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## Obesity Treatment

# Systematic review and meta-analysis of internet-delivered interventions providing personalized feedback for weight loss in overweight and obese adults

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### Summary

**Background:** Obesity levels continue to rise annually. Face-to-face weight loss consultations have previously identified mixed effectiveness and face high demand with limited resources. Therefore, alternative interventions, such as internet-delivered interventions, warrant further investigation. The aim was to assess whether internet-delivered weight loss interventions providing personalized feedback were more effective for weight loss in overweight and obese adults in comparison with control groups receiving no personalized feedback.

**Method:** Nine databases were searched, and 12 studies were identified that met all inclusion criteria.

**Results:** Meta-analysis, identified participants receiving personalized feedback via internet-delivered interventions, had 2.13 kg mean difference (SMD) greater weight loss (and BMI change, waist circumference change and 5% weight loss) in comparison with control groups providing no personalized feedback. This was also true for results at 3 and 6-month time points but not for studies where interventions lasted  $\geq 12$  months.

**Conclusion:** This suggests that personalized feedback may be an important behaviour change technique (BCT) to incorporate within internet-delivered weight loss interventions. However, meta-analysis results revealed no differences between internet-delivered weight loss interventions with personalized feedback and control interventions  $\geq 12$  months. Further investigation into longer term internet-delivered interventions is required to examine how weight loss could be maintained. Future research examining which BCTs are most effective for internet-delivered weight loss interventions is suggested.

**Keywords:** Feedback, internet interventions, obesity, weight loss.

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## Introduction

Obesity is of growing concern owing to the rise in prevalence with levels reaching 26% in men and 24% in women within the UK (1). In 2013, 83% of UK households had access to the internet, the vast majority through broadband connections, with over half of users able to connect to the

internet via their mobile phones (2). Globally, the internet is accessed by over three billion people, over 40% of the world population (3).

Traditional weight loss interventions, such as in-person consultations, have reported mixed findings for effectiveness in terms of weight loss and its sustainability (4,5), which may be related to poor adherence rates. Reasons for

non-adherence within in-person consultations include personal reasons, cost of travel, limited availability and lack of parking at venues (6). Internet-delivered weight loss interventions could minimize these problems by increasing the convenience and control for the user and health professional and reducing the cost of an intervention (7,8). The number of studies incorporating internet-delivered weight loss interventions has increased over recent years (9). Previous reviews have demonstrated that internet-delivered weight loss interventions can be effective in promoting weight loss and changes in physical activity and diet (10–13). However, several reviews have shown heterogeneity in results between studies, with several reporting no consistent benefits of internet-delivered weight loss interventions in comparison with control groups (10,11,14–16). Furthermore, many studies have demonstrated high attrition rates for both intervention and control groups (10,13,17).

Previous reviews have identified the need to identify which components of internet interventions contribute to weight loss and the effectiveness of an intervention. Taxonomies have been developed to provide definitions of active ingredients within interventions based on pre-established descriptions of behaviour change techniques (BCTs) and how these relate to theories (18). Using these taxonomies allows researchers to identify the presence of BCTs within an intervention and promotes consistent reporting whilst enabling comparison and replication of intervention features (19).

Feedback has been identified as an important and effective component within technology-based weight loss interventions (20–22). Feedback delivered by a person as part of an internet-delivered intervention can encourage, motivate and assist patients in successfully completing a weight loss program (23). Control theory (24) incorporates the BCT of ‘providing feedback’. The theory’s basic construct is known as the discrepancy-reducing feedback loop. This process is considered to be key to self-regulation. Self-regulation processes can be used to reduce the intention-behaviour gap and facilitate the understanding of the progression from intention to action. Self-regulation-based interventions have been identified as twice as effective as interventions without self-regulation strategies (25). The use of internet-delivered interventions can enhance weight loss effectiveness when individualized feedback and email counselling are integrated (21). Personalized feedback is generally delivered via specific tailored contacts, either web-based messaging, emails, short message service or in-person (26). It is important to identify and evaluate the types of feedback, which can be delivered via the internet.

The aim of the current study was to assess whether internet-delivered weight loss interventions providing personalized feedback (IWLPF) were more effective for weight loss in overweight and obese adults in comparison with control groups either placed on a wait list, receiving a minimal face-to-face intervention or receiving internet-delivered

weight loss interventions without personalized feedback. In addition, it aims to describe how feedback is provided and to identify the BCTs incorporated within internet-delivered weight loss interventions.

## Method

Guidelines set out in the Cochrane handbook for systematic reviews of interventions were followed (27), and reporting is in accordance with the PRISMA statement checklist (28). The review proposal was accepted onto PROSPERO (international prospective register for systematic reviews) on 17 May 2012, registration number: CRD42012002115.

## Search methods for identification of studies

### *Electronic databases*

Databases searched were Scopus (1960-present), Web of Science (1970-present), EMBASE (1974-present), MEDLINE (1948-present), PsycINFO (1967-present), ASSIA (1987-present), IBSS (1951-present), the Sociological Abstracts (1952-present), CINAHL (1981-present) and Clinical Trial registers (ISRCTN registry, EU Clinical Trials registry, WHO International Clinical Trials registry platform).

### *Search strategy*

Databases were searched with combinations of the key words ‘internet’, ‘web’, ‘computer’, ‘online’, ‘eHealth’, ‘nutrition’, ‘diet\*’, ‘physical activity’, ‘exercise’, ‘weight’, ‘weight loss’, ‘overweight’, ‘obes\*’, ‘randomi\*ed controlled trial’, ‘randomi\*ed’, ‘randomi\*ed trial’, ‘randomi\*ed clinical’, ‘controlled clinical trial’ and ‘clinical trial’.

### *Inclusion criteria*

Criteria for considering studies are outlined in Table 1. The definition used to code for the BCT feedback was taken from the CALO-RE taxonomy definition of “Provide feedback on performance - This involves providing the participant with data about their own recorded behaviour or commenting on a person’s behavioural performance (e.g. identifying a discrepancy between behavioural performance and a set goal or a discrepancy between one’s own performance in relation to others).” pg. 9 (29). This definition was used throughout to guide the selection and inclusion process, coding and analysis. Reference lists of identified studies and citation indexes of papers citing the identified studies were searched. Relevant authors in the field were contacted and asked if aware of any other studies relevant to the review.

## Data collection

### *Selection of studies*

All studies generated from the previously defined search strategies were evaluated against the pre-defined inclusion

**Table 1** Inclusion criteria to select studies for the systematic review

	Inclusion criteria
Population	Adult (18+ years) participants with BMI > 25 kg/m <sup>2</sup>
Interventions	Targeting diet and/or physical activity for weight loss Delivered at least in part via the internet Incorporating any form of individualized feedback to the participants either human-delivered (provided by a health care professional or researcher) or computer-generated personalized feedback (using algorithms that sent pre-programmed responses based on participant input or choices) delivered via web-based messages or email Definition of feedback used to guide process "Provide feedback on performance - This involves providing the participant with data about their own recorded behaviour or commenting on a person's behavioural performance (e.g. identifying a discrepancy between behavioural performance and a set goal or a discrepancy between one's own performance in relation to others)." pg. 9 (29)
Comparator	Arms comprising no individualized feedback, e.g. wait list, treatment-as-usual, intervention without feedback
Outcome	Primary: body weight change Secondary: body fat, waist circumference or BMI change, retention rates
Study design	Randomized controlled trials (including pilot studies)

criteria by two reviewers. Any disparities were addressed by involving a third reviewer and reaching an agreement. The studies that qualified for inclusion into the review were assessed with regards to their methodological quality by two reviewers. Studies were assigned a quality rating of low, high or unclear risk of bias for each criterion based on the Cochrane Collaboration's tool for assessing risk of bias (27). Studies were scored in relation to randomisation, allocation concealment, reporting of blinding, incomplete outcome data, selective outcome reporting and any other sources of bias (Supplementary materials Table S1). The two reviewers showed high inter-rater reliability, and a third reviewer was not required ( $\kappa = 0.89$ ).

## Data extraction, synthesis and analysis

### Primary outcome analysis

Weight loss was analysed at 3, 6 and 12 (or more) month data collection points as well as for the end of each study intervention.

### Secondary outcome analysis

Outcomes of 5% weight loss, BMI change and waist circumference change were analysed at 3, 6 and 12 (or more) month data collection points as well as the end of each study intervention.

Retention rates are number of participants remaining and adhering to the randomized arm and also number of

participants remaining in study for data collection (comparison with rates in the control group).

Coding of the BCTs was conducted for each of the studies, with 20% independently checked by the second reviewer. These were coded based on CALO-RE taxonomy of BCTs to help people change their eating and physical activity behaviours (29). When coding for the presence of BCTs within an intervention, no assumptions were made. The standardized vocabulary within the BCT taxonomy was adhered to in order to state the presence of any BCT, explicitly or implicitly, within the interventions reported in each included paper, thus promoting consistent reporting and coding between researchers (19).

### Analysis

Statistical analysis of the data was carried out using Review Manager 5. Data were analysed using mean (SD) change for each IWLPF and control group receiving no personalized feedback and compared whether significant differences were present between the different arms for each outcome measure: weight loss, BMI, waist circumference and 5% weight loss. Meta-analysis was conducted to examine the studies at the end of each study intervention. As intervention length varied between the studies, time points were examined separately, including 3, 6 and 12-month analysis in addition to the end of intervention. Meta-analysis was conducted, with intention-to-treat analysis data if available from the published data, along with tests for heterogeneity. All study data included in the meta-analysis used results measured at the end of the intervention. One of the included studies, by van Wier (30), conducted a follow-up at 24 months (after a 6-month intervention). Therefore, only post intervention data was used within the meta-analysis. The follow-up data of this study, 24 month, was not included to avoid the conflation of active loss and maintenance stage results. As a variety of control groups were included in the review, e.g. wait list, face-to-face and internet-delivered, subgroup analyses were performed to separate the effect of feedback from that of delivery mode. Control groups were categorized into 'waiting list or minimal face-to-face interventions' and 'control internet-delivered interventions without personalized feedback', refer to Table 2.

## Results

Fourteen articles reporting on 12 separate studies were included in the review (Fig. 1).

Study quality assessment identified that only two of the studies assessed received low risk of bias for all criteria. All quality assessments can be found in Supplementary material Table S1. Selective reporting was the only criterion to receive high risk of bias scores for four of the studies (22,30–32). Three studies provided monetary incentives for the completion of assessments that may have acted as a co-intervention in respect of retention rates (22,33,34).

Table 2 Study descriptions

Study	Intervention group descriptions	Feedback type provided	Control group descriptions	Control group category
Appel (37)	In person – a lifestyle intervention: 9 introductory modules and 21 additional modules Remote support – same features as the 'in person' intervention previously mentioned but delivered remotely, via an internet website Basic – received individualized tailored calorie plan and instructions on use of the weight management software system Enhanced – same as basic intervention but also included behavioural weight management strategies Basic – web-based nutritional and exercise program Enhanced – same as previously mentioned but added automated personalized feedback	Computer-generated Computer-generated	Control – self-directed weight loss Waiting list control	Wait list/minimal face-to-face intervention
Chambless (38)	Behavioural internet therapy (BIT) plus usual care, asked to restrict calories and increase PA. LEARN programme, behavioural modification approach to weight management. Personalized advice based on diet and physical activity inputted data, received online.	Human delivered	Usual care – refer to primary care provider for a preventative health visit	Wait list/minimal face-to-face intervention
Collins (31)	Achieve together website implementing 36 weight control behaviours, e.g. eating healthy snacks, plan what you will eat, write down what you eat and drink	Computer-generated Computer-generated	Waiting list control	Wait list/minimal face-to-face intervention
Hunter (32)	Intervention website: combination of dietary advice, PA advice and behaviour therapy Workplace POWER program providing weight loss advice with a counsellor via a website	Human delivered	Usual care – refer to primary care provider for a preventative health visit	Wait list/minimal face-to-face intervention
Kraschnewski (35)	SHED-IT internet group, weight loss workplace website with online counsellor sessions	Computer-generated	Waiting list control	Wait list/minimal face-to-face intervention
McConnon (36,47)	Website access resources about diet and exercise with included individualized feedback	Computer-generated	Usual approach to weight loss care and printed information Wait list control	Wait list/minimal face-to-face intervention
Morgan (39)	Website providing a tutorial on weight loss with communication with weight loss counsellor Automatic counselling – use of Slim Fast website and pre-programmed computer feedback Human counselling – use of Slim Fast website and feedback via human weight loss counsellor	Human delivered	Usual approach to weight loss care and printed information Wait list control	Wait list/minimal face-to-face intervention
Morgan (40,48)	Website access resources about diet and exercise with included individualized feedback	Human delivered	One face-to-face information session, weight loss booklet but no website access Internet behavioural therapy (IBT) – website access resources about diet and exercise	Wait list/minimal face-to-face intervention
Tate (34)	Website providing a tutorial on weight loss with communication with weight loss counsellor Automatic counselling – use of Slim Fast website and pre-programmed computer feedback Human counselling – use of Slim Fast website and feedback via human weight loss counsellor	Human delivered	Basic internet group – website providing a tutorial on weight loss No counselling – use of Slim Fast website, weekly reports on diet intake, physical activity and weight loss	Control internet-delivered intervention receiving no personal feedback
Tate (22)	Phone – lifestyle intervention workbook and consultations provided via telephone with their counsellor Internet – workbook accessed through an interactive website and contacted by their counsellor via the website	Human delivered	Self-help brochures about overweight, healthy diet and PA	Wait list/minimal face-to-face intervention
Tate (33)		Computer-generated Human delivered		Control internet-delivered intervention receiving no personal feedback Control internet-delivered intervention receiving no personal feedback
Van Wier (30)		Human delivered		

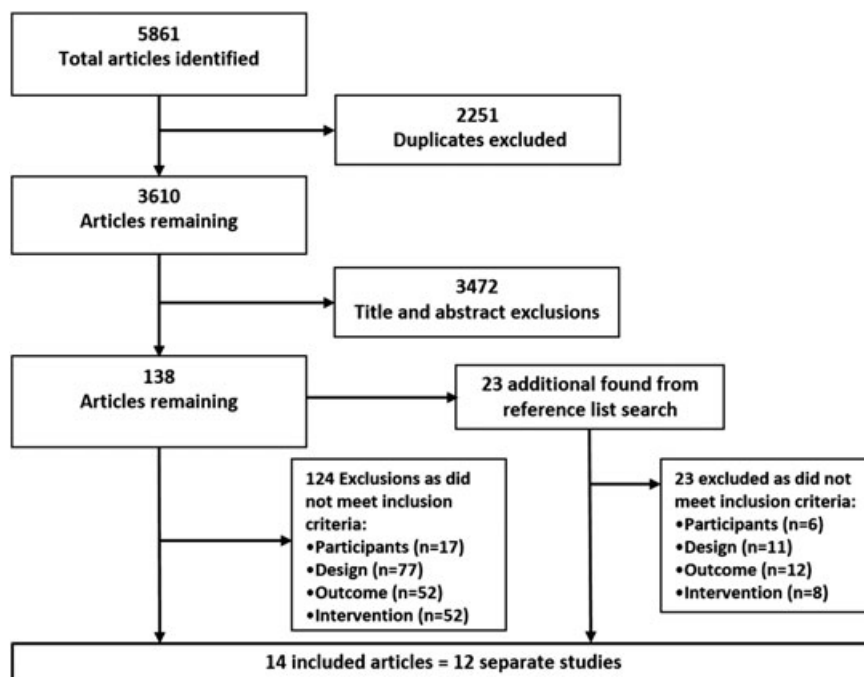


Figure 1 Screening for eligible studies.

## Description of included studies

The characteristics of the included studies are summarized in Tables 2 and 3. All studies took place between 2001 and 2012. The majority (seven) were conducted in the USA, three in Australia, one in the Netherlands and one in the UK. The total number of participants was 3547 with 1816 females (51.2%). All 12 studies targeted changes to physical activity and diet. The length of the active interventions ranged from 3 to 24 months (21-month range, mean 8.4, SD 5.7). Seven studies included two arms, and five studies included three arms. The studies varied in terms of the features of control/comparison arms (Table 2).

## Provision of individualized feedback

Across the 12 studies, 8 incorporated human-delivered internet feedback and 5 provided computer-generated internet feedback (Table 2). One study provided the personalized feedback using both formats as the study contained two internet-delivered intervention groups (33). These two terms have been used to distinguish between interventions using personalized feedback provided by a health care professional or researcher (human-delivered) in contrast to personalized feedback created using algorithms to send pre-programmed responses based on participant input or choices (computer-generated). All 12 studies used personalized feedback to target information received on participant's weight loss progress or individual behaviour change, such as diet or physical activity

level. Participant access to the internet-delivered personalized feedback was via the website (four studies) or via emails containing the feedback (six studies), with two studies remaining unclear in how it was administered. Frequency of feedback varied, the majority of studies (seven) providing it on a weekly basis. In addition to personalized feedback, two studies sent computer-generated messages when participants logged into the website (35,36). One study provided computer-generated messages to participants on completion of lesson modules or assessments (30).

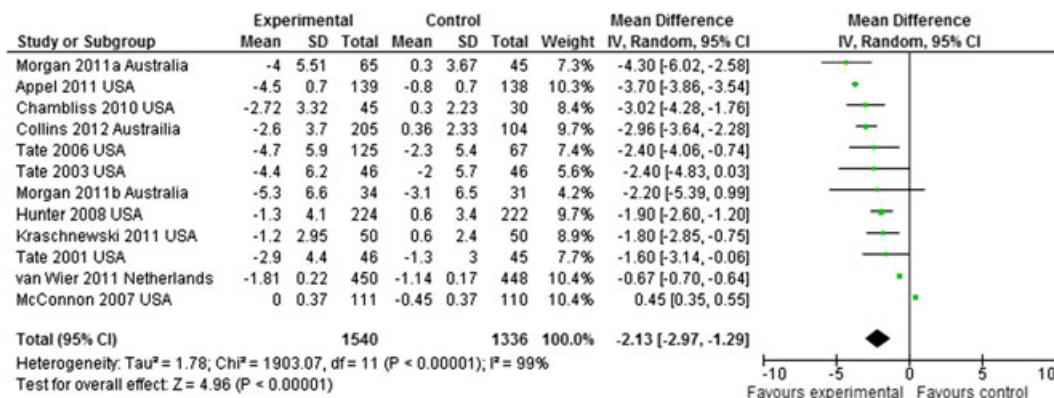
## Meta-analysis/synthesis of results

### *Internet weight loss interventions providing personalized feedback versus control groups receiving no personalized feedback*

The primary outcome, weight loss, is shown in Fig. 2 illustrating the meta-analysis forest plot for the 12 studies. Meta-analysis identified that provision of feedback resulted in 2.13 kg (mean difference [MD]) ( $p < 0.00001$ ) greater weight loss for the IWLPF in comparison with control groups receiving no personalized feedback. Heterogeneity levels showed considerable and significant heterogeneity ( $I^2 = 99%$ ,  $p < 0.001$ ) between control groups not receiving personalized feedback and the IWLPF. All outcomes were found to be statistically and clinically ( $\geq 5%$  body weight loss) significant for study end of intervention results (Table 4). This was also true for results from data collection conducted at 3 and 6 months. In contrast, studies with duration 12 months or

**Table 3** Study recruitment, retention and intervention length

Study	Setting	N	N per arm	Percentage of females	Retention	Intervention length	Follow-up
Appel 2011 (37)	USA	415	A) 138 B) 138 C) 139	264/415 (63.6%)	394/415 (94.9%)	24 months	None
Chambless (38)	USA	120	A) 30 B) 45 C) 45	99/120 (83%)	95/120 (79.2%)	3 months	None
Collins (31)	Australia	309	A) 104 B) 99 C) 106	180/309 (58%)	260/30 (84.1%)	3 months	None
Hunter (32)	USA	446	A) 222 B) 224	224/446 (50%)	399/446 (89.5%)	6 months	None
Kraschnewski 2011 (35)	USA	100	A) 50 B) 50	69/100 (69%)	88/100 (88%)	3 months	None
McConnon 2007/2009 (36) (47)	UK	221	110 B) 111	170/221 (77%)	131/221 (59.3%)	12 months	None
Morgan 2011a (39)	Australia	110	A) 45 B) 65	All male (0%)	90/110 (81.8%)	3 months	14 weeks
Morgan 2011b (40) (48)	Australia	65	A) 31 B) 34	All male (0%)	46/65 (70.8%)	12 months	None
Tate 2001 (34)	USA	91	A) 45 B) 46	81/91 (89%)	71/91 (78%)	6 months	None
Tate 2003 (22)	USA	92	A) 46 B) 46	83/92 (90%)	77/92 (83.7%)	12 months	None
Tate 2006 (33)	USA	192	A) 67 B) 61 C) 64	162/192 (84.3%)	155/192 (80.7%)	6 months	None
Van Wier 2011 (30)	Netherlands	1386	A) 448 B) 453 C) 450	457/1386 (33%)	792/1386 (57.1%)	6 months	24 months



**Figure 2** Forest plot weight loss results.

over did not identify significantly greater weight loss for the IWLPF compared with control groups receiving no personalized feedback. A higher proportion of intervention participants reached  $\geq 5\%$  weight loss, but this was not significantly different at  $\geq 12$  months (1.53 [0.82, 2.84];  $p = 0.18$ ). Only BMI and waist circumference outcomes illustrated statistically significantly greater losses for the IWLPF

compared with the control groups receiving no personalized feedback  $\geq 12$  months. All meta-analysis forest plots can be found as supplementary material (Supplementary materials Figures S1–S4).

Retention rates were calculated by the number of participants who provided follow-up data at the last assessment point (varying between studies). In total, intervention groups retained

**Table 4** Intervention versus control group meta-analysis results at each data collection point

Time (months)	N	Weight loss	N	5% Weight loss (risk ratio)	N	BMI change	N	Waist circumference
End of intervention	12	-2.13 [-2.97, -1.29]*	10	2.13 [1.56, 2.90]*	8	-0.99 [-1.28, -0.70]*	8	-2.42 [-3.65, -1.19]**
3	7	-2.62 [-3.14, -2.09]*	3	8.26 [3.24, 21.07]*	5	-1.02 [-1.23, -0.81]*	5	-2.39 [-4.67, -0.11]**
6	7	-1.82 [-3.32, -0.32]**	5	2.30 [1.49, 3.55]**	3	-0.95 [-1.79, -0.11]**	4	-2.35 [-3.95, -0.76]**
≥12	4	-2.18 [-5.80, -1.44]	2	1.53 [0.82, 2.84]	3	-1.20 [-1.74, -0.66]**	2	-2.44 [-4.45, -0.42]**

Mean difference [95% CI].

\* $p < 0.00001$ .

\*\* $p < 0.0001$ .

\*\*\* $p < 0.05$ .

N, number of studies included in meta-analysis.

73.5% (1132/1540) of participants, whilst control groups retained 77.5% (1036/1336), a significant difference in retention rates between intervention and control groups ( $p < 0.05$ ).

### Subgroup analysis

In nine studies, the control groups not receiving personalized feedback took the form of wait list or minimal face-to-face interventions (30–32,35–40). Minimal interventions included one-off usual care appointments where participants received standardized weight loss-printed information. Meta-analysis showed a statistically significantly greater weight loss (2.14 kg MD,  $p < 0.001$ ) for those in the IWLPF in comparison with the wait list or minimal interventions. Heterogeneity was considerable and significant between the wait list or minimal control groups and intervention groups ( $I^2 = 100%$ ,  $p < 0.00001$ ) (Supplementary Figure S5).

Meta-analysis was performed for the three studies using control internet-delivered interventions without personal feedback (22,33,34). Results showed 2.05 kg ( $p < 0.0001$ ) greater weight loss for the IWLPF in comparison with the control internet-delivered interventions receiving no personal feedback. Heterogeneity was not important and non-significant between the control internet-delivered interventions receiving no personal feedback and the IWLPF ( $I^2 = 0%$ ,  $p > 0.05$ ) (Supplementary Figure S6).

### Behaviour change techniques

More BCTs were present within the IWLPF (median = 8, IQR = 6) in comparison with the control groups receiving no personalized feedback (median = 1, IQR = 3). Across the included 12 studies, IWLPF incorporated 25 different BCTs, out of the 40 BCTs outlined within the CALO-RE taxonomy (29), while the control groups receiving no personalized feedback included only 17; 14/40 BCTs were not included in any study arms. The number of BCTs included in the IWLPF varied widely (4–19). The most effective studies (33,37,40) in terms of weight loss (kg) ranged from 7 to 14 BCTs and were not consistent in relation to included BCTs.

The BCTs incorporated most frequently are represented in Table 5 along with mean weight loss for each study's intervention and control group. The most prevalent BCT was 'providing information on consequences in general'. This

was the only BCT that was present in the majority of the control groups receiving no personalized feedback. Common techniques within the IWLPF, aside from 'provide feedback on performance', were 'planning social support/social change', 'prompting self-monitoring of behaviour/behavioural outcome' and 'goal setting (behaviour and outcome)'. These most commonly used BCTs tended to be clustered within the studies.

## Discussion

### Summary of key findings

Findings from this systematic review suggest that incorporating personalized feedback may be an important BCT for effective weight loss interventions delivered via the internet. Participants within the IWLPF were identified as twice more likely to achieve 5% weight loss than those in control groups. Shorter term data collection, 3 or 6 months, produced significant differences between the IWLPF and the control groups receiving no personalized feedback for all outcomes (weight loss, 5% weight loss, BMI and waist circumference change). In contrast, interventions lasting 12 months or longer did not produce significant differences between IWLPF and control groups receiving no personalized feedback for weight loss or 5% weight loss outcomes. Subgroup analysis identified significantly greater weight loss for the IWLPF irrespective of the comparator used, whether wait list/minimal face-to-face interventions or control internet-delivered interventions receiving no personalized feedback.

### Comparison with previous literature

As in previous reviews, internet-delivered weight loss interventions appeared to be more effective than comparison groups (13,15). However, previously, in terms of significant differences between groups or clinical effectiveness of internet interventions, results were mixed (10,11,14,16). The study by van Wier (30) conducting longer term follow-up once the intervention had ended found similar findings to the results identified in this review. The significant difference between intervention and control groups identified after the intervention was delivered was lost by the 2-year follow-up.



**Table 5** Most commonly incorporated BCTs and effectiveness (mean weight change)

Study	Mean weight change	Info about consequences	Self-monitoring (behaviour)	Feedback on performance	Goal setting (behaviour)	Social Support	Self-monitoring (outcome)	Instruction on performing behaviour	Goal setting (outcome)	Barrier identification
<b>Intervention groups</b>										
Tate Human (33)	-7.3	X	X	X	X	X	X	X	X	X
Morgan (40)	-5.3	X	X	X		X	X	X	X	X
Tate Automatic (33)	-4.9	X	X	X	X	X	X	X		X
Appel (37)	-4.5	X	X	X	X	X	X		X	X
Tate (22)	-4.4	X	X	X						
Morgan (39)	-4.0	X	X	X		X		X	X	X
Tate (34)	-2.9	X	X	X		X	X	X		
Chambless (38)	-2.7	X	X	X	X					
Collins (31)	-2.6	X	X	X	X	X	X	X	X	
Van Wier (30)	-1.8	X	X	X	X	X	X	X	X	X
Hunter (32)	-1.3	X	X	X	X	X	X	X	X	
Kraschnewski (35)	-1.2	X	X	X	X	X	X	X	X	
McConn (36)	0.0	X	X	X	X	8/5	X	7/6	6/7	5/8
Trials using/hot using		13/0	13/0	13/0	9/4	8/5	8/5			
<b>Control groups</b>										
Morgan (40)	-3.1	X								
Tate (33)	-2.6	X	X				X	X		
Tate (22)	-2.0	X	X							
Tate (34)	-1.3	X	X							
Van Wier (30)	-1.1	X	X							
Appel (37)	-0.8	X	X		X	X			X	
McConn (36)	-0.5	X	X							
Chambless (38)	0.3									
Morgan (39)	0.3									
Collins (31)	0.4									
Hunter (32)	0.6	X						X		
Kraschnewski (35)	0.6									
Trials using/hot using		8/4	2/10	0/12	1/11	3/9	1/11	2/10	1/11	0/12

X = BCT present within the study group.

Heterogeneity between included studies was evident and is a finding common in earlier reviews (41–43). Control group type appeared to impact on heterogeneity levels. Significant heterogeneity was identified between wait list/minimal face-to-face interventions and IWLPF. In contrast, heterogeneity levels between the control internet-delivered interventions receiving no personalized feedback and the IWLPF were not significant, suggesting that the addition of feedback alone did not increase heterogeneity. Low heterogeneity suggests that feedback does not explain a great deal of the variability in interventions. The results from the BCT coding of study arms illustrated the variability between control groups receiving no personal feedback and IWLPF, with interventions containing more BCTs than the control groups. However, variability was also evident between the 12 IWLPF. The variability in included BCTs and weight loss achieved made it difficult to identify why particular studies were more effective. BCT coding identified that feedback was not the sole component that was commonly incorporated within the IWLPF. Instead, it appeared that the IWLPF used similar clusters of BCTs. However, one of these was self-monitoring that is inherent to feedback in that participants would need to monitor their weight in order to gain feedback on it.

Attrition rates from previous reviews ranged from 20 to 43% (10,13,17,44). Attrition rates in this review ranged from 12 to 47% and therefore are similar to previous findings. The review identified studies not reporting on several quality assessment criteria, with only two studies perceived low risk of bias for all criteria. Previous reviews also found mixed standards for reporting of quality criteria (11). This review identified the need for further improvement on the reporting of allocation concealment and blinding.

### Strengths and limitations of review

This review focused on personalized feedback in an attempt to explain differences in findings across the studies. It has illustrated how complex and variable internet weight loss interventions can be. A limitation of the review is the inability to control for all differences emerging from the different features, often leading to high heterogeneity levels identified and therefore makes comparison of internet-delivered weight loss effectiveness very difficult to investigate. As a result, the influence of personalized feedback cannot be completely isolated from other intervention components. The BCTs used within the intervention groups were not consistent. Even within the most effective studies (in terms of weight loss), BCTs were incorporated differently. However, this approach highlights the need for researchers to both describe and investigate the exact content of interventions, to both improve replicability and to help isolate the effective components of interventions. The need to try to deconstruct complex interventions into their

component elements to see what are the most effective 'active ingredients' is emphasized (45).

All the studies provided personalized feedback for weight loss or behaviour change (diet/physical activity). However, two studies generated messages when participants logged onto the websites (35,36) and, one study (30), on the completion of modules or assessments. Both these participant interactions could have a potential effect on the intervention outcome; however, this does not appear to be the case with the three studies being placed in the four least effective studies when comparing mean weight loss difference between the intervention group and control group.

The lack of a set description when defining internet-delivered weight loss intervention groups was a limitation with intervention names varied greatly, e.g. remote support, enhanced group or behavioural internet therapy. This was also a problem within the control groups, e.g. variability in the use of the term usual care. Following frameworks, such as TIDieR (46), may help to maintain a minimum standard when reporting intervention descriptions. Control groups tended to be wait list or usual care. Usual care allows real-world practices to be examined in comparison to internet-delivered weight loss interventions, but these were often what could be classified as minimal face-to-face interventions.

The majority of studies had high percentages of white, female participants, which could impact on the generalisability of the findings. Three studies provided monetary incentives for the completion of assessments, which may have biased the findings in terms of retention rates and thus outcome results (22,33,34).

### Implications for policy, practice and further research

Meta-analysis results identified no significant weight loss for the IWLPF at longer term follow-up ( $\geq 12$  months). Long-term maintenance is essential for health benefits, and therefore, more investigation is required to examine how weight loss could be maintained across time and how internet-delivered interventions could be refined to better support weight maintenance. Further investigation into all BCTs used in each IWLPF and the relationship to effectiveness would be an important path to explore. Owing to small sample sizes within the included studies, analysing the relationship between effectiveness and BCTs could not be conducted in this review. This would be useful to examine in future research and would enable not only individual BCT impact to be investigated but also exploration of synergistic effects between clusters of BCTs and weight loss.

Human-delivered internet feedback took the form of health care professionals or researchers producing individually created responses (emails/web-based messages) to each participant, although the use of pre-scripted responses for common queries/topics could be used. This causes potential

limitations of scaling up an intervention as greater resources, labour and therefore costs would be incurred. This is especially true when compared against computer-generated options available, which are less labour-intensive after initial set-up. However, human-delivered internet feedback could still be more efficient in comparison with traditional face-to-face methods as there are wider issues such as the ability to provide health care advice quicker and easier because of greater flexibility, convenience and time efficiency for both health care professional and the patient. In addition, consultants have more readily accessible patient outcome data. Therefore, human-delivered internet feedback is an important research area to investigate. One study (33) within this review compared internet feedback examining human-delivered versus computer-generated (with results favouring human-delivered feedback), but research remains limited. Further research could highlight the advantages and disadvantages both options provide. Implications for practice relate to the use of IWLPF as alternative ways to provide weight management services. Further research is needed to establish whether internet-delivered weight loss interventions provide additional benefit than in-person services in current health care practice and to identify the most effective ways of providing personalized feedback.

### Conflict of interest statement

No conflict of interest was declared.

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### Supporting information

Additional Supporting Information may be found in the online version of this article, <http://dx.doi.org/10.1111/obr.12396>

**Table S1:** Study quality assessment.

**Figure S1:** Internet feedback versus no feedback weight loss (kg).

**Figure S2:** Internet feedback versus no feedback 5% weight loss.

**Figure S3:** Internet feedback versus no feedback mean waist circumference change.

**Figure S4:** Internet feedback versus no feedback mean BMI change.

**Figure S5:** Wait list control/minimal intervention versus internet feedback interventions mean weight loss (kg).

**Figure S6:** Control interventions with no feedback versus internet feedback interventions mean weight loss (kg).

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