

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

3

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18

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21

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24

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5 **Potential Conflicts of Interest**

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

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12

1 **Abstract**

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

1 **Introduction**

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

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

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

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

3

4 **Methods**

5 This systematic review was conducted using a pre-defined protocol registered with
6 PROSPERO (CRD42013004425)

7 http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42013004425

8

9 ***Criteria for study inclusion***

10 *Types of participants:* Adults aged ≥ 18 years.

11 *Types of interventions:* Behavioral weight loss, weight loss maintenance or weight
12 maintenance/weight gain prevention interventions delivered using eHealth exclusively and/or
13 as a component of the intervention. ‘eHealth’ included Internet, computers, including tablets,
14 e-mail, personal digital assistants (PDAs), mobile/smartphones, and digital games.

15 *Types of comparators:* No intervention control group, standard care or another delivery mode
16 (e.g. face-to-face), or another eHealth intervention.

17 *Types of outcomes:* A weight-related primary outcome (e.g. weight, body mass index,
18 percentage body fat, waist circumference).

19 *Types of studies:* Randomized controlled trials published in the English language

20

21 ***Literature search***

22 Eight databases (The Cochrane Library, MEDLINE/PREMEDLINE, EMBASE, CINAHL,
23 Web of Science, Scopus, PubMed, and PsycINFO) were searched using pre-determined
24 keywords and index terms with searches limited to studies published in English from 1995 to
25 17th September 2014 (Supporting Information Table S1 Search Syntax). The reference lists of
26 all retrieved articles and relevant systematic reviews identified by the search were also
27 searched.

28

29 ***Study selection***

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

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

3

4 ***Risk of bias***

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

9

10 ***Data extraction***

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

15

16 ***Data synthesis***

17 Results were described in a narrative summary. Weight-related results were pooled in meta-
18 analysis if they were available as either change scores or final values, the number of
19 participants was recorded, and interventions and comparators were sufficiently similar for
20 comparison. If standard deviations (SD) were not available but other statistics (e.g. 95% CI or
21 standard errors) were available they were converted to SD¹⁷. If results were reported in
22 imperial units (pounds), they were converted to metric units (kilograms). If more than one
23 intervention arm from a study was eligible for inclusion in a meta-analysis, the sample size of
24 the shared comparator group was divided by the number of arms included to avoid the
25 participants being counted multiple times¹⁷. Heterogeneity was assessed by I² statistics, and
26 considered to be low if I² was ≤40%, and high if I² was ≥75%. A random effects model for
27 meta-analysis was used if there was significant heterogeneity (I² >40%), and fixed effects
28 when homogeneous (I² ≤ 40%)¹⁷. The data from individual studies were combined using
29 mean difference (MD). All meta-analyses were conducted using Review Manager (RevMan)
30 Analyses Version 5.2 (Copenhagen: The Nordic Cochrane Centre, The Cochrane
31 Collaboration, 2012). Studies included in each meta-analysis were evaluated for potential
32 publication bias by visual evaluation of funnel plots for each meta-analysis in RevMan. No
33 evidence of publication bias was evident with studies distributed symmetrically around the
34 mean.

1 Within each meta-analysis, studies were grouped by the primary type of eHealth intervention
2 (e.g. web, mobile, computer) and whether the intervention was delivered solely using eHealth
3 technologies or included other non-eHealth components. In addition, all weight loss meta-
4 analyses were repeated with studies grouped by key study characteristics to explore what
5 characteristics may have influenced outcomes and/or study heterogeneity. The characteristics
6 included: study quality (higher; moderate; lower); statistical analysis approach (intention to
7 treat (ITT); completers); length of intervention (<6 months; 6-months or more); retention
8 rates at post-intervention (80% or more; <80%); date of publication (2010 onwards; Prior to
9 2010), and continent where the intervention was undertaken (North America/US; Europe/UK;
10 Australia/New Zealand; Asia)

11

12 **Results**

13 *Description of included studies*

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

19

20 Fifty four studies had two study arms, 24 had three, five had four and one had five. The
21 length of interventions ranged from six weeks to 30 months. Thirty study interventions
22 (35.7%) were three months or shorter in duration, 25 were six to <12-months (29.8%) and 18
23 12 to <18-months (21.4%). The majority of studies assessed outcomes at pre and post
24 intervention. The mean retention rate at post-intervention was 78 ± 17 (Range 16 to 98%),
25 with 58.3% (n= 49) studies with retention rates $\geq 80\%$ at post-intervention. The 14 studies with
26 later follow-up included intervention durations ranging from one month to 12-months. Only
27 14 studies (16.7%) assessed outcomes at later follow-up. The follow-ups occurred as early as
28 two weeks after the completion of the intervention up to 18-months, but most (n=8) were
29 between three and/or six months after the completion of the intervention. Retention rates
30 ranged from 11 to 91% at later follow-up, with 6 out of 14 studies achieving retention rates
31 $\geq 80\%$.

32

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

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

4
5 The total number of participants across all studies was 24010, with sample sizes ranging from
6 20 to 2862 (Mean 286±473. Median 126). The average age of participants in most studies
7 (82.1%, n=69) ranged from 35 to 65 years. The mean percentage of females across the
8 included studies was 74.8%, with 13 studies including only females¹⁸⁻²⁵ and 4 only males²⁶⁻
9²⁹. The majority of studies included both overweight and obese individuals (72.6%, n=61).
10 Many studies did not provide a description of the socio-economic status (41.7%, n=35 did not
11 report education level). Of those that did, most included predominantly (≥50%) college
12 educated participants (50.0%, n=42). There were an almost equal number of studies that
13 reported a predominantly (≥80%) 'white' sample (36.9%, n=31) to those that did not (34.5%,
14 n=29). The majority (n=72, 85.7%) of included studies presented results as absolute weight
15 change or weight at post intervention and 36.9% (n=31) presented results as percentage
16 weight change. Therefore, results are presented as absolute weight change.

17 18 ***Risk of bias of included studies***

19 Twenty-three (27.4%) of studies were classified as higher quality, 67.9% (n=57) moderate
20 quality and 10.7% (n=9) lower quality (Supporting Information Table S3 Methodological
21 Quality of Included Studies). All studies measured outcomes consistently for both groups,
22 and the majority treated groups identically other than the stated intervention (97.6%, n=82)
23 and used appropriate statistical analysis (96.4%, n=81). Many studies conducted ITT analysis
24 (72.6%, n=61), reported that study groups were comparable at entry (n=65, 77.4%), and
25 measured outcomes in a reliable manner (78.6%, n=66). Notably, eight studies (9.5%) used
26 self-reported weight as the primary outcome. Approximately half of the studies (51.2%,
27 n=43) randomly allocated participants to study groups using appropriate methods, however
28 46.4% (n=39) did not describe the randomization method. Only 36.9% of studies (n=31)
29 reported whether allocation to treatment groups was blinded, of which 29 (35.4%) used
30 appropriate allocation concealment methods. Only one quarter of studies (n=21) reported
31 assessor blinding. Only nine studies (10.7%) reported participant blinding, although this was
32 not feasible for the majority of intervention designs.

1 ***Description of eHealth interventions***

2 The 84 included studies had a total of 205 study arms, of which 183 were active intervention
3 arms. Of the 183 intervention arms, 76.0% (n=139) had at least one component that was
4 delivered using eHealth. Less than half of these interventions (43.2%, n=60) were delivered
5 solely using eHealth technologies. Of the 139 interventions delivered using eHealth, 60.4%
6 (n=84) used only one type of technology, 33.8% (n=47) used two, 5.0% three (n=7) and one
7 intervention five types of technology. Seventy-eight percent of interventions used the
8 internet/website (n=109), 33.8% email (n=47), 9.4% text messages (n=13), 7.9% a
9 monitoring device (n=11), 5.0% a mobile application (n=7), 4.3% a computer program (n=6),
10 2.9% podcasts (n=4), and 2.2% PDA (n=3). Of the 59 eHealth intervention arms that
11 included non-ehealth components, the non-eHealth intervention components were delivered
12 in written/paper-based form (e.g. educational materials, self-monitoring diaries); via
13 telephone (e.g. feedback, counselling or reminders to participate in eHealth components); via
14 face-to-face individual or group sessions (e.g. for education or counselling) or via DVD (e.g.
15 for education). The level of use of non-eHealth components varied considerably across the
16 interventions arms, with the number of contacts (e.g. number of face-to-face sessions, paper-
17 based resources) with a different non-eHealth component ranging from one to 52.

18

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

20 *eHealth interventions vs control*

21 Thirty studies compared an eHealth weight loss intervention to a control group^{18, 21, 25-52}. Ten
22 of these studies evaluated interventions that were delivered using eHealth only^{21, 29, 35, 37, 38, 41,}
23 ^{44, 46, 47, 52}, seven of which were delivered primarily via a website^{21, 29, 35, 37, 38, 44, 47}, two via
24 mobile devices (one text message⁴¹ and one text message plus application⁴⁶), and one using
25 a combination of website, email and smart scales⁵². The remaining 20 studies evaluated
26 interventions that incorporated eHealth combined with other delivery modes (e.g. face-to-
27 face, telephone counselling, written materials)^{18, 25-28, 30-34, 36, 39, 40, 42, 43, 45}. At the individual
28 study level, 21 of the 30 studies^{18, 26, 27, 30-36, 38, 39, 44-52} reported significantly greater weight
29 loss in the eHealth intervention compared to a control group. The studies were further divided
30 into those that included a true control group (i.e. no intervention)^{21, 26, 27, 33, 35, 38, 40, 46, 47, 52} and
31 those that were described as a control group but provided a minimal intervention^{18, 25, 28-32, 34,}
32 ^{36, 37, 39, 41-45}^{18, 25-28, 30-34, 36, 39, 40, 42, 43, 45, 48-51}. The minimal interventions predominantly
33 included the provision of self-help written materials (e.g. dietary guidelines)^{18, 25, 29-32, 34, 36, 37,}
34 ^{39, 41, 43-45, 48-50}, with three studies including a one-off face to face group session^{28, 42, 51}.

1

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

11

12 The second meta-analysis (Figure 3) pooled 16 studies that compared weight change in
13 eHealth interventions ($n = 9$ web^{18, 25, 28, 30-32, 37, 44, 48}, $n = 3$ mobile text messaging^{39, 41 51}, $n = 2$
14 computer^{34, 45}, $n = 2$ monitoring device^{42, 43}) to a control group that received a minimal
15 intervention. The studies were significantly heterogeneous ($I^2 = 72\%$, $p < 0.001$) and there was
16 a significantly greater decrease in weight (kg) in the eHealth interventions at post-
17 intervention (MD -1.40 [-1.98,-0.82], $p < 0.0001$) compared to the minimal intervention group.
18 There were also significant differences by intervention sub-group type ($p = 0.005$), with only
19 website, mobile text-messaging and computer-based interventions that were combined with
20 other non eHealth intervention components demonstrating significantly greater weight loss in
21 the intervention compared to the minimal intervention group (website MD -2.65 [-3.76,-
22 1.54], $p < 0.0001$, $n = 6$; mobile text messaging MD -1.81 [-2.49,-1.12], $p < 0.0001$, $n = 2$; and
23 computer MD -1.13 [-1.36, -0.89], $p < 0.0001$, $n = 2$).

24

25 *eHealth interventions vs another mode of delivery*

26 Six studies compared an eHealth weight loss intervention to an intervention delivered using a
27 non-eHealth medium. Four studies found no significant difference in weight loss at post
28 intervention between the two groups. These studies compared: a 9-month web-based
29 intervention with a device to monitor physical activity to a face-to-face group weight loss
30 program⁴³; a 6-month web-based intervention to weekly tele-counselling with written
31 materials⁴⁴; a 6-months of intensive face-to-face counselling to a self-management
32 intervention delivered using a mobile application⁵³; and a 6-month predominantly text
33 message and email-based intervention to two face-to face sessions combined with a video

1 series⁵⁴. Conversely, two studies found significantly greater weight loss in the intervention
2 delivered using non-eHealth medium. Harvey-Berino *et al*⁵⁵ found significantly greater
3 weight loss was achieved in a 6-month weight loss program with face-to-face group
4 meetings, compared to online meetings (-8.0±6.1kg vs. -5.5±5.6kg, p<0.01). Sullivan *et al*
5 demonstrated significantly greater weight loss in a weekly group-based clinic for 3-months
6 delivered face-to-face, compared with virtual reality (10.8% vs. 7.6%, p<0.05)⁵⁶.

7
8 Nine studies^{33, 53, 55, 57-62} compared an eHealth intervention to the same eHealth intervention
9 combined with another mode of delivery. Six of the studies compared an eHealth intervention
10 alone (website n=5 and mobile application n=1) to the eHealth intervention combined with
11 face-to-face sessions^{53, 55, 57, 59, 60, 62}. Two studies compared the provision of a web-based
12 program alone to a web-based program with portion controlled foods/meal replacements^{58, 61}.
13 Chamblis *et al*³³ compared daily web-based self-monitoring, weekly automated email
14 counselling/feedback and face-to-face contact consisting of three individual and one group
15 sessions, to the same intervention plus monthly telephone counselling, email newsletters and
16 an extra 1-hour group session that focused on behavioral weight management strategies. At
17 an the individual level, seven of the studies found no significant difference in weight loss
18 between the two groups at post-intervention^{33, 53, 55, 58, 60-62} Whereas, two studies demonstrated
19 greater weight loss in a eHealth group with face-to-face sessions, compared to a eHealth
20 intervention alone^{57, 59}.

21
22 Five studies with seven intervention arms were combined in meta-analysis to compare weight
23 change (kg) at post-intervention (Figure 4) in an eHealth intervention alone versus eHealth
24 combined with face-to-face sessions. The studies were homogenous ($I^2 = 34\%$, p=0.17) with
25 no significant difference in weight change between eHealth only and eHealth plus face-to-
26 face sessions groups (MD 0.58 [-0.13, 1.29], p=0.11) at post-intervention. There was no
27 significant difference in results by eHealth medium sub-group (i.e. website or mobile
28 application delivery).

29
30 Seven studies^{43, 53, 55, 63-66} evaluated whether the addition of eHealth technologies to a
31 standard care weight loss intervention typically delivered face-to-face influenced the weight
32 loss achieved. At the individual study level, two of the studies^{63, 65} found greater weight loss
33 at post-intervention among participants randomized to the standard care intervention plus
34 eHealth technologies, four^{43, 53, 64, 66} found no significant difference in weight loss between

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

9

10 *Comparisons of eHealth-delivered interventions*

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

19

20 Fourteen of the studies investigated the addition of intervention features, such as self-
21 monitoring tools, feedback, reminders to engage with the program, email counselling, online
22 group meetings/discussion groups and online lessons to web-based weight loss programs ^{22-24,}
23 ^{35, 58, 59, 68, 70-72, 75-78}. Five of the studies investigated different approaches to the delivery of the
24 intervention: focusing on diet or diet and exercise ⁶⁷; providing a directive intervention versus
25 non-directive participant driven intervention ⁶⁹; standard motivational interviewing compared
26 to motivational interviewing with the addition of values discussion ²⁴; providing automated
27 versus personalized email counselling to participants ⁷⁷; and delivering standard podcast
28 versus podcasts based on social cognitive theory ⁷⁴. Two studies evaluated the effect of
29 adding a new technology to an eHealth intervention ^{38, 73}. Napolitano *et al* ³⁸ evaluated the
30 addition of text messages to an intervention delivered via social networking site Facebook.
31 Turner McGrievy *et al* ⁷³ investigated the addition of a Smartphone application for self-
32 monitoring, as well as social networking (Twitter) to an existing theory-based series of
33 podcasts.

34

1 At the individual level, 11 of the studies reported significantly greater weight loss with the
2 addition of new intervention features and/or new technologies^{22, 38, 58, 59, 70, 72, 74-78}, eight
3 found no between group differences in weight loss^{23, 24, 35, 67, 69, 71, 73, 75} and one study did not
4 report the significance of the results⁶⁸ Twelve of the studies, with 13 intervention arms, were
5 combined in a meta-analysis (Figure 6) and were shown to be significantly heterogeneous
6 ($I^2 = 60\%$, $P = 0.002$). Significantly greater weight loss was achieved in the group with the
7 additional features delivered using eHealth technologies (MD 1.46 [0.80, 2.13], $p < 0.001$)
8 compared to the standard eHealth program. There were no significant sub-group differences
9 ($p = 0.08$) for type of eHealth intervention.

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

12 *eHealth vs control*

13 Seven studies compared an eHealth weight loss maintenance intervention to a control or
14 minimal intervention group^{19, 79-84}. Six of the studies evaluated interventions that were
15 delivered primarily using eHealth (four Internet, one email, one text message)^{19, 79-82, 84}. The
16 other study combined a web-based weight loss maintenance intervention with face-to-face
17 counselling sessions (one individual and three group sessions)⁸³. Five of the studies' control
18 groups were self-directed/no intervention groups^{19, 79, 81-83}, one provided written materials
19 only⁸⁴ and one provided general health related text messages⁸⁰. Six of the studies found no
20 significant difference in weight change between the eHealth and control groups from pre to
21 post the weight loss maintenance intervention^{19, 79-82, 84}. One of the studies found no
22 significant difference in weight change between the two groups from baseline of the weight
23 loss phase to after the weight loss maintenance intervention⁸³. Three of the studies were
24 combined in meta-analysis (Figure 7) and were homogenous ($I^2 = 0\%$, $p = 0.99$). There was
25 no significant difference in weight change between groups from pre to post a weight loss
26 maintenance intervention (MD -0.27 [-0.96, 0.42] $p = 0.44$).

28 *eHealth vs another mode of delivery*

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

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

11

12 *Comparison of eHealth delivery*

13 One study compared a self-directed commercial web-based program (eDiets) to a therapist
14 led behavioral web-based program (Vtrim), which included a 6-month weight loss phase and
15 a 6-month weight loss maintenance phase. They found the behavioral program (VTrim)
16 participants maintained a greater weight loss at 12-months (7.8±7.5kg) than the commercial
17 program (3.4±5.8kg, p=0.002)⁷⁰. Another study compared the use of daily text messaging for
18 based on regulatory focus theory that were either approach or prevention based⁸⁰ and found
19 no significant difference in the sustained weight loss between the two groups after 3-months.

20

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

22 *eHealth vs control*

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

34

1 *eHealth vs another delivery mode*

2 Two studies compared an eHealth weight gain prevention intervention to face-to-face
3 delivery^{20, 89}. Lachausse *et al*⁸⁹ compared a 12-week interactive internet-based college
4 nutrition and physical education course to the program delivered via 12 face-to-face group
5 sessions and found no significant differences in weight change between groups. Lombard *et*
6 *al*²⁰ compared the effectiveness of a 12-month weight gain prevention intervention delivered
7 in four one-hour group sessions and complemented by monthly text messages to usual care (1
8 face-to face-session). They found significant mean differences in weight change (-1.13kg,
9 95% CI -2.03 to -0.24kg, p<0.05) between groups from baseline to 12-months, with the usual
10 care group gaining weight (0.83kg) and the intervention group losing weight (-0.20kg).

11

12 *Delivery of eHealth interventions*

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

25

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

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

32

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

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

4
5 The statistical analysis approach influenced the results for eHealth intervention vs control
6 studies ($p=0.01$) with studies that used an ITT approach demonstrating significantly greater
7 differences in weight loss between the eHealth and control groups than the studies that
8 presented completers analysis only (ITT -3.11 [-3.70,-2.51], $p<0.00001$ $n=8$; Completers -
9 1.75 [-2.61, -0.90], $p<0.0001$ $n=3$). This result was not replicated for the other meta-analyses.

10
11 Interventions of less than 6 months in duration demonstrated a significantly greater mean
12 difference in weight loss ($p=0.009$) between the eHealth and minimal interventions than the
13 interventions of 6 months or more (<6 months -2.75 [-3.83, -1.66], $p<0.00001$ $n=3$; 6 months
14 or more -1.09 [-1.69, -0.05], $p=0.004$ $n=13$). Studies comparing a standard eHealth
15 intervention to an eHealth intervention with additional features demonstrated significantly
16 greater ($p=0.02$) mean difference in weight change for interventions of 6 months or more in
17 duration compared to those of less than 6 months (<6 months 0.78 [-0.01,1.56], $p=0.06$ $n=7$;
18 6 months or more 2.18 [1.34, 3.02], $p<0.0001$ $n=7$). No other meta-analyses demonstrated
19 differences in mean weight change by intervention length.

20
21 There was a significant difference in mean weight change among studies comparing an
22 eHealth intervention to a minimal intervention by retention rates ($p=0.02$). Studies with
23 higher retention rates (80% or more) demonstrated significantly greater mean differences in
24 weight loss (-2.06 [-2.73, -1.38] $p<0.0001$, $n=9$) than those studies where less than 80% of
25 participants were retained (-0.07 [-1.21, 1.07], $p=0.85$, $n=7$). No other meta-analyses found
26 differences in mean weight change by retention rates.

27
28 For studies that compared standard eHealth interventions to the same program with additional
29 features, the year of publication significantly influenced results ($p=0.02$). Studies that were
30 published before 2010 demonstrated a significantly greater mean difference in weight change
31 (2.29 [1.28, 3.30], $p<0.0001$, $n=8$) compared to those published from 2010 onwards (0.84
32 [0.22,1.46], $p=0.05$ $n=6$). Studies that compared an eHealth intervention to the same eHealth
33 intervention combined with face-to-face sessions were also influenced by the year of
34 publication, with the one study published from 2010 onwards demonstrating a significantly

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

5
6 Studies comparing a standard care intervention alone to standard care with eHealth
7 demonstrated significantly greater ($p=0.01$) mean difference in weight change for an
8 intervention conducted in Europe/UK compared to those conducted in North America
9 (Europe UK -10.40 [-17.23, -3.57], $p=0.003$ $n=1$; North America -1.54 [-3.75, 0.68], $p=0.17$
10 $n=6$). Similarly, there was a trend ($p=0.05$) for studies comparing an eHealth intervention to a
11 control group to demonstrate greater weight change if conducted in Australia or New
12 Zealand, than Europe/UK or North America. No other meta-analyses found a difference in
13 mean weight change by continent the study was undertaken.

14 15 **Discussion**

16 This systematic review of 84 randomized controlled trials is the first review to
17 comprehensively consider all types of eHealth technology modes, as well as interventions for
18 weight loss, weight loss maintenance and weight gain prevention among adults. This review
19 provides a current synthesis of the evidence with over 70% ($n=60$) of the included studies
20 published from 2010 onwards, including all of the weight gain prevention studies. A wide
21 variety of research questions were explored and thus the evidence presented is diverse. The
22 research questions included (i) determining the effectiveness of eHealth intervention
23 compared to no or minimal intervention; (ii) comparing eHealth interventions to traditional
24 modes of intervention delivery; and (iii) comparing the effectiveness of different eHealth
25 interventions for weight loss, maintenance of lost weight and weight gain prevention. Most
26 included studies ($n = 66$) focused on weight loss, with just 13 studies reporting results for
27 weight loss maintenance, and eight evaluating weight gain prevention interventions.

28 **Meta-analyses conducted in the current review demonstrated that eHealth weight loss**
29 **interventions achieved modest, but statistically significant weight loss compared to no or**
30 **minimal treatment,** and that eHealth interventions with extra features/components or
31 technologies were more effective than standard programs, but there is insufficient evidence to
32 determine whether eHealth weight loss maintenance or weight gain prevention interventions
33 are effective.

34

1 *Weight loss interventions*

2 The two meta-analyses conducted found that eHealth interventions achieve greater post-
3 intervention weight loss compared to no-intervention controls and minimal intervention
4 groups. Two previous meta-analyses reported inconsistent findings for the difference in
5 weight loss achieved by web-based ¹² or computer-based ¹⁴ interventions compared to no or
6 minimal intervention control groups. Neve *et al* ¹² demonstrated in a meta-analysis of three
7 studies no significant difference in weight change between the two groups. Conversely,
8 Wieland *et al* ¹⁴ found significantly greater weight loss for computer-based interventions
9 when two studies were meta-analyzed. Our results support and strengthen the results of
10 Wieland *et al*, by meta-analyzing 10 and 16 studies respectively and confirmed that eHealth
11 weight loss interventions achieve significantly greater weight loss than no-intervention
12 controls and minimal intervention groups. Although the results are statistically significant,
13 the clinical significance of the mean difference in weight loss of 1.4 and 2.7kg demonstrated
14 in the current meta-analysis of eHealth interventions compared to no or minimal
15 interventions, is inferior to traditional behavioral weight loss interventions (16 to 26 weeks of
16 weekly group based lifestyle counselling whereby participants lose on average 10.7kg⁹³).
17 The potential of eHealth interventions for greater accessibility and affordability may offset
18 some of the difference in weight loss.

19

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

1 reach, engagement and cost-effectiveness of the treatment approaches, for which there is
2 currently limited evidence⁹⁴.

3
4 Using meta-analysis a previous review reported that web-based weight loss interventions
5 with enhanced behavioral features (such as individualized counseling and feedback) have
6 been shown to be more effective than those that provided education only¹². However, the
7 external validity of these results were questioned due to the small number of studies (n=3)
8 included in the meta-analysis¹². The current review included a larger number of studies
9 (n=12) in the meta-analyses and also demonstrates significantly greater weight loss for
10 eHealth interventions that include additional components (e.g. individualized feedback) or
11 technologies (e.g. text messages), compared to standard eHealth programs. The potential
12 impact of the eHealth interventions with additional features or technologies on other key
13 outcomes such as participant engagement (e.g.⁷⁶), retention (e.g.⁹⁵), behavior change (e.g.⁹⁶),
14 along with the small but significant amount of additional weight loss achieved (i.e. 1.5kg
15 greater weight loss) provide some support for preferential use of such eHealth interventions
16 for obesity treatment.

17
18 Of interest is the analysis stratified by year of publication, which demonstrates that only
19 studies published before 2010 produced a significantly greater mean difference in weight loss
20 between the standard programs when compared to those with enhanced features, suggesting
21 more recent studies have been unable to demonstrate additional weight loss effects from these
22 enhanced features. This difference is most likely due to the nature of the ‘standard’ eHealth
23 programs in earlier studies, whereby only information was provided without interactive
24 components. The studies were therefore evaluating the addition of ‘enhanced’ features that
25 are already well-recognized behavioral weight control strategies, such as self-monitoring and
26 personalized feedback/counselling. More recent studies provide these key behavioral weight
27 control features as part of their ‘standard’ programs, and are instead evaluating whether
28 providing ‘more’ of those features (e.g. Collins *et al* providing more email/online feedback
29³⁵) or providing them in a different way (e.g. Napolitano *et al* addition of text messages³⁸)
30 further increases program effectiveness. Therefore, while our meta-analysis results support
31 the use of eHealth weight loss interventions that provide evidence-based weight control
32 strategies, they do not specifically highlight which behavioral features and/or eHealth
33 technologies are most imperative, and in what dose (i.e. timing, frequency, duration). This
34 research question can potentially be answered via statistical analysis of the association

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

9
10 In studies comparing eHealth weight loss interventions to minimal interventions, shorter
11 intervention durations (<6 months) were shown to demonstrate significantly greater mean
12 difference in weight change between groups, than interventions 6-months or more. This is
13 consistent with traditional weight loss programs ⁹³ which are also more effective in the short
14 term. For eHealth interventions specifically it is likely due to the well documented poor
15 intervention engagement with eHealth interventions, whereby usage declines over the longer
16 term ¹⁰¹. This is consistent with our finding in the meta-analysis comparing standard eHealth
17 weight loss interventions to standard eHealth programs with additional features, whereby
18 there was a significantly greater mean difference in weight change between groups for
19 interventions of 6-months or more. Many of the studies focused on evaluating ‘additional
20 features’ because these features may facilitate engagement over time. For example, Collins
21 and colleagues demonstrated no significant difference in weight loss after 6-months for a
22 basic vs. enhanced web-based commercial program, but found a significantly higher
23 proportion of enhanced group participants who attended 6-month followed-up appointments
24 and logged-on to the website over the 6-months³⁵. Although beyond the scope of this
25 systematic review, these findings highlight the potential influence of user-engagement on
26 intervention effectiveness. Therefore, future systematic reviews could specifically evaluate
27 how participant usage of eHealth interventions influences weight change, and other treatment
28 outcomes.

30 ***Weight loss maintenance***

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

1 at post-intervention (WMD -0.30 [$-0.34, -0.26$] $P < 0.0001$) but concluded further research
2 was required due to only two studies being included¹². Similarly, Wieland *et al* concluded
3 that computer-based weight loss maintenance interventions resulted in lower levels of weight
4 regain compared to a minimal or no treatment condition¹⁴. This conclusion was based on a
5 series of meta-analyses which found the computer based interventions produced significantly
6 less weight regain after 6 (n=2), 12 (n=3) and 24 months (n=1), but not 18 (n=2) or 30
7 months (n=1). The same three studies included in Wieland *et al*'s systematic review were
8 included in our meta-analysis, but we evaluated the level of weight change from pre to post
9 weight loss maintenance intervention irrespective of intervention length (Figure 7) in all three
10 studies collectively. We found no significant difference in weight change between the
11 eHealth weight loss maintenance intervention and the control group. **Therefore, our**
12 **systematic review does not provide evidence that eHealth interventions are effective for**
13 **weight loss maintenance and hence further high quality studies are needed to determine their**
14 **effectiveness.**

15
16 Previous meta-analyses have also highlighted that web- and computer-based interventions
17 may achieve similar weight loss maintenance to face-to-face programs^{12, 14}. Both studies
18 acknowledged the high heterogeneity across the included studies, and therefore the
19 uncertainty of the results^{12, 14}. Although the literature searches for these previous reviews
20 were completed in May 2011 and April 2008 respectively, no new studies were identified by
21 this review. Therefore, further high quality multi-arm randomized controlled trials comparing
22 the effectiveness of eHealth interventions to control groups (minimal/no treatment) and other
23 treatment modalities (e.g. face-to-face individual or group sessions, telephone counselling)
24 are required.

25 26 ***Weight gain prevention***

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

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

3

4 *Types of eHealth interventions*

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

17 **Due to the diversity in the types and dose of ‘eHealth’ used across the included studies, as
18 well as changes in the capabilities of individual technologies over time, it is challenging to
19 determine what components of eHealth interventions are effective.**

20

21 To help address the diversity of eHealth intervention design across the included studies, we
22 acknowledged the types of eHealth technologies and whether an intervention was delivered
23 exclusively using eHealth technologies or with other non-eHealth components via sub-group
24 analyses within the meta-analyses. These analyses are a strength of this review, as a recent
25 systematic review of reviews of self-directed weight loss interventions recommended that a
26 comprehensive review be undertaken that considers multiple delivery formats¹⁰⁴. Most
27 notably, the mean difference in weight loss between eHealth interventions with non-eHealth
28 intervention components and minimal intervention groups, were significantly greater than the
29 mean difference between eHealth interventions alone and control/minimal intervention
30 groups. The non-eHealth components predominantly included face-to-face group or
31 individual sessions or telephone counselling. These results suggest that direct human contact
32 may help intensify the effect of eHealth technologies. Therefore, further research to
33 determine the most appropriate dose of eHealth vs non-eHealth technologies to achieve
34 significant weight loss in the most resource efficient manner is warranted.

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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 interventions⁹³. 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 it was available, but otherwise results from completer's analysis were included. Finally, although the review grouped and compared

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

8

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

17

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

1 Factorial research designs such as Sequential Multiple Assignment Randomized Trials
2 (SMART) have been recommended for the design of adaptive eHealth interventions⁹⁹.

3

4 *Strengths and limitations*

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

11

12 Finally, although this systematic review provides a comprehensive evaluation of a range of
13 eHealth technologies, it largely assumes that other than treatment delivery mode, the
14 interventions were comparable. Therefore, it does not consider the potential impact of
15 individual and co-occurring intervention components (e.g., social support, self-monitoring,
16 feedback, use of theoretical frameworks), the varying modes of delivery of these components,
17 the frequency and/or intensity at which the intervention components were delivered, nor
18 whether participants actually engaged with the interventions components. As per the
19 recommendations of a recent review of reviews¹⁰⁴, future systematic reviews could
20 specifically evaluate how differences in type, combination, mode of delivery, intensity and
21 use of eHealth intervention components influences weight change, and other treatment
22 outcomes. However, such an evaluation would rely heavily on published manuscripts
23 providing an ample description of all intervention components, which was limited for many
24 of the included studies. Therefore, researchers should be encouraged to publish study
25 protocols or descriptions of intervention development methods, to provide sufficient details
26 of intervention components for such a systematic review to be adequately conducted ¹⁰⁹.

27

28 **Conclusion**

29 *Implications for practice*

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

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

11

12 *Implications for research*

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

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

- 1 • Give greater consideration to individual treatment preferences and engagement with
2 different eHealth technologies/features and/or other treatment modalities in order to
3 improve the reach of eHealth interventions. This may be achieved through the creation and
4 evaluation of adaptive eHealth interventions. Factorial research designs, such as SMART,
5 may be used to achieve this aim.
- 6 • Recruit and engage more heterogeneous population groups, in terms of sex, age and socio-
7 demographic status.
- 8 • Comprehensively describe the eHealth interventions being investigated to allow future
9 systematic reviews to analyze the impact of intervention components on weight loss
10 outcomes.
- 11 • Evaluate the long-term impact of eHealth interventions to determine if behavior changes
12 are sustained beyond the intervention period, and result in long-term weight control.
- 13 • Present results as mean percentage weight change to allow comparability across studies
14 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%)

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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
<i>eHealth vs control</i>									
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		
<i>eHealth vs minimal intervention</i>									
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		
<i>Standard eHealth vs standard eHealth + additional eHealth features</i>									
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		
<i>Standard care vs standard care with eHealth</i>									
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		
<i>eHealth vs eHealth + face-to-face sessions</i>									
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		

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