interventions at follow-up of one year or longer but the small numbers of studies available prohibit firm conclusions on this question. Weight loss is typically regained after 3-5 years in individuals who participate in various weight management programmes (Dansinger, Tatsioni, Wong,

Chung, & Balk, 2007; Katan, 2009), so it may be that different approaches—such as online behavioural counselling, weekly face-to-face or group weight management sessions—are needed to ensure weight loss maintenance.

Our findings are consistent with those of Hartmann-Boyce et al. (2015) who found that an overlapping set of trials of "self-help" interventions, some including ongoing professional support, were effective at promoting weight loss among overweight and obese users. These authors findings at 6 months follow up (*MD* = -1.85 kg, CI -2.86, -0.83 based on 7 studies) are similar to our 0-4 month follow up findings (3.1-month follow-up median) for self-directed interventions (*MD* = -1.65 kg, CI -2.40, -0.89 based on 13 studies including 20 evaluations). Hartmann-Boyce et al. (2015) reported that self-help interventions were not effective at 12 months and we also found that self-directed interventions did not generate sustained weight loss gains beyond 12 months. It is interesting to compare findings for our sub-group of internet-based self-directed interventions (*MD* = -1.72 kg, CI -2.60, -0.84; 13 studies) with those reported by Hutchesson et al. (2015) (*MD*= -2.70 kg, CI -3.33, -2.08; 9 studies) and Wieland et al. (2012) (*MD* = -1.5 kg, CI -2.1, -0.9; two studies), which both included internet-based interventions involving professional contact. Hutchesson et al. (2015) reported greater weight loss (additional 0.98 kg) when compared to a minimum or no treatment comparison group whereas Wieland et al. (2012) reported less weight loss, based on a meta-analysis including just two studies. Given the broadly similar findings found across all four reviews, it is interesting to question whether professional contact, which adds to costs, is necessary for self-initiated weight loss up to six months and whether effectiveness depends on online collaborative sessions between professionals and users. If, as our findings suggest, self-directed interventions can generate weight loss up to six months without ongoing professional contact this could greatly enhance the cost effectiveness of weight loss services, including those targeting diabetes prevention.

Our review is the first to identify and assess the effects of including particular change techniques in self-directed interventions. Unfortunately, however, our categorisation of change techniques from intervention descriptions provided in published papers offers little insight into optimal design. We were only able to compare interventions that did or did not include five change techniques and found no significant weight-loss differences between intervention including and excluding these techniques. We cannot infer that the inclusion of these change techniques makes no difference to effectiveness because the relatively small numbers of intervention compared vary in many other respects. Moreover, our capacity to characterise intervention content may have been limited by the brief descriptions provided in the papers we examined, such analyses may be better undertaken using full intervention manuals (Abraham & Michie, 2008). It would be helpful if trials evaluating self-directed interventions described their interventions in more detail (e.g. in supplementary documents) and provided readily available manuals to allow researchers and commissioners to examine content in detail. When more trials are available, further research may clarify whether factors other than the inclusion of change techniques are more important in these interventions or whether our study was simply not powered to find small but potentially important increments in effectiveness that may follow from inclusion of particular self-regulatory techniques.

This review has both strengths and limitations. It is the first review to focus exclusively on self-directed interventions and we found that most of these were internet-based. Consequently, our data allows conclusions to be drawn about a specific group of weight loss interventions. On the other hand, we had small samples, which may have reduced power to identify the effects of intervention content on heterogeneity of effect sizes and to draw conclusions about maintenance of weight loss. Heterogeneity was large across all meta-analytic calculations even when subgroup analyses accounted for length of follow-up. This wide variation may be the result of several factors including diverse target populations,

intervention content, applied theoretical frameworks, inaccuracy of study descriptions, intervention intensity and duration, and study quality. It is noteworthy too that while our inclusion criteria specified healthy adults, many of the samples in this review were not, on average, overweight or obese, perhaps further limiting the implications of our findings for clinical applications of these interventions.

Although every effort was made to eliminate bias in the search, selection of studies, data extraction, and data analysis, it is possible that we excluded some relevant studies due to inadequate intervention descriptions in study abstracts. It is also important to note that the methods employed in many trials here indicated a risk of bias in interpretation. Finally, this review emphasise the importance of using objective measures of weight loss and weight maintenance at 12 months and beyond.

In conclusion, self-directed weight-loss interventions that do not involve ongoing professional support, including those delivered using the internet, can generate modest significant weight loss at up to six months but, as yet, there is little evidence to suggest that they promote weight loss maintenance. Since they are likely to be cost effective, when effective, they may provide useful adjuncts to existing community and clinical services, and could potentially be used exclusively to generate clinically meaningful weight loss. Further, high-quality trials are needed to establish the longer-term effects of self-directed interventions in a wider range of formats.

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Author order represents extent of contribution.

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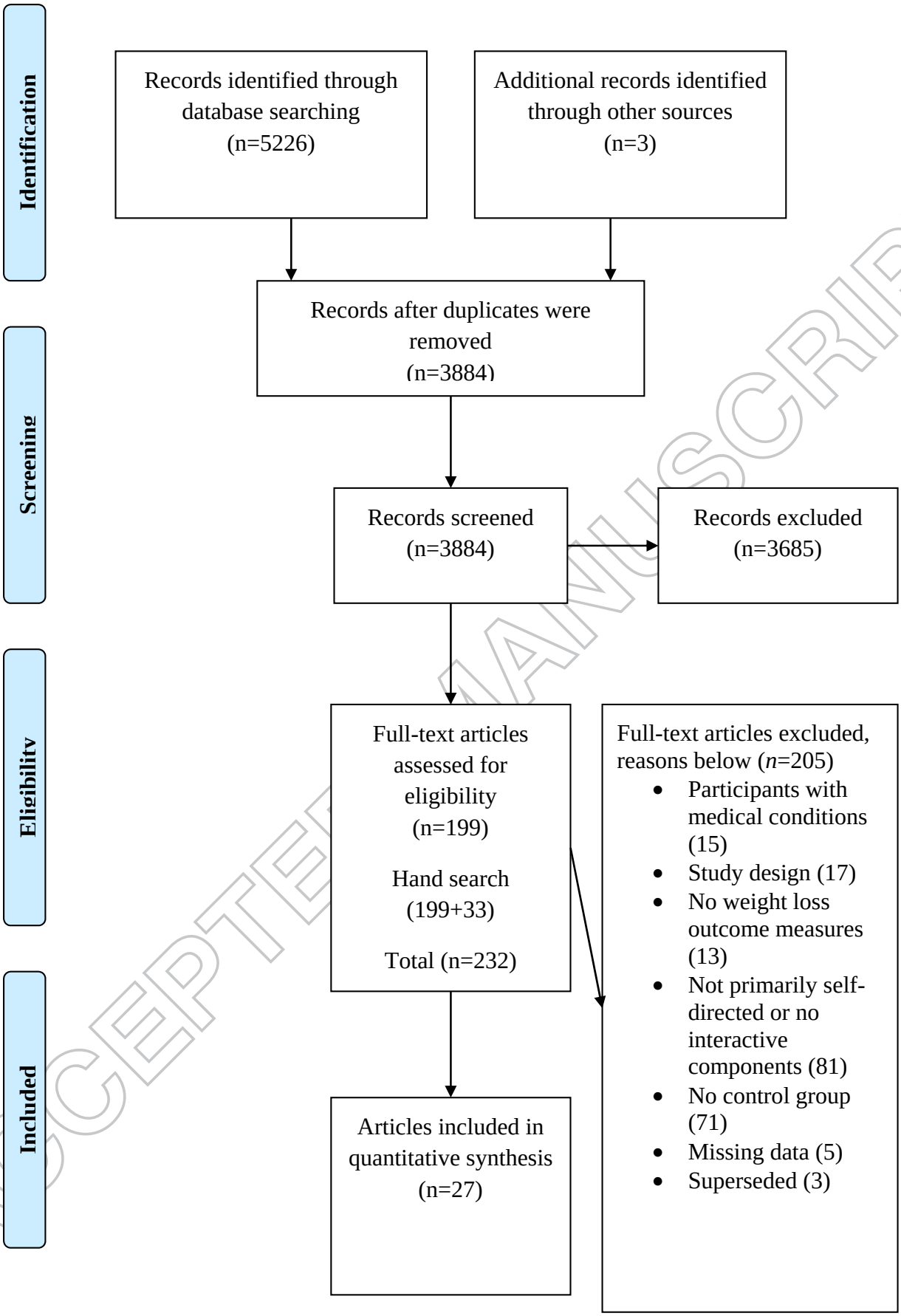

Figure 1.

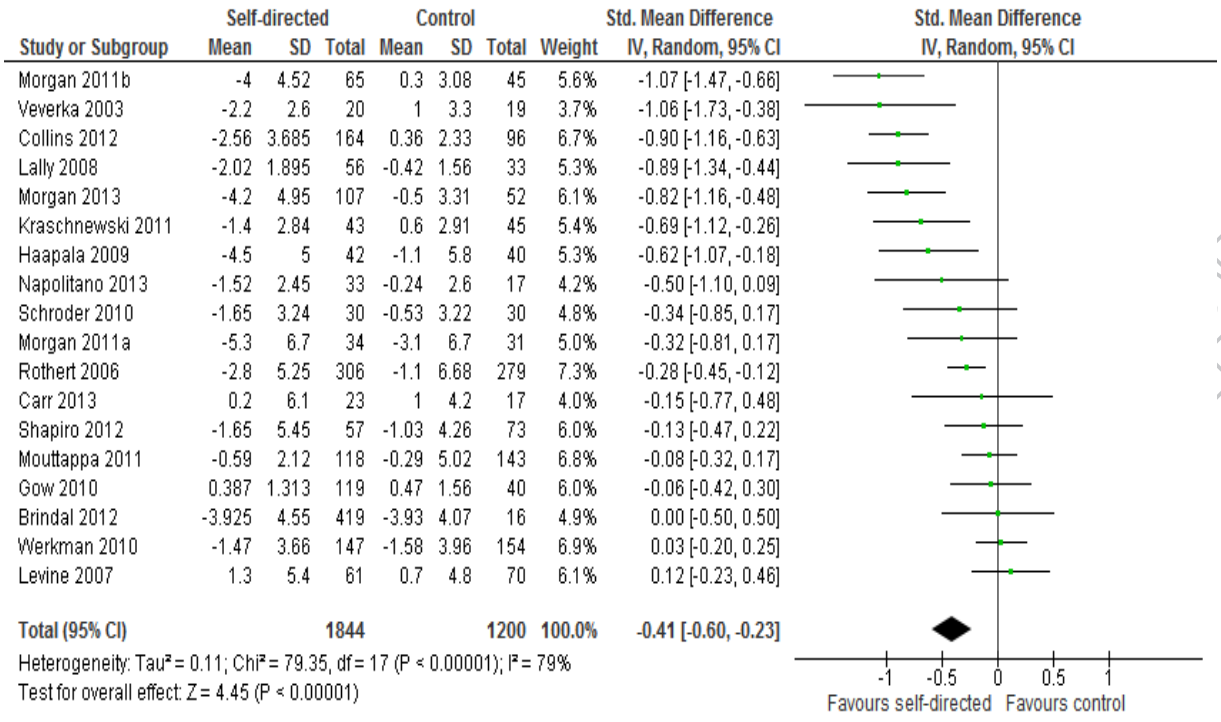

Figure 2.