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Short message service (SMS) text messaging as an intervention medium for weight loss: A literature review

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Abstract

Nearly 68% of American adults are obese or overweight. Mobile devices such as mobile phones have emerged as a mode of intervention delivery to help people improve their health, particularly in relation to weight loss. This literature review examines the relationship between the use of short message service (SMS) text messaging as an intervention medium and weight loss. Results from this literature review (n = 14) suggest that SMS as an intervention tool for weight loss is still in its infancy. Initial results are promising but continued investigation is needed. We offer several recommendations for future research.

Keywords

eHealth, IT healthcare evaluation, mobile health, pervasive technologies, telecare

Introduction

Nearly 68% of American adults are obese or overweight[1] contributing to chronic disease, mental health problems[2] and disability.[3] The dramatic increase in the rates of obesity in the last 20 years is a result of increases in calorie intake, eating nutrient-poor foods and reductions in physical activity.[4, 5] Weight-loss interventions utilizing a reduced-energy diet and exercise are associated with effective 5–8.5 kg (5–9%) weight loss that plateaus at approximately six months.[6] Despite the effectiveness of these interventions, people continue to be overweight and obese. Even though we may understand how people lose weight, we must continue to develop effective interventions that people will use and adopt. One potentially effective intervention approach that is easy to use and to adopt is the use of mobile devices, such as mobile phones.

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Mobile devices such as mobile phones have emerged as a mode of intervention delivery to help people improve their health, particularly in relation to weight loss.[7] In the USA alone, more than 87% of the population use a mobile phone.[8] Using mobile phones as a medium to deliver weight loss interventions has distinct advantages in that it reaches across geographic and economic boundaries, can be delivered directly to people and is easy to use.[9–12] Furthermore, short message service (SMS) also known as text messaging, has grown in popularity as a way to deliver health information owing to its simplicity, low cost and ability to serve as a cue to action.[9–12] SMS is a messaging service of up 160 characters in length to and from fixed line and mobile phone devices. SMS text messaging is the most widely used data application in the world, with over 2.4 billion users; twice the number of people who use the Internet uses SMS.[8]

Many commercial weight-loss programs have adopted SMS as a tool to help clients in their weight loss. A quick Internet search reveals many online text-based weight loss tools, including many 'apps' for smart phones that message users about their diet and exercise. Although there is increasing popularity of SMS-based weight loss tools, an evaluation of their effectiveness is needed. Thus, the purpose of this review was to answer the following question: What is the relationship between the use of SMS as an intervention medium and weight loss?

The review

Search methods

A comprehensive search using Medline (PubMed), the Cumulative Index for Nursing and Allied Health Literature (CINAHL), Proquest, PSYCHINFO and Google Scholar was undertaken. Keywords used to search for relevant literature included obese, overweight AND intervention, AND short message service OR SMS OR text messaging OR mobile health OR mHealth OR multimedia message service OR MMS. In addition, back referencing and citation searching of the selected studies was undertaken. Limits were set at studies published in English or that had an English translation.

Inclusion and exclusion criteria

Inclusion criteria required that studies be randomized or quasi-experimental intervention trials of participants who are managing their weight. All interventions had to focus on the use of SMS on reducing obesity, overweight or promoting weight loss. Studies that used other information technologies, such as e-mail, phone calls and video conferencing, were only included if SMS was a primary mode of communication. Studies were required to measure the impact of SMS on a weight loss-related variable post-intervention, including body weight, body mass index (BMI), waist circumference, physical activity or diet. In addition, all studies had to be published in a peer-reviewed journal or under a similar peer-reviewed process such as a dissertation.

Search outcomes

Using the aforementioned keywords resulted in 205 articles. After screening of titles and abstracts, 43 studies were read entirely. Eleven non-research studies were removed and six studies that did not measure a weight loss-related outcome post-intervention (i.e. BMI, body fat percentage, exercise, diet) were removed. In addition, two studies were removed that were purely qualitative and another was removed that used mobile phones as a portal to a web-based weight-management program without SMS.[13] Fourteen studies were included in the final analysis.

Synthesis

Meta-analysis of the data was not appropriate because there was a great deal of diversity in the interventions and outcomes measures. Many studies had small sample sizes (n <50) and only 5 had a sample size greater than 100. In this review, the main focus was on extracting data on descriptions of interventions (study design, samples and intervention overviews), outcomes measures and evaluation of the effectiveness of interventions. The quality of study design was assessed using a scoring system adapted from a review of eHealth interventions.[14, 15] Nine methodological characteristics were used to score the studies. These included the following: individual randomization, use of a control group for comparison, isolation of text messaging technology, use of pre-test/post-test design, retention, equivalence of baseline groups, consideration of missing data, power analysis and validity of measures.

Findings

All 14 studies focused on increasing physical activity or reducing sedentary behavior; 11 focused on improving dietary habits, 3 measured the effects of SMS on blood pressure (BP) as an outcome from weight loss and 10 assessed the acceptability or feasibility of SMS as a mode of delivery for weight loss. Studies were conducted worldwide. Although SMS has been used an intervention medium to promote behavior change since 2004,[16] studies reporting the use of SMS for weight loss were not found prior to 2007. Mean age ranged from 10 to 65 years and, in general, there were more female participants than male (1863 vs. 385). A clear theoretical or conceptual model was found to guide all but three studies.[17–19] These included, but were not limited to, social cognitive theory,[20] self-efficacy theory,[20] the elaboration likelihood model,[21] the theory of planned behavior[22] and frameworks of self-monitoring and/or tailoring (Table 1).[13, 18, 19, 23–26]

Randomization was used in 10 studies[18, 24, 25, 27–33] and a comparison control group was used in 11.[18, 24, 25, 27–34] The majority of studies had a single baseline measurement and a single post-intervention measurement. Intervention duration ranged from 2 weeks to 12 months. Only 2 studies intervened greater than 6 months: one for 36 weeks and the other for 12 months. For those studies that had a control group, usual diet and exercise care was the norm. All studies used SMS as an intervention tool, with one adding multimedia messaging service (MMS) as an intervention tool.[24] MMS extends the capability of SMS to include pictures, videos and other multimedia.

Time of delivery of messages was reported in six studies and varied from mornings to just before bed. Delivery frequency varied dramatically between two and five times per day to once a month. Automation of the SMS was reported in nine studies. There was limited information reported on the specifics, such as software of the SMS programs used for delivery. All of the studies transmitted information from the researchers to the participants. Seven of the studies had two-way communication where participants transmitted information such as weight or physical activity via SMS to the researchers.

SMS feasibility and acceptability

Seven studies measured feasibility and acceptability of SMS as a mode for weight loss interventions.[19, 23–25, 27, 33, 34] Feasibility was defined as the ability to transmit data via SMS to participants, the receipt of information by participants and the ability to communicate back to the researchers. Acceptability was defined as feeling comfortable with receiving messages to a personal mobile phone, feeling that messages were personally relevant and that they were helpful. SMS was found

Table 1. Summary of studies included in review (n = 14)

Author/ date	Behaviors	Sample	Theoretical/ conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and measures	Results
Randomized controlled trials (RCT)										
Fjeldsoe et al., 2010 [28]	PA	n = 88, post-natal, 100% female, Australia	Social cognitive theory	Two- group RCT, pre-test/post-test at 6 and 13 weeks; total duration: 12 weeks	12 weeks	Timing: not reported; frequency: 3–5 × week; automated: no	Usual care	Face-to face PA goal-setting consultation, tailored SMS and a support person who received SMS	Frequency and duration of PA	Primary outcome: increased PA by 1.82 days/week and walking frequency by 1.08 days/week (p <0.05). Positive trends in duration of PA and walking
Haapala et al., 2009 [29]	PA, diet, weight reporting	n = 125, age mean: 38, BMI mean: 30, 79% women, Finland	Contingency model, self-efficacy theory	2 × 2 RCT, pre-test/ post-test at 3, 6, 9 and 12 months; total duration: 12 months	52 weeks	Timing: not reported; frequency: participant initiated. 8 × week to 3–4 × week by end of 12 months; automated: yes	No contact	Website tracked diet and weight. Weight sent in via SMS. Tailored diet and PA SMS delivered	Weight, height, waist circumference, perceived usefulness, attitudes of SMS, frequency of use, diet, PA, diet self-efficacy	Primary outcome: 4.5 kg lost at 12 months (p <0.01) versus 1.1 kg in control. Decreased waist circumference (p <0.01) Secondary outcome: moderate–high satisfaction, dietary improvements, increased PA and dietary self-efficacy increased in those who maintained weight loss, but decreased in those who re-gained weight

Table 1. (Continued)

Author/date	Behaviors	Sample	Theoretical/conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and measures	Results
Hurling et al., 2007 [30]	PA	n = 77, mean age = 40.4, mean BMI: 26, Finland	Social comparison, decisional balance, elaboration likelihood, goal theory	Two-group RCT, pre-test/post-test; total duration: nine weeks	Nine weeks	Timing: not reported; frequency: not reported; automated: yes	No support	Tailored solutions for perceived barriers, a schedule to plan weekly exercise sessions with SMS and e-mail reminders, message board to share experiences, and feedback on level of PA	Accelerometer, PA, weight, % body fat, height, BP, motivation, perceived control, intent to exercise, exercise knowledge	Primary outcome: significant difference in perceived control and intent to exercise (p <0.01) Secondary outcome: significant difference in percent body fat -2.18% in intervention group (p = 0.04) versus -0.17% in control; no significant difference in motivation, BMI or BP
Newton et al., 2009 [18]	PA	n = 78, mean age 14, 53% female, type 1 diabetes, New Zealand	Not reported	Two-group RCT, pre-test/post-test; total duration: 12 weeks	12 weeks	Timing: not reported; frequency: weekly; automated: not reported	Usual care	Wore a pedometer and received motivational SMS	Daily step count, PA, HbA1c, BP, BMI, quality of life, insulin dose	Primary outcome: no significant changes. At 12 weeks, mean daily step count was not significantly different (p = 0.4). Mean self-reported physical activity increased by 38.5 min/week in the control group and by 48.4 in the intervention group (p = 0.9)

(Continued)

Table 1. (Continued)

Author/date	Behaviors	Sample	Theoretical/conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and measures	Results
Patrick et al., 2009 [24]	PA, diet	n = 65, mean age: 45, mean BMI: 33.2, 80% female, USA	Self-monitoring and tailored messages	Two-group RCT, pre-test/post-test; total duration: four months	Four months	Timing: varied; frequency: 2–5 × day; automated: yes	Monthly printed materials on weight control	SMS and MMS with tips and positive reinforcement. Printed materials and monthly phone calls, as well. Participants reported weight via SMS once a week	Weight, adherence, satisfaction, validated self-reported questionnaires	Primary outcome: intervention lost 1.97 kg more than control (p <0.05) Secondary outcome: 67% adherence by week 16, majority of participants would recommend intervention
Prestwich et al., 2010 [32]	PA	n = 149, mean age: 23, female 64%, UK	Implementation intentions	Three-group RCT, pre-test/post-test; total duration: four weeks	Four weeks	Timing: varied; frequency: varied; automated: yes	Usual care and completed a goal recall test at end of study	SMS plan and goal reminders. Completed a goal recall task at the end of the study	PA, implementation intentions, goal recall, weight, waist-to-hip ratio	Primary outcome: increased brisk walking (p <0.01), goal reminder group lost the most weight (p <0.05) Secondary outcome: total exercise increased in the implementation goal reminder group compared with control (p <0.05), but no difference in other groups

Table 1. (Continued)

Author/date	Behaviors	Sample	Theoretical/conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and measures	Results
Shapiro et al., 2008 [25]	PA, diet	n = 58, aged: 5–13, 91% female, BMI mean 27, USA	Self-monitoring	Three-group RCT, pre-test/post-test; total duration: eight weeks	Eight weeks	Timing: varied; frequency: 2 × day; automated: yes	Group 1: paper diaries, Group 2: monitoring control	Three educational sessions per week for three weeks on pedometers, beverage serving sizes and screen time. Parent and child texted behaviors in. Automated text was sent in return. SMS used as a diary tool	Acceptability, self-monitoring adherence	Primary outcome: increase in self-monitoring in SMS group (43%) versus control (19%) Secondary outcome: reduction in screen-time in SMS group
Sirriyeh et al., 2010 [33]	PA	n = 120, aged: 16–19, 70% female, UK	Theory of planned behavior	Four-group RCT, pre-test/post-test; total duration: two weeks	Two weeks	Timing: 4 pm; frequency: 1 × day; Automated: not reported	Two text messages total with a neutral message	Daily SMS of either affective beliefs, instrumental beliefs, or a combinations	PA	Primary outcome: 31.5 min. increase in PA across all groups (p <0.05) Inactive participants at baseline increased activity levels significantly more (p <0.05)
Zuercher, 2009 [27]	PA, diet, sedentary behavior	n = 177, aged: 18-30, female, USA	Social cognitive theory, elaboration likelihood and social support theory	Randomized pre-test/post-test; total duration: one month	One month	Timing: before bed; frequency: daily; automated: yes	Stress management, pedometer, called on five random days and asked questions about previous day behaviors	Monitored behaviors daily, inputting answers to three questions into their phones and received automated feedback to answers based on how close they were to achieving a daily goal	Weight/BMI, daily steps, sugar-sweetened beverages, screen-time, self-directedness, self-efficacy, social support, elaboration likelihood, self-monitoring, acceptance	Primary outcome: no significant changes in PA Secondary outcome: decrease in screen time in both groups. SMS was viewed as acceptable

(continued)

Table 1. (Continued)

Author/ date	Behaviors	Sample	Theoretical/ conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and measures	Results
Quasi-experimental										
Bauer et al., 2010 [23]	PA, diet, emotions	n = 40, mean age: 10, 58% female, BMI-SDS mean: 2.62, Germany	Self-monitoring and tailored feedback	Pre-test/post-test; total duration: 36 weeks	36 weeks	Timing: not reported; frequency: weekly; automated: yes	N/A	Self-monitoring of diet, exercise and emotions via SMS following a cognitive behavioral therapy group. Tailored feedback was given after each response	Adherence, BMI	Primary outcome: feasible for children to self-report eating and exercise behaviors, 67% of the weekly SMS were submitted Secondary outcome: no significant difference in BMI
Fukuoka et al., 2010 [19]	PA	n = 41, mean age: 48, BMI: 33, 100% female, USA	Not reported	Pre-test/post-test; total duration: three weeks	Three weeks	Timing: not reported; frequency: daily; automated: yes	N/A	SMS encouraged participants to increase steps by 20% from the previous week	Total steps, self-efficacy, overall barriers, social support	Primary outcome: total steps increased by 15% over three weeks (p <0.001) and will-power improved (p <0.001). Secondary outcome: no change in self-efficacy, overall barriers, and social support
Joo and Kim, 2007 [17]	PA, diet	n = 927, 89% women, BMI mean: 25.7, South Korea	Not reported	Quasi-experimental pre-test/ post-test	12 weeks	Timing: not reported; frequency: weekly; automated: not reported	N/A	SMS on behavior modification on exercise, diet and information brochures by post	Weight, waist circumference, BMI, BP, satisfaction	Primary outcome: significant weight loss of 1.6 kg, waist circumference of 4.3 cm and BMI -0.6 kg/m^2 (p <0.01) Secondary outcome: majority were satisfied with intervention

Table 1. (Continued)

Author/ date	Behaviors	Sample	Theoretical/ conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and measures	Results
McGraa, 2010 [34]	PA, diet	n = 65, age range: 18–70+, 80% female USA	Captology, cognitive theory, social learning theory, persuasive tactics	Two arm, pre-test/post-test; total duration: five weeks	Five weeks	Timing: 8 a.m.; frequency: varied up to 3 × day; automated: yes	Already on a diet and exercise program and did not receive SMS	Daily SMS log of diet, exercise, levels of motivation and stress, and weight. Weekly e-mail asking how often they exercised, logged diet, and level of stress and motivation.	Personality traits on using mobile phone as intervention coach, adherence, exercise frequency, weight	Primary outcome: no significant effects on exercise frequency or weight
Park et al., 2009 [26]	PA, diet, medication	n = 49, mean age: 54, 57% female, BMI mean: 26.6, hypertensive, South Korea	Self-monitoring and tailored feedback	Quasi-experimental post-test evaluation	Eight weeks	Timing: not reported; frequency: weekly; automated: no	N/A	Recorded BP and body weight via a website or mobile phone. Tailored recommendations via the Internet and SMS were sent	BP, weight, waist circumference	Primary outcome: significant changes in SBP of -9.1 mmHg, DBP of -7.2 mmHg, weight of -1.7 kg, and waist circumference 2.8 cm (p <0.05)

BP, blood pressure; BMI, body mass index; BMI-SDS, Body Mass Index Standard Deviation Score; DBP, diastolic blood pressure; HbA1c, glycosylated hemoglobin; PA, physical activity; SBP, systolic blood pressure.

feasible and acceptable in all seven studies. Bauer[23] found it feasible for children (n = 40, mean age: 10 years) to self-report data on eating, exercise and emotions via SMS for 36 weeks. Additionally, several studies reported that people were positive towards the SMS system.[13, 17, 24, 27]

Self-efficacy and social support

Of the three studies that measured the effects of SMS on self-efficacy, two found no significant change in physical activity self-efficacy.[19, 27] One study showed a statistically significant increase ($p < 0.05$) in dietary self-efficacy in comparison with a control group.[29] One study measured social support yet found no change from baseline to post-baseline in comparison with a control group.[27]

Physical activity

Three out of six studies that measured the frequency or duration of physical activity found a statistically significant difference. All studies reported the use of validated physical activity instruments. Fjeldsoe[28] found an increase of physical activity of 0.74 days/week in a group of post-natal women who received tailored exercise SMS compared with a control group ($p < 0.05$). Prestwich[32] reported that participants in the SMS groups increased the number of days on which they met physical activity daily guidelines, through brisk and fast walking, significantly more ($p < 0.05$) than the control group did. Haapala[29] found physical activity increased in both the SMS and control groups, from 2–3 times per month to once per week ($p < 0{\cdot}05$), on average; differences between the SMS and control groups were not reported. Hurling[30] found a significant increase in intent to exercise of 0.46 ($p < 0.01$) and perceived control of 0.84 ($p < 0.01$) in the SMS group compared with the control group. However, McGraa,[34] and Newton[18] found no significant effect of physical activity in a group of people receiving motivational exercise SMS compared with a control group.

Diet

Four studies measured the effects of an SMS intervention on dietary habits. Three of the four studies used instruments to measure diet specific variables.[25, 27, 29] Of these, only two used validated instruments.[27, 29] Shapiro[25] found that diet and exercise self-monitoring increased by 43% in the group reporting their behaviors via SMS versus 19% in the paper diary control group. However, Zuercher[27] found no significant difference in the amount of sugar-sweetened beverages consumed by a group of women (n = 177) receiving SMS tips on improving dietary behavior. Haapala[29] also found no significant difference in caloric intake in the SMS group receiving tailored dietary feedback compared with a non-intervention control group. Joo[17] found recipients of weekly diet and exercise SMS lost 1.6 kg over 12 months ($p < 0.01$); however, diet specific variables were not reported in the outcome measures.

Blood pressure

Two of three studies that measured the effect on BP from weight loss found SMS statistically and clinically significantly reduced BP ($p < 0.05$). For example, Park[26] found systolic and diastolic BPs decreased significantly by 9.1 and 7.2 mmHg, respectively, at 8 weeks from baseline (135.7 ± 8.8 mmHg) in the intervention group ($p < 0.05$) with no significant change in BPs in a control group. Joo[17] found a within-group decrease ($p < 0.05$) in systolic BP by 4.4 mmHg respectively at 12 weeks from baseline (125.9 mmHg).

Weight loss

Overall, 11 (79%) of the 14 studies had a statistically significant effect (p <0.05) on weight loss-specific variables (i.e. weight, physical activity or diet). Of the 10 studies that measured BMI or weight as an outcome, 5 (50%) demonstrated a statistically and clinically significant difference in BMI post-intervention (p <0.05). Hurling[30] showed an average 2.01% decrease in body fat in the group receiving tailored physical activity SMS compared with control (p <0.05); however, no significant difference in BMI was found. Compared with a control group, Haapala[29] found that the exercise SMS group lost 3.4 kg over 12 months (p <0.01) and that the percentage of people achieving at least 5% weight loss and keeping it off for 12 months was 25% greater in the experimental than in the control group. Patrick[24] found that the experimental group that received tailored SMS and MMS with tips, suggestions and positive reinforcement over 4 months lost 1.97 kg more compared with a control group that received monthly printed materials (p <0.01). In addition, Prestwich[32] found that the group that received goal reminders or plan reminders via SMS lost 0.39 kg more over a month compared with a usual care control group (p <0.05). From baseline to follow-up, Joo[17] found recipients of weekly diet and exercise SMS lost 1.6 kg over 12 months (p <0.01). Three studies found no significant decrease in BMI or body fat percentage compared with control[18, 27, 34] and one found no significant difference from baseline to follow-up.[23]

Design quality

The average quality of the study designs was 66% (Table 2). Ten studies used randomization and a comparison control group. Retention was above 80% for 8 of the 14 studies. Three studies conducted a power analysis and recruited the respective required sample sizes. Many of the studies were pilot or feasibility and did not have a power analysis for sample size calculation. All but two studies reported to use validated scales.

Discussion

There is a continuing challenge to develop interventions that successfully help people improve their health and lose weight. Results from this literature review demonstrate that SMS as an intervention tool for weight loss is still in its infancy, as indicated by the paucity of randomized clinical trials with limited sample sizes. At the same time, 14 studies within a four-year time frame demonstrate the increased attention that SMS has gained as an intervention approach to promote weight loss behaviors. SMS was found to be feasible and acceptable as an intervention medium to transmit and receive diet and exercise messages. Acceptability was determined by people stating they felt comfortable receiving messages, were able to access and receive messages to their mobile phone, and felt that the messages were helpful. This is important as mobile phones are a personal entryway into people's lives that provide a direct link of contact at any time and any place.

Of the 14 interventions in this review, 11 showed a statistically significant effect on weight loss, diet or exercise, and one study showed a statistically significant effect on BP. Clinical significance may be garnered from the results that indicated increases in physical activity, decreases in weight loss and improvement in systolic blood pressure. Nevertheless, 3 of the 14 interventions did not demonstrate a statistically significant effect on weight loss, diet or exercise.

Design of the interventions varied significantly. Notably, the timing and frequency of delivery of SMS were inconsistent. Owing to the inconsistency of timing and delivery it is difficult to understand how often, and when, people should receive diet and exercise SMS. Of the six studies

Table 2. Quality score of study design and scoring criteria

Author, Year	Individual randomization	Control group	Isolate technology	Pre-test/ post-test	Retention ≥80%	Baseline groups equivalent	Missing data	Sample size calculation	Validated measures	Score (% of maximum)
Bauer et al., 2010 [23]	N	N	Y	Y	Y	N/A	N	N/A	Y	44
Fjeldsoe et al., 2010 [28]	Y	Y	Y	Y	N	Y	Y	N	Y	78
Fukuoka et al., 2010 [19]	N	N	Y	Y	Y	N/A	N	N/A	Y	44
Haapala et al., 2009 [29]	Y	Y	N	Y	N	Y	Y	Y	Y	78
Hurling et al., 2007 [30]	Y	Y	N	Y	N	Y	N	N	Y	56
Joo and Kim, 2007 [17]	N	N	Y	Y	N	Y	N	N	N	33
McGraa, 2010 [34]	Y	Y	Y	Y	N	Y	N	N/A	Y	67
Newton et al., 2009 [18]	Y	Y	N	Y	Y	N	Y	N	Y	67
Park et al., 2009 [26]	N	N	Y	Y	Y	Y	N	Y	Y	67
Patrick et al., 2009 [24]	Y	Y	N	Y	Y	N	Y	N/A	Y	67
Prestwich et al., 2010 [32]	Y	Y	Y	Y	Y	Y	Y	Y	Y	100
Shapiro et al., 2008 [25]	Y	Y	Y	Y	N	Y	N	N/A	N	56
Sirriyeh et al., 2010 [33]	Y	Y	Y	Y	Y	Y	N	N/A	Y	78
Zuercher, 2009 [27]	Y	Y	Y	Y	Y	Y	Y	N/A	Y	89

Table heading	Scoring criteria
Individual randomization	Were participants randomly assigned to study conditions? If so, was randomization at the individual level? Stratified and blocked randomization is acceptable. Studies that used individual randomization combined with a small proportion of randomized matched pairs are also considered Y. Appropriately designed and powered group randomization would also be acceptable if group was also unit of analysis. Individual randomization is N when the authors fail to mention randomization, specify that another method of assigning group status was used, or randomize at the group level and analyze at the individual level.
Control group	Did the study include a comparison group? Comparison group could be a no treatment, treatment as usual or alternate treatment group.
Isolate technology	Did study design allow for test of effectiveness of the technology (e.g. web-based delivery vs. no treatment)? To isolate the technology, the authors had to test the technology alone and compare with a group with no technology (Y). Packaged interventions in which the technological components cannot be parsed out are coded as not isolating the technology (N).

Table 2. (Continued)

Author, Year	Individual randomization	Control group	Isolate technology	Pre-test/ post-test	Retention ≥80%	Baseline groups equivalent	Missing data	Sample size calculation	Validated measures	Score (% of maximum)
Pre-test/post-test design		Was assessment of behavior completed pre- and post-intervention?								
Retention		Was study retention at least 80% of subjects who initially agreed to participate in the study? Retention is calculated for the entire sample and not by group. For studies that did not report retention or dropout rates, retention can be calculated by using the sample sizes used for analyses (e.g. 300 randomized but only 250 included in analyses = 83.3% retention).								
Baseline groups equivalent		Were tests conducted to determine whether groups were equivalent at baseline regarding important variables (e.g. gender, age, weight)? If no tests mentioned then = unknown/unclear. If subset of tests indicated any group differences at baseline, then = N								
Missing data		Were analyses conducted with consideration for missing data that maintain the fidelity of the randomization (e.g. intent to treat, imputation)? Listwise, case deletion (completer analysis) = N if only analysis conducted. If 100% retention, then completer analysis is appropriate = Y. If authors compared the 'dropped subgroup' with the selected or randomized sample but did not consider the impact of the dropped subgroup on randomization (e.g. intent to treat or imputation), then code as N.								
Sample size calculation		Was power analysis reported to determine study sample size? If a feasibility or exploratory study for which sample size cannot be calculated beforehand, then N/A.								
Validated measures		Did description of measures include reliability and validity information? If reference or coefficients, then Y. If well-established measure known to be validated, then Y. For objective measures without validity evidence, if the objective measure is used as a proxy (e.g., food receipts for nutrition intake), then N. If the objective measure is used as a direct measure of behavior (e.g. food receipts for food purchase), then Y. If validity not reported and measure unknown, then unknown/unclear.								
Total		Sum of Ys								

N, no; N/A, not applicable; Y, yes.

that delivered at least one SMS per day, five demonstrated significant improvement in weight loss behaviors. From these results, effectiveness and optimal use cannot yet be determined. Nonetheless, at least one SMS per day may be appropriate in helping motivate people to engage in weight loss behaviors without generating a considerable burden. Two studies used SMS to intervene or measure outcomes for longer than six months,[23, 29] with only one showing a significant difference.[29] The effectiveness of SMS longitudinally for weight loss remains undetermined at present.

SMS is often touted as an affordable and low-cost method of delivering intervention to, and communication between, patient and providers. However, among the studies reviewed, there was limited discussion or evaluation on the cost-effectiveness of SMS. One study reported that participants received £140 for mobile phone costs, but there were no specific details.[30] Bauer et al.[23] spoke about the cost-effectiveness of their SMS messaging intervention and Patrick et al.[24] reported that costs were low because the tailoring of the messages was automated and additional users could be added at a low cost. Nevertheless, details were limited.

Continued research is needed on many fronts. Large randomized controlled trials with a significant sample size and longitudinal measurements are needed to understand how to best use and understand the benefits of SMS as an intervention medium. Informative research is required to find out exactly what should be written in a message and to understand the best timing and frequency of message delivery. In addition, it may not be that SMS is the most effective intervention approach, but just one of many that should be used in combination to support and help people change their diet and exercise lifestyle.

Recommendations

Based on the findings of this review, the following recommendations for future research are offered:

1. large randomized controlled trials with a significant sample size that can be used to determine effect sizes and statistical significance;
2. intervention trials that are longitudinal in nature and evaluate maintenance of weight loss behaviors (12 months or longer);
3. specific evaluation of cost-effectiveness, frequency, timing and optimal use of SMS;
4. more detailed reporting of intervention content and outcomes with respect to the magnitude of between-group differences at follow-up, and the direction and magnitude of change between end-of-intervention and follow-up.

Conclusion

Text messaging and mobile telephone technology have emerged as an encouraging tool in promoting health that can reach people directly wherever they are, that is affordable and is easy to use. Quickly becoming a popular and major area of focus, SMS is part of a larger field of mobile health, known as mHealth: the practice of medicine, nursing and public health supported by mobile devices. The US National Institutes of Health (NIH) alone have a dedicated mHealth research focus which partners with several NIH Institutes. Other public institutes such as the Centers for Disease Control offer free mobile tips and alerts through SMS on how to improve your health. Private corporations, such as Microsoft, have recently held a healthy apps competition where developers compete to create the best health focus application that can be run on a mobile phone. As more sophisticated mobile devices such as smart phones become ubiquitous, SMS will be just a part of a cadre of mHealth technologies that will become available. This affords the opportunity for research applications that were not previously available, such as simultaneously assessing behavioral, physiological and psychological states in the real world and in real-time. The use of mobile technology, including SMS, affords numerous methodologic advantages over traditional methods, including 'reduced memory bias, the ability to capture time-intensive longitudinal data, date- and time-stamped data, and the potential for personalizing information in real-time'.[35] However, continued investigation is needed on how to best leverage this emerging technology to promote lifestyle change towards diet, exercise and weight loss.

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