TITLE: A systematic review of the effectiveness of smartphone applications that encourage dietary self-regulatory strategies for weight loss in overweight and obese adults

Authors: Dr Heather Semper*, Dr Rachel Povey, & Professor David Clark-Carter

Affiliation: Centre for Health Psychology, School of Psychology, Sports, and Exercise, Staffordshire University, Stoke on Trent UK.

*Corresponding Author

Address for correspondence:

Centre for Health Psychology,

School of Psychology, Sport and Exercise,

Faculty of Health Sciences,

Staffordshire University

Stoke-On-Trent

Staffordshire

ST4 2DF

UK

Email: heather.semper@staffs.ac.uk

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SUMMARY

The aim of this paper is to systematically review the evidence to explore whether smartphone applications that use self-regulatory strategies are beneficial for weight loss in overweight and obese adults over the age of eighteen years. Sixteen electronic databases were searched for articles published up to April 2015 including MEDLINE, OVID, Ingenta, PSYCARTICLES and PSYCINFO, CINAHL, Sportdiscus, Science Direct, Web of Knowledge, Cochrane Library, JSTOR, EBSCO, Proquest, Wiley, and Google Scholar. Twenty nine eligible studies were retrieved of which six studies met the inclusion criteria. Studies that recruited participants under the age of 18 years, adults with a chronic condition, or did not report weight loss outcomes were excluded. Study findings were combined using a narrative synthesis. Overall, evidence suggests that smartphone applications may be a useful tool for self-regulating diet for weight loss as participants in the smartphone application group in all studies lost at least some bodyweight. However, when compared to other self-monitoring methods, there was no significant difference in the amount of weight lost. Findings should be interpreted with caution based on the design of the studies and the comparator groups used. Future research needs to be more methodologically rigorous and incorporate measures of whether eating habits become healthier in addition to measuring weight and BMI.

INTRODUCTION

Obesity is argued to be a significant global health problem with approximately 1.48 billion of the world's population being overweight (1). In the UK it is estimated that 60% of the population is currently overweight or obese (2). In the United States, this figure is higher; it is estimated that three out of four people in the USA will be overweight or obese by 2020 (2). Obesity and overweight have been identified as major lifestyle risk factors for serious health conditions such as type II diabetes (3), cardiovascular disease (4), stroke (5) and some cancers (6) resulting in higher mortality rates for obese individuals (7). In addition, there are psychological consequences of being obese such as low self-esteem (8), depression (9), and feelings of stigma (10). Therefore it is important to develop interventions that can help to reduce the incidence of obesity.

As two of the major causes of obesity are the consumption of an unhealthy diet and a sedentary lifestyle (11), it is important to develop interventions to support people with weight loss and to change their behavior to a more active and healthier lifestyle (12). This behavior change can include increasing physical activity and consuming a healthier diet by reducing calorie and fat intake, and increasing fruit and vegetable consumption (13). However, in order to understand how to help someone to change their eating behavior it is essential to understand the psychological factors that can influence behavior (14). One psychological theory that has been shown to be effective in explaining weight loss and improvements in diet is the Social Cognitive Theory of Self-regulation (15). This theory suggests that behavior is regulated and motivated by self-influence through self-reflection, goal setting and feedback. That is, behavior is goal directed, and interventions are process oriented involving helping people to identify how to change (14). Self-monitoring of eating and exercise behavior and

feedback on progress towards weight loss goals can help people to identify where change is necessary, and identify behavioral adjustments needed in order to achieve their goals (16).

A number of self-regulatory interventions have been developed to attempt to help people with weight loss with varying success (17). One of the more successful approaches to weight loss involves encouraging self-regulatory strategies where the person losing the weight attempts to monitor their food intake and exercise routine, to achieve pre-set realistic goals, with feedback from health professionals on their progress (18). Up until fairly recently, this was typically carried out using a pen and paper and a calorie counter book for monitoring dietary intake, and has had modest successes (16). However, one problem for these types of intervention is the time burden it places on individuals participating in the weight loss intervention. It can be argued that it is very time consuming for participants to manually complete food diaries after every meal, look up and log calorie intake, and compare their behavior with eating goals. As a result individuals tend to drop out of these interventions citing time and effort as the main reasons for attrition (19). In addition goal setting and feedback from health professionals has tended to be provided distally from the eating behavior (e.g. 20). Research evidence shows that feedback is most effective when it is provided proximally to the behavior under review (21). Therefore paper and pen methods of monitoring, with feedback in later face to face sessions with health professionals might not be the optimal way of encouraging and supporting weight loss. One avenue that has been explored to reduce this burden and make dietary monitoring easier and more immediate is the use of portable technology (22).

Over the past ten years, technology has advanced dramatically with the advent of smartphone technology (23). Smartphones are more than mobile telephones designed to make calls and send text messages. Smartphones also contain powerful microchip technology meaning that individuals can have powerful portable computers in their own pocket (24). Smartphones

have software called “applications” (or “apps”) that can be developed to support weight loss, indeed there are many smartphone applications available on the different smartphone platforms that claim to be for that purpose (25). It is important that with the proliferation of smartphone applications developed for weight loss, these are tested for efficacy. In addition, when companies are developing these applications, it is important for them to use strategies that are based on empirical evidence to ensure that they are as effective as is possible (24). For example, based on a review of interventions (26) it was identified that self-monitoring, professional feedback, goal setting, along with social support and a structured program, are key components that need to be included in technology delivered interventions for successfully supporting weight loss. As such, they recommended that smartphone interventions need to have these components inherent in their design.

A number of studies have developed new weight loss applications, and some have evaluated existing weight loss applications that incorporate dietary self-regulatory strategies. Therefore it would be useful to summarise the evidence to date on how effective these smartphone applications are for weight loss. In light of self-regulation strategies being shown as effective for weight loss in overweight and obese individuals (16), in particular in technology based interventions (26) and the exponential development of smartphone applications for weight loss (25), the purpose of this paper is to systematically review the intervention research to determine the effectiveness of smartphone applications that use dietary self-regulatory strategies for weight loss.

Review question: How effective are smartphone applications that encourage dietary self-regulatory strategies for weight loss in overweight and obese adults?

METHODS

The systematic review was conducted using an unpublished study protocol that was developed and agreed by all authors. The review was developed in accordance with the Preferred Reporting Items for Systematic Reviews (PRISMA) statement (27).

Data sources and search strategy

A systematic search of the literature was undertaken between May 2014 and June 2014 with an updated search conducted in April 2015. This search was undertaken to identify papers that reported the development and testing of smartphone applications that encourage dietary self-regulatory strategies of goal setting, self-monitoring and feedback for weight loss. Sixteen databases were searched for published literature which were; MEDLINE, PUBMED, OVID, Ingenta, PSYCARTICLES, PSYCINFO, CINAHL, Sportdiscus, Science Direct, Web of Knowledge, Cochrane Library, JSTOR, EBSCO, Proquest (ASSIA), Wiley, and Google Scholar. In addition, the following journals were manually searched for relevant articles; BMC Obesity Journal, Journal of Medical Internet Research, and Obesity Research. Reference lists of relevant articles were also searched for other potential articles. A search for grey literature was carried out using Mendeley catalogue, ResearchGate, Academia.edu and LinkedIn where researchers can post non-peer reviewed studies, conference posters and conference abstracts. Searches on social media platform Twitter were also conducted using relevant hashtags (#smartphone #obesity #selfregulation #weightlossintervention) to identify any other non-published research.

The search keywords were selected using the PICOS search tool to guide the specificity and sensitivity of searches in systematic reviews (28). Search terms were chosen to cover terms for smartphone application interventions that adopt self-regulatory strategies for diet and weight loss. The following keywords were used; (Overweight OR Obes*) AND (intervention

OR program*) AND (self regulat* OR self evaluat* OR self monitor*) AND (Smartphone OR 'cell phone' OR 'mobile phone') AND ('weight loss' OR 'weight maintenance' OR 'weight loss maintenance' OR 'body weight changes OR 'weight reduction') AND (BMI or 'body mass index' OR weight).

There was no limit placed on date; however as smartphone applications are a relatively new technology, there were no research studies found that were published prior to 2010.

Study Selection

The inclusion criteria that were applied to all research studies are shown in Table 1. There was no limit on study design types so that case studies, quasi-experimental randomized controlled trials, and randomized trials could be included in the review (29). Qualitative papers were also considered in order to capture an in depth insight into the mechanisms of interventions of this nature.

[Insert Table 1 here]

Full texts of the remaining studies were obtained. Studies were excluded from the review if they included children (participants under the age of 18 years) in the sample or if the target population had a long term condition such as diabetes, cancer, stroke, cardiovascular disease and this disease was the focus of the weight loss. Intervention protocols, studies with no outcome related to weight loss or dietary change, review papers, and papers not written in English were also excluded from the review. Articles and studies reporting data from the same participants were combined, and reviewed as one study.

Quality assessment

A McMaster quality assessment (30) was conducted on all quantitative studies identified for inclusion. The McMaster tool is used to assess the quality of the study along seven

dimensions; selection bias, study design, confounders, blinding, data collection methods, withdrawals and drop outs, and outcomes (30). Each of these dimensions is rated on a scale of 1-3, with 1= strong, 2= moderate, 3= weak. Each study was independently checked for quality by two reviewers (the first and second authors). A third reviewer was available to arbitrate should the two reviewers disagree after discussion of the criteria; however this was not necessary as the reviewers reached 100% consensus after discussion. Table 2 contains quality ratings for each study.

[Insert Table 2 here]

Data extraction

A standardised data extraction sheet was developed in accordance with recommendations by Cochrane (31) for the purpose of the review. This included a thorough and in depth extraction of information in the following areas: general information, study characteristics, sample characteristics at baseline, inclusion/exclusion criteria, measures used, intervention details, and analyses and statistical findings. This sheet was developed and then independently checked by two authors to agree content prior to data extraction.

Data synthesis

The studies retrieved for inclusion were considered for meta-analysis to synthesise the data. Whilst the outcome measures used were similar (weight in kg and BMI) and the time points were similar (6 months) the intervention studies were too heterogeneous in their design and in the elements that made up the intervention (29), therefore making meta-analysis an unsuitable method for synthesising the data (32). This review therefore presents a narrative synthesis of the study findings.

RESULTS

Study selection

[Insert Figure 1 here]

Figure 1 summarises the study selection stages for the review. In total 6070 papers were identified from the search process. These include 45 from CINAHL, 7 from Cochrane, 5 from EBSCO, 213 from Google Scholar, 105 from Ingenta, 894 from JSTOR, 289 from MEDLINE, 31 from OVID, 1512 from Proquest/ASSIA, 12 from PSYCARTICLES, 115 from PSYCINFO, 659 from PUBMED, 149 from science direct, 41 from Sportdiscus, 491 from Wiley, 671 from Web of Knowledge. In addition, 831 were identified from hand searches and grey literature searching including; 7 from Obesity Journals, 122 from reference lists of relevant articles, 699 from Mendeley, and 3 from social media. Of the 6070 papers, 1380 were duplicates and removed from the searches. After title and abstract review, 4661 studies were excluded leaving 29 eligible studies. The last search for the study was conducted on 12th April 2015. After the full texts of the 29 studies were screened in detail using the data inclusion/exclusion sheets 10 percent of these were reviewed independently by the second author and 100% agreement on inclusion/exclusion was reached. (A list of the 29 studies with reasons for inclusion/exclusion can be found in Table S1 in Appendix 1 - supporting information). Nine studies were identified as meeting the eligibility criteria. Of these nine papers, five reported data from the same two studies (three papers reported one study, and two papers reported a second study), these were merged leaving six studies for full review.

Study characteristics

Table 3 provides a summary of the main characteristics of the six studies included in the review(33-38), The studies were reviewed and compared on samples who participated, the

designs of the intervention studies, and the components included in the interventions including application characteristics, practitioner input, and dietary counselling provided. Findings were synthesised on the effect of the interventions on weight loss, and adherence to study protocols. Each of these will be reviewed in turn below.

[Insert Table 3 here]

Research quality and design

Based on the McMaster tool (30) ratings, the studies all achieved an overall quality rating of "moderate". Study design was determined using the Cochrane tool for study design features (39). Four of the studies used a randomized controlled trial design, which is argued to be the gold standard for quantitative intervention study design (40). Of these four studies, only one had a control (usual care) comparator group (35), the rest of the studies had comparison groups of other types of self-monitoring weight loss interventions such as website monitoring (34), paper and pencil diaries (34, 37) and use of a smartphone application only without any other counselling (33). One study (38) used a non-randomized controlled trial design where participants were allocated to the intervention group only if they already owned an IPhone. This could introduce some bias into the findings; however when they compared the intervention group with their paper and pencil group on baseline measures there was no difference in any of the potential confounders identified. Nonetheless, it needs to be noted that this lack of difference may be due to lack of power in the study. One study used a longitudinal pre-post design to test the efficacy of a smartphone intervention with participants' scores at baseline acting as control measures.

Sample characteristics recruitment and attrition

There are some similarities in the samples that participated in the interventions. Five of the six studies were conducted in the United States of America (33, 35-38), and one in the United Kingdom (34). All studies recruited overweight or obese adults through a number of methods including television and newspaper advertisements, flyers, in routine appointments and physician referrals. All studies reported that there were no differences between their control condition group and the intervention group on demographic and anthropometric data such as age, gender, BMI, weight, or energy intake at baseline. Participants in all studies had an average age of between 42 - 44 years old with the exception of one study (36), whose participants' average age was slightly higher at 53 years. All studies had more females participating in their studies than males, and all participants had a BMI ranging between 25kg/m^2 and 50kg/m^2 at baseline. Between 42 - 91% of participants in the studies were white, and 5 - 49% of participants were Black. Three studies (33, 36, 37) reported the marital status of participants with around half of participants reported being married in each study. Three studies reported educational level (33, 35, 36) and reported that the majority of participants had some level of college education. There were some variations in attrition from the studies ranging from 10% to 36%; however all studies concluded that they had non-problematic rates of drop out. Only two studies fully reported conducting a power analysis to determine appropriate sample size for detecting differences (35, 37).

Smartphone Application characteristics

Four studies used pre-existing smartphone applications currently available via either android or IPhone stores (33, 35, 37, 38) two studies (33, 38) used the LoseIt! application, whereas one (35) used the MyFitnessPal application, and one (37) used the Fat Secret Calorie Counter application. Two studies (34, 36) developed their own smartphone application based on weight loss programs specifically for the study. The two smartphone applications that were developed were similar in their functionality to the pre-existing applications and contained

goal setting, self-monitoring and feedback functions. All studies reported that training in how to use the applications was provided. This varied in how participants were trained; two studies (34, 36) provided links to self-help videos that described the features of the application and demonstrated how it worked, the other studies (33, 35, 37, 38) trained the participants in how to use the application at the time that baseline measures were taken.

All applications used in the studies were primarily used as a self-monitoring tool where participants could voluntarily log their dietary intake on a daily basis. Each application had a database of foods along with nutritional content. In addition, the applications made use of the bar code scan function of the smartphone to help the user to log their food intake. All applications also had a function where participants could log physical activity. The applications provided feedback on progress in terms of calorie intake against calorie goals. This feedback was typically provided in graphical format; either pie charts or bar charts. Two of the studies provided extra feedback (34, 36) in the form of tailored text messages to participants. However, the content and timing of these messages differed between the two studies. One study (34) sent weekly motivational messages that encouraged self-efficacy for weight loss and rehearsal of weight loss goals. These were automatic messages that were triggered at specific points in progress towards weight loss goals. Whereas another study (36) sent messages one to three times per week that were tailored to the specific participant's current weight loss and caloric intake. What determined the frequency of delivery of text messages was not reported. These messages gave tips and advice on diet and exercise.

Applications used in all of the studies had a goal setting function where a weight loss or calorific intake goal could be inputted for comparison with progress. In two studies (34, 36), the goals that were set were determined by the participant. In one study (36), this was set to a limit of between 0.23 and 0.9 kg per week weight loss whereas limits are not reported in the other study (34). In three of the studies the researchers set the weight loss goals for the

participant. Typically this was the same goal for all participants in all conditions of the study. One study (38) set the weight loss goal at 0.45 kg per week, whereas (36) set the goal at between 0.45 and 0.9 kg per week with an aim to lose 10% of body weight over the six month study. One study (33) specified that participants were aiming to lose 5% of weight by the end of six months and increase physical activity to 150 minutes per week.

In the two studies that created their own weight loss application (34, 36), there was no report of any social support or social media functions available to participants. However, there was a social media function available in pre-existing smartphone applications. Two of the studies that used the pre-existing applications (35, 37) actively encouraged the use of social media functions, with one study using the social media function to encourage contact with the study counsellors. The other study that used an application with social media function did not report how much their participants engaged with this aspect of the application, or whether this was encouraged even though it was available (33).

Practitioner involvement and dietary counselling

Two of the studies (33, 36) had more regular face to face contact with participants than just at measurement time points of baseline, three and six months. One study (36) had weekly weigh in sessions where behavioral targets and behavioral prompts were created and programmed into the application so that they could be delivered at an appropriate time. In the other study (33), participants had varying degrees of contact with researchers depending on which condition the participants were allocated to. In the intensive counselling group participants had weekly contact with nutrition counsellors in the first month then every two weeks for the remainder of the trial. In the less intensive counselling group, participants had contact with nutrition counsellors every fortnight for the first month then monthly for the remainder of the trial. Participants in the smartphone condition had only one session of basic nutritional

counselling at the start of the trial. In one study (38) participants who were not in the smartphone application group were given a personalised nutritional plan, and were sent weekly emails to encourage healthy eating.

In contrast, two studies (36, 37) provided electronic means of nutritional counselling. Participants in one study (37) could regularly download podcasts that encouraged healthy eating along with emphasising the importance of self-monitoring of diet and exercise. Whereas in the other study (36), participants were provided with video weight loss lessons comprising information on the importance of planning meals, self-monitoring of diet, and motivational information. In (35), participants were given a one page educational leaflet on healthy eating and dietary advice at three months.

Weight loss across time

[Insert Table 4 here]

As Table 4 shows, three studies found a statistically significant difference in weight loss across time in all comparator groups (34, 37, 38). Two of these studies (34, 37) reported that the majority of participants had lost clinically significant amounts of weight across the six months of the trials. One study (36) reported the greatest amount of weight loss in the smartphone application condition. Two studies (33, 36) reported no significant change in body weight across time though both studies report participants as having lost weight across all conditions. It needs to be noted here that both of these studies report insufficient power therefore their findings need to be interpreted with caution. One study (35) reported that there was no significant difference in weight across time in their intervention group and the usual care group actually increased their weight over the duration of the study.

Weight loss differences between groups

Four of the six studies (33, 35, 37, 38) reported that there was no significant difference between comparison groups in the amount of weight lost over the six month period. The only other study that compared different groups of participants (34) found that those participants who were assigned to the smartphone application condition lost significantly more weight than those allocated to a website logging condition, but there was no significant difference in weight loss between those in a paper diary group and smartphone application group.

Dietary intake changes

Two studies (33, 37) examined dietary intake in addition to weight and BMI. One (37) also examined energy intake and found that participants in the podcast plus smartphone application group consumed significantly less calories and fat at six months than the podcast plus paper diary group. Two (35, 38) found no significant difference between groups on self-reported dietary behaviors. One (38) reported no difference in healthy eating indices across the study, or between groups. Neither (34) nor (36) reported examining dietary behavior in their study.

Adherence to study protocols

In three studies (34, 35, 38), there was a significant difference in drop out across the comparison groups. On the whole, participants were less likely to drop out from the smartphone application groups, than groups that have other methods of self-monitoring such as a paper diary. In all of the studies that compared different groups of participants, the number of days over the trial period that participants engaged in smartphone self-monitoring of diet was higher than other monitoring methods. However, one study (35) reported a significant decrease in the number of logins to the application in the final month of the study with some participants reporting recording of intake as tedious, and that they were too stressed or too busy.

DISCUSSION

The purpose of this review was to systematically explore the research examining the effectiveness of smartphone applications that use self-regulatory strategies for weight loss in overweight and obese adults. The authors rigorously reviewed six studies that met the inclusion criteria of using dietary self-regulatory strategies in a smartphone application for weight loss in overweight or obese adults in one or more conditions of the study.

Overall, the findings suggest that smartphone applications for dietary self-monitoring are effective at encouraging weight loss. All of the studies reported that participants who used smartphone applications for dietary tracking lost some weight over the duration of the study. Three studies reported that this was a significant amount of weight lost over time, and two studies reported that the weight lost was clinically significant at between 5-10% of body weight lost over the duration of the intervention. The studies also reported that participants were more likely to remain adherent to self-monitoring protocols if they were using a smartphone application for tracking dietary intake. These findings are encouraging as smartphone applications could be a useful additional tool to support overweight or obese individuals with weight loss.

Nonetheless, four studies reported that there were no significant differences in weight loss between all comparison groups meaning that participants in all groups were losing similar amounts of body weight by self-monitoring their dietary intake. It should however be noted though that the majority of the studies did not employ a non-intervention comparator group in their design. This means that the participants in other comparison groups were receiving some level of self-regulatory weight loss intervention making the actual scale of the efficacy of smartphone applications difficult to discern. As a result it is difficult to conclude that smartphone applications are any more effective for weight loss than other monitoring

methods. However, whilst not significant, there was a trend for participants in the smartphone application groups to lose slightly more weight than other groups - even when compared to a usual care group. Future studies should ensure that there is a usual care or no intervention condition in addition to other monitoring methods to determine whether smartphone applications are a useful tool to support or aid weight loss.

The design of the studies can also be called into question as some of the studies did not provide comparable treatments and controls to all conditions meaning that other extraneous influences may have affected the findings. For example, one study (38) offered nutritional counselling and diet planning to the comparison groups but not to the smartphone application group. This might have obfuscated the benefits of the smartphone application. If the smartphone application group had also received nutritional counselling and diet planning, there is a possibility that the level of effect of the smartphone application alone might have become clearer.

While the findings on the efficacy of using smartphone applications for weight loss in comparison to other self-regulation strategies is not clear, what seemed to be demonstrated in the studies is that participants were less likely to drop out from the smartphone self-monitoring condition than other methods of self-monitoring such as paper diaries or websites. This is important for two reasons; firstly, this means that those individuals who did not drop out from the other types of self-monitoring might be more motivated to continue as paper diary methods are time consuming. Secondly, it appears that the portable instant access, calculation of nutritional content of the food, and calculation of remaining caloric intake for the remainder of the day means that participants have less effort to put into self-monitoring, have instant access to feedback on progress, and are more likely to continue monitoring for longer. Nonetheless, one study showed that without contact with researchers, the participants tended to lessen the amount of logins to a smartphone application (35). As such, the

importance of practitioner input seems to be key in influencing adherence to smartphone application use and needs further investigation.

Surprisingly only three of the studies measured aspects of dietary change such as fat intake, calorie intake, or other healthy eating indices. As the focus of the interventions was weight loss through dietary change it is important to determine whether self-monitoring, goal setting and feedback have any effect on both the quality and quantity of food consumed in terms of healthiness. Furthermore, it is important to examine whether providing detailed information on nutrition intake changes makes any difference to dietary intake over the course of an intervention- particularly when studies have employed nutritional counselling or other dietary educational measures.

It is recommended that technology based interventions such as smartphone applications need to contain five key components in order to be effective (26). These are self-monitoring, tailored goal setting, feedback from nutritional/dietary counsellors, a structured program and social support. All applications had self-monitoring, goal setting, and feedback. Some applications had social media functions which some investigators used to motivate the participants, where others used it to encourage social support. However, reporting of the use of this function varied and was limited. Some studies encouraged social media use for social support, and others only briefly mentioned it but did not report how much participants engaged with the feature.

As it appears that practitioner input is important for adherence to smartphone application use, it would be useful to explore social media functions of mobile phone applications as a means of communication between practitioner and participant. This might support participants with adherence to dietary self-monitoring for weight loss. Goal setting as part of a regulatory strategy for dietary intake and/or weight loss needs to be tailored to the individual and should

be set by a health care professional as an untrained individual might set goals that are not achievable which has consequences for motivation (41).

Limitations of included studies

Whilst the findings of this review are promising, they need to be interpreted with caution as the quality of the studies was rated as moderate overall. The main two issues in the quality of the studies was randomisation, and controlling for potential confounds. In addition, some of the studies tended to have limited sample sizes, with two studies (33, 36) having insufficient power to detect differences. Furthermore, the research participants in each of the studies tended to be white, fairly well educated, middle aged women, meaning the representativeness of the samples was fairly limited. As sex, socio-economic status, and ethnicity are all factors that may influence engagement with technology and weight loss programmes (42) it is important that studies should attempt to recruit more balanced samples, control for these factors, or focus on one specific subsample so that interventions can be more tailored to the specific group.

Critique of the review

Before any recommendations can be made, it is important to acknowledge the potential strengths and limitations of this review. The review was conducted using rigorous methodology in accordance with guidelines developed by Cochrane (31). The review assessed the risk of bias by using a standard quality assessment tool. However, the review is limited by the specific search terms used in the searches. Alternative search terms may have revealed different studies. Nonetheless, the PICOS tool was used to ensure that the search terms were as comprehensive and sensitive as possible (28). There are also large variations in reporting practices across intervention studies. This makes it difficult to accurately appraise or synthesise the research evidence (29). Studies that evaluate smartphone application

interventions for weight loss need to ensure that they rigorously report all relevant demographics such as marital status, and educational level as these have been shown to influence weight loss and adherence to weight loss interventions (42). In addition, studies should report power analyses as standard to demonstrate adequate sample sizes for detecting differences across time (44).

Summary of recommendations

Future smartphone application intervention studies designed to promote and support weight loss through dietary change need to: have a rigorous design, reduce confounds, adhere to consort reporting guidelines, conduct a priori power analyses, assess actual dietary intake in terms of nutritional content and healthiness of food consumed, use practitioner set realistic weight loss goals, and provide equivalent and comparable treatments in all conditions. Future studies should also adopt mixed design to compare group performance at each time point and across time. They need to also avoid the risk of confounds by ensuring parity across the intervention groups and ensuring that there is a no intervention control group who are asked whether they adopted any monitoring methods.

Conclusion

Smartphone applications present an interesting and potentially useful avenue for developing interventions to support weight management. This is particularly the case for those interventions that encourage self-regulatory strategies such as self-monitoring, goal setting, and feedback as individuals who use smartphone applications for tracking diet tend to remain adherent to monitoring. However, this review has determined that the evidence to support the beneficial effects of dietary self-regulation smartphone applications alone needs attention.

There seems to be evidential support for increasing weight loss using smartphone applications. Nonetheless, it is important to have professional input to help with setting goals, and changing dietary behaviors if weight management interventions are to be successful. Furthermore, it should also be noted that further research is required to evaluate smartphone applications using more rigorous evaluative techniques with better controls to obtain a clearer picture of how smartphone applications may be a useful addition to weight management interventions.

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Table 1: Inclusion criteria

PICOS	Inclusion criteria
Population	Obese or overweight adults over the age of 18 years.
Intervention	Smartphone application intervention that uses some element of self-regulation such as goal setting, self-monitoring, and feedback for dietary control and weight loss or maintenance.
Comparators	Control group with usual care, or other method of dietary regulation, or pre and post measures.
Outcomes	Weight loss or BMI are the primary outcomes, secondary outcomes can include waist circumference or weight maintenance, measures of dietary change
Study Design	RCTs, Experimental, Quasi-experimental Longitudinal, single group pre and post.

Table 2: Quality assessment ratings for each included study.

Study	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals/drop outs	Outcome rating
Allen et al 2013	2	1	2	2	1	2	2
Wharton et al 2014	2	1	3	2	1	1	2
Turner-McGrievy et al 2011 and 2013	1	1	3	3	1	1	2
Thomas & Wing 2013	2	2	2	3	1	1	2
Carter et al 2013	2	1	2	1	1	2	2
Laing et al 2014	2	1	2	3	1	2	2

Note: Quality rating scores 1 = Strong, 2 = Moderate, 3 = WeakOverall outcome was calculated as the average score across the assessments.

Commented [H1]: I hope this explains how the outcome rating was calculated.

NB: Studies with no weak ratings and at least four strong ratings are considered strong. Studies with no strong ratings and at least four weak ratings are considered weak.

Table 3: Intervention characteristics of smartphone based weight loss interventions that employ self-regulatory strategies.

Study	Population and Sample size	Study design	Length and time points measures taken	Intervention group	Comparison group(s)	Primary Outcome measure
Wharton, Johnston, Cunningham & Sterner, (2014) **USA**	Weight stable adults with a BMI of 25-40 kg/m^2 average age of 42 years. 35 females 12 Males (dropout of 11 at 8 weeks)	Randomised trial with no control group. Compared different interventions longitudinally	8 weeks (baseline 8 weeks)	Lose it! Weight loss application with immediate goal setting, self-monitoring and feedback.	1) Nutrition counselling at baseline, Pencil and paper recording with weekly emails. 2) Nutrition counselling at baseline with smartphone memo function use	BMI weight (kgs)
Turner-McGrievy & Tate, (2011) **USA**	Overweight and obese adults with a BMI of 25-45 kg/m^2 average age of 43 years 72 females 24 Males (dropout of 10)	Non-randomised, longitudinal trial with no control group	24 weeks (Baseline, 12 Weeks, 24 Weeks)	Podcast plus self-monitoring application (of choice) and twitter application	Podcast plus Paper and pencil diary	BMI, weight (kgs) energy intake (kcal/day)
Thomas & Wing, (2013) **USA**	Overweight and obese adults with a BMI of 25-50 kg/m^2 Average age of 53 years. 19 Females 1 Male (dropout 0 at 12 weeks, 5 at 24 weeks)	Longitudinal pre-post design	24 Weeks (Baseline 12 Weeks 24 Weeks)	Health E-Call smartphone application with self-monitoring, goal setting and feedback	Baseline measures (pre-post study)	Weight in kg BMI
Allen, Stephens, Dennison-Himmelfarb, Stewart, & Hauck (2013) **USA**	Overweight or obese adults with a BMI of 28-42 kg/m^2 average age of 44 years 53 Females 15 Males (dropout 25 at 24 weeks)	Randomised trial with no control group; compares different interventions longitudinally	24 weeks (Baseline 24 weeks)	(SLIM) Smart coach for lifestyle management: Smartphone application; Lose it! (feedback, self-monitoring, social networking) plus diet and exercise intensive counselling	1) Intensive counselling only 2) Less intensive counselling + smartphone application 3) Smartphone only	Weight in kg BMI waist circumference in cm dietary intake (kcal/day)

Study	Population and sample size	Study design	Length and time points measures taken	Intervention group	Comparison group(s)	Primary Outcome measure
Carter, Burley, Wark, Evans, Greenwood, Hardie, Frost, & Cade (2013) **UK**	Overweight and obese adults with a BMI of greater than 27 kg/m^2 and a mean age of 42 years 99 females 20 Males (dropout 34 at 6 weeks, 49 at 24 weeks)	Randomised trial with no control group; compares different interventions longitudinally	24 Weeks (Baseline 6 weeks, 24 weeks)	'My Meal Mate' intervention: Smartphone application incorporating goal setting, self- monitoring, and feedback to aid weight loss.	1) Pencil and paper diary group with goal setting and self-monitoring 2) Website group with goal setting and self-monitoring (NB uses same database of foods as the smartphone application)	Weight (in kg) BMI
Laing, Mangione, Tseng, leng, Vaisberg, Mahida, Bholat, Glazier, Morisky, Bell (2014) **USA**	Overweight and obese adults with a BMI of greater than 25 kg/m^2 and a mean age of 43 years. 154 Females 58 Males (dropout 40 at 24 months)	Randomised controlled trial	24 weeks (Baseline, 12 weeks 24 weeks)	My Fitness Pal Smartphone application incorporating goal setting, self-monitoring, feedback and social media functions	Control condition- 'usual care'	Weight (in kg) BMI Healthy diet

Table 4: Comparison of Study findings

Study	Comparison groups	Weight loss in kg (SD)	Difference in weight across time	Difference in weight between groups at final time point
Wharton et al, 2014 (38)	Smartphone Application group	-1.58 (2.21)	Significant p<.001	Non-significant
	Paper diary and counselling	-2.00 (2.09)	Significant p<.001	P=.19
	Smartphone Memo	-2.95 (2.71)	Significant p<.001	Cohen's d= 0.07
Turner McGrievy, et al 2011 (37)	Smartphone Application and podcast	-2.7 (5.60)	Significant p<.05	P=.88 Non-significant
	Paper diary and podcast	-2.7 (5.60)	Significant p<.05	Cohen's d=0.04
Thomas & Wing, 2013 (36)	Smartphone application group	-10.9 (1.10)	Not reported- low power	N/A pre-post design
Allen et al, 2013 (33)	Intensive counselling	-2.5 (4.10)	Not significant- low power	Not significant p=0.89
	Intensive counselling plus smartphone application	-5.4 (4.00)	Not significant- low power	Cohen's d=0.67
	Less intensive counselling plus smartphone application	-3.3 (5.90)	Not significant- low power	
	Smartphone application only	-1.8 (3.70)	Not significant- low power	
Carter et al 2013 (34)	Smartphone application	-4.6 (SD not reported)	Significant difference p<.01	Significant difference between smartphone group and website group p=.004 No significant difference between smartphone and paper diary group p=.12
	Paper diary	-2.9	Significant difference p<.01	
	Website logging	-1.3	Significant difference p<.01	
Laing et al 2014 (35)	Smartphone application	-0.03 (SD not reported)	Not significant	No significant difference between the groups p=0.53
	Control condition	+0.24	Not significant	

Figure 1: Flow Chart using PRISMA guidelines (Moher et al 2009)