**Title** eHealth interventions for the prevention and treatment of overweight and obesity in adults: A systematic review with meta-analysis

**Authors**

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**Potential Conflicts of Interest**

Hutchesson, Krukowski, Harvey, Morgan, Callister, Plotnikoff and Collins are all authors of studies included in the review, however to ensure an independent review, no authors appraised or extracted data for any included studies on which they were an author. No other conflicts of interest.

**Abstract**

A systematic review of randomized controlled trials was conducted to evaluate the effectiveness of eHealth interventions for the prevention and treatment of overweight and obesity in adults. Eight databases were searched for studies published in English from 1995 to September 17th 2014. Eighty-four studies were included, with 183 intervention arms, of which 76.0% (n=139) included an eHealth component. Sixty-one studies had the primary aim of weight loss, ten weight loss maintenance, eight weight gain prevention, and five weight loss and maintenance. eHealth interventions were predominantly delivered using the internet, but also email, text messages, monitoring devices, mobile applications, computer programs, podcasts and personal digital assistants. Forty percent (n=55) of interventions used more than one type of technology, and 43.2% (n=60) were delivered solely using eHealth technologies. Meta-analyses demonstrated significantly greater weight loss (kg) in eHealth weight loss interventions compared to control (MD -2.70 [-3.33,-2.08], $p<0.001$) or minimal interventions (MD -1.40 [-1.98,-0.82], $p<0.001$), and in eHealth weight loss interventions with extra components or technologies (MD 1.46 [0.80, 2.13], $p<0.001$) compared to standard eHealth programs. The findings support the use of eHealth interventions as a treatment option for obesity, but there is insufficient evidence for the effectiveness of eHealth interventions for weight loss maintenance or weight gain prevention.

## Introduction

It is estimated that over half a billion adults worldwide are obese [1]. Therefore, a comprehensive approach to obesity management is required that considers prevention of weight gain among all population groups; weight loss among those who are overweight or obese, and maintenance of weight loss among those who have lost excess weight [2]. eHealth interventions combine the use of emerging communication technologies, such as the Internet and Smartphones, to facilitate behavior change and improvements in health [3], and offer a wide-reaching and potentially appealing intervention option across all levels of obesity management. By the end of 2014, 40% of the world's population will use the internet, including 78% of the population in developed countries [4]. Furthermore, 32% of the world's population has access to mobile broadband. This includes 84% of the population in developed countries, where the number of mobile broadband subscriptions has multiplied by five times since 2008 [4]. eHealth technologies are a common way for individuals to access information about their health. In the United States, 72% of adults use the Internet and 52% their smartphone to find health-related information [5]. In particular, 24% look online specifically for information about losing or controlling their weight [6].

A number of systematic reviews have attempted to examine the potential of eHealth interventions for the prevention and treatment of overweight and obesity among adults [7-16], however, these reviews have several limitations. Firstly, they are generally restricted to only one form of eHealth technology. For example, most of the reviews have focused on web or computer-based interventions [7, 10, 11, 14, 16], with more recent reviews examining mobile technologies only [8, 13, 15]. Only one review [9] has more broadly reviewed 'technology' interventions for weight loss and maintenance, but the inclusion criteria were limited to studies published in 2010 and 2011. Therefore, the reviews conducted to date have not evaluated the effectiveness of all information technologies or the combined use of different technologies. Secondly, the reviews typically only consider one of the three levels of prevention (primary, secondary or tertiary), and therefore do not amalgamate the evidence for the effectiveness of eHealth interventions to both prevent and treat overweight and obesity. The majority of reviews have focused on weight loss interventions only [7, 8, 11, 13, 15], some have considered both weight loss and weight loss maintenance [9, 12, 14, 16], but no review has also considered weight gain prevention.

Therefore, given the limited scope of previous reviews, the primary objective of this systematic review was to assess the effectiveness of eHealth interventions for the prevention

and treatment of overweight and obesity in adults. For the purposes of this review, effectiveness was evaluated through assessment of weight-related outcomes.

## Methods

This systematic review was conducted using a pre-defined protocol registered with PROSPERO (CRD42013004425) http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42013004425

### *Criteria for study inclusion*

*Types of participants:* Adults aged ≥18 years.
*Types of interventions:* Behavioral weight loss, weight loss maintenance or weight maintenance/weight gain prevention interventions delivered using eHealth exclusively and/or as a component of the intervention. 'eHealth' included Internet, computers, including tablets, e-mail, personal digital assistants (PDAs), mobile/smartphones, and digital games.
*Types of comparators:* No intervention control group, standard care or another delivery mode (e.g. face-to-face), or another eHealth intervention.
*Types of outcomes:* A weight-related primary outcome (e.g. weight, body mass index, percentage body fat, waist circumference).
*Types of studies:* Randomized controlled trials published in the English language

### *Literature search*

Eight databases (The Cochrane Library, MEDLINE/PREMEDLINE, EMBASE, CINAHL, Web of Science, Scopus, PubMed, and PsycINFO) were searched using pre-determined keywords and index terms with searches limited to studies published in English from 1995 to 17$^{th}$ September 2014 (Supporting Information Table S1 Search Syntax). The reference lists of all retrieved articles and relevant systematic reviews identified by the search were also searched.

### *Study selection*

The title, abstract and keywords of all identified articles were assessed by two independent reviewers. For records assessed as meeting the inclusion criteria or determined unclear by either reviewer, the full-text was retrieved. Two reviewers independently screened the full-

text articles for inclusion or exclusion, with a third reviewer used where disagreement existed.

***Risk of bias***

All included studies were appraised for study quality using the 10-item Joanna Briggs Institute Meta-Analysis of Statistics Assessment and Review Instrument by two independent reviewers with a third reviewer used where disagreement existed. Studies were classified as higher (8-10 items met); moderate (5-7 items met) and lower (<5 items met) quality.

***Data extraction***

Data relating to study participants (e.g. number, sex, body mass index, age), methodology (e.g. intervention duration and purpose), and the effect on weight (e.g. weight outcomes reported and significance of results) were extracted by one reviewer and checked by a second reviewer.

***Data synthesis***

Results were described in a narrative summary. Weight-related results were pooled in meta-analysis if they were available as either change scores or final values, the number of participants was recorded, and interventions and comparators were sufficiently similar for comparison. If standard deviations (SD) were not available but other statistics (e.g. 95% CI or standard errors) were available they were converted to SD [17]. If results were reported in imperial units (pounds), they were converted to metric units (kilograms). If more than one intervention arm from a study was eligible for inclusion in a meta-analysis, the sample size of the shared comparator group was divided by the number of arms included to avoid the participants being counted multiple times [17]. Heterogeneity was assessed by $I^2$ statistics, and considered to be low if $I^2$ was $\leq$40%, and high if $I^2$ was $\geq$75%. A random effects model for meta-analysis was used if there was significant heterogeneity ($I^2$ >40%), and fixed effects when homogeneous ($I^2 \leq 40\%$) [17]. The data from individual studies were combined using mean difference (MD). All meta-analyses were conducted using Review Manager (RevMan) Analyses Version 5.2 (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012). Studies included in each meta-analysis were evaluated for potential publication bias by visual evaluation of funnel plots for each meta-analysis in RevMan. No evidence of publication bias was evident with studies distributed symmetrically around the mean.

Within each meta-analysis, studies were grouped by the primary type of eHealth intervention (e.g. web, mobile, computer) and whether the intervention was delivered solely using eHealth technologies or included other non-eHealth components. In addition, all weight loss meta-analyses were repeated with studies grouped by key study characteristics to explore what characteristics may have influenced outcomes and/or study heterogeneity. The characteristics included: study quality (higher; moderate; lower); statistical analysis approach (intention to treat (ITT); completers); length of intervention (<6 months; 6-months or more); retention rates at post-intervention (80% or more; <80%); date of publication (2010 onwards; Prior to 2010), and continent where the intervention was undertaken (North America/US; Europe/UK; Australia/New Zealand; Asia)

## Results

### *Description of included studies*

Of the 3909 articles identified, 140 articles met the inclusion criteria (Figure 1). Of the 140 articles, 13 were classified as ongoing studies whereby the study methods met the inclusion criteria but no intervention outcome measures had been published. The remaining 127 articles reported results from 84 separate studies, with study characteristics summarized in Table 1 (Supporting Information Table S2 Detailed Summary of Included Studies).

Fifty four studies had two study arms, 24 had three, five had four and one had five. The length of interventions ranged from six weeks to 30 months. Thirty study interventions (35.7%) were three months or shorter in duration, 25 were six to <12-months (29.8%) and 18 12 to <18-months (21.4%). The majority of studies assessed outcomes at pre and post intervention. The mean retention rate at post-intervention was 78±17 (Range 16 to 98%), with 58.3% (n= 49) studies with retention rates ≥80% at post-intervention. The 14 studies with later follow-up included intervention durations ranging from one month to 12-months. Only 14 studies (16.7%) assessed outcomes at later follow-up. The follow-ups occurred as early as two weeks after the completion of the intervention up to 18-months, but most (n=8) were between three and/or six months after the completion of the intervention. Retention rates ranged from 11 to 91% at later follow-up, with 6 out of 14 studies achieving retention rates ≥80%.

The majority (72.6%, n=61) of studies had the primary aim of weight loss, while 10 focused on weight loss maintenance and eight on weight gain prevention. Five studies investigated

both weight loss and weight loss maintenance, of which three reported on separate weight loss and weight loss maintenance phases. These studies were considered with the studies that focused on weight loss alone and/or weight loss maintenance alone.

The total number of participants across all studies was 24010, with sample sizes ranging from 20 to 2862 (Mean 286±473. Median 126). The average age of participants in most studies (82.1%, n=69) ranged from 35 to 65 years. The mean percentage of females across the included studies was 74.8%, with 13 studies including only females [18-25] and 4 only males [26-29]. The majority of studies included both overweight and obese individuals (72.6%, n=61). Many studies did not provide a description of the socio-economic status (41.7%, n=35 did not report education level). Of those that did, most included predominantly (≥50%) college educated participants (50.0%, n=42). There were an almost equal number of studies that reported a predominantly (≥80%) 'white' sample (36.9%, n=31) to those that did not (34.5%, n=29). The majority (n=72, 85.7%) of included studies presented results as absolute weight change or weight at post intervention and 36.9% (n=31) presented results as percentage weight change. Therefore, results are presented as absolute weight change.

***Risk of bias of included studies***

Twenty-three (27.4%) of studies were classified as higher quality, 67.9% (n=57) moderate quality and 10.7% (n=9) lower quality (Supporting Information Table S3 Methodological Quality of Included Studies). All studies measured outcomes consistently for both groups, and the majority treated groups identically other than the stated intervention (97.6%, n=82) and used appropriate statistical analysis (96.4%, n=81). Many studies conducted ITT analysis (72.6%, n=61), reported that study groups were comparable at entry (n=65, 77.4%), and measured outcomes in a reliable manner (78,6%, n=66). Notably, eight studies (9.5%) used self-reported weight as the primary outcome. Approximately half of the studies (51.2%, n=43) randomly allocated participants to study groups using appropriate methods, however 46.4% (n=39) did not describe the randomization method. Only 36.9% of studies (n=31) reported whether allocation to treatment groups was blinded, of which 29 (35.4%) used appropriate allocation concealment methods. Only one quarter of studies (n=21) reported assessor blinding. Only nine studies (10.7%) reported participant blinding, although this was not feasible for the majority of intervention designs.

***Description of eHealth interventions***

The 84 included studies had a total of 205 study arms, of which 183 were active intervention arms. Of the 183 intervention arms, 76.0% (n=139) had at least one component that was delivered using eHealth. Less than half of these interventions (43.2%, n=60) were delivered solely using eHealth technologies. Of the 139 interventions delivered using eHealth, 60.4% (n=84) used only one type of technology, 33.8% (n=47) used two, 5.0% three (n=7) and one intervention five types of technology. Seventy-eight percent of interventions used the internet/website (n=109), 33.8% email (n=47), 9.4% text messages (n=13), 7.9% a monitoring device (n=11), 5.0% a mobile application (n=7), 4.3% a computer program (n=6), 2.9% podcasts (n=4), and 2.2% PDA (n=3). Of the 59 eHealth intervention arms that included non-ehealth components, the non-eHealth intervention components were delivered in written/paper-based form (e.g. educational materials, self-monitoring diaries); via telephone (e.g. feedback, counselling or reminders to participate in eHealth components); via face-to-face individual or group sessions (e.g. for education or counselling) or via DVD (e.g. for education). The level of use of non-eHealth components varied considerably across the interventions arms, with the number of contacts (e.g. number of face-to-face sessions, paper-based resources) with a different non-eHealth component ranging from one to 52.

***Effectiveness of eHealth interventions aiming to achieve weight loss***

*eHealth interventions vs control*

Thirty studies compared an eHealth weight loss intervention to a control group [18, 21, 25-52]. Ten of these studies evaluated interventions that were delivered using eHealth only [21, 29, 35, 37, 38, 41, 44, 46, 47, 52], seven of which were delivered primarily via a website [21, 29, 35, 37, 38, 44, 47], two via mobile devices (one text message [41] and one text message plus application [46]), and one using a combination of website, email and smart scales[52]. The remaining 20 studies evaluated interventions that incorporated eHealth combined with other delivery modes (e.g. face-to-face, telephone counselling, written materials) [18, 25-28, 30-34, 36, 39, 40, 42, 43, 45]. At the individual study level, 21 of the 30 studies [18, 26, 27, 30-36, 38, 39, 44-52] reported significantly greater weight loss in the eHealth intervention compared to a control group. The studies were further divided into those that included a true control group (i.e. no intervention) [21, 26, 27, 33, 35, 38, 40, 46, 47, 52] and those that were described as a control group but provided a minimal intervention [18, 25, 28-32, 34, 36, 37, 39, 41-45 18, 25-28, 30-34, 36, 39, 40, 42, 43, 45, 48-51]. The minimal interventions predominantly included the provision of self-help written materials (e.g. dietary guidelines) [18, 25, 29-32, 34, 36, 37, 39, 41, 43-45, 48-50], with three studies including a one-off face to face group session [28, 42, 51].

Nine studies with 11 arms that compared weight change in eHealth interventions to a no intervention control group were combined in a meta-analysis (Figure 2). The studies were heterogeneous ($I^2$ = 49%, p= 0.04) and there was a significantly greater decrease in weight (kg) in the eHealth interventions (MD -2.70 [-3.33,-2.08], p<0.00001) compared to the control group at post intervention. There was a trend for differences by intervention type (p=0.05), with the greatest mean difference in weight loss for web-based interventions that also incorporated non-eHealth components (MD -3.70 [-4.46, -2.94], p<0.001, n=3), followed by mobile interventions (MD -2.40[-4.09,-0.71], p=0.005, n=1) and web-based interventions delivered only using eHealth technologies (MD -2.21 [-2.98,-1.44], p<0.001, n=6).

The second meta-analysis (Figure 3) pooled 16 studies that compared weight change in eHealth interventions (n=9 web [18, 25, 28, 30-32, 37, 44, 48], n=3 mobile text messaging [39, 41 51], n=2 computer[34, 45], n=2 monitoring device[42, 43]) to a control group that received a minimal intervention. The studies were significantly heterogeneous ($I^2$ = 72%, p<0.001) and there was a significantly greater decrease in weight (kg) in the eHealth interventions at post-intervention (MD -1.40 [-1.98,-0.82], p<0.0001) compared to the minimal intervention group. There were also significant differences by intervention sub-group type (p=0.005), with only website, mobile text-messaging and computer-based interventions that were combined with other non eHealth intervention components demonstrating significantly greater weight loss in the intervention compared to the minimal intervention group (website MD -2.65 [-3.76,-1.54], p<0.0001, n=6; mobile text messaging MD -1.81 [-2.49,-1.12], p<0.0001, n=2; and computer MD -1.13 [-1.36, -0.89], p<0.0001, n=2).

*eHealth interventions vs another mode of delivery*

Six studies compared an eHealth weight loss intervention to an intervention delivered using a non-eHealth medium. Four studies found no significant difference in weight loss at post intervention between the two groups. These studies compared: a 9-month web-based intervention with a device to monitor physical activity to a face-to-face group weight loss program [43]; a 6-month web-based intervention to weekly tele-counselling with written materials [44]; a 6-months of intensive face-to-face counselling to a self-management intervention delivered using a mobile application[53] ; and a 6-month predominantly text message and email-based intervention to two face-to face sessions combined with a video

series [54]. Conversely, two studies found significantly greater weight loss in the intervention delivered using non-eHealth medium. Harvey-Berino *et al* [55] found significantly greater weight loss was achieved in a 6-month weight loss program with face-to-face group meetings, compared to online meetings (-8.0±6.1kg vs. -5.5±5.6kg, p<0.01). Sullivan *et al* demonstrated significantly greater weight loss in a weekly group-based clinic for 3-months delivered face-to-face, compared with virtual reality (10.8% vs. 7.6%, p<0.05)[56].

Nine studies [33, 53, 55, 57-62] compared an eHealth intervention to the same eHealth intervention combined with another mode of delivery. Six of the studies compared an eHealth intervention alone (website n=5 and mobile application n=1) to the eHealth intervention combined with face-to-face sessions [53, 55, 57, 59, 60, 62]. Two studies compared the provision of a web-based program alone to a web-based program with portion controlled foods/meal replacements[58, 61]. Chamblis *et al* [33] compared daily web-based self-monitoring, weekly automated email counselling/feedback and face-to-face contact consisting of three individual and one group sessions, to the same intervention plus monthly telephone counselling, email newsletters and an extra 1-hour group session that focused on behavioral weight management strategies. At an the individual level, seven of the studies found no significant difference in weight loss between the two groups at post-intervention[33, 53, 55, 58, 60-62] Whereas, two studies demonstrated greater weight loss in a eHealth group with face-to-face sessions, compared to a eHealth intervention alone [57, 59].

Five studies with seven intervention arms were combined in meta-analysis to compare weight change (kg) at post-intervention (Figure 4) in an eHealth intervention alone versus eHealth combined with face-to-face sessions. The studies were homogenous ($I^2$ = 34%, p=0.17) with no significant difference in weight change between eHealth only and eHealth plus face-to-face sessions groups (MD 0.58 [-0.13, 1.29], p=0.11) at post-intervention. There was no significant difference in results by eHealth medium sub-group (i.e. website or mobile application delivery).

Seven studies [43, 53, 55, 63-66]evaluated whether the addition of eHealth technologies to a standard care weight loss intervention typically delivered face-to-face influenced the weight loss achieved. At the individual study level, two of the studies [63, 65] found greater weight loss at post-intervention among participants randomized to the standard care intervention plus eHealth technologies, four [43, 53, 64, 66] found no significant difference in weight loss between

the two groups and two [43, 55]found significantly greater weight loss in the standard care only group. The seven studies were pooled in a meta-analysis to compare weight change at post intervention (Figure 5). The studies were significantly heterogeneous ($I^2$ = 83%, p< 0.00001) with no significant difference in weight loss (kg) in the standard care plus eHealth group (MD -2.31 [-4.69,0.07], p=0.06) compared to standard care alone at post-intervention. There was a significant sub-group difference (p=0.0001) with the addition of monitoring devices (MD -4.86 [-8.17,-1.55] p=0.004) and mobile applications (MD -2.90 [-5.63, -0.17], p=0.04) to standard care producing significantly greater weight loss than standard care alone.

*Comparisons of eHealth-delivered interventions*

Twenty-one studies compared a standard eHealth intervention to the same eHealth intervention with extra features/components or technologies. Fifteen of the studies evaluated interventions that were delivered using only eHealth [22, 24, 35, 38, 67-75 58], of which 13 were primarily delivered via the Internet [22, 24, 35, 38, 58, 67-72, 75] and two via podcasts [73, 74]. Five of the remaining studies evaluated interventions that incorporated eHealth combined with one face-to-face individual counselling session, and the eHealth components were primarily delivered via a website [23, 75-78], whereas one study evaluated a web-based intervention combined with written materials for self-monitoring and newsletters [59].

Fourteen of the studies investigated the addition of intervention features, such as self-monitoring tools, feedback, reminders to engage with the program, email counselling, online group meetings/discussion groups and online lessons to web-based weight loss programs[22-24, 35, 58, 59, 68, 70-72, 75-78]. Five of the studies investigated different approaches to the delivery of the intervention: focusing on diet or diet and exercise [67]; providing a directive intervention versus non-directive participant driven intervention [69]; standard motivational interviewing compared to motivational interviewing with the addition of values discussion [24]; providing automated versus personalized email counselling to participants [77]; and delivering standard podcast versus podcasts based on social cognitive theory [74]. Two studies evaluated the effect of adding a new technology to an eHealth intervention [38, 73]. Napolitano *et al* [38] evaluated the addition of text messages to an intervention delivered via social networking site Facebook. Turner McGrievy *et al* [73] investigated the addition of a Smartphone application for self-monitoring, as well as social networking (Twitter) to an existing theory-based series of podcasts.

At the individual level, 11 of the studies reported significantly greater weight loss with the addition of new intervention features and/or new technologies [22, 38, 58, 59, 70, 72, 74-78] , eight found no between group differences in weight loss[23, 24, 35, 67, 69, 71, 73, 75] and one study did not report the significance of the results [68] Twelve of the studies, with 13 intervention arms, were combined in a meta-analysis (Figure 6) and were shown to be significantly heterogeneous ($I^2$ = 60%, $P$= 0.002). Significantly greater weight loss was achieved in the group with the additional features delivered using eHealth technologies (MD 1.46 [0.80, 2.13], p<0.001) compared to the standard eHealth program. There were no significant sub-group differences (p=0.08) for type of eHealth intervention.

***Effectiveness of eHealth interventions aiming to achieve weight loss maintenance***

*eHealth vs control*

Seven studies compared an eHealth weight loss maintenance intervention to a control or minimal intervention group [19, 79-84]. Six of the studies evaluated interventions that were delivered primarily using eHealth (four Internet, one email, one text message) [19, 79-82, 84]. The other study combined a web-based weight loss maintenance intervention with face-to-face counselling sessions (one individual and three group sessions) [83]. Five of the studies' control groups were self-directed/no intervention groups [19, 79, 81-83], one provided written materials only [84] and one provided general health related text messages[80]. Six of the studies found no significant difference in weight change between the eHealth and control groups from pre to post the weight loss maintenance intervention [19, 79-82, 84]. One of the studies found no significant difference in weight change between the two groups from baseline of the weight loss phase to after the weight loss maintenance intervention [83]. Three of the studies were combined in meta-analysis (Figure 7) and were homogenous ($I^2$ = 0%, p = 0.99). There was no significant difference in weight change between groups from pre to post a weight loss maintenance intervention (MD -0.27 [-0.96,0.42] p=0.44).

*eHealth vs another mode of delivery*

Five studies compared delivering a weight loss maintenance intervention using eHealth technologies (all web-based) to another mode of delivery [79, 81, 84-86]. Two of the studies comparator arms were delivered via face-to-face group sessions [85, 86], and five were delivered using a combination of face-to-face sessions (four group and one individual) and telephone counselling [19, 79, 81-83]. Three of the studies found no significant difference in the weight change between the eHealth intervention and the other mode of delivery [79, 84, 86], two of which

presented weight change results from the commencement of weight loss to post weight loss maintenance intervention [79, 86], and the third examined weight change from pre to post weight loss maintenance intervention [84]. Alternatively, Harvey-Berino *et al* [85] demonstrated that from the commencement of weight loss (6-month intervention) to after a 12-month intervention, a frequent (-10.4±6.3kg) or minimal (-10.3±6.3kg) in-person intervention achieved significantly greater weight loss than an internet intervention (-5.7±5.9kg). Svetkey *et al* [81] also demonstrated that from the commencement of weight loss (6-month intervention) to after a 30-month intervention that a monthly personal contact intervention (face-to-face or telephone) produced significantly more weight loss than a web-based intervention (-4.2±0.4 vs -3.3±0.4kg, $p<0.001$).

*Comparison of eHealth delivery*

One study compared a self-directed commercial web-based program (eDiets) to a therapist led behavioral web-based program (Vtrim), which included a 6-month weight loss phase and a 6-month weight loss maintenance phase. They found the behavioral program (VTrim) participants maintained a greater weight loss at 12-months (7.8±7.5kg) than the commercial program (3.4±5.8kg, $p=0.002$)[70]. Another study compared the use of daily text messaging for based on regulatory focus theory that were either approach or prevention based[80] and found no significant difference in the sustained weight loss between the two groups after 3-months.

***Effectiveness of eHealth interventions aiming to achieve weight gain prevention***

*eHealth vs control*

Four studies compared eHealth weight gain prevention interventions to control groups, with all finding no significant differences in weight-related outcomes between groups at post intervention [87-90]. Gow *et al* [87] compared three 6-week interventions (provision of email feedback on weight self-monitoring, a web-based intervention, or the website and email feedback combined) to a no-intervention control group. Kelders *et al*[88]compared a 12-week web-based intervention with email newsletters and reminders to a waiting list control group whereas Lachausse *et al* [89] compared a 12-week interactive internet-based college nutrition and physical education course to no intervention. Hebden *et al* compared a 12-week intervention for young adults that combined mobile applications, text messages (2 per week, also sent as an email), internet forums, a one individual appointment with a dietitian and written materials to the dietitian appointment and written material alone [90].

*eHealth vs another delivery mode*

Two studies compared an eHealth weight gain prevention intervention to face-to-face delivery [20, 89]. Lachausse *et al* [89] compared a 12-week interactive internet-based college nutrition and physical education course to the program delivered via 12 face-to-face group sessions and found no significant differences in weight change between groups. Lombard *et al*[20] compared the effectiveness of a 12-month weight gain prevention intervention delivered in four one-hour group sessions and complemented by monthly text messages to usual care (1 face-to face-session). They found significant mean differences in weight change (-1.13kg, 95% CI -2.03 to -0.24kg, $p<0.05$) between groups from baseline to 12-months, with the usual care group gaining weight (0.83kg) and the intervention group losing weight (-0.20kg).

*Delivery of eHealth interventions*

Three studies compared a standard eHealth intervention to the same eHealth intervention with extra features/components or technologies, with all finding no significant differences between groups [87, 91, 92]. Gow *et al* [87] compared the effects of three 6-week interventions (email feedback, a web-based intervention, or the website plus email feedback combined). Van Genugten *et al* [91] compared the provision of a tailored module-based web-based weight gain prevention intervention (including goal setting, self-monitoring, a forum for social support, educational materials, reminder emails) to a generic website with general information about weight gain prevention. Winett *et al* [92] compared a basic (comprehensive 52-week module program based on social cognitive program) and enhanced (basic + detailed approach to self-regulation including tailored planning, feedback, and goal setting) version of a web-based weight gain prevention program. They found that participants on average lost 3% of initial body weight, but analysis of between group differences in weight change were not presented.

***Study characteristics potentially influencing outcomes and/or heterogeneity***

The influence of study quality, statistical analysis approach, intervention length, retention rates, publication year and continent of origin on the meta-analysis results were considered (Table 3). This was performed for the each of the previously reported meta-analyses for weight loss interventions (Figure 2 to 6). The analyses were not performed for the weight loss maintenance meta-analysis due to the small number of studies (n=3).

Study quality influenced the results for studies comparing eHealth interventions to control groups (p=0.04), with higher and moderate quality studies demonstrating significantly greater

mean difference in weight loss in the eHealth intervention group compared to the control group (Higher quality MD -3.19 [-3.89,-2.49], p<0.00001 n=6; Moderate quality MD -2.10 [-2.95,-1.25] p<0.00001 n=3). This result was not replicated in the other meta-analyses.

The statistical analysis approach influenced the results for eHealth intervention vs control studies (p=0.01) with studies that used an ITT approach demonstrating significantly greater differences in weight loss between the eHealth and control groups than the studies that presented completers analysis only (ITT -3.11 [-3.70,-2.51], p<0.00001 n=8; Completers -1.75 [-2.61, -0.90], p<0.0001 n=3). This result was not replicated for the other meta-analyses.

Interventions of less than 6 months in duration demonstrated a significantly greater mean difference in weight loss (p=0.009) between the eHealth and minimal interventions than the interventions of 6 months or more (<6 months -2.75 [-3.83, -1.66], p<0.00001 n=3; 6 months or more -1.09 [-1.69, -0.05], p=0.004 n=13). Studies comparing a standard eHealth intervention to an eHealth intervention with additional features demonstrated significantly greater (p=0.02) mean difference in weight change for interventions of 6 months or more in duration compared to those of less than 6 months (<6 months 0.78 [-0.01,1.56], p=0.06 n=7; 6 months or more 2.18 [1.34, 3.02], p<0.0001 n=7). No other meta-analyses demonstrated differences in mean weight change by intervention length.

There was a significant difference in mean weight change among studies comparing an eHealth intervention to a minimal intervention by retention rates (p=0.02). Studies with higher retention rates (80% or more) demonstrated significantly greater mean differences in weight loss (-2.06 [-2.73, -1.38] p<0.0001, n=9) than those studies where less than 80% of participants were retained (-0.07 [-1.21, 1.07], p=0.85, n=7). No other meta-analyses found differences in mean weight change by retention rates.

For studies that compared standard eHealth interventions to the same program with additional features, the year of publication significantly influenced results (p=0.02). Studies that were published before 2010 demonstrated a significantly greater mean difference in weight change (2.29 [1.28, 3.30], p<0.0001, n=8] compared to those published from 2010 onwards (0.84 [0.22,1.46], p=0.05 n=6]. Studies that compared an eHealth intervention to the same eHealth intervention combined with face-to-face sessions were also influenced by the year of publication, with the one study published from 2010 onwards demonstrating a significantly

greater mean weight change in the eHealth with face-to-face sessions compared to eHealth alone (0.84 [0.09, 1.59], p=0.03 n=6). Whereas the one study published before 2010 demonstrated a no difference in weight change between the two groups at post-intervention. No other meta-analyses found differences in mean weight change by year of publication.

Studies comparing a standard care intervention alone to standard care with eHealth demonstrated significantly greater (p=0.01) mean difference in weight change for an intervention conducted in Europe/UK compared to those conducted in North America (Europe UK -10.40 [-17.23, -3.57], p=0.003 n=1; North America -1.54 [-3.75, 0.68], p=0.17 n=6). Similarly, there was a trend (p=0.05) for studies comparing an eHealth intervention to a control group to demonstrate greater weight change if conducted in Australia or New Zealand, than Europe/UK or North America. No other meta-analyses found a difference in mean weight change by continent the study was undertaken.

**Discussion**

This systematic review of 84 randomized controlled trials is the first review to comprehensively consider all types of eHealth technology modes, as well as interventions for weight loss, weight loss maintenance and weight gain prevention among adults. This review provides a current synthesis of the evidence with over 70% (n=60) of the included studies published from 2010 onwards, including all of the weight gain prevention studies. A wide variety of research questions were explored and thus the evidence presented is diverse. The research questions included (i) determining the effectiveness of eHealth intervention compared to no or minimal intervention; (ii) comparing eHealth interventions to traditional modes of intervention delivery; and (iii) comparing the effectiveness of different eHealth interventions for weight loss, maintenance of lost weight and weight gain prevention. Most included studies (n = 66) focused on weight loss, with just 13 studies reporting results for weight loss maintenance, and eight evaluating weight gain prevention interventions. Meta-analyses conducted in the current review demonstrated that eHealth weight loss interventions achieved modest, but statistically significant weight loss compared to no or minimal treatment, and that eHealth interventions with extra features/components or technologies were more effective than standard programs, but there is insufficient evidence to determine whether eHealth weight loss maintenance or weight gain prevention interventions are effective.

***Weight loss interventions***

The two meta-analyses conducted found that eHealth interventions achieve greater post-intervention weight loss compared to no-intervention controls and minimal intervention groups. Two previous meta-analyses reported inconsistent findings for the difference in weight loss achieved by web-based [12] or computer-based [14] interventions compared to no or minimal intervention control groups. Neve *et al* [12] demonstrated in a meta-analysis of three studies no significant difference in weight change between the two groups. Conversely, Wieland *et al* [14] found significantly greater weight loss for computer-based interventions when two studies were meta-analyzed. Our results support and strengthen the results of Wieland *et al,* by meta-analyzing 10 and 16 studies respectively and confirmed that eHealth weight loss interventions achieve significantly greater weight loss than no-intervention controls and minimal intervention groups. Although the results are statistically significant, the clinical significance of the mean difference in weight loss of 1.4 and 2.7kg demonstrated in the current meta-analysis of eHealth interventions compared to no or minimal interventions, is inferior to traditional behavioral weight loss interventions (16 to 26 weeks of weekly group based lifestyle counselling whereby participants lose on average 10.7kg[93]). The potential of eHealth interventions for greater accessibility and affordability may offset some of the difference in weight loss.

However, this systematic review found there are currently an insufficient number of studies that have directly compared eHealth weight loss interventions to traditional modes of treatment delivery (e.g. face-to-face delivery). Interestingly, meta-analyses demonstrated that there was no difference in weight change when eHealth interventions were compared to eHealth interventions combined with face-to-face counselling. However, meta-analyses also indicated a trend (p=0.06) for greater weight loss when an eHealth intervention was added to standard care (typically face to face counselling), when compared to standard care alone. These two distinctive meta-analyses provide uncertain but optimistic evidence for the potential advantage of adding eHealth technologies to traditional treatment modes. Furthermore, they provide justification for the comparison of eHealth delivery of weight loss interventions to other treatment modalities to determine the most effective obesity treatment approach. Given the high prevalence of adult obesity worldwide, and therefore potential demands for treatment programs, a priority should be to establish the most effective treatment approaches and then disseminating them. These studies must also consider the differences in

reach, engagement and cost-effectiveness of the treatment approaches, for which there is currently limited evidence [94].

Using meta-analysis a previous review reported that web-based weight loss interventions with enhanced behavioral features (such as individualized counseling and feedback) have been shown to be more effective than those that provided education only [12]. However, the external validity of these results were questioned due to the small number of studies (n=3) included in the meta-analysis[12]. The current review included a larger number of studies (n=12) in the meta-analyses and also demonstrates significantly greater weight loss for eHealth interventions that include additional components (e.g. individualized feedback) or technologies (e.g. text messages), compared to standard eHealth programs. The potential impact of the eHealth interventions with additional features or technologies on other key outcomes such as participant engagement (e.g.[76] ), retention (e.g.[95]), behavior change (e.g [96]), along with the small but significant amount of additional weight loss achieved (i.e. 1.5kg greater weight loss) provide some support for preferential use of such eHealth interventions for obesity treatment.

Of interest is the analysis stratified by year of publication, which demonstrates that only studies published before 2010 produced a significantly greater mean difference in weight loss between the standard programs when compared to those with enhanced features, suggesting more recent studies have been unable to demonstrate additional weight loss effects from these enhanced features. This difference is most likely due to the nature of the 'standard' eHealth programs in earlier studies, whereby only information was provided without interactive components. The studies were therefore evaluating the addition of 'enhanced' features that are already well-recognized behavioral weight control strategies, such as self-monitoring and personalized feedback/counselling. More recent studies provide these key behavioral weight control features as part of their 'standard' programs, and are instead evaluating whether providing 'more' of those features (e.g. Collins *et al* providing more email/online feedback [35]) or providing them in a different way (e.g. Napolitano *et al* addition of text messages [38]) further increases program effectiveness. Therefore, while our meta-analysis results support the use of eHealth weight loss interventions that provide evidence-based weight control strategies, they do not specifically highlight which behavioral features and/or eHealth technologies are most imperative, and in what dose (i.e. timing, frequency, duration). This research question can potentially be answered via statistical analysis of the association

between usage of eHealth program components and weight loss, to determine which program component is most predictive of weight loss success (e.g. [97, 98]). However, obesity researchers must also give greater consideration to their study designs in order to answer this research question. Collins *et al* recommend considering the Multiphase Optimization Strategy (MOST) as a research approach to the systematic design of eHealth interventions with appropriate program components provided at the ideal dose [99] . While this approach has been used for other eHealth interventions (e.g. smoking cessation), only one weight loss intervention has utilized this approach to date, and that study is currently ongoing [100].

In studies comparing eHealth weight loss interventions to minimal interventions, shorter intervention durations (<6 months) were shown to demonstrate significantly greater mean difference in weight change between groups, than interventions 6-months or more. This is consistent with traditional weight loss programs [93] which are also more effective in the short term. For eHealth interventions specifically it is likely due to the well documented poor intervention engagement with eHealth interventions, whereby usage declines over the longer term [101]. This is consistent with our finding in the meta-analysis comparing standard eHealth weight loss interventions to standard eHealth programs with additional features, whereby there was a significantly greater mean difference in weight change between groups for interventions of 6-months or more. Many of the studies focused on evaluating 'additional features' because these features may facilitate engagement over time. For example, Collins and colleagues demonstrated no significant difference in weight loss after 6-months for a basic vs. enhanced web-based commercial program, but found a significantly higher proportion of enhanced group participants who attended 6-month followed-up appointments and logged-on to the website over the 6-months[35]. Although beyond the scope of this systematic review, these findings highlight the potential influence of user-engagement on intervention effectiveness. Therefore, future systematic reviews could specifically evaluate how participant usage of eHealth interventions influences weight change, and other treatment outcomes.

***Weight loss maintenance***

Two previous meta-analyses have suggested that web and computer-based weight loss maintenance interventions achieve significantly greater weight loss maintenance than minimal or no intervention control groups [12, 14]. Neve *et al* combined two studies and found the web-based intervention groups regained significantly less weight than the control groups

at post-intervention (WMD −0.30 [−0.34,−0.26] $P < 0.0001$]) but concluded further research was required due to only two studies being included [12]. Similarly, Wieland *et al* concluded that computer-based weight loss maintenance interventions resulted in lower levels of weight regain compared to a minimal or no treatment condition[14]. This conclusion was based on a series of meta-analyses which found the computer based interventions produced significantly less weight regain after 6 (n=2), 12 (n=3) and 24 months (n=1), but not 18 (n=2) or 30 months (n=1). The same three studies included in Wieland *et al*'s systematic review were included in our meta-analysis, but we evaluated the level of weight change from pre to post weight loss maintenance intervention irrespective of intervention length (Figure 7) in all three studies collectively. We found no significant difference in weight change between the eHealth weight loss maintenance intervention and the control group. Therefore, our systematic review does not provide evidence that eHealth interventions are effective for weight loss maintenance and hence further high quality studies are needed to determine their effectiveness.

Previous meta-analyses have also highlighted that web- and computer-based interventions may achieve similar weight loss maintenance to face-to-face programs[12, 14]. Both studies acknowledged the high heterogeneity across the included studies, and therefore the uncertainty of the results[12, 14]. Although the literature searches for these previous reviews were completed in May 2011 and April 2008 respectively, no new studies were identified by this review. Therefore, further high quality multi-arm randomized controlled trials comparing the effectiveness of eHealth interventions to control groups (minimal/no treatment) and other treatment modalities (e.g. face-to-face individual or group sessions, telephone counselling) are required.

***Weight gain prevention***

Despite obesity prevention being described as the most practical, cost-effective and effective way to combat the high prevalence of overweight and obesity among adults, previous systematic reviews of obesity prevention interventions for adults have highlighted limited research in the area [102, 103]. The findings of this review are consistent with the previous reviews, with only eight weight gain prevention studies included. Due to the differences in study aims, intervention types and duration, there are still too few studies to evaluate the effectiveness of eHealth interventions for weight gain prevention. Given the broader population based approach required for weight gain prevention, coupled with the accessibility

and population interest in eHealth technologies, further intervention development and evaluation in this area is required.

***Types of eHealth interventions***

Overall, this systematic review highlights the diversity of the ways in which technology is being used for the treatment and prevention of obesity among adults. Although websites were the most commonly used technology, a growing number of researchers are investigating the use of other technologies such as email, text messages, monitoring devices and mobile phone applications. More studies are testing technologies in combination rather than isolation, with approximately 40% of the included interventions using more than one type of technology. More recent studies were more likely to utilize new technologies, or multiple technologies, highlighting the rapidly changing technology environment. Many of the included interventions incorporated non-eHealth components (e.g. face-to-face, telephone counselling, written materials), with less than half (43%) of the interventions being solely delivered via technology. The intervention dose delivered using non-eHealth components also varied greatly (e.g. from one face-to-face orientation session up to 52 telephone counselling calls). Due to the diversity in the types and dose of 'eHealth' used across the included studies, as well as changes in the capabilities of individual technologies over time, it is challenging to determine what components of eHealth interventions are effective.

To help address the diversity of eHealth intervention design across the included studies, we acknowledged the types of eHealth technologies and whether an intervention was delivered exclusively using eHealth technologies or with other non-eHealth components via sub-group analyses within the meta-analyses. These analyses are a strength of this review, as a recent systematic review of reviews of self-directed weight loss interventions recommended that a comprehensive review be undertaken that considers multiple delivery formats [104]. Most notably, the mean difference in weight loss between eHealth interventions with non-eHealth intervention components and minimal intervention groups, were significantly greater than the mean difference between eHealth interventions alone and control/minimal intervention groups. The non-eHealth components predominantly included face-to-face group or individual sessions or telephone counselling. These results suggest that direct human contact may help intensify the effect of eHealth technologies. Therefore, further research to determine the most appropriate dose of eHealth vs non-eHealth technologies to achieve significant weight loss in the most resource efficient manner is warranted.

Another important finding of these analyses was that addition of a monitoring device or mobile application to standard care achieved significantly greater weight loss than standard care alone, whereas the addition of other eHealth technologies (website/computer) to standard care was no more effective. Three out of the four monitoring device studies provided participants with a wearable device to monitor their physical activity (Body Media Sense Wear), which was downloaded to a website for them to track their activity. With the growing popularity and availability of wearable devices to monitor physical activity (e.g. Jawbone UP, Fitbit, Shine), as well as promising early developments of similar ubiquitous approaches to monitor and evaluate dietary intake and eating habits (e.g.[105, 106]) further investigations of monitoring devices to potentially enhance traditional and eHealth interventions is warranted. Similarly, the effective mobile application was also used for self-monitoring, but of weight and food intake. Participants were provided with automated feedback on their energy intake, as well as opportunities for social networking with other participants. Therefore, the use of mobile applications for self-monitoring as part of a weight management intervention may also offer a cost-effective and engaging adjunct to existing treatment options. However, despite the multitude of mobile applications currently freely available to the public, few have been rigorously evaluated.

***Study quality and characteristics***

Overall the majority of studies included within the review were of moderate-to-high quality. The main methodological weaknesses of included studies included failing to report the method of randomization, allocation concealment and assessor blinding. To improve the quality and reporting of studies we suggest future studies attend to these aspects of study design.

Most studies (n=56) were of 6-month duration or less, and one third (n=30) 3-months or less, with very few following-up participants beyond the completion of the intervention. The 3- to 6-month period is likely to be the most important in terms of success in weight control. Retention rates, at an average of 78% at post-intervention, were consistent with other lifestyle weight loss interventions[93]. However, retention rates varied considerably (16 to 98%). Most studies (73%, n=61) conducted ITT analysis. The ITT analysis results were included in the meta-analysis for those studies for which is was available, but otherwise results from completer's analysis were included. Finally, although the review grouped and compared

studies based on their intervention (e.g. web-based, text-message) and comparator arms (e.g. no intervention, minimal intervention) this grouping does not account for differences between the studies (e.g. minimal interventions providing written information compared to a one-off face-to-face session). Differences in study characteristics, including but not limited to intervention components and duration, comparator arms, retention rates, or approaches to analysis may have influenced the individual study, and collective results of the review, and under or overestimated the true effectiveness of the eHealth interventions.

The additional analyses of study characteristics that may have influenced outcomes or heterogeneity revealed additional significant results, although they were not consistent across all meta-analyses. Similar to the results of Kodama *et al* [11], factors such as poor study quality, no ITT analysis and low retention rates, all negatively influenced the mean difference demonstrated between groups for at least one meta-analysis. This finding highlights the importance examining how different study characteristics may influence overall results and/or study heterogeneity via sub-group analyses within meta-analysis, and the importance of interpreting the meta-analysis results with caution.

Participant characteristics across the included studies were similar with the majority recruiting predominantly female middle-aged participants. Although many studies failed to report the socio-economic status or ethnicity of the participants, those that did were largely well-educated and 'white'. One of the potential benefits of eHealth technologies commonly identified is their ability to reach diverse population groups. However, the majority of studies conducted to date have failed to evaluate eHealth interventions amongst diverse population groups, and therefore the external validity of the results is questionable. Future studies should attempt to recruit more heterogeneous population groups, including more males; young and older adults; and socio-economically and ethnically diverse samples; to help determine whether eHealth interventions work for the population groups most in-need of intervention. This may be achieved through the use of more innovative recruitment strategies than traditional leaflets or media releases. For example to reach young women Leonard *et al* [107]recommended the use of social media. In addition, greater engagement of vulnerable groups may be achieved by ensuring that eHealth interventions are relevant. This can be achieved through the use of formative research to determine the target groups intervention preferences (e.g. [108]) or adaptive interventions that provide a variety of treatment options tailored to individual user characteristics (e.g. baseline characteristics, response to treatment).

Factorial research designs such as Sequential Multiple Assignment Randomized Trials (SMART) have been recommended for the design of adaptive eHealth interventions[99].

*Strengths and limitations*

Strengths of this systematic review include that it is of robust methodological quality, completed as per the PRISMA statement. A limitation is that only studies published in English were included. In addition, this review reports intervention effectiveness using absolute weight change, as few studies reported percentage weight change. Absolute weight change does not allow for direct comparison of intervention results, due to potential baseline differences in weight.

Finally, although this systematic review provides a comprehensive evaluation of a range of eHealth technologies, it largely assumes that other than treatment delivery mode, the interventions were comparable. Therefore, it does not consider the potential impact of individual and co-occurring intervention components (e.g., social support, self-monitoring, feedback, use of theoretical frameworks), the varying modes of delivery of these components, the frequency and/or intensity at which the intervention components were delivered, nor whether participants actually engaged with the interventions components. As per the recommendations of a recent review of reviews[104], future systematic reviews could specifically evaluate how differences in type, combination, mode of delivery, intensity and use of eHealth intervention components influences weight change, and other treatment outcomes. However, such an evaluation would rely heavily on published manuscripts providing an ample description of all intervention components, which was limited for many of the included studies. Therefore, researchers should be encouraged to publish study protocols or descriptions of intervention development methods, to provide sufficient details of intervention components for such a systematic review to be adequately conducted [109].

## Conclusion

### *Implications for practice*

eHealth weight loss interventions achieve modest weight loss (-1.4 to -2.7 kg) at post intervention compared to no or minimal treatment, and therefore offer an additional obesity treatment option. In addition eHealth weight loss interventions with evidence-based behavioral features (e.g. self-monitoring, personalized feedback) also appear to achieve significantly greater weight loss (-1.5kg). However, at this point, no specific

recommendations can be made regarding what intervention components that are necessary for successful weight loss. Despite some promising results from individual studies, there is insufficient evidence to recommend the use of eHealth interventions for weight loss maintenance or weight gain prevention. Overall, while the evidence is inconclusive, current research suggests that individuals considering eHealth weight loss interventions should be encouraged to choose programs with evidence-based behavioral features (e.g. self-monitoring, personalized feedback, social support) that incorporate monitoring devices (e.g. accelerometers) for self-monitoring. To potentially improve accountability individuals may choose a program that incorporates non-eHealth components (e.g. face to face appointments, telephone counselling) although these may not be imperative to success.

***Implications for research***

Overall, while great advances have been made in this research area in recent years due to a rapidly growing number of research studies being undertaken, a more coordinated approach is required to enrich the current evidence base. Research conducted to date, and particularly the number of studies published since 2010 show evidence of a somewhat ad hoc approach. Researchers need to give greater consideration to how their research is contributing to the existing evidence-base, and how their research question and design will provide a meaningful contribution to determining whether eHealth interventions are an effective treatment option. In summary, future research evaluating eHealth interventions for the treatment and prevention of overweight and obesity in adults should:

- Compare eHealth interventions to other treatment modalities to determine which treatment modality is most effective. 'Effectiveness' should consider weight, behavior and health-related outcomes, as well as cost-effectiveness, reach and engagement.
- Investigate weight loss maintenance and weight gain prevention interventions. Ideally, such studies would be multi-arm and compare the eHealth intervention to other treatment modalities, as well as a control group.
- Undertake secondary analyses or consider using the MOST approach to determine which specific eHealth technologies and behavioral components/features are essential, and in what dose (i.e. timing, frequency and duration). Such studies must determine whether eHealth only approaches are effective, or if some traditional forms of contact (e.g. face-to-face or telephone sessions) are imperative to success.

- Give greater consideration to individual treatment preferences and engagement with different eHealth technologies/features and/or other treatment modalities in order to improve the reach of eHealth interventions. This may be achieved through the creation and evaluation of adaptive eHealth interventions. Factorial research designs, such as SMART, may be used to achieve this aim.
- Recruit and engage more heterogeneous population groups, in terms of sex, age and socio-demographic status.
- Comprehensively describe the eHealth interventions being investigated to allow future systematic reviews to analyze the impact of intervention components on weight loss outcomes.
- Evaluate the long-term impact of eHealth interventions to determine if behavior changes are sustained beyond the intervention period, and result in long-term weight control.
- Present results as mean percentage weight change to allow comparability across studies and to be used in future meta-analyses of eHealth interventions.

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1 **Table 1 Summary of study characteristics**

| | | |
|---|---|---|
| Publication year (primary outcomes paper) | Prior to 2000 n (%) | 0 (0) |
| | 2001-2005 n (%) | 8 (9.5%) |
| | 2006-2009 n (%) | 18 (21.4%) |
| | 2010-2014 n (%) | 58 (69.1%) |
| Continent/Country | North America (United States or Canada) n (%) | 63 (75.0%) |
| | Europe/UK n (%) | 10 (10.8%) |
| | Australia and New Zealand n (%) | 8 (9.6%) |
| | Asia n (%) | 2 (2.4%) |
| | Multisite/country n (%) | 1 (1.2%) |
| Number of participants | Total number | 24010 |
| | Mean | 286 |
| | Median | 126 |
| | Range | 20 to 2862 |
| Gender | Mean Female% | 74.8% |
| | All female n (%) | 13 (15.5%) |
| | All male n (%) | 4 (4.8%) |
| Mean age of study sample | <35 years n (%) | 8 (9.5%) |
| | 35- 65 years n (%) | 69 (82.1%) |
| | > 65 years n (%) | 0 (0%) |
| | Not reported n (%) | 7 (8.3%) |
| Ethnicity/Race | ≥80% defined as 'white' | 31 (36.9%) |
| | <80% defined as 'white' | 29 (34.5%) |
| | Not reported | 24 (28.6%) |
| Education level | ≥50% with college/university degree | 42 (50.0%) |
| | <50% with college/university degree | 7 (8.3%) |
| | Not reported | 35 (41.7%) |
| Purpose of intervention | Weight loss n (%) | 61 (72.6%) |
| | Weight loss maintenance n (%) | 10 (11.9%) |
| | Weight gain prevention n (%) | 8 (9.5%) |
| | Weight loss and weight loss maintenance n (%) | 5 (6.0%) |
| Targeted sample | No BMI criteria n (%) | 8 (9.5%) |
| | Healthy weight, overweight and obese n (%) | 4 (4.8%) |
| | Healthy weight and overweight n (%) | 1 (1.2%) |
| | Overweight only n (%) | 1 (1.2%) |
| | Obese only n (%) | 9 (10.7%) |

| | | |
|---|---|---|
| | Overweight and obese n (%) | 61 (72.6%) |
| Duration of intervention | ≤3 months n (%) | 30 (35.7%) |
| | >3 to <6months n (%) | 5 (6.0%) |
| | 6- <12 months n (%) | 25 (29.8%) |
| | 12- <18 months n (%) | 18 (21.4%) |
| | 18 to 24 months n (%) | 2 (2.4%) |
| | ≥24 months n (%) | 4 (4.8%) |
| Retention rates at post-intervention | Range | 16 to 98% |
| | ≥90% n (%) | 21 (25.0%) |
| | ≥80% to <90% n (%) | 28 (33.3%) |
| | ≥60 to <80% n (%) | 26 (31.0%) |
| | <60% n (%) | 8 (9.5%) |
| | Not reported | 1 (1.2%) |
| Passive follow-up | Has follow-up n (%) | 14 (16.7%) |
| | No follow-up n (%) | 70 (83.3%) |
| Retention rates at passive follow-up | Range n (%) | 11 to 91% |
| | ≥90% n (%) | 1 (7.1%) |
| | ≥80% to <90% n (%) | 5 (35.7%) |
| | ≥60 to <80% n (%) | 3 (21.4%) |
| | <60% n (%) | 5 (35.7%) |

1

2

3

**Table 2 Results of analysis of influence of study characteristics on five eHealth weight loss intervention meta-analysis**

| | | *Number of studies* | *Number of participants* | Sub-group results | | | | Sub-group differences | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Mean difference (95 % CI), kg* | $I^2$ (%) | P-*value for heterogeneity* | Significance | $I^2$ (%) | Significance |
| ***eHealth vs control*** | | | | | | | | | |
| Study quality | Higher | 6 | 1040 | -3.19 [-3.89,-2.49] | 44 | 0.11 | <0.00001 | 68.6% | 0.04 |
| | Moderate | 3 | 272 | -2.10 [-2.95,-1.25] | 0 | 0.92 | <0.00001 | | |
| | Lower | 2 | 51 | -1.26 [-2.99,0.47] | 29 | 0.24 | 0.15 | | |
| Analysis approach | ITT | 8 | 1224 | -3.11 [-3.70,-2.51] | 28 | 0.20 | <0.00001 | 84.5% | 0.01 |
| | Completers | 3 | 139 | -1.75 [-2.61,-0.90] | 4 | 0.34 | <0.0001 | | |
| Intervention length | <6 months | 8 | 738 | -2.82 [-3.52,-2.12] | 59 | 0.02 | <0.00001 | 11.3% | 0.29 |
| | 6 months or more | 3 | 625 | -1.95[-3.40,-0.51] | 0 | 0.58 | 0.008 | | |
| Retention rates | 80% or more | 8 | 738 | -2.82 [-3.52,-2.12] | 59 | 0.02 | <0.00001 | 11.3% | 0.29 |
| | <80% | 3 | 625 | -1.95[-3.40,-0.51] | 0 | 0.58 | 0.008 | | |
| Publication year | 2010 onwards | 9 | 1134 | -2.57 [-3.28,-1.86] | 51 | 0.04 | <0.00001 | 0% | 0.41 |
| | Before 2010 | 2 | 229 | -3.25 [-4.70, -1.79] | 47 | 0.17 | <0.001 | | |
| Continent/ country | North America | 6 | 715 | -2.02 [-2.78, -1.25] | 13 | 0.33 | <0.00001 | 67.5% | 0.05 |
| | Europe/UK | 4 | 524 | -2.40 [-4.09, -0.71] | 48 | 0.12 | 0.005 | | |
| | Australia and New Zealand | 1 | 124 | -3.39 [-4.17, -2.61] | NA | NA | <0.00001 | | |
| ***eHealth vs minimal intervention*** | | | | | | | | | |
| Study quality | Higher | 5 | 1851 | -1.18 [-2.46, 0.10] | 72 | 0.007 | 0.07 | 0% | 0.56 |
| | Moderate | 9 | 907 | -1.67 [-2.69, -0.64] | 74 | 0.0001 | 0.001 | | |
| | Lower | 2 | 300 | -1.10 [-1.24, -0.96] | 0 | 0.77 | <0.00001 | | |
| Analysis approach | ITT | 12 | 2468 | -1.34 [-2.22, -0.47] | 76 | <0.0001 | 0.003 | 0% | 0.99 |
| | Completers | 4 | 590 | -1.35 [-2.05, -0.66] | 29 | 0.24 | 0.0001 | | |
| Intervention length | <6 months | 3 | 216 | -2.75 [-3.83,-1.66] | 26 | 0.26 | <0.00001 | 85.3% | 0.009 |
| | 6 months or more | 13 | 2842 | -1.09 [-1.69,-0.50] | 67 | 0.0002 | 0.0003 | | |
| Retention rates | 80% or more | 9 | 1537 | -2.06 [-2.73,-1.38] | 74 | 0.001 | <0.00001 | 88.4% | 0.003 |
| | <80% | 7 | 1521 | -0.07 [-1.21, 1.07] | 57 | 0.03 | 0.90 | | |
| Publication year | 2010 onwards | 12 | 2660 | -1.72 [-2.35, -1.09] | 69 | 0.0002 | <0.00001 | 52.3% | 0.15 |
| | Before 2010 | 4 | 398 | -0.35 [-2.09, 1.40] | 79 | 0.003 | 0.70 | | |
| Continent/ | North America | 13 | 1843 | -1.63 [-2.33, -0.93] | 74 | <0.00001 | <0.00001 | 16.5% | 0.30 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| country | Europe/UK | 3 | 1210 | -0.51 [-1.79, 0.77] | NA | NA | 0.09 | | |
| | Australia and New Zealand | 1 | 65 | -1.80 [-3.89, 0.29] | 56 | 0.10 | 0.43 | | |
| ***Standard eHealth vs standard eHealth + additional eHealth features*** | | | | | | | | | |
| Study quality | Higher | 4 | 586 | 2.37 [0.70,4.04] | 62 | 0.05 | 0.005 | 17.9% | 0.30 |
| | Moderate | 8 | 941 | 1.10 [0.33,1.86] | 63 | 0.009 | 0.005 | | |
| | Lower | 2 | 54 | 3.50 [-2.09,9.09] | 50 | 0.16 | 0.22 | | |
| Analysis approach | ITT | 11 | 1460 | 1.73 [1.04,2.42] | 58 | 0.008 | <0.00001 | 57.1% | 0.13 |
| | Completers | 3 | 121 | 0.03 [-2.05,2.10] | 67 | 0.05 | 0.98 | | |
| Intervention length | <6 months | 7 | 702 | 0.78 [-0.01, 1.56] | 53 | 0.05 | 0.06 | 82.5% | 0.02 |
| | 6 months or more | 7 | 879 | 2.18 [1.34,3.02] | 35 | 0.16 | <0.0001 | | |
| Retention rates | 80% or more | 8 | 948 | 1.38 [0.50,2.26] | 66 | 0.004 | 0.002 | 0% | 0.74 |
| | <80% | 6 | 633 | 1.62 [0.57,2.66] | 47 | 0.09 | 0.002 | | |
| Publication year | 2010 onwards | 6 | 964 | 0.84 [0.22,1.46] | 44 | 0.12 | 0.008 | 82.6% | 0.02 |
| | Before 2010 | 8 | 617 | 2.29 [1.28,3.30] | 41 | 0.11 | <0.0001 | | |
| Continent/ country | North America | 13 | 1280 | 1.54 [0.81, 2.27] | 63 | 0.001 | <0.0001 | 0% | 0.38 |
| | Australia and New Zealand | 1 | 301 | 0.90 [-0.32, 2.12] | NA | NA | 0.15 | | |
| ***Standard care vs standard care with eHealth*** | | | | | | | | | |
| Study quality | Moderate | 6 | 724 | -2.24 [-4.89,0.42] | 84 | <0.0001 | 0.10 | 0 | 0.73 |
| | Lower | 1 | 34 | -2.90 [-5.63, -0.17] | NA | NA | 0.04 | | |
| Analysis approach | ITT | 6 | 724 | -2.24 [-4.89,0.42] | 84 | <0.0001 | 0.10 | 0 | 0.73 |
| | Completers | 1 | 34 | -2.90 [-5.63, -0.17] | NA | NA | 0.04 | | |
| Intervention length | <6 months | 2 | 150 | -0.82 [-3.06, 1.42] | 64 | 0.09 | 0.47 | 30.5% | 0.23 |
| | 6 months or more | 5 | 608 | -3.77 [-8.04, 0.50] | 87 | <0.0001 | 0.08 | | |
| Retention rates | 80% or more | 3 | 481 | -2.30 [-6.91, 2.32] | 90 | <0.0001 | 0.33 | 0 | 0.89 |
| | <80% | 4 | 277 | -2.67 [-5.65,0.30] | 71 | 0.02 | 0.08 | | |
| Publication year | 2010 onwards | 5 | 597 | -1.46 [-4.05,1.12] | 82 | 0.0002 | 0.27 | 0 | 0.34 |
| | Before 2010 | 2 | 161 | -5.59 [-13.62,2.44] | 81 | 0.02 | 0.17 | | |
| Continent/ country | North America | 6 | 636 | -1.54 [-3.75, 0.68] | 81 | <0.0001 | 0.17 | 82.9% | 0.02 |
| | Europe/UK | 1 | 122 | -10.40 [-17.23,-3.57] | NA | NA | 0.003 | | |
| ***eHealth vs eHealth + face-to-face sessions*** | | | | | | | | | |
| Study quality | Moderate | 4 | 599 | 0.63 [0.16, 1.42] | 0 | 0.69 | 0.12 | 0 | 0.78 |
| | Lower | 3 | 174 | 0.38 [-1.23, 1.98] | 74 | 0.02 | 0.65 | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Analysis approach | ITT | 4 | 583 | 0.21 [-0.71, 1.12] | 35 | 0.20 | 0.65 | 39.2% | 0.2 |
| | Completers | 3 | 190 | 1.16 [0.03, 2.30] | 30 | 0.24 | 0.05 | | |
| Retention rates | 80% or more | 1 | 140 | 0.70 [-0.60, 2.00] | NA | NA | 0.29 | 0 | 0.83 |
| | <80% | 6 | 634 | 0.53 [-0.32,1.38] | 45 | 0.10 | 0.22 | | |
| Publication year | 2010 onwards | 6 | 650 | 0.84 [0.09, 1,59] | 0 | 0.43 | 0.03 | 76.7% | 0.04 |
| | Before 2010 | 1 | 123 | -1.60 [-3.78,0.58] | NA | NA | 0.15 | | |
| Continent/ country | North America | 5 | 636 | 0.53 [-0.71, 1.76] | 50 | 0.09 | 0.41 | 0% | 0.42 |
| | Europe/UK | 2 | 137 | 1.42 [-0.35,3.18] | 0 | 0.67 | 0.11 | | |

**List of Figures:**