

## Systematic Review and Meta Analyses

# Impact of digital technologies for communicating messages on weight loss maintenance: a systematic literature review

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**Background:** Research into the use of digital technology for weight loss maintenance (intentionally losing at least 10% of initial body weight and actively maintaining it) is limited. The aim of this article was to systematically review randomized controlled trials (RCTs) reporting on the use of digital technologies for communicating on weight loss maintenance to determine its effectiveness, and identify gaps and areas for further research. **Methods:** A systematic literature review was conducted by searching electronic databases to locate publications dated between 2006 and February 2018. Criteria were applied, and RCTs using digital technologies for weight loss maintenance were selected. **Results:** Seven RCTs were selected from a total of 6541 hits after de-duplication and criteria applied. Three trials used text messaging, one used e-mail, one used a web-based system and two compared such a system with face-to-face contact. From the seven RCTs, one included children ( $n=141$ ) and reported no difference in BMI Standard Deviation between groups. From the seven trials, four reported that technology is effective for significantly aiding weight loss maintenance compared with control (no contact) or face-to-face contact in the short term (between 3 and 24 months). **Conclusions:** It was concluded that digital technologies have the potential to be effective communication tools for significantly aiding weight loss maintenance, especially in the short term (from 3 to 24 months). Further research is required into the long-term effectiveness of contemporary technologies.

## Introduction

Obesity is a key health priority on a global scale.<sup>1</sup> The World Health Organization<sup>1</sup> defined obesity as body mass index (BMI) greater than 30 kg/m<sup>2</sup>, and overweight as BMI greater than 25 kg/m<sup>2</sup>. Obesity and overweight are recognized worldwide as significant risk factors for several non-communicable diseases, such as type two diabetes, stroke, cancer and cardiovascular diseases. Internationally, there are currently approximately 600 million adults are obese, and around 1.9 billion are overweight.<sup>1</sup> On a global scale, more people die due to obesity and overweight than due to underweight (BMI less than 18.5 kg/m<sup>2</sup>).<sup>1</sup> Health authorities recognize that even losing 3% of body weight will significantly improve health outcomes.<sup>2</sup> Weight loss is difficult, but for many individuals the even greater challenge is maintaining weight that has been lost.

Research by Moorhead *et al.*<sup>3</sup> highlighted the importance of effective health communication and suggested that while successful communication provides positive benefits, it is often hindered by complex and conflicting information. It was reported that health messages communicated by professionals are most effective when they are accurate, honest and sensitive, but health professionals regarded obesity as a sensitive and challenging subject to address. Many health professionals have referred to discussing obesity with patients to bearing bad news.<sup>3</sup>

The use of digital technology in healthcare is increasing. Several types of digital health technologies exist.<sup>4</sup> Some of these are specialized systems for health professionals, such as disease diagnosis tools, training systems, patient management systems and

communication tools. There are also numerous personal health apps available for use on smart devices. These fulfil a range of functions, from diabetes management to personal diet planners. A recent review of the thirteen most popular nutrition related mobile apps in Google and Apple stores identified significant limitations of these apps.<sup>5</sup> For example, the ability connecting app users with healthcare professionals was identified as a useful function, but only one of the thirteen apps actually possessed this functionality.<sup>5</sup> The potential use of technology for weight loss is a topic of contemporary research.

The University of Auckland's DIET (Dietary Interventions: Evidence and Translation) programme is an example of contemporary research into the use of technology for healthcare. This research programme aims to develop innovative healthcare practices, and consists of five core projects investigating the effects of factors such as food labelling, food prices, salt, fat and sugar consumption and environment on public health.<sup>6</sup> One such project, the Starlight trial was a randomized controlled trial (RCT) of a smartphone-based food label analysis tool [Food Label Trial (FLT)].<sup>6</sup> From the 3000 users who downloaded the application, 1500 were eligible (New Zealand residents, smartphone owners and the main shopper for their household, making at least one weekly supermarket visit) and participated.<sup>7</sup> The FLT is recognized as one of the first smartphone apps for delivering fully automated RCTs. Early testing identified great potential for RCTs delivered by smartphone, in terms of both data collection and intervention delivery.<sup>6</sup>

There is evidence to suggest that digital technologies are effective for weight management (preventing weight gain or stopping weight

gain where a steady increase in weight has been observed<sup>8</sup>), however, there is limited research into their effectiveness for weight loss maintenance. The definition of weight loss maintenance is 'intentionally losing at least 10% of initial body weight and keeping it off for at least 1 year'.<sup>9</sup> However, the most relevant RCTs available and thus included in this article, include participants who have only just lost weight and now are trying to actively maintain this weight loss. Thus, for the purposes of this article, weight loss maintenance is defined as 'weight loss maintenance is intentionally losing at least 10% of initial body weight and actively maintaining it'.

The aim of this article was to systematically review RCTs reporting on the use of digital technologies for communicating on weight loss maintenance to determine its' effectiveness, and identify gaps and areas for further research.

## Methods

This systematic review followed PRISMA guidelines<sup>10</sup> and used a systematic approach to retrieve relevant articles. The PRISMA diagram for the process is presented in figure 1. The literature search was performed in February 2018 using the following electronic databases: EMBASE, MEDLINE and PubMed (2006–February 2018). The search was designed to focus on the key concepts of 'Digital Technologies' and 'Weight Loss Maintenance'. Each concept was expanded to consider possible keywords (e.g. Digital Technologies: Cell phones, Smartphones, Mobile Applications, Telemedicine) and variations (e.g. Smartphone, smart phone, smartphones). These were used to develop a search term (e.g. smartphone\* OR smart phone\*) and all search terms were combined into the final search string, which is included in Supplementary appendix S1. Searching the above databases returned 6538 hits. A further three papers were identified during full text screening. In total, 6541 papers were identified.

Titles and abstracts were screened for duplication, relevance and to determine if they met the inclusion criteria. Articles were selected for inclusion if they fulfil the inclusion and exclusion criteria as outlined in table 1. These studies focused on weight loss maintenance using digital technologies, and where weight loss maintenance was the primary outcome. Articles were excluded if weight loss maintenance was a secondary outcome, where no digital technologies were used, if the participants were undergoing treatment for diseases (such as cancer or cardiovascular diseases), or if they were pregnant. Articles using digital technologies to facilitate treatment or management of other conditions (such as diabetes or smoking) were excluded. Two researchers (S.H. and A.M.) independently reviewed the studies and reached consensus on inclusion and number of papers to be included in this review.

From the searches, seven final papers reported on RCTs, and thus were included in our review. As childhood obesity is a growing global epidemic, especially in the UK, and as it has been reported that obese children can become obese adults<sup>11,12</sup> an RCT<sup>13</sup> involving obese children was included. Measuring obesity is different for adults and children, as BMI is used to indicate obesity in adults, but in this included RCT involving children BMI standard deviation was used.

## Results

The seven identified trials are summarized by aim, sample, intervention arms, data collection tools, outcome measures, key results, conclusions and implications for weight loss maintenance in table 2. A range of technologies were used for intervention delivery, these were text messaging,<sup>13–15</sup> e-mail<sup>16</sup> and web-based systems.<sup>17–19</sup> A diverse range of outcome measures were included and they all included change (kg or %) in body weight.

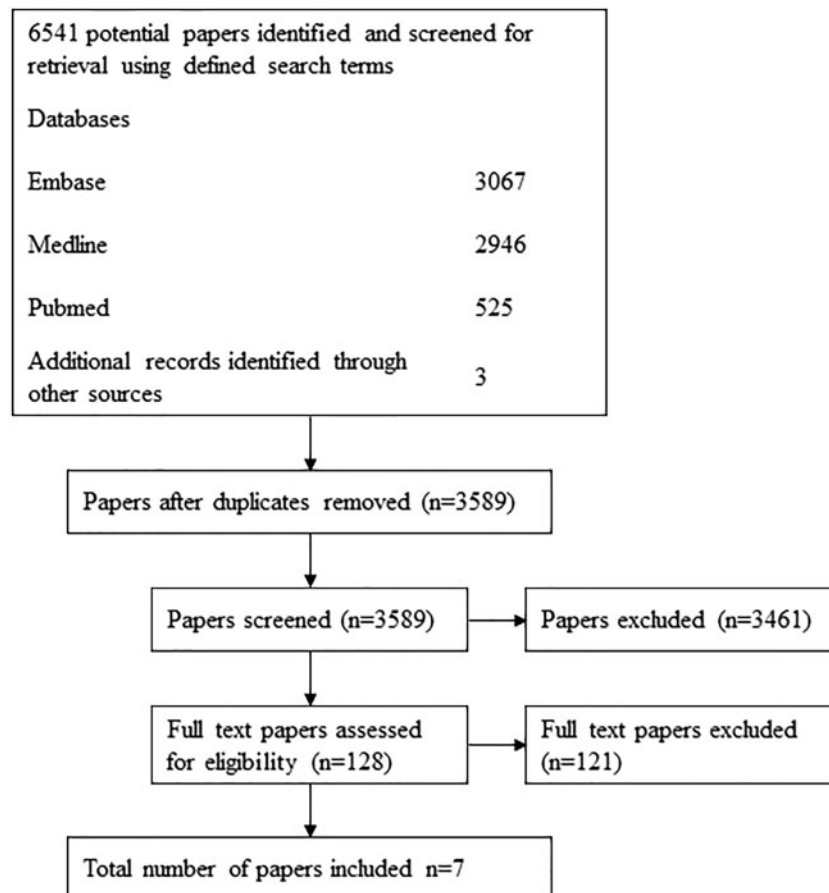


Figure 1 The PRISMA diagram

**Table 1** Inclusion and exclusion criteria for screening articles

Inclusion	Exclusion
Dated 2006–February 2018	Dated before 2006
Written in English	
Focusing on weight loss maintenance	Focusing on disorders such as hypertension, diabetes, irritable bowel disorder or eating disorders
	Focusing on drug addiction or smoking cessation (even if obesity mentioned)
	Focusing on healthy lifestyles, diet or exercise as primary outcomes
Relating to cancer if weight loss maintenance is the primary outcome	Focusing on cancer prevention
Relating to pregnancy if weight loss maintenance is the primary outcome	Relating to pregnancy related disorders such as gestational diabetes mellitus
Digital health technologies only, e.g. text message based systems, e-mail, websites	Non-digital technologies, e.g. drugs, portion control plates
Other relevant developments, e.g. development of technologies, participant feedback, suggested app functionality	
Written in English	Not related to weight loss maintenance and contains nothing else relevant

### Participants

The total number of participants across all trials was 1939, and the mean was 277. The minimum number of participants used in a single trial was 34,<sup>14</sup> and the maximum was 1032.<sup>19</sup> Participants in all but one trial<sup>13</sup> had previously completed structured weight loss interventions. All but one trial<sup>13</sup> included only adult participants. This remaining trial included only children aged between 7 and 12 years (participants were engaged in an existing intervention).<sup>13</sup> One trial included only women.<sup>18</sup>

Participant demographic data were reported for all trials<sup>13–15,17–19</sup> except one.<sup>16</sup> All trials recruited more women than men participants. There were almost three times as many female participants per trial (mean 63%) as there were male (mean 22%). The mean age of children in the study where they were included was 9.9 years.<sup>13</sup> The mean age of adults in trials was 44.5 years.

### Trial duration

The mode trial duration was 6 months.<sup>15,16</sup> The shortest trial ran for 3 months<sup>14</sup> and the longest for 30 months,<sup>19</sup> which also included the largest number of participants. The mean trial duration was 12 months.

### Intervention type

Five trials included two arms,<sup>13–16,18</sup> while two compared two different intervention styles (face-to-face and technology-based) with a control arm.<sup>17,19</sup> Three trials used text messaging for intervention delivery,<sup>13–15</sup> three used internet-based systems<sup>17–19</sup> and one used e-mail.<sup>16</sup>

### Text messaging

Short Messaging Service Maintenance Treatment<sup>13</sup> was an add-on to 'Big Friends Club', a Dutch healthy lifestyle intervention for children aged 7–12 years. Both group participants transitioned as normal into BFC phase two,<sup>13</sup> the less intensive, post 3-month phase, however, intervention group participants' phase two participation was augmented by weekly self-reporting by text-message of physical activity, diet and mood.<sup>13</sup> Participants received tailored feedback messages based on previous self-reports.<sup>13</sup>

Lifestyle Eating and Activity Programme (LEAP) Beep<sup>14</sup> followed on from the NHS Lifestyle Eating and Activity Programme (LEAP), led by a dietitian. All participants self-reported by text-message one day a week and at weekends,<sup>14</sup> however, while the control group received no responses, the intervention group received tailored feedback, which was either congratulatory or motivational (if goals had not been met).<sup>14</sup>

Get Healthy Stay Healthy (GSH)<sup>15</sup> followed on from the Australian Get Healthy Information & Coaching Service (GHS), a telephone-based weight loss coaching initiative.<sup>15</sup> Participants in the GSH intervention group set goals and identified rewards, benefits, preparatory behaviours and barriers, and solutions.<sup>15</sup> Personalized text messages were sent only to the intervention group and were highly personalized based on timing, frequency and content. Control group participants received only general feedback.<sup>15</sup>

### Internet-based systems

Study to Prevent Regain (STOP Regain)<sup>17</sup> compared face-to-face delivery of a weight loss maintenance intervention with a technology-based approach. Both interventions were identical other than delivery method. Participants had lost 10% of their body weight in the previous 2 years. Intervention participants self-reported weight and physical activity and tracked their progress using a traffic light system of green, yellow and red levels for weight regain with appropriate responses.<sup>17</sup> Participants had access to a weight loss toolkit containing various resources and attended regular meetings, either online (internet group) or in person (face-to-face group). Control group participants received a quarterly newsletter and other than at assessments had no contact with the researchers.<sup>17</sup>

Participants in Healthy Weight for Life<sup>18</sup> had been randomly selected from a 4-month weight loss programme<sup>18</sup> and randomized into either Internet or self-directed groups. Internet group participants were given access to the intervention website where they self-reported weekly and anticipated with online support groups and Q&A sessions. They also had access to diet and exercise information.<sup>18</sup> Self-directed participants had no further contact with the intervention team but were encouraged to continue to practice behaviour change techniques they had learnt during the weight loss intervention.<sup>18</sup>

Weight Loss Maintenance (WLM) Randomized Controlled Trial<sup>19</sup> participants had previously successfully lost weight and were randomized into one of three groups, comparing two interventions [face-to-face contact and an internet-based (Technology) intervention] with a control group. Technology group participants used a web-based portal to self-report and practice problem solving techniques.<sup>19</sup> Social support was facilitated through an online bulletin board. The personalized contact group attended regular coaching sessions. These were normally telephone-based, but every fourth month were more intensive and delivered face-to-face.<sup>19</sup>

### E-mail

Thomas *et al.*<sup>16</sup> used e-mail, and the participants in both intervention and control groups of the trial self-reported weight once a

**Table 2** Summary of the RCTs (n = 7)

RCT	Aim	Samples	Intervention arms	Data collection tools	Outcome measures	Key results	Conclusions	Implications for weight loss maintenance
Wing <i>et al.</i> <sup>17</sup>	Study to Prevent Regain (STOP Regain): To test the efficacy of a weight loss maintenance programme based on self-efficacy delivered via the internet or face-to-face	314 participants—mean loss of 19.3 kg in the past 2 years	<p>3-arms:</p> <p>(1) Control group Quarterly newsletter (genetic advice) No further contact except for assessments</p> <p>(2) Face-to-face intervention Weekly (first month) then monthly face-to-face meetings</p> <p>(3) Internet-based intervention (IT) Meetings via chat room Access to message board and weekly tips Self-report via website</p>	<ul style="list-style-type: none"> <li>Calibrated scales (weight)</li> <li>Paffenberger physical activity questionnaire</li> <li>Block food frequency questionnaire</li> <li>Custom Likert scale for ranking importance of behaviour change strategies</li> <li>Wall-mounted stadiometer height</li> </ul>	Weight regain	Mean weight re-gain lowest in face-to-face group (2.5 ± 6.7 kg) compared with internet (4.7 ± 8.6 kg) and control (4.9 ± 6.5 kg) groups No significant difference [0.2 kg, 95% confidence interval (CI) -4.9 to 5.9; P = 1.00] between IT intervention and control group	Weight loss maintenance was improved by the intervention when delivered face-to-face but not via the internet	No significant difference
Cussler <i>et al.</i> <sup>18</sup>	Healthy Weight for Life: To compare the effectiveness of an internet-based weight loss maintenance intervention with self-directed maintenance over 12 months in perimenopausal women (the Healthy Weight for Life trial)	135 participants—perimenopausal women completed a 4-month behavioural weight loss programme	<p>2-arms:</p> <p>(1) Intervention group: Self-report weekly via website Personalized progress reports Online social support (chat rooms)</p> <p>(2) Control group: No further contact with study staff No website access</p>	<ul style="list-style-type: none"> <li>Electronic scale (weight)</li> <li>Stadiometer (height)</li> <li>Dual energy X-ray absorptiometry (total body fat mass, fat percentage)</li> <li>Seven day physical activity recall interview (physical activity)</li> <li>Diet logs and ESHA Food Processor software (dietary practices)</li> </ul>	<ul style="list-style-type: none"> <li>Body weight</li> <li>BMI</li> <li>Percentage body fat</li> <li>Total body fat</li> <li>Fat-free body mass</li> <li>Physical activity</li> <li>Diet</li> <li>Exercise expenditure</li> <li>Energy intake</li> </ul>	No significant difference in outcome measures between groups (0.4 ± 5.0 kg vs. 0.6 ± 4.0 kg, P = 0.5)	Internet intervention did not significantly outperform self-direction for weight loss maintenance	No significant difference
Svetkey <i>et al.</i> <sup>19</sup>	Weight Loss Maintenance (WLM) Randomized Controlled Trial: To compare two weight loss maintenance interventions with a self-directed control group	1032 participants—adults overweight/obese, hypertension, dyslipidaemia or both lost min. Four kilograms during 6-month weight loss programme	<p>3-arms:</p> <p>(1) Self-directed group General guidance at baseline 12-month follow up</p> <p>(2) Inter-active technology group (IT) Self-report via website Social support via bulletin board No personalized coaching Personalized reminders to log in</p> <p>(3) Personalized contact group Regular contact Personalized progress and goal reviews No website access</p>	<ul style="list-style-type: none"> <li>Calibrated digital scale (weight)</li> <li>Calibrated, wall-mounted stadiometer (height)</li> <li>Block food frequency questionnaire (dietary intake)</li> <li>Calibrated tri-axial accelerometer (physical activity)</li> </ul>	<ul style="list-style-type: none"> <li>Change in weight from randomization to trial end (30 months)</li> <li>Total energy intake</li> <li>Moderate-vigorous physical activity</li> </ul>	IT intervention showed benefits over self-directed group at 18 months (mean difference -1.1 kg, 95% CI -1.9 to -0.4 kg; P = 0.003) and 24 months (mean difference -0.9 kg, 95% CI -1.7 to -0.02 kg; P = 0.04) but not at 30 months (mean difference -0.3 kg, 95% CI -1.2 to 0.6 kg; P = 0.51) Personalized contact group regained least weight overall	Technology intervention showed early but short-term benefits for weight loss maintenance but not long-term	Technology (internet) significantly aided weight loss maintenance at 18 and 24 months but not at 30 months

(continued)

Table 2 Continued

RCT	Aim	Samples	Intervention arms	Data collection tools	Outcome measures	Key results	Conclusions	Implications for weight loss maintenance
Thomas <i>et al.</i> <sup>16</sup>	To assess the effects of e-mail based support on weight loss maintenance for patients who have successfully lost weight	55 patients who had lost minimum of 5% body weight	2-arms: (1) Intervention group Weekly 'Tip of the week' e-mail from dietitian Self-report via e-mail monthly (2) Control group Six-month follow-up clinic visit only	<ul style="list-style-type: none"> <li>Likert scale questionnaires (at start and finish) to assess: Effort</li> <li>Attention</li> <li>Pleasure</li> <li>Dietary habits</li> <li>Effort subtracted from pleasure to rate intervention</li> </ul>	<ul style="list-style-type: none"> <li>Weight change (loss or regain)</li> <li>BMI</li> <li>Diet</li> <li>Exercise</li> </ul>	Intervention group regained less weight after 6 months (average 10% maintenance) than control group (average 7.3% maintenance) Control experienced reduced pleasure in maintaining weight after 6 months	Compared with no contact, e-mail contact is effective for weight loss maintenance	Technology (e-mail) significantly aided weight loss maintenance at 6 months
de Niet <i>et al.</i> <sup>13</sup>	Short Messaging Service Maintenance Treatment (SMS-MT): To analyze effects of a text message-based maintenance treatment with personalized feedback on weight, lifestyle and well-being	141 participants—aged 7–12, obese/overweight, 3 months into 'Big Friends Club' (BFC) behaviour change intervention	2-arms: (1) Intervention group Self-report weekly via text message Tailored feedback (2) Control group Minimal contact phase No self-reporting or feedback	<ul style="list-style-type: none"> <li>Growth Analyser v.3.5—BMI-SDS</li> <li>Dutch Eating Behaviour Questionnaire (DEBQ)—Eating behaviour</li> <li>Eating Behaviour Self-perception</li> <li>Self-perception for Children—Self-perception</li> <li>Child Health Questionnaire PF50 (CHQ-PF50)—Health Related Quality of Life</li> <li>Five-point Likert scale—SMSMT Evaluation</li> </ul>	<ul style="list-style-type: none"> <li>BMI-SDS (BMI Standard Deviation Score)</li> <li>Eating behaviour</li> <li>Self-perception</li> <li>Health related quality of life</li> </ul>	Maintenance intervention did not improve outcomes of 'Big Friends Club' intervention	Overall no positive effects on outcome measures	No significant difference
Donaldson <i>et al.</i> <sup>14</sup>	Lifestyle Eating and Activity Programme (LEAP) Beep: To determine if a 12-week text messaging based programme is effective for weight loss maintenance (or further weight loss) following a weight loss programme	34 participants—adults overweight or obese had completed LEAP (Lifestyle Eating and Activity Programme)	2-arms: (1) Intervention group Weekly goal setting and reporting via SMS Personalized feedback (2) Control group Weight checks only (no feedback or goals)	<ul style="list-style-type: none"> <li>Impact of Weight on Quality of Life tool (IWQOL) (Kokotkin <i>et al.</i>, 2001<sup>26</sup>)—QOL in relation to weight (5-points scale)</li> <li>Hospital Anxiety and Depression Scale (Zigmond &amp; Snaith, 1983<sup>27</sup>)—depression and anxiety</li> <li>Digital scales—BMI</li> <li>Constant tension measuring tape—waist circumference</li> </ul>	<ul style="list-style-type: none"> <li>Quality of life (QOL) relative to weight</li> <li>Depression</li> <li>Anxiety</li> <li>BMI</li> <li>Waist circumference (WC)</li> </ul>	Intervention showed benefits for body weight (−1.6 vs. 0.7 kg m <sup>-2</sup> , P=0.006), BMI (−0.6 vs. 0.7 kg m <sup>-2</sup> , P=0.03), waist circumference (−2.2 vs. 1.5 cm, P=0.0005) and depression (−0.2 vs. 0.2 points, P=0.228) but not anxiety (−0.1 vs. −0.1 points)	Test messaging is effective for weight loss maintenance	Technology (SMS) significantly aided weight loss maintenance at 3 months
Fjeldsoe <i>et al.</i> <sup>15</sup>	Get Healthy Stay Healthy (GHS): To evaluate SMS delivered intervention as a follow on from a weight loss intervention—Get Healthy Information & Coaching Service (GHS)	228 participants—adults had completed 6-month weight loss programme	2-arms: (1) Intervention group Personalized text messages Self-report via SMS (2) Control group General feedback after data collection No further contact	<ul style="list-style-type: none"> <li>3-item assessment tool—physical activity</li> <li>Fat and fibre</li> <li>behavioural questionnaire—dietary practices</li> <li>Standard anthropometric tools—body weight and waist circumference</li> </ul>	<ul style="list-style-type: none"> <li>Primary: BMI</li> <li>Physical activity</li> <li>Dietary practices</li> <li>Secondary: Feasibility</li> <li>Acceptability</li> <li>Cost</li> </ul>	Intervention showed benefits for weight (−1.35 kg, 95% CI −2.24 to −0.46, P=0.003) and weekly moderate-vigorous physical activity (MVPA) (0.56 sessions/week, 95% CI 0.15 to 0.96, P=0.008) and accelerometer assessed MVPA (24.16 min/week, 95% CI 5.07 to 43.25, P=0.007) but not waist circumference or diet	Significant benefits for maintenance of positive lifestyle changes	Technology (SMS) significantly aided weight loss maintenance at 6 months

month and attended a follow-up clinic and weight check after 6 months.<sup>16</sup> The intervention group received a weekly e-mail from a dietitian with diet and exercise advice. Control group participants had no further contact with the intervention team other than the clinic visit at 6 months.<sup>16</sup>

### Outcome measures

The outcome measures are summarized in table 2. BMI was the primary outcome measure for four trials.<sup>14–16,18</sup> Four trials<sup>17–19,22</sup> measured weight change or regain. One trial<sup>13</sup> measured BMI Standard Deviation Score (BMI-SDS).

### Key results

The key results from the seven trials are summarized in table 2. From the seven trials, four<sup>14–16,19</sup> reported that technology is effective for significantly aiding weight loss maintenance compared with control (no contact) or face-to-face contact in the short term (between 3 and 24 months). The other three trials<sup>13,17,18</sup> showed no significant effect of technology for aiding weight loss maintenance compared with the control (no intervention) or face-to-face contact intervention. Interactive Technology (IT) group participants in the Weight Loss Maintenance (WLM) Trial<sup>19</sup> experienced significantly less weight regain than the control group at 18 months (mean difference  $-1.1$  kg) and 24 months (mean difference  $-0.9$  kg), but not at 30 months (mean difference  $-0.3$  kg). The LEAP Beep<sup>14</sup> and Get Healthy Stay Healthy<sup>15</sup> trials reported reduced weight gain among intervention group participants ( $-1.6$  kg<sup>14</sup> and  $-0.89$  kg<sup>15</sup>) compared with control group participants ( $+0.7$  kg<sup>14</sup> and  $+0.30$  kg<sup>15</sup>). Intervention participants in the e-mail-based trial by Thomas *et al.*<sup>16</sup> successfully maintained a greater average weight loss (10%, median 9.6 kg<sup>16</sup>) over the trial duration of 6 months than those in the control group (7.3%, median 7.8 kg<sup>16</sup>). The remaining three trials did not report any significant difference, these include the Study to Prevent Regain (STOP Regain) trial<sup>17</sup> where the mean weight regain was lowest in the face-to-face group ( $2.5 \pm 6.7$  kg),<sup>17</sup> but there was no significant difference between the internet group ( $4.7 \pm 8.6$  kg) and control group ( $4.9 \pm 6.5$  kg).<sup>17</sup> On completion of Healthy Weight for Life,<sup>18</sup> there was no significant difference observed in weight gain between the internet group (0.4 kg) and the self-directed group (0.6 kg).<sup>18</sup> The Short Message Service Maintenance Treatment (SMS-MT) did not significantly improve outcomes of the Big Friends Club (BFC) intervention.<sup>13</sup> These results clearly are mixed but do indicate that technology has the potential to be effective for significantly aiding weight loss maintenance, especially in the short term (from 3 to 24 months).

### Uses of digital health technology for weight loss maintenance

In total, seven uses of digital health technology for weight loss maintenance were identified from the RCTs in this review. These seven uses, which can be mapped to the Behaviour Change Technique Taxonomy v1 (BCTTv1),<sup>22</sup> include self-monitoring and reporting, behaviour reinforcement, extending practitioner contact through remote support, motivation, goal setting and reviewing, social support and reminder prompts. The most common uses were self-monitoring and reporting, and behaviour reinforcement, as all the trials used the intervention technologies for these purposes. Self-monitoring is recognized as a key part of weight management initiatives,<sup>23</sup> as it improves self-awareness, provides early warning of potential issues,<sup>24</sup> and can lead to positive behaviour changes.<sup>25</sup> Self-monitoring is identified within the BCTTv1 as techniques, Self-Monitoring of Behaviour, and Self-Monitoring of the Outcomes of Behaviour. Self-reporting has also resulted in improved intervention outcomes.<sup>26,27</sup> Behaviour Reinforcement is identified within the BCTTv1 as technique, Behavioural Practice and Rehearsal, but is also a component of BCT cluster 10 (Reward & Threat), and

technique, Reward Alternate behaviour. While only 82% of LEAP Beep intervention participants completed their satisfaction surveys, all who did were generally satisfied that the intervention helped them reinforce behaviours leading to positive lifestyle changes.<sup>14</sup> Participants in GSHS trial found reminder prompts useful in helping to reinforce their goals.<sup>15</sup> Reminder prompts correspond to BCT 'Prompts/cues'. The second most commonly reported uses were extending practitioner contact through remote support, motivation, goal setting and reviewing, social support and reminder prompts. Remote support was an important aspect of five trials.<sup>14–17,19</sup> Thomas *et al.*<sup>16</sup> suggested that long-term face-to-face contact with a dietitian is not cost effective, and that technology-based solutions are a feasible means of providing this extended contact to large numbers of patients. Practitioner contact is an important aspect of behaviour change interventions as it provides participants with a 'credible source'.

The internet provides an effective platform for frequent monitoring without incurring the high costs associated with face-to-face contact.<sup>18</sup> Motivation was a key theme of five trials.<sup>13–15,18,19</sup> Participant engagement in weight loss maintenance interventions is strongly linked to motivation,<sup>13,14,19</sup> which may be improved by regular personalized contact with a health practitioner or researcher.<sup>15</sup> The concept of motivation is covered in Problem Solving, where it is suggested that participants may be encouraged to identify barriers to motivation and ways to overcome these. Such discussions may be facilitated through regular contact with a health practitioner. Where participant motivation was particularly high, it is proposed that this may be a result of either previous success in weight loss maintenance,<sup>18</sup> particularly if the participant has been praised for their previous successes ('focus on past successes'). Alternatively, motivation may be high simply as a result of participation in a weight loss maintenance intervention trial,<sup>14</sup> creating a desire to succeed. Five trials suggested that technology-based interventions could support goal setting and reviewing<sup>13,15,17–19</sup> and social support.<sup>13,15,17–19</sup> Often, personalized feedback is linked to goal setting and checking, and was used for this purpose in GSHS Trial.<sup>15</sup> Participants in the intervention arm of this trial set goals and regularly reported their progress. Goal setting is identified as a core group in the Group 1, Goals and Planning, and is specifically covered in 'Goal setting and Behaviour', 'Goal setting and outcome' and 'Reviewing outcome goals'. Personalized feedback was given to each intervention arm participant based on their progress. This goal setting and monitoring functionality was very well received by recipients, who said they found the accountability very helpful in motivating them to achieve their goals.<sup>15</sup>

Social support was found to be a major factor in weight loss maintenance. There was no significant difference in weight regain between the groups in Healthy Weight for Life. It was suggested that this may be partly because control group participants unofficially met socially during the trial.<sup>18</sup> SMS-MT and GSHS trials used specifically worded text messages to facilitate social support<sup>13,15</sup> and GSHS used social contact with friends and family as a reward for meeting goals.<sup>15</sup> The participants in the GSHS trial were asked to nominate a specific person who could support them, and the actions they could take. Social support covers Unspecified Social Support, Practical Social Support and Emotional Social Support. Personalized contact was a core aspect of four trials.<sup>13–16</sup> Personalized contact was particularly popular with participants in two of these trials<sup>14,15</sup> who reported that the messages received were very relevant to them.

### Strengths of the identified RCTs

All trials reported that the intervention used was feasible and acceptable to participants. It was suggested that text-message based interventions are effective because they require little effort on the user's part.<sup>14</sup> Text messages are delivered to the user automatically, and the user is not required to manually visit a website or make a phone call. SMS-MT did not improve outcomes of the Big Friends

Club intervention but did improve participant engagement and reduce attrition rates.<sup>13</sup> The authors suggested that the simplicity of such an intervention makes it popular and engaging for participants.<sup>13</sup> This type of intervention provides participants with almost instant access to the information they need. All trials reported low attrition rates, and where participant satisfaction was recorded it was generally very high. GSHS trial participants found texts very effective for motivation and considered that they were relevant.<sup>15</sup>

### *Limitations of the identified RCTs*

All trials identified potential limitations. Two most reported limitations were limited sample and the duration of each trial. The mean trial duration was 12 months. All researchers acknowledged the difficulty in assessing the effectiveness of the interventions over a longer period. It was observed that participation in LEAP Beep resulted in higher motivation but this could be a result of participants attending simply to gain congratulations from the research team—it is unknown whether this is the case, or whether participation in this intervention genuinely stimulated weight management.<sup>14</sup> In a previous RCT (the BBC Diet Trials), it was suggested that participants may be motivated simply by taking part in the study,<sup>28</sup> a principle known as the Hawthorne effect.<sup>29</sup> Additionally, it can be argued that participants are already highly motivated to change if they are willing to take part in such an intervention. It has previously been discussed that there was no significant difference in weight regain between the two Healthy Weight for Life groups,<sup>18</sup> partly due to control group participants unofficially meeting together for social support. However, it could also be a result of the Avis effect, a modern variant of the John Henry effect, where participants in the control group seek to directly compete with those in the intervention group.<sup>30</sup> This behaviour was observed by the research team during the trial.<sup>18</sup>

## **Discussion**

This review has shown that technology has the potential to be effective for significantly aiding weight loss maintenance, especially in the short term (from 3 to 24 months). However, research into their use for weight loss maintenance (intentionally losing 10% body weight and actively maintaining it) is still very limited. Where digital technologies have been used in weight loss maintenance interventions, these have mainly used older digital technologies, such as text messaging,<sup>13–15</sup> e-mail<sup>16</sup> or web-based systems.<sup>17–19</sup> To date, there has not been any substantive research into the use of contemporary technologies (such as smartphone-based systems, natural language processing or conversational artificial intelligence) for weight loss maintenance. MotiMate is a smartphone-based weight loss maintenance app currently under development and is proposed for clinical trial using multiple technologies (wireless connected scales, mobile-web based app and text messaging) for weight loss maintenance. The trial protocol for MotiMate acknowledges the limited effectiveness of previous internet based-interventions.<sup>28</sup>

### *Effectiveness of digital technology for weight loss maintenance*

Results from the identified papers suggested that in the relatively short-term (3–24 months), digital health technologies produce generally positive results for reducing weight regain and maintaining BMI; and also enjoy high participant acceptability and result in reduced attrition in comparison to standard or no-contact interventions. Digital health technologies have been observed to be slightly (though not significantly) less effective than similar interventions delivered via face-to-face personal contact.<sup>17</sup> From the seven trials, four reported that technology is effective for significantly aiding weight loss maintenance compared with control (no contact) or face-to-face-contact in the relatively short term (between 3 and

24 months). The longer-term effectiveness of digital health technology for weight loss maintenance requires further research.

### *Communication of messages*

Within this review, the communication channels included internet systems, e-mail and text messages (SMS), which were all deemed to be effective in communicating messages on weight loss maintenance. Text messages were viewed favourably by participants in two trials.<sup>16,17</sup> Post-trial, 75% of Get Healthy Stay Healthy (GSHS) participants reported that they were either ‘satisfied’ or ‘extremely satisfied’ with the intervention.<sup>15</sup> Participants reported that text messages were very helpful for reinforcing behaviour, creating accountability and raising awareness of their behaviour.<sup>17</sup> GSHS provided opportunities for participants to highly personalize their messages, and this was recognized as another strong positive of the intervention as participants consider text messages were very personally relevant to them. It was reported in Lifestyle Eating and Activity Programme (LEAP) Beep that regular contact with participants had strongly positive effects on motivation and attendance of follow-up clinics.<sup>14</sup> The authors also suggested that text messaging is an effective means of communication with participants because of its simplicity.<sup>14</sup>

### *Limitations of this review*

The main limitation of this review is the small sample size, as seven RCTs were identified that fulfilled the inclusion criteria. Although more studies would provide more results, it was considered acceptable to conduct a review using the seven RCTs as they were considered to be conclusive and deemed suitable to identify the shortcomings of technology use in weight loss maintenance. Additionally, no meta-analysis of results was performed, therefore, the small sample size was considered to be less important. The fact that seven RCTs were identified indicates limited research into the topic of weight loss maintenance using digital technology.

### *Further research*

This systematic literature review has shown that digital technologies have a variety of uses in weight loss maintenance, with numerous benefits. There is limited research into this area, and several gaps have been identified that should be addressed. Study duration has been identified as a limitation. It is suggested that further trials assess the effectiveness of digital technologies over longer periods, i.e. longer than 12 months.<sup>14,16</sup> The identified trials all used older technology types for intervention delivery. However, as personal technology becomes smarter, new avenues for communication open. In 2017, Ofcom reported that short messaging service (SMS) sending had fallen steadily for the fourth year in a row.<sup>31</sup> It is suggested that this is because smarter devices open new avenues of communication, specifically in relation to social media and instant messaging (e.g. WhatsApp).<sup>31</sup> Users tend to use the latest advances rather than more traditional technologies, and it is unknown what effects these advances will have on weight loss maintenance and how they will benefit the user. It would be of benefit to investigate the effectiveness of contemporary technologies such as these for weight loss maintenance.

Feedback sent to LEAP Beep participants was written and sent by a human operator, a healthcare professional. The researchers acknowledge that this is a significant limitation in that it relies on availability of the operator,<sup>15</sup> who may not be willing to remain ‘on standby’ in the evenings or at weekends to send personalized messages. It is possible to automate this feedback, but at a risk of losing the personal touch, of messages seeming artificial. It would be beneficial to investigate ways of fully automating feedback while preserving the ‘personal touch’. Another issue is bi-directional communication. All messages sent to participants during this trial were based on previous submitted data by the individual participant.<sup>13</sup> It

has been suggested that it would be of interest to compare this system with one relying solely on one-way communication (researcher to participant) with no input from participants.

The two trials that compared technology-based interventions with face-to-face contact<sup>17,19</sup> commented on the limitations of the technology-based interventions and suggested that future research should focus on ways to improve efficiency of these interventions to maximize their effectiveness. It is proposed that effectiveness of the technology used in the WLM trial could be improved with greater individual tailoring.<sup>19</sup> Tailoring of interventions was deemed highly acceptable by GSHS participants.<sup>15</sup>

Based on the findings from this review, the following are possible topics for further research:

- Investigate the effectiveness of digital technology for weight loss maintenance over longer periods.
- Investigate the effectiveness of newer digital technologies for weight loss maintenance.
- Explore techniques for providing fully automated feedback without losing the personal contact.
- Explore the feasibility and effectiveness of using one-way communication to support weight loss maintenance.
- Investigate ways to maximize the efficiency of digital technology solutions for weight loss maintenance.

To date, the vast majority of research into the use of digital technologies for weight loss maintenance has used older technologies, such as e-mail, text messaging and web-based systems. These systems have proved to be effective and feasible for delivering weight loss maintenance interventions in the short term, though cannot realistically compete with face-to-face contact interventions. Research into the use of newer technologies is limited, therefore, it is essential to explore the effectiveness of newer technologies for this purpose, specifically to investigate the possibility of automating personalized feedback, and to determine ways to maximize the efficiency of technology-based systems.

## Conclusion

This article has built upon the literature by highlighting the importance and role of the technology for weight loss maintenance, and for the first time reported systematically and comprehensively the shortcomings of existing technologies in weight loss maintenance, and provided suggested areas for further research. It was concluded that digital technologies have the potential to be effective communication tools for significantly aiding weight loss maintenance, especially in the short term (from 3 to 24 months). Further research is required into the long-term effectiveness of contemporary technologies.

## Supplementary data

Supplementary data are available at *EURPUB* online.

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*Conflicts of interest:* None declared.

## Key points

- Research into digital technology for weight loss maintenance is limited.
- Existing technologies in weight loss maintenance have shortcomings such as out-of-date delivery methods.

- Digital technologies have the potential to be effective communication tools for significantly aiding weight loss maintenance, especially in the short term (from 3–24 months).
- Digital technologies have a role and are important for weight loss maintenance, especially in the short term.
- Further research is required into the long-term effectiveness of contemporary technologies.

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## Socioeconomic and psychosocial determinants of adherence to the Mediterranean diet in a general adult Italian population

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**Background:** To evaluate the adherence to Mediterranean diet (MD) and its major socioeconomic and psychosocial determinants in a large sample of the Italian population, covering three main geographical areas of the Country (Southern, Central and Northern). **Methods:** Data were obtained from the Italian Nutrition & Health Survey (INHES), including a total of 7, 430 participants (age >20) recruited from all over Italy (2010–13). Dietary information was collected by the European Food Propensity Questionnaire. Adherence to MD was assessed by using the MedDietScore based on 11 food groups. Associations were tested by multivariable logistic regression analysis (Odds ratio [OR] with 95% CI). **Results:** Adherence to MD was higher in Southern Italy as compared with the Northern (OR = 1.34; 95% CI 1.18–1.53), and was closely associated with adult age (OR= 2.40; 1.61–3.58 for those aged > 75 years as compared with 20–34 years) and higher educational level (OR = 1.77; 1.40–2.24 for post-secondary education as opposed to lowest educational attainment). Subjects reporting adverse life events and those with family-related stress were less likely to show an optimal adherence to MD (OR = 0.55; 0.46–0.67 and OR = 0.44; 0.28–0.69, for highest vs. lowest tertile, respectively) as compared with adequate controls. A number of eating behaviours were also inversely associated with MD, such as consuming higher amount of alcohol in the weekend than in week days. **Conclusions:** Adherence to MD is strongly determined by age, geographical area and educational level. Psychosocial factors and several eating behaviours are also closely associated.

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## Introduction

The Mediterranean diet (MD) is a traditional dietary pattern mainly followed in the Mediterranean regions<sup>1–3</sup> and is considered the golden standard of healthy nutrition, being strongly associated with decreased morbidity and mortality, especially from cardiovascular and cerebrovascular causes.<sup>4,5</sup>

More recently, a global shifting from the MD was documented especially in the Mediterranean regions that experienced the greatest loss of adherence as opposed to non-Mediterranean Countries,<sup>6–8</sup> to such an extent that a nutrition transition issue emerged also for Mediterranean populations.<sup>9,10</sup> Moreover, this downward trend

was observed also for children and adolescents.<sup>11–13</sup> The withdrawal from an MD could be influenced by numerous factors, and more recently a likely impact of the economic crisis has been proposed as a major cause for the shifting from this dietary pattern.<sup>8,14</sup> In this context, improving the understanding of the major determinants associated with an MD is of crucial importance. Adherence to MD clusters with other healthy behaviours (i.e. physical activity and abstention from tobacco) is strongly associated with socioeconomic status,<sup>15</sup> and age.<sup>16</sup> The socioeconomic gradient of diet quality has been well documented mainly in Northern European and US settings,<sup>17,18</sup> although evidence from Mediterranean regions has been recently presented.<sup>15</sup>