

Text Messaging as a Tool for Behavior Change in Disease Prevention and Management

Heather Cole-Lewis* and Trace Kershaw

* Correspondence to Heather Cole-Lewis, Yale University School of Epidemiology and Public Health, P.O. Box 208034, New Haven, CT 06520-8034 (e-mail: heather.cole-lewis@yale.edu).

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Mobile phone text messaging is a potentially powerful tool for behavior change because it is widely available, inexpensive, and instant. This systematic review provides an overview of behavior change interventions for disease management and prevention delivered through text messaging. Evidence on behavior change and clinical outcomes was compiled from randomized or quasi-experimental controlled trials of text message interventions published in peer-reviewed journals by June 2009. Only those interventions using text message as the primary mode of communication were included. Study quality was assessed by using a standardized measure. Seventeen articles representing 12 studies (5 disease prevention and 7 disease management) were included. Intervention length ranged from 3 months to 12 months, none had long-term follow-up, and message frequency varied. Of 9 sufficiently powered studies, 8 found evidence to support text messaging as a tool for behavior change. Effects exist across age, minority status, and nationality. Nine countries are represented in this review, but it is problematic that only one is a developing country, given potential benefits of such a widely accessible, relatively inexpensive tool for health behavior change. Methodological issues and gaps in the literature are highlighted, and recommendations for future studies are provided.

cellular phone; health behavior; intervention studies; review

Abbreviations: HIV, human immunodeficiency virus; mHealth, mobile health.

BACKGROUND

By the end of 2008, there were an estimated 4 billion mobile phone subscribers worldwide. Since there were only 1 billion subscribers in 2002, it is apparent that use of this technology is growing rapidly (1). Ninety-five percent of countries in the world have mobile phone networks, and the majority of these countries have more mobile phone than landline subscriptions (2, 3). In nearly a third of the countries, the number of cell phones in use is greater than the number of people living in those countries (4).

Mobile phones have had a considerable impact in developing countries (3, 5, 6). Communication by mobile phone is less expensive than alternative options such as landline telephones or standard Internet (1, 7). Millions of people across Africa and Asia who never had access to traditional phone communication now use mobile phones on a regular basis (3, 5, 8). Additionally, across the world (in both developing and developed countries), people are gaining access to the Internet via mobile phones. For many, the mobile

phone is currently the primary mode of accessing the Internet, which the Pew Internet & American Life Project suggests will be the case for the entire world by 2020 (5, 9). In a recent survey, 23% of Americans reported accessing the Internet via their mobile phone on a typical day, reflecting a 64% increase from 2007 (10). United Nations leaders report that the widespread use of mobile technology demonstrates feasibility for the use of information and communication technologies throughout the world. This is important, given the potential of these technologies to serve as catalysts for reaching the Millennium Development Goals for 2015 (8).

Mobile technology has already been widely adopted around the world; its utilization is growing at a rapid rate, not just for interpersonal communication but as an important aspect of communication infrastructure for industries including finance, education, and marketing (3, 5, 11, 12). Mobile technology is also increasingly used to promote health and prevent disease (11, 13–17). Mobile health (mHealth) is the use of mobile phone technology to deliver

health care. Mobile phone technologies that have been utilized for mHealth include, but are not limited to, text messaging, video messaging, voice calling, and Internet connectivity (5, 13, 14, 18).

mHealth innovations have been developed that address an array of issues such as improving the convenience, speed, and accuracy of diagnostic tests; monitoring chronic conditions, medication adherence, appointment keeping, and medical test result delivery; and improving patient-provider communication, health information communication, remote diagnosis, data collection, disease and emergency tracking, and access to health records (5, 6, 13). For example, in South Africa, Project Masiluleke uses text messaging to increase rates of testing for tuberculosis and human immunodeficiency virus (HIV) and to provide counseling for patients (19). The CelloPhone Project, developed in the United States, creates an optical imaging platform that allows body fluids to be analyzed with a mobile phone (20). Another project in the United States uses mobile video messaging to deliver soap operas that model HIV prevention messages for young women (21). In Uganda, EpiHandy—a mobile-phone-based data collection and records access tool—was found to reduce data entry errors and improve cost-efficiency when compared with traditional paper surveys (6).

mHealth has been used because it offers interactive 2-way communication, which provides a wide range of opportunities from improving self-monitoring for those with chronic diseases to improving public health infrastructure in rural areas (e.g., remote access to data and health records) (6, 22–24). mHealth also allows researchers to capitalize on the existing cultural behaviors of young populations, given their rates of access and use of mobile technology (3, 23–28).

This review focuses on the least advanced, but most widely adopted and least expensive technological feature of mHealth—text messaging (3, 13, 14, 28, 29). Text messaging is a short form of communication transmitted between mobile phones on a bandwidth lower than that of a phone call, and it is usually limited to 160 characters. An estimated 98% of cell phones worldwide have text message capabilities, but text messaging usage rates vary by age, culture, and country (3, 28, 30). For instance, 58% of US mobile users send text messages, and 30% of US teens send messages daily (25, 30). However, rates of text messaging vary by region and country. Even among countries with the highest usage, rates vary from as high as 89% in Mexico to 48% in India (3, 30). Furthermore, users of this technology tend to be high-frequency users, optimizing its use as a way to initiate behavior change. For example, 30% of South Korean teens send an average of 100 messages per day (3). In the United States, where 89% of teens use text messaging, the monthly average number of text messages sent and received is 2,899 (31).

Text messaging demonstrates strong potential as a tool for health care improvement for several reasons; it is available on almost every model of mobile phone, the cost is relatively low, its use is widespread, it does not require great technological expertise, and it is widely applicable to a variety of health behaviors and conditions (1, 2, 13, 29). Text messaging also has the advantage of being asynchronous

because it can be accessed at any time that is personally convenient (13, 14). Furthermore, even if a phone has been turned off, messages will be delivered when the phone is turned back on (29). Additionally, text messaging is an mHealth innovation for which utility remains even in resource-poor settings in which people may not have access to expensive technology (14, 15, 29). Text messaging is suitable for behavior change interventions because it allows for in-the-moment, personally tailored health communication and reinforcement.

Text messaging can be used as a way to deliver prevention components based on theoretical models such as the theory of planned behavior and the health belief model (32). Therefore, it can be viewed as an alternative approach to program delivery instead of personal- or group-delivered programs. However, the process of text messaging itself may tap important constructs (e.g., cues to action, reinforcement, social support) central to many behavioral theories even when the developer of the program did not explicitly base the content of the message on a theory. Studies have found that periodic prompts and reminders are an effective method to encourage and reinforce healthy behaviors (33). Therefore, increased communication, accountability, and reinforcement created by text messaging may increase the likelihood of remembering the changes that one should be making. Despite this advantage, data suggest that most prevention programs achieve stronger results when the content is theory based (33–35).

This review is important because mHealth is a rapidly growing area of research with the potential to promote health equity (8, 36). mHealth is quickly growing in practice as well, as health care professionals around the world continuously develop practical text message campaigns in the field to improve health behavior (15, 16). In a recent global survey, 86% of workers in nongovernmental organizations reported use of a mobile phone in their job, and text messaging was the second most commonly used feature (83%) (37). Furthermore, mHealth appeals to health care consumers. A recent study found that nearly 8 in 10 Americans expressed interest in mHealth (36).

This review assesses current research on the effect of text messaging in the realms of disease prevention and management using established guidelines and best practices for systematic reviews (38–40). It differs from existing reviews because of a specific focus on text messaging as the main intervention component, inclusion of only randomized controlled trials and quasi-experimental studies, and consideration of all behaviors related to disease prevention and management (13–15, 18). Text messaging is of particular interest in this review because of the unique promise of mHealth—it is the most widely available and frequently used mobile data service (3, 30). Only the most rigorous of study designs are included in this review to provide the best existing empirical evidence on text messaging. Furthermore, inclusion of the full range of disease prevention and management behaviors provides an opportunity to learn from the successes and failures of each and to identify commonalities and differences. This information will be important to identify gaps and issues in the literature for investigators as well as best practices to guide practitioners in the field.

Table 1. Disease Prevention Studies

First Author, Year (Reference No.)	Target Behavior	Methods	Population and Sample Sizes	Intervention	Control	Outcomes and Measures	Results
Cocosila, 2009 (45)	Adherence to vitamin regimen	RCT feasibility study; <u>total duration</u> : 1 month	102 healthy adults aged ≥ 18 years recruited from a university in Canada; <u>mean age</u> : 24 years; <u>female</u> : 56%, no.—I: 52, C: 50	Automated text messages with a basic reminder to take vitamin C and a request to reply after adherence, and subsequent reinforcement or correction reminders delivered in nonformal language; <u>dose</u> : 1–2 messages daily for 2 weeks, 0–2 \times /day intermittently for 2 weeks; <u>additional services</u> : information on importance of vitamin C at baseline and in reinforcement/correction messages, jokes, and “smileys” for reinforcement messages	No text messaging	<u>Primary outcome</u> : 1) adherence to vitamin C at 4 weeks; <u>secondary outcomes</u> : 2) correlation between self-report and text replies in week 4, 3) attitude toward object of adherence; <u>measures</u> : 1–2) self-report using Brief Medication Questionnaire, 3) beliefs about Medicines Questionnaire (scale: 1–7)	<u>Retention</u> : 97%; <u>outcomes</u> : inconclusive—study not powered to detect significant results (power = 54%), 1) adherence increased in both groups but nonsignificant difference between groups at 4 weeks (I: 246% vs. C: 131%, $P = 0.134$), 2) significant correlation (unspecified coefficient = -0.352 , $P = 0.01$), 3) attitudes appear similar (I: 5.1 vs. C: 5.3, $P = \text{unknown/unclear}$)
Haapala, 2009 (46)	Weight loss	RCT; <u>total duration</u> : 12 months	126 overweight adults aged 25–44 years, BMI 25–36 kg/m ² , recruited from the general population in Finland; <u>mean age</u> : 38 years; <u>female</u> : 77%; no.—I: 62, C: 63	Automated, targeted, weight-specific tailored text messages to reduce daily food intake, increase physical activity, encourage daily weight recording, and provide instant feedback; study participants chose target weight with optional adjustment every 3 months; assessed at 3, 6, 9, and 12 months to protect internal validity; <u>dose</u> : participant initiated as often as desired; <u>additional services</u> : daily weight could be recorded via a personalized website, which provided links to reliable nutrition and physical activity information sources	No contact but offered intervention at the end of the study, assessed at baseline and 12-month follow-up only	<u>Primary outcomes</u> : changes in 1) weight and 2) waist circumference at 12 months and 3 months, respectively, in the intervention group; <u>secondary outcomes</u> : 3) frequency of use, 4) dietary habits, nutritional intake, and physical activity, 5) strongest predictors of weight loss at 12 months, 6) preferred method for weight reporting; <u>measures</u> : 1–2) BMI assessed by study nurses, 3–6) self-report using various validated questionnaires and scales	<u>Retention</u> : 68%; <u>outcomes</u> : 1) intervention group lost more weight than control group at 12 months (I: 4.5 kg/m ² vs. C: 1.1 kg/m ² , $P = 0.006$), 2) decrease in waist circumference at 12 months greater for intervention group (I: 6.3 cm vs. C: 2.4 cm, $P < 0.001$), and most weight loss in the intervention group took place in the first 3 months, 3) frequency of use faded from 8 \times /week to 3–4 \times /week by 12 months, and those with >5% weight loss reported greater weekly use at 3 months compared with <5% loss (9.7 \times vs. 7.0 \times , $P < 0.05$), 4) dietary habits improved at 3 months for the intervention group, nutritional intake did not differ between groups, and physical activity increased in both groups from 2–3 \times /month to 1 \times /week, 5) early weight loss, self-efficacy, contact frequency, attitude toward technology, life changes, dietary changes predict weight loss, 6) mobile phone preferred to Internet as the medium for weight reporting (4.4 \times vs. 1–2 \times /week at 3 months)

Newton, 2009 (47)	Physical activity	Single-blind RCT; <u>total duration:</u> 3 months	78 diabetic adolescents aged 11–18 years recruited from 4 regional outpatient diabetic services in New Zealand; <u>mean age:</u> 14 years; <u>female:</u> 53%; no.—I: 38, C: 40	Automated text messages with reminder to wear pedometer and be active, combined with an open pedometer to be worn every day for 12 weeks and goal of 10,000 steps/day; <u>dose:</u> 1×/week; <u>additional services:</u> pedometer could be opened to record steps taken, steps per day recorded on a chart	No text messaging, standard care	<u>Primary outcome:</u> 1) change in physical activity at 12 weeks; <u>secondary outcomes:</u> 2) hemoglobin A1c, blood pressure, BMI z score, quality of life at 12 weeks, 3) adherence to pedometer use; <u>measures:</u> 1) step count recorded from closed pedometer worn by both groups for 4 days and 7-day self-report using validated questionnaires, 2) not specified, 3) weekly text messages and daily step chart	<u>Retention:</u> 95%; <u>outcomes:</u> inconclusive—study not powered to detect significant results, 1) nonsignificant decrease in daily step count at 12 weeks for both groups, no between- group difference (I: –840 vs. C: –22, $P = 0.4$), 2) nonsignificant change and no between-group differences in A1c ($P = 0.2$), blood pressure ($P = 0.7$), BMI z score ($P = 0.9$), quality of life (P $= 0.06$), 3) 37% nonadherence—14 participants stopped wearing pedometers before follow-up, 45% (17 participants) had to have lost pedometers replaced before the study ended
Patrick, 2009 (48)	Weight loss	RCT feasibility study; <u>total duration:</u> 4 months	65 overweight adults aged 25–55 years, BMI 25–39.9 kg/m ² , recruited from the general population in California; <u>mean age:</u> 45 years; <u>female:</u> 80%; no.—I: 33, C: 32	Automated, unique text messages with weekly topics on behavioral and dietary strategies, goal setting, weight monitoring, and weight reporting via phone; participant could alter number and timing of messages; <u>dose:</u> 2–5× daily; <u>additional services:</u> multimedia messages, graph of weight change provided weekly, supplement binder with nutrition and behavioral information, 5–15- minute phone calls from counselors to encourage participation and problem shoot technical difficulties	No text messaging, mailed 1–2 pages of print materials 1×/ month for 4 months	<u>Primary outcome:</u> 1) change in weight (kg) at 4 months; <u>secondary outcomes:</u> 2) adherence to text messages, 3) satisfaction with intervention; <u>measures:</u> 1) measured in study office by using calibrated scale, 2) percentage of messages prompting reply that were answered, 3) self-report questionnaire	<u>Retention:</u> 100%; <u>outcomes:</u> 1) intervention group lost more weight than the control group at 4 months (I: 2.88 kg vs. C: 0.91 kg, $P = 0.02$), 2) 100% adherence in the first week, 67% (2 of 3 messages) by week 16, 3) 92% participants would recommend the intervention to friends and family
Rodgers, 2005 (27); Bramley, 2005 (49)	Smoking cessation	Single-blind RCT; <u>total duration:</u> 6.5 months	1,705 smokers aged ≥16 years recruited from the general population in New Zealand; <u>mean age:</u> 25 years; <u>female:</u> 58%; no.—I: 852, C: 853, Maori: 355	Automated, but individually tailored text messages with advice, support, and distraction delivered in nonformal language; <u>dose:</u> 5× daily for 6 weeks, 3× weekly for 20 weeks; <u>additional services:</u> tips for craving on- demand (using short codes), link to quit buddy via text, optional polling topics and quizzes	No regular texts for advice, support, and distraction; follow-up reminders via text 1× every 2 weeks	<u>Primary outcomes:</u> 1) prevalence of current nonsmoking (no smoking in the past week) at 6 weeks, 2) effectiveness for Maori vs. non-Maori participants; <u>secondary outcomes:</u> 3) current nonsmoking at 12 weeks and 4) 26 weeks, 5) continuous abstinence for 24 weeks; <u>measures:</u> self- report with biologic verification for a random subset at 6 weeks	<u>Retention:</u> 74%; <u>outcomes:</u> 1) greater prevalence of current nonsmoking at 6 weeks in the intervention group (I: 28% vs. C: 13%, $P < 0.0001$), 2) no significant difference in Maori vs. non-Maori (RR = 2.34 vs. RR = 2.16), 3) 12 weeks' difference significant (I: 29% vs. C: 19%, $P < 0.0001$), 4) 26 weeks' difference not significant ($P = 0.4$), 5) inconclusive

Abbreviations: BMI, body mass index; C, control group; I, intervention group; RCT, randomized controlled trial; RR, relative risk.

Table 2. Disease Management Studies

First Author, Year (Reference No.)	Target Behavior	Methods	Population and Sample Sizes	Intervention	Control	Outcomes and Measures	Results
Benhamou, 2007 (50)	Diabetes management	Randomized crossover trial (bicenter, 2-period, 1-month run-in period); total duration: 12 months	30 type 1 diabetics with poor control aged ≥ 18 years, hemoglobin A1c 7.5%–10%, recruited at an outpatient hospital in France; mean age: 41 years; female: 50%; no.—T: 30, C: 30	Text messages with medical advice based on review of SMBG; dose: weekly for 6 months; additional services: PDA to measure SMBG and quality-of-life survey, submission via infrared between PDA and phone, routine clinic visits every 3 months	No text message support for blood glucose values, clinic visits every 3 months, PDA used to measure SMBG	Primary outcome: 1) glycemic control; secondary outcomes: 2) quality of life, 3) adherence, 4) safety; measures: 1) hemoglobin A1c measured at 3-month clinic visits, SMBG, 2) DQOL questionnaire administered via PDA every 3 months (scale: 0–100), 3–4) SMBG values on server	Retention: 100%; outcomes: 1) nonsignificant trend in hemoglobin A1c reduction (I: -0.14% vs. C: 0.12% , $P = 0.10$), mean blood glucose (I: -6 mg/dL vs. C: 5 mg/dL, $P = 0.06$), 2) significant quality-of-life score improvement (I: 5.6 vs. C: 0.0 , $P < 0.05$), 3) no group difference observed in frequency of SMBG, 4) no group difference in number of low glucose episodes
Cho, 2009 (51)	Diabetes management	RCT; total duration: 3 months	75 type 2 diabetic adults recruited from an outpatient diabetes clinic in Korea; mean age: NR for entire sample; female: 22%; no.—T: 35, C: 34	Text messages with medical advice based on review of SMBG sent by phone glucose reader; dose: every other week; additional services: Web-based visual display of glucose levels, glucose control summary for 1 day, 1 week, 1 month, reminder message sent after 1 week of no entry	Internet-based management system for SMBG entry and medical advice, visual display of glucose levels, glucose control summary for 1 day, 1 week, 1 month, reminder message sent after 1 week of no entry	Primary outcome: 1) glycemic control; secondary outcomes: 2) patient satisfaction, 3) adherence to medical advice, 4) frequency of glucose monitoring; measures: 1) hemoglobin A1c measured at 3 months, SMBG, 2–3) self-report via questionnaire, 4) SMBG reports	Retention: 92%; outcomes: 1) hemoglobin A1c levels decreased significantly in both groups, between-group difference not significant ($P < 0.01$), nonsignificant between-group differences in 2) satisfaction ($P = 0.94$), 3) adherence ($P = 0.999$), and 4) frequency of glucose monitoring (mean I: 2.4 vs. C: 2.3 , $P = 0.3$)
Franklin, 2006 (52)	Diabetes management	RCT (3 groups); total duration: 12 months	92 type 1 diabetics aged 8–18 years on conventional insulin therapy recruited from a pediatric diabetes clinic in Scotland; mean age: NR for the entire sample; female: 46%; no.—T (CIT): 33, I (IIT): 31, C: 28	Primary intervention: automated, goal-specific text messages tailored to age, gender, and insulin regimen, aimed at improving self-efficacy, adherence, and glycemic control (Sweet Talk ^a); dose: daily messages; additional services: CIT secondary intervention: Sweet Talk + IIT	CIT only	Primary outcome: 1) glycemic control at 12 months; secondary outcomes: behavior change, 2) SED, 3) DKN, 4) diabetes social support; measures: 1) hemoglobin A1c and self-report via validated questionnaires, 2) SED score, 3) DKN score, 4) DSSI (higher scores better)	Retention: 98%; outcomes: 1) no group differences in Sweet Talk vs. CIT only, mean hemoglobin A1c improved only in the IIT group (9.2% (standard deviation, 2.2), $P \leq 0.001$); Sweet Talk improved 2) self-efficacy ($P = 0.003$) and adherence ($P = 0.042$) but had no effect on 3) DKN and 4) diabetes social support

Table continues

Hanauer, 2009 (23)	Diabetes management	RCT feasibility/pilot study; total duration: 3 months	40 diabetic patients aged 12–25 years recruited in a diabetes center in Massachusetts; mean age: 18 years; female: 55%; no.—I: 22, C: 18	Text message reminders for blood glucose monitoring, SMBG sent via text message; dose: number and frequency of reminders set by participants; additional services: website to set up reminder schedule, blood glucose values could be viewed and printed immediately on website, weekly reminder to print blood glucose value diary	E-mail reminders for blood glucose monitoring, number, remainder of treatment exactly the same as for the intervention group	Primary outcome: 1) frequency of blood glucose monitoring behavior; secondary outcomes: 2) participant acceptance; measures: 1) frequency of reminders and responses, 2) questionnaire	Retention: 73%; outcomes: 1) phone users requested more reminders, responded to a higher percentage of them within 30 minutes, and submitted significantly more blood glucose measurements (I: 33.1 vs. C: 2.3, $P < 0.02$) compared with e-mail users, 2) most reported phone as the preferred way to access the system
Ostojic, 2005 (53)	Asthma management	RCT feasibility study; total duration: 4 months	16 asthmatic adults recruited from a pulmonary clinic in Croatia; mean age: 25 years; female: 44%; no.—I: 8, C: 8	Text messages sent with medical advice on therapy adjustment based on PEF results the participant sent via text messaging; dose: participant sent data daily, medical advice provided 1× weekly; additional services: 1-hour asthma education session, PEF paper diary, request for office visits sent via text	No text messaging, 1-hour asthma education session, PEF paper diary, diary reviewed at end of study	Primary outcome: 1) PEF levels; secondary outcomes: 2) PEF variability, 3) cough and night symptoms; measures: daily PEF values and symptoms reported by participants	Retention: 100%; outcomes: inconclusive—study not powered to detect significant results, 1) nonsignificant between-group differences in PEF levels, 2) PEF variability significantly smaller in the intervention group (I: 16.12% vs. C: 27.24%, $P = 0.049$), 3) cough ($P < 0.05$) and night symptoms ($P < 0.05$)
Rami, 2006 (54)	Diabetes management	Randomized crossover trial; total duration: 6 months	36 type 1 diabetic adolescents aged 10–19 years with hemoglobin A1c $\geq 8\%$ recruited from a diabetes clinic in Austria; median age: 15 years; female: 44%; no.—I: 36, C: 36	Text messages with medical advice on therapy adjustment based on blood glucose, carbohydrate intake, and insulin dosage sent by participant via text messaging (automated messages used when no change in therapy necessary); dose: participant sent data 4× daily, medical advice provided 1× weekly, both for 3 months; additional services: paper diary, 3-month office visits	No text messaging, paper diary, 3-month office visits	Primary outcome: 1) glycemic control at 3 months; secondary outcomes: 2) safety, 3) patient satisfaction; measures: 1) hemoglobin A1c, 2) self-report via paper diaries and patient interview, 3) self-report via questionnaire	Retention: 100%; outcomes: 1) hemoglobin A1c improved with intervention ($P < 0.05$), 2) adverse events similar in both groups, 3) participants found the service useful but often had technical difficulties and used less than 1 minute to send messages

Table 2. Continued

First Author, Year (Reference No.)	Target Behavior	Methods	Population and Sample Sizes	Intervention	Control	Outcomes and Measures	Results
Yoon, 2008 (55); Kim, 2007 (56); Kim, 2007 (57); Kim, 2008 (58); Kim, 2008 (59)	Diabetes management	Quasi- experimental trial; total duration: 12 months	60 type 2 diabetic adults recruited from an outpatient clinic in South Korea; mean age: unknown/ unclear for entire sample; female: 57%; no.—I: 25, C: 26	Text messages from nurse on treatment adjustment based on SMBG, insulin levels, and medication sent by participant via Internet on phone or computer; follow-up at 3, 6, 9, and 12 months; dose: at discretion of participant but at least 1×/week, medical advice provided 1× weekly; additional services: Internet used to send data, messages sent via e-mail as well as text, reminder messages sent after 1 week of no activity	No text messaging, standard care	<u>Primary outcomes:</u> 1) plasma glucose levels, 2) plasma glucose levels in obese diabetics; <u>secondary</u> <u>outcomes:</u> 3) serum lipids; <u>measures:</u> 1) hemoglobin A1c, FPG, 2HPMG, 2) hemoglobin A1c, FPG, 2HPPT, 3) total cholesterol, triglyceride, HDL cholesterol	<u>Retention:</u> 85%; <u>outcomes:</u> 1) hemoglobin A1c differed significantly between the 2 groups ($P = 0.001$) and over time ($P = 0.011$), time- group interaction significant ($P = 0.001$), hemoglobin A1c significantly decreased over time in the intervention group (12 months = -1.32% , $P <$ 0.05) but not the control group; FPG not significant between groups or over time, no interaction; 2HPMG differed between the 2 groups and over time, with interaction; 2) obese diabetics: hemoglobin similar results for A1c and FPG, 2HPPT did not differ between groups or with time but had group-time interaction ($P = 0.001$), 3) total cholesterol, triglyceride, HDL cholesterol did not differ between groups or over time, with no interaction

Abbreviations: BMI, body mass index; C, control group; CIT, conventional insulin therapy; DKN, diabetes knowledge; DQOL, Diabetes Quality of Life; DSSI, diabetes social support interview; FPG, fasting plasma glucose; HDL, high density lipoprotein; 2HPMG, 2-hour postmeal glucose; 2HPPT, 2-hour postprandial test; I, intervention group; IIT, intensifying insulin therapy; NR, not reported; PDA, personal digital assistant; PEF, peak expiratory flow; RCT, randomized controlled trial; RR, relative risk; SED, self-efficacy for diabetes; SMBG, self-measured blood glucose.

^a The intervention system being tested in a randomized trial.

The primary objective of this systematic review is to assess the effectiveness of behavior change interventions for disease management and prevention delivered primarily through text messaging. Evidence on behavior change and clinical outcomes was compiled from randomized controlled trials and quasi-experimental studies of text message interventions addressing a range of health behaviors.

METHODS

Inclusion and exclusion criteria

Inclusion criteria required that studies be randomized or quasi-experimental controlled trials of interventions for disease prevention or management in any population that used text messaging as the primary mode of intervention delivery. Studies were required to measure the impact of text message interventions by assessing change in health behavior, health outcomes, and/or clinical outcomes using pre-/posttests. Additionally, studies had to be published in a peer-reviewed journal. Possible topics for disease prevention studies included physical activity, nutrition, risky sexual behavior, smoking, and adherence to preventive health measures (e.g., vitamins during the cold season, folic acid prior to pregnancy). Options for conditions for disease management studies included diabetes, asthma, hypertension, and HIV. Feasibility and pilot studies were included if they met all other criteria.

Studies utilizing communication technologies other than mobile phone text messaging, such as the Internet, e-mail, phone calls, or video messaging, were included only if text messaging was the primary mode of communication and the other technologies were supplementary. Interventions primarily for appointment reminders were excluded because these studies are more focused on improving clinical efficiency. Adherence studies were excluded unless they targeted an ongoing preventive health behavior. Studies originally published in languages other than English were included only if a full-text English-language version of the article was available.

Search methods

A comprehensive electronic literature search was conducted between May and June 2009 for relevant articles published to date using MEDLINE (US National Library of Medicine, National Institutes of Health, Bethesda, Maryland), Cochrane Library (Wiley InterScience, Malden, Massachusetts), Google Scholar (Google, Mountain View, California), PsychINFO (American Psychological Association, Washington, DC), and PubMed (US National Library of Medicine, National Institutes of Health, Bethesda, Maryland). Text messaging is a rather novel technology for health care, so it was not necessary to place time parameters on the search to exclude older articles. The following search terms were included in various combinations: phone, wireless, cell phone, mobile phone, text, text message, short message service, SMS, mhealth, ehealth, health, health behavior, prevention, intervention, adherence, telemedicine, randomized controlled trial. References in articles meeting search criteria

were reviewed for additional articles in addition to papers citing articles meeting review criteria (backward searching). The search was conducted in English.

Data collection and analysis

The above selection criteria were applied to studies retrieved from the search by reviewing their titles and abstracts. Data for eligible studies were extracted from full-text articles. Extracted data included participant characteristics, intervention details, dose and duration of text messaging, follow-up times, outcome measures, and results. Quality of study design was assessed and a score assigned based on 9 methodological characteristics: individual randomization, use of a control group for comparison, isolation of text messaging technology, use of pre-/posttest design, retention, equivalence of baseline groups, consideration of missing data, power analysis for sample size consideration, and validity of measures. This scoring system was adapted from a review of technology interventions for health (41). The range of possible scores was 0%–100%, and there was no minimum score requirement for inclusion in the study.

RESULTS

Of 30 articles identified from the comprehensive search, 17 articles representing 12 studies met criteria for inclusion in the study. Notable reasons for exclusion included text messaging being an optional component of a combination technology intervention (42, 43) and lack of a full-text English version of a given article (44). Disease prevention behaviors (27, 45–49) were represented less often in the literature than disease management behaviors (23, 44, 50–59). Multiple reports of the same study were linked; thus, 12 research studies in this review are represented by 17 articles. One study was represented by 2 articles (27, 49) and another by 5 (55–59); these studies are referred to by the primary article from this point onward. Of the 12 studies of interventions using text messaging as a platform for behavior change, 5 were for disease prevention (27, 45–48) and 7 for disease management (23, 50–55). Tables 1 and 2 list characteristics of each study.

Studies were traditional randomized controlled trials, with the exception of 2 randomized crossover trials (50, 54) and one quasi-experimental trial (30). Four studies were feasibility trials (23, 45, 48, 53), and 2 utilized single blinding (27, 47). Disease prevention studies targeted preventive medication adherence (45), weight loss (46, 48), physical activity (47), and smoking cessation (27). All disease management studies targeted behaviors for diabetes with the exception of one focused on asthma management (53).

The earliest year of publication of the 12 studies was 2005. One had a sample size of 1,705 (27), but all others ranged from 16 (53) to 126 (46) participants. Studies took place in an array of countries: Canada (45), Finland (46), New Zealand (27, 47), United States (23, 48), France (50), South Korea (51, 55), Scotland (52), Croatia (53), and Austria (54). Samples were recruited mostly from the general population in the disease prevention studies and from

clinics in the disease management studies. Only one recruited healthy individuals, whereas the rest were targeted toward people with a specific disease or condition (45). Average age in the studies ranged from 15 years (54) to 45 years (48); 4 studies specifically targeted adolescents and young adults (23, 47, 52, 54). Gender was nearly equally distributed in most studies, with the exception of 3 studies in which females were greatly overrepresented (46, 48) or underrepresented (51).

Intervention characteristics

Intervention length ranged from 3 months to 12 months, and, for all studies, follow-up was conducted at baseline and immediately after the intervention. Some studies included intermediate follow-up times, but none had long-term follow-up that extended beyond completion of the intervention. Frequency of text messaging varied greatly, ranging from once weekly to 5 times per day or more. Two disease prevention studies varied texting frequency over the duration of the intervention, decreasing intensity of messaging as the study progressed (27, 45). Three of the 12 studies allowed participants to dictate the frequency of messaging (23, 46, 48).

Other features used to tailor messages to individuals included using a participant's nickname, allowing participants to write their own reminder messages, and incorporating information specific to personal goals, culture, gender, age, or current health status. One study was unique in that patients never received the same message twice (48). Only 2 studies reported using informal language (27, 45).

Most studies had an interactive component that requested input via text messaging from the participant; only 2 were unidirectional (47, 52). In all studies, text messaging was initiated by the researcher with the exception of one disease prevention (46) and 2 disease management (52, 53) studies, where researchers communicated with participants only after the participant sent a text message. All disease prevention studies used automated messaging, and, despite automation, all studies provided tailored messages except for 2 (45, 47). All disease management studies used messages written by a medical professional upon chart review except one that provided automated, tailored messages (52). In only one disease management study could a participant reply to physicians' medical advice with questions (51).

Text messaging was the only intervention component in 5 studies (27, 45, 52–54), whereas others included supplementary components such as e-mail and the Internet. Only one of the disease prevention studies provided an additional tool for patient self-monitoring (47); all disease management studies required an additional tool for patient self-monitoring. All but 3 of the disease management studies provided participants with new innovations as opposed to the standard of care (i.e., a new glucose monitoring tool vs. the traditional finger-stick blood testing for diabetes) (23, 54, 55). Three of the 12 studies provided phones to patients, whereas the remaining studies asked patients to use their personal phones (50, 51, 54). None of these was a disease prevention study.

Effect of text messaging

The primary outcomes utilized were frequency of health behavior in 4 studies (23, 27, 45, 47) and clinical outcomes in 8 studies (46, 48, 50–55). All disease management studies utilized clinical outcomes with the exception of one (23). Three of the 12 studies reported not being statistically powered to detect a difference in the primary outcome and therefore produced inconclusive results (45, 47, 53). Eight of the 9 sufficiently powered studies found evidence to support the effectiveness of text messaging as a tool for behavior change in disease prevention (27, 46, 48) and management (23, 51, 52, 54, 55).

Significant behavior change outcomes observed included greater prevalence of current nonsmoking by smokers at 6 and 12 weeks (same effect observed in minority subgroup analysis) (27) and increase in frequency of blood glucose monitoring and reporting via text message compared with e-mail among diabetic adolescents and young adults (23). Behavior change outcomes for which results were inconclusive included adherence to using vitamins by healthy college students (increased in both groups, no evidence of effect) (45) and physical activity as measured by daily step count (unexpected decrease in both groups, no evidence of effect) (23).

Significant clinical outcomes observed included greater weight loss in obese adults at 4 and 12 months (46, 48) and greater decrease in hemoglobin A1c levels in adolescents and obese and nonobese adult diabetics (51, 52, 54, 55). The clinical outcome for which results were inconclusive was peak expiratory levels in asthmatic adults; the study found no evidence of a difference between groups (53).

It is of note that 4 of the 12 studies failed to isolate the effect of the text messaging technology (23, 47, 48, 55). Additionally, in one study that had 2 intervention conditions, text messaging could be isolated by one comparison to the control group but not the other (52). Only 2 studies measured whether text messaging is as effective as other technologies for communication (23, 51). These studies found that text reminders result in increased frequency of blood glucose monitoring when compared with e-mail reminders (23) and that hemoglobin A1c levels decreased when compared with an Internet-based monitoring system (51). In these studies, researchers provided the same amount of communication to the intervention and control groups. All other studies provided the intervention group with opportunities for increased communication compared with standard of care.

Assessment of risk of bias

The average study design quality scores were 76% for disease prevention studies and 81% for disease management studies (Table 3). Retention was above 80% for all but 3 studies (Tables 1 and 2) (23, 27, 46). Only 2 studies specified a theoretical framework (46, 52). All studies utilized blind allocation of participants to condition during randomization. Blinding of participants to condition is not possible in this type of study, but only 2 studies utilized blinding of research staff during assessment (27, 47). One study had noticeable

Table 3. Study Design Quality Score Tabulation and Study Quality Coding Criteria

First Author, Year (Reference No.)	Individual Randomization	Control Group	Isolate Technology	Pre-/ Posttest Design	Retention ≥80%	Baseline Groups Equivalent	Missing Data	Sample Size Calculation	Validated Measures	Score (% of Maximum)
Cocosila, 2009 (45)	Y	Y	Y	Y	Y	Y	Y	NA	Y	89
Haapala, 2009 (46)	Y	Y	N	Y	N	Y	Y	Y	Y	78
Newton, 2009 (47)	Y	Y	N	Y	Y	N	Y	N	Y	67
Patrick, 2009 (48)	Y	Y	N	Y	Y	N	Y	NA	Y	67
Rodgers, 2005 (27)	Y	Y	Y	Y	N	Y	Y	Y	N	78
Benhamou, 2007 (50)	Y	Y	Y	Y	Y	Y	Y	Y	Y	100
Cho, 2009 (51)	Y	Y	Y	Y	Y	Y	N	N	Y	78
Franklin, 2006 (52)	Y	Y	Y	Y	Y	Y	Y	Y	Y	100
Hanauer, 2009 (23)	Y	Y	Y	Y	N	Y	N	NA	N	56
Ostojic, 2005 (53)	Y	Y	Y	Y	Y	Y	Y	N	N	78
Rami, 2006 (54)	Y	Y	Y	Y	Y	Y	Y	Y	N	89
Yoon, 2008 (55)	Y	Y	N	Y	Y	Y	N	Y	Y	78

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).										
Pre-/posttest design	Was assessment of behavior completed preintervention and postintervention?										
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 NA.										
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 Y's.										

Abbreviations: N, no; NA, not applicable; Y, yes.

rates of nonadherence to the intervention protocol that may have reduced the effectiveness of the intervention. Several participants failed to wear pedometers, which was hypothesized to decrease physical activity when used in conjunction with text messaging (47). Another study with a low retention rate did not specify whether attrition was differential (23).

DISCUSSION

Twelve randomized controlled trials published between 2005 and June 2009 of interventions for disease prevention and management using text messaging were reviewed (Tables 1 and 2). Nine countries were represented, only one of which is a developing country (53).

The majority of the studies (8) found evidence of a short-term effect regarding a behavioral or clinical outcome related to disease prevention and management. Of those that found no evidence of effect, only one had sufficient power to detect an effect in the primary outcome. Evidence for text messaging in disease prevention and management interventions was observed for weight loss, smoking cessation, and diabetes management. Effects appeared to exist among adolescents and adults, among minority and nonminority populations, and across nationalities.

This evidence is consistent with existing literature suggesting that mobile phones are a useful tool for interventions seeking improvement in health outcomes (15, 18, 22). Specifically, it supports recent evidence that text messaging is a useful tool for behavior change interventions (14). Given that studies included in this review were restricted to randomized controlled trials, the “gold standard” for assessing effect, this evidence is the best to date on text messaging for behavior change.

Because of the relative newness of text messaging as a method of delivery for behavior change interventions, there is a paucity of data, and the health behavior studies included in this review are quite heterogeneous. There were no clear differences in intervention outcomes based on age, gender, or length of messages. In the future, meta-analyses of interventions delivered via text message targeting specific behaviors in specific populations will provide more information. Currently, the area of diabetes management is most advanced because it represented all but one of the disease management randomized controlled trials in this review. However, the evidence base for other health topics is sparse, despite exploratory evidence that text messaging may be useful.

This review retrieved no randomized controlled trials assessing the effect of text messaging on medication adherence in diseased populations. Nevertheless, several studies of medication adherence interventions show the benefits of medication reminders (24). There is also evidence of the benefits of periodic prompts and reminders as stand-alone interventions for health behavior (33). This information, coupled with evidence of the benefits of mobile phones as an inexpensive, personal, efficient, and widely accessible way to intervene on health (14, 18, 61), provides a very strong rationale for extending research on text mes-

saging to medication adherence, especially in the context of global diseases such as HIV. This is just one example of the implications of the research gaps identified by this review.

It is also of note that only one of the studies in this review was conducted in a developing country (53), which is alarming. Developing countries could arguably benefit most from such an inexpensive method of health promotion that builds upon existing infrastructure (6, 29). Given that cell phones are frequently used in developing countries, this finding suggests that technology is being adopted at a much quicker rate than development, implementation, and assessment of disease prevention programs based on that technology (6, 7, 62, 63). This gap between the literature and global field practices can lead to missed opportunities for learning about and improving text messaging as a tool for behavior change.

Despite the strengths of text messaging highlighted in this review, some weaknesses should also be noted. A potential drawback to the use of text-message-based mHealth interventions is potential marginalization of certain populations, such as those that are illiterate or do not have access to a mobile phone for financial reasons. However, these limitations may be reduced as mobile technology advances. For example, innovations exist that provide voice response systems and pictures instead of text for those with limited literacy (64). Furthermore, total cost of ownership, the amount of a person's income necessary to connect, decreased 20% between 2005 and 2008 (65). Another potential limitation of mHealth is that delivery of interventions can be interrupted if the mobile phone is stolen or lost. However, the same limitations exist with many other forms of communication (e.g., postal mail may be delivered to the wrong address, e-mail boxes may be too full to receive messages).

Additionally, this review highlights some methodological factors of importance. Few studies in this sample specified a theoretical rationale. However, research has shown that messaging interventions designed and measured by using behavioral theory are more likely to be successful (33–35). Text messaging should not be considered a stand-alone model for behavior change but rather as a tool by which behavior change methods can be administered. The tendency to view text messaging as a stand-alone method itself is understandable, because it naturally encompasses concepts that positively influence behavior change; however, we must be careful to understand the mechanisms of change in order to build upon the way that text messaging works for behavior change. If text message intervention studies are built on evidence and theory, the potential impact of these studies will be much greater. Other methodological issues include lack of rigor in study design with regard to statistical power to detect a significant difference and, perhaps most importantly, failure to isolate the text messaging technology.

A strength of this review is that it synthesizes evidence from randomized controlled trials and quasi-experimental studies. Although this is the best evidence available from which to draw conclusions about text messaging, it may be limited regarding knowledge of how to improve future studies. Most of the studies on this subject are still in the

exploratory stages, and this technology is being adopted rapidly; so, much information exists outside of the traditional scientific literature (newspapers, blogs, private industry reports, etc.). It is imperative to bridge this gap between practice and scientific knowledge. Given the immature state of the field, additional information on efficacy (e.g., dose, message frequency, message content) may be gained from systematic reviews of nonrandomized trials.

Limitations of this review include that the heterogeneity of topics prevented presentation of an empirical summary of results. Heterogeneity also resulted in an inability to draw conclusions about whether text messaging is more effective for disease prevention or management. Additionally, as with all systematic reviews, the present study is subject to publication bias. This review supports the feasibility of using text messaging to effect behavior change. Future studies should ensure rigorous methods and sufficient power in order to contribute to the existing body of literature seeking to determine whether the behavior change observed is sufficient to produce relevant public health and clinical outcomes. More information is also needed on what combinations of text message factors (dose, duration, complimentary technologies, etc.) produce the best results, because opportunities exist to adapt successful interventions to new populations and diseases. Additionally, more information is needed on the long-term effects of text message interventions.

There is much evidence to prove that the way a message is framed can affect whether a person is receptive to making a behavior change (66). Future studies must take this factor into consideration to ensure that the text messages are written in the most appropriate way for the population. Researchers should also address ethical concerns that may arise from delivering health care via a mobile phone. Cost-benefit analyses should be considered as well.

Text messaging is a tool that has value to both researchers and practitioners, and use of these technologies may facilitate more active collaboration between research and clinical practice. Given the positive results so far, and the increasing uptake of mobile technologies, text messaging may improve existing practices and interventions. This research agenda should be approached with urgency; text messaging may be an important tool to reduce the global burden on health care by providing more effective disease prevention and management support.

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Author affiliation: Division of Chronic Disease Epidemiology, School of Epidemiology and Public Health, Yale University, New Haven, Connecticut.

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