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Use of Text Messaging for Maternal and Infant Health: A Systematic Review of the Literature

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Abstract Text messaging is an increasingly popular communication tool in health interventions, but has been little studied in maternal and infant health. This literature review evaluates studies of text messaging that may be applied to the promotion of maternal and infant health. Articles from peer-reviewed journals published before June 2012 were included if they were experimental or quasi-experimental studies of behaviors endorsed either by the American College of Obstetrics and Gynecology, the American Pediatrics Association, or the United States Preventive Services Task Force; included reproductive age women (12–50 years) or infants up to 2 years of age; and were available in English. Qualitative studies of text messaging specific to pregnant women were also included. Studies were compared and contrasted by key variables, including: design, time-period, study population, and results. Forty-eight articles were included, 30 of which were randomized controlled trials. Interventions vary greatly in effectiveness and soundness of methodology, but collectively indicate that there is a wide range of preventative behaviors that text message interventions can effectively promote, including smoking cessation, diabetes control, appointment reminders, medication adherence, weight loss, and vaccine uptake. Common methodological issues include not accounting for attention affect and not aligning text message content to measured outcomes. Those interventions that are based on an established theory of behavior change and use motivational as opposed to informational language are more likely to be successful. Building on the growing body of evidence for text message interventions reviewed here, as well as the growing popularity of text messaging as a medium, researchers should be able to use this technology to engage difficult to reach populations.

Keywords mHealth · Prenatal · Cellular phone · Maternal

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Introduction

Text messaging has become a routine and inexpensive method of communication around the world. In a 2011 Pew Research Center survey of people in 21 representative countries, 75 % of cell phone owners communicated via text; text messaging was more common in the poorest nations [1]. In a survey of cell phone owners the same year in the United States, 73 % of cell phone users overall used text messaging, and 95 % of 18–29 year old cell phone owners used text messaging [2]. This survey also found that those who are poor and less educated are more likely to use text messaging, and send a higher average number of

texts daily. Those who identified as black sent an average of 70.1 texts a day, compared to 31.2 texts for whites. Text messaging is thus a powerful medium for communicating health messages to underserved populations: minorities, the young, impoverished, and less educated.

Several review articles have indicated that text messaging is an effective tool for a variety of health behavior changes [3–6]. Most of the target groups in these studies are patients with chronic diseases, especially diabetes and asthma, or those with unhealthy lifestyle factors, such as obesity and smoking. The delivery of text messages to healthy populations is less well studied.

One area for expansion of mobile health programs is in maternal and infant health promotion. Pregnant women and mothers of young children fall into the age groups most likely to use text messaging, and many behaviors in the prenatal and postpartum period can be targeted for health promotion. One mhealth program specific to this population is the nationwide text4Baby program, which provides text messages to pregnant and postpartum women, timed to their due date or child's birthdate. Text4Baby launched nationally in the United States in 2010 [7]. So far, its impact has been difficult to measure, due to the breadth of its message content and small sample size of pilot studies [8].

While few text message interventions have specifically targeted pregnant women or infants, many have explored issues that are of particular importance to maternal health. The goal of this review article is to identify studies of interventions relevant to the use of text messaging related to maternal health and infant care. Relevant studies were critically evaluated to assess if text messages can impact knowledge, attitudes, and behaviors in preconception, prenatal, postpartum, and early infant care.

Methods

Our team identified five databases for identifying experimental trials of behavioral interventions delivered by text message. The databases searched were Embase, Pubmed, CINAHL, Web of Science, and PsycInfo. Titles and abstracts were searched for the following terms: "cell phone," "text message," "mobile phone," "texting," "SMS," or "mhealth" combined with "health," "maternal health," "pregnancy," and "infants." In addition, meta-analyses on topics in mhealth were hand-searched. The primary search was conducted by the lead author in June, 2012. All articles published before 2012 were eligible for inclusion. We also included the only evaluation of text4baby in the literature, published after the initial search [8].

Included studies focused on interventions in the preconception, prenatal, or postpartum period endorsed by at least one of the following organizations: The American College of Obstetrics and Gynecology, the American Pediatrics Association, or the United States Preventive Services Task Force. Studies had to include reproductive age women (12–50 years) or infants up to 2 years of age; and be available in English. Interventions that utilized other communication methods were included only if text messaging was the primary mode of communication. Given the lack of studies targeting the specified population, qualitative and pilot studies of text messaging interventions were included if specific to maternal or infant health promotion.

A two-step exclusion process identified relevant articles. First, the titles and abstracts were reviewed by the study's lead author to determine if they met inclusion and exclusion criteria. If there was concern about inclusion, the article was reviewed with other team members to determine if the article met inclusion criteria. Each full article was then read by the study's lead author to determine if it met the criteria. Articles were divided into three time period groupings: the preconception period, pregnancy, and postpartum and infancy. For the preconception period, studies focused on family planning, the treatment and prevention of sexually transmitted diseases, and vitamin adherence. In the pregnancy category, studies addressed increased access to and utilization of outpatient care, smoking cessation, substance abuse, and diabetes control. Studies related to postpartum and infant care included those related to weight loss, depression, and vaccine promotion. Articles were compared by objective, text message intervention, bidirectionality of messaging, supportive interventions, design, population, and findings. Each author thoroughly reviewed the summary tables for accuracy and relevance.

Results

The search identified 1,311 unique articles (Fig. 1). After reviewing titles and abstracts, a total of 251 articles met initial inclusion criteria. After reading each full article, 48 met all inclusion and exclusion criteria: 30 randomized controlled trials (RCTs); two non-randomized or partially randomized controlled trials; two cohort studies; three uncontrolled trials; five cross-sectional or ecological studies; three pilot studies; two historical case controls; and one focus group (Table 1). Six studies specifically targeted pregnant women, and one targeted infants.

Preconception Period

Family Planning

Two RCTs used text messaging to promote adherence to oral contraceptives (OCPs) (Table 2). In the first, the

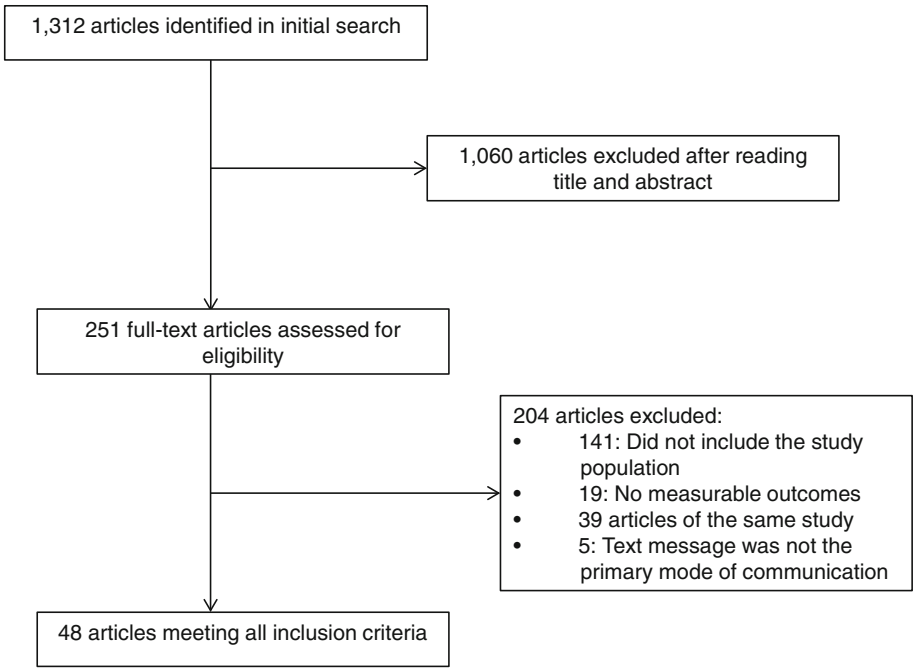

Fig. 1 Identification of articles for systematic review of maternal and infant health text message interventions

intervention group received the same message at the same time every day [9]. There was no statistical difference in the primary outcome, number of pills missed per cycle. In contrast, a second study found that those that received a daily, unique message about the health effects of OCPs were 10 % more likely to adhere to OCP use at 6 month follow-up [10]. Twelve messages also allowed participants to text back regarding their experience with the program.

Sexually-Transmitted Infections

Twelve studies of sexually-transmitted infections (STIs) were targeted to both men and women. One study focused directly at sexual health promotion through text message campaigns. This study recruited mobile phone subscribers in Australia, ages 16–29, from a music festival in Melbourne, Australia [11]. Participants received a total of twelve educational messages over 5 months. Results indicated a significant increase in sexual health knowledge and STI testing. However, the effect on behaviors was mixed, with participants reporting a reduction in the number of new partners but less consistent condom use.

Four studies tested the viability of text messages for communicating STI test results. Two patient surveys, one conducted in Ireland and one conducted in London, indicated that patients would not prefer to receive text message notification of STI results over conventional means of communication, such as phone calls and mailings [12, 13]. However, two RCTs comparing text message to conventional means of results communication found that either there was no difference between the text message and conventional notification in time-to-treatment of STI, or that text message was superior [6, 14].

HIV

Two large-scale studies looked at the use of mobile phones to promote HIV awareness and testing in Uganda and South Africa [15, 16]. In the Ugandan study, researchers sent HIV quiz questions to 10,000 mobile phone subscribers identified by a local telecommunications company in an uncontrolled trial. One-fifth responded to the text messages, and only 233 of participants accessed free HIV testing. Lack of a comparison in this study made it difficult to determine the effect of the intervention. In the South African study, mobile phone users were randomized to receive either motivational messages (encouraging them to get tested), or informational text messages (explaining the importance of getting tested), versus a control group that received no messages. Only those that received motivational messages were significantly more likely to seek HIV counseling and testing services.

Several studies evaluated the effectiveness of text messages in promoting adherence to highly active antiretroviral (HAART) therapy among those with HIV. The two largest (n = 431 and n = 538), both conducted in Kenya, found that patients receiving weekly text message reminders had slightly increased adherence compared to those who received no messages [17, 18]. In the group receiving daily text message reminders, however, there was no significant increase in adherence. A smaller study (n = 19) in Brazil found no significant increase in self-

Table 1 Included studies by type, author, and year

Type of study	Author	Year (reference number)
Randomized controlled trial	Rodgers	2005 [37]
	Kim	2007 [43]
	Leong	2007 [26]
	Chen	2008 [25]
	Fairhurst	2008 [27]
	Jareethum	2008 [23]
	Cocosila	2009 [22]
	Haapala	2009 [46]
	Haug	2009 [36]
	Patrick	2009 [47]
	Hou	2010 [9]
	Lester	2010 [18]
	Prestwich	2010 [48]
	Sirriyeh	2010 [49]
	Donaldson	2011 [45]
	Free	2011 [38]
	Gold	2011 [11]
	Nelson	2011 [28]
	Pop-Eleches	2011 [17]
	Ahlers-Schmidt	2012 [52]
	Castano	2012 [10]
	de Tolly	2012 [16]
	da Costa	2012 [19]
	Evans	2012 [8]
	Naughton	2012 [35]
	Prasad	2012 [29]
	Stockwell	2012 [53]
	Suffoletto	2012 [41]
	Taylor	2012 [30]
	Whittaker	2012 [50]
Non-randomized controlled trials	Menon-Johannson	2006 [14]
	Perez-Ferre	2010 [42]
Cohort studies	Lim	2008 [6]
	Kharbanda	2011 [54]
Uncontrolled trials	Harris	2010 [21]
	Ammassari	2011 [20]
	Chib	2012 [15]
Cross-sectional and ecological studies	Brown	2008 [13]
	Da Costa	2010 [34]
	Kaewkungwal	2010 [24]
	Brugha	2011 [12]
	Sims	2012 [33]
Pilot studies	Obermayer	2004 [39]
	Abroms	2012 [40]
	Mulvaney	2012 [44]
Historical case–control	Downer	2005 [31]
	Geraghty	2011 [32]
Focus group	Kharbanda	2011 [51]

reported medication adherence, while a study in Italy found a significant increase in self-reported adherence and viral suppression [19, 20]. Finally, an uncontrolled trial examined the accuracy of self-reported adherence, demonstrating that participants reported adherence of 90.3 %, versus 53.6 % recorded by electronic bottle cap monitoring (MEMS) [21].

Vitamin Supplementation

One study used text message to promote routine vitamin use. In a small (n = 102) RCT published in 2009, male and female students at a Canadian university were randomized to receive a daily text message promoting vitamin use, or simply report adherence at the end of the study. Participants in the intervention group received a daily text message reminder with content that was either informational or motivational. Participants were able to text back whether they had taken their vitamin that day. The researchers found no significant difference in the number of pills missed weekly [22].

Pregnancy Period

Comprehensive Pregnancy Education Programs

Two studies, both conducted in Thailand, reported on comprehensive prenatal care programs (Table 3). The first, an RCT published in 2008, sent biweekly informational text messages regarding warning signs in pregnancy, versus usual care in the control [23]. The intervention group was more likely to be satisfied with their prenatal care, but did not differ from controls in delivery outcomes. The second study used text messages to remind women along the Thai/Myanmar border about their scheduled prenatal and childhood immunization appointments [24]. They found a significant increase in the number of participants who kept their scheduled appointments compared to a historical control.

One pilot program in Virginia evaluated text message effectiveness amongst pregnant women enrolled [8]. Researchers randomly allocated 123 women recruited from the Fairfax health department to text4baby plus usual care (intervention group) versus usual care alone (control

Table 2 Studies of text message interventions during the preconception period

Topic	Reference (author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheo-retical model	Other study interventions	Study design	Target population	Findings
Family planning	Hou 2010 [9]	Number of oral contraceptives missed per cycle	Daily medication reminder sent for 3 months	No	No	None	RCT	New users of oral contraceptives at a Boston Planned Parenthood clinic who returned for a second appointment (N = 82)	No significant difference in number of pills missed per cycle between the text message intervention and the control group (4.9 intervention vs. 4.6 control, $p = .60$)
	Castano 2012 [10]	Primary: OCP continuation at 6 months; Secondary: Adherence to OCP schedule	Daily text messages on the risks and benefits of OCP	Yes (12 quality control messages)	No	None	RCT	Women under 25 recruited from a Planned Parenthood clinic in New York (N = 968)	Intervention group had 10 % increase in OCP use at follow up and 11 % increase in adherence, $p < .01$
Sexually transmitted diseases HIV	Gold 2011 [11]	Changes in sexual health knowledge, condom use, treatment for STDs	Twelve educational messages sent over 5 months	No	No	None	RCT	Mobile phone subscribers ages 16–29 in Australia (N = 3,803, 185 completed follow up)	Intervention group showed an increase in knowledge ($p = .02$), but no change in condom use or STI screening
	Brugha 2011 [12]	Preferred method of communication for Chlamydia test results	Text messages of STI results and appointment reminders	NA	NA	NA	Cross-sectional survey	18–29 year olds at several clinical sites in Ireland (N = 6,085)	4.7 % and 8.9 % of respondents preferred a text message with a positive and negative chlamydia results, respectively; 23.9 % preferred SMS reminders of clinical appointments (third most popular) $p < .01$
	Brown 2008 [13]	Acceptability of various forms of notification of STI test results	Text messages of STI results	NA	NA	NA	Cross-sectional survey	Patients at an STI in Birmingham, UK clinic and surrounding neighborhoods (N = 746)	Less than 5 % preferred text message to in-person or face-to-face results

Table 2 continued

Topic	Reference (author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheo-retical model	Other study interventions	Study design	Target population	Findings
	Lim 2008 [6]	Improved time to treatment for Chlamydia trachomatis	Message asking patients with positive results to call the clinic	No	NA	None	Cohort study with historical control	Cases of Chlamydia trachomatis at a GU clinic in New Zealand that were not treated immediately (N = 303) vs. unmatched historical controls (N = 293)	No significant difference in time to treatment in the intervention group (4 days) and historical controls (3 days) $p > .05$
	Menon-Johannson 2006 [14]	(1) Improved time to treatment of Chlamydia trachomatis (2) Improved efficiency of staff time	Message asking patients with positive results to call the clinic	No	NA	None	Non-randomized cohort study	Cases of questionable Chlamydia trachomatis at a genitourinary medicine clinic in London (N = 952)	1) Estimated 46 h/month of staff time saved; 2) Mean time to treatment was 7.9 days in the intervention group vs. 11.2 days in the control group ($p = .005$)
	Chib 2012 [15]	Participation in a mass HIV education campaign to encourage HIV counseling and testing	SMS quiz questions delivered and correct answers provided to those who responded	Yes	No	None	Uncontrolled trial	Ugandan mobile phone subscribers (N = 10,000)	2.3 % of participants accessed HIV counseling and testing; only 23.6 % of the sample responded to at least one message
	de Tolly 2012 [16]	Primary: Efficacy of SMS reminders to encourage HIV testing; Secondary: type and dose of SMS reminders considered effective	Informational text messages (three or ten total) and motivational text messages (three or ten) sent to participants to encourage HIV testing	Yes	No	None	RCT (in five arms)	South African adult mobile phone users (N = 2,533)	Only ten total motivational text messages demonstrated a significant increase in HIV testing (OR = 1.7; $p = .0036$)

Table 2 continued

Topic	Reference (author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheo-retical model	Other study interventions	Study design	Target population	Findings
	Pop-Eleches 2011 [17]	Adherence to Haart regimens	Daily or weekly medication reminders that were either simple reminders, or a reminder with an encouraging message	No	No	Participants were provided with a Nokia phone, as only 48 % had access to a cell phone	RCT (in five arms)	HIV patients in Kenya over 18 years that had initiated ART less than 3 months prior to the study (N = 431)	Those receiving weekly messages had significantly improved adherence at 48 weeks (53 % vs. 40 %, $p < .05$)
	Lester 2010 [18]	Adherence to HAART regimens; viral suppression	Weekly message from provider asking if the patient had any problems; patients responded that everything was fine or that there was a problem	Yes	No	Phone calls by providers to patients who texted researchers with a problem	RCT	Patients > 18 years old, recruited from three Kenyan clinics, initiating ART, and with access to a mobile phone (N = 538)	Intervention group had increased adherence (62 % vs. 50 %, $p = .006$), and increased viral suppression (57 % vs. 48 %, $p = .04$)
	da Costa 2012 [19]	Efficacy of SMS reminders for HIV medication adherence	Medication reminders 30 min before last required dose 5× per week	No	No	None	RCT	Brazilian women seeking care for HIV (N = 19)	100 % of those in the intervention group remained adherent at 4 months; 84.6 % in the control group remained adherent at 4 months ($p > .2$)
	Ammassari 2011 [20]	Primary: Change in self-reported adherence; Secondary: Virologic outcomes	Timed reminders to improve ART adherence and virologic outcomes	No	No	None	Uncontrolled trial	Suboptimally adherent HIV-infected adults in Italy (N = 145)	Participants had improved viral suppression self-reported adherence $p < .01$
	Harris 2010 [21]	Adherence to Haart regimens	Between one and eight daily medication reminders, and weekly question about adherence	Yes	No	None	Uncontrolled trial	Patients in Seattle starting a new HAART regimen or changing at least two medications (N = 224)	Pager reported 90.3 % 3-day adherence; 53.6 % MEMS (bottle capable of recording opening) adherence

Table 2 continued

Topic	Reference (author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheo-retical model	Other study interventions	Study design	Target population	Findings
Vitamin adherence	Cocosila 2009 [22]	Text message to increase adherence to daily vitamin C pill	Daily text message	Yes	No	Website on the benefits of vitamin C	RCT	Healthy adults recruited from a university in Canada (N = 102)	Greater increase in adherence in the intervention group (2.5 pills missed weekly) versus control (3.3 pills missed weekly), but not significantly powered ($p = .54$)

group), and tested agreement with eight statements related to prenatal health. They found that the intervention group was significantly more likely to agree with the statement "I am prepared to be a new mother;" all other differences were not significant, which may reflect the small sample size.

Clinic Attendance

No studies were identified that specifically looked at prenatal care appointments; however, six RCTs assessed the efficacy of text message appointment reminders at various outpatient clinics to reduce the no-show rate at outpatient appointments [25–30]. Four of these six studies found that text messaging was an effective and efficient appointment reminder tool, one found no statistical difference, and one found text message to be inferior to voicemail reminders. Four other studies that used historical controls found that text messaging reduced no-shows over no reminder, and required fewer hours than phone calls to implement [31–34].

Smoking Cessation

Six studies were identified that examined the use of text messaging in smoking cessation: four RCTs and two pilot studies. One of these specifically targeted pregnant smokers recruited from midwifery practices in the UK [35]. Pregnant women received up to two messages a day for 11 weeks, tailored to a baseline questionnaire about their motivations for quitting. No difference was found in smoking rates at 12 weeks. Another study of university students recruited from a German university cafeteria found no difference in smoking rates was observed in two intervention groups, where participants received one or three messages a week for 3 months, compared to a control group which received no messages [36]. In contrast, two studies found text messages significantly increased quit rates. One study conducted in New Zealand sent participants up to five messages a day, timed to their quit date. Quit rates were 2.2 times higher at 6 weeks compared to the control [37]. Another RCT of smokers in the UK using the same number of text messages found that smoking abstinence at 6 months continued to be higher in the intervention group, though quit rates overall were low [38]. Two pilot studies found participants had high quit rates and high levels of satisfaction with text messaging support programs [39, 40].

The smoking cessation programs illustrate a powerful tool for behavioral change, known in clinical practice as the "stages of change" model, or transtheoretical model. This theory of behavior change identifies where participants are in their ability to change a health related behavior, from pre-contemplation (not being aware of the

Table 3 Studies of text message interventions during the pregnancy period

Topic	Reference (Author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheo-retical model	Other study interventions	Study design	Target population	Findings
Comprehensive prenatal care health promotion	Jareethum 2008 [22]	(1) Satisfaction with pregnancy care in those who received prenatal SMS support versus those who did not (2) Pregnancy outcomes in SMS group versus control	Biweekly informational text messages regarding stages of pregnancy	No	No	None	RCT	Pregnant women in Bangkok at less than 28 weeks gestation, singleton pregnancy, no medical or obstetric complications (N = 68)	Satisfaction with prenatal care was 9.25/10 in the intervention group vs. 8/10 in the control group ($p < .0001$); birth outcomes were not different
	Kaewkungwal 2010 [23]	Arriving at scheduled prenatal and childhood immunization appointments	Appointment reminders to families	No	No	Health information sent to healthcare workers' smartphones	Ecological study	Pregnant women and mothers along the Thai/Myanmar border (N = 280)	Women were 2.97 times more likely to receive antenatal care at the scheduled time, and children were 1.48 times more likely to arrive at scheduled immunization dates ($p < .05$)
	Evans 2012 [24]	Bivariate pre-post comparison of 8 beliefs about prenatal health	Three educational messages sent weekly to new pregnant women	No	No	None	RCT	Pregnant women recruited from the Fairfax, VA health department (N = 123)	Text4baby participants were more likely to agree with the statement "I am prepared to be a mother" ($p = .042$); All other differences were insignificant
Clinic attendance	Chen 2008 [25]	Effect on clinic attendance of SMS and phone call reminders and cost-effectiveness of reminders	SMS appointment reminder	No	N/A	Phone call reminder	RCT (in three arms)	Attendees at a health promotion center in China (N = 1,859)	SMS and phone call groups had higher odds of attendance (1.698 and 1.829, respectively, $p < .01$); SMS was more cost-effective

Table 3 continued

Topic	Reference (Author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheoretical model	Other study interventions	Study design	Target population	Findings
	Leong 2007 [26]	(1) Improved attendance rates at primary care clinics; (2) Cost-effectiveness of interventions	Appointment reminders 24–48 h before scheduled appointment	No	N/A	Phone call reminder to third group	RCT (in three arms)	Patients with follow-up appointments at one of seven primary care centers in Malaysia (N = 993)	Participants in both the text message and phone call reminder group were significantly more likely to attend their follow-up appointments (OR of 1.59 and 1.55, respectively, $p < .01$); Text messaging was more cost-effective
	Fairhurst 2008 [27]	Reduction in missed primary care appointments	Appointment reminders sent approximately twelve hours before the appointment	No	N/A	None	RCT	Patients in Scottland who had failed to appear at two or more appointments in the previous year (N = 415)	5 % reduction in missed appointments, which did not reach statistical significance ($p = .13$)
	Nelson 2011 [28]	Reduction in missed dental care appointments at a pediatric clinic	Appointment reminder 48 h before scheduled appointment	No	N/A	Comparison: voicemail reminder 48 h before scheduled appointment	RCT	Parents of children at a pediatric dental clinic (N = 318)	Those who received text message reminders were 2.42 times as likely to miss their appointment as those who received voicemail reminders (17.7 % no show rate versus 8.2 % no show rate, $p = .011$)
	Prasad 2012 [29]	Reduction in missed dental care appointments	Text message reminder 24 h before scheduled appointment	No	N/A	None	RCT	Patients at an Indian dental clinic who had provided a cell phone contact number (N = 206)	Attendance rate was 79.2 % in the intervention group vs. 35.5 % in the control group ($p < .05$)

Table 3 continued

Topic	Reference (Author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheo-retical model	Other study interventions	Study design	Target population	Findings
	Taylor 2012 [30]	Reduction in non-attendance at a physical therapy clinic	Appointment reminder 2–3 days before the scheduled appointment	No	N/A	None	RCT	Patients with a scheduled appointment at a physical therapy clinic (N = 679)	Patients in the intervention group were less likely to miss their appointment than the control grop (16 % vs. 11 %, $p < .05$) and had no significant difference in cancellation rates
	Downer 2005 [31]	Efficacy of appointment reminders	Appointment reminders sent three working days before scheduled appointment	No	N/A	None	Historical case control	Patients who had scheduled an appointment in August 2004 and September 2004 (N = 22,658)	9 % decrease overall in no-show rate (no *p* value)
	Geraghty 2011 [32]	Reduction in missed ENT appointments	Reminder sent three days before the appointment	No	N/A	None	Historical case control	Patients in an Irish ENT clinic (N = 8,966)	10 % reduction in missed appointments, $p = .0001$
	Sims 2012 [33]	Reduction in missed psychiatric appointments	Messages sent five to seven days before the scheduled appointment	No	N/A	None	Ecological study	Appointments at four community mental health clinics in the UK between 2008 and 2010 (N = 2,817)	Comparing months of different years, there were significantly less missed appointments in the intervention years, 2009 and 2010, than in the historical control year, 2008 (27 and 26 % vs. 36 %, $p < .01$)
	da Costa 2010 [34]	Impact of SMS reminders on outpatient clinic attendance	Appointment reminders	No	N/A	None	Ecological study	Wealthy Brazilian patients at private clinics (Number of appointments = 7,890)	6.15 % reduction in non-attendance

Table 3 continued

Topic	Reference (Author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheo-retical model	Other study interventions	Study design	Target population	Findings
Smoking cessation	Naughton 2012 [35]	Smoking cessation	80 messages sent over 11 weeks tailored to baseline questionnaire (0–2 messages a day)	Yes	Yes	Leaflet about quitting sent to both groups	RCT	Pregnant smokers identified by midwives in UK communty clinics (N = 207)	No difference in smoking rates at 12 weeks (22 % vs. 19.6 %, $p > .05$), but intervention group was slightly more likely to set a quit date (44.8 % vs. 30.4 %, $p < .05$)
	Haug 2009 [36]	Smoking cessation	One or three educational messages a week for 3 months	Yes	No	SMS craving helpline	RCT (in three arms)	Smokers recruited from a university cafeteria in Germany (N = 174)	No significant difference in smoking habits between the control group or two intervention arms
	Rodgers 2005 [37]	Primary: Smoking cessation at 6 weeks Secondary: Smoking cessation at 26 weeks	Five educational or motivational messages a day for the first month, then three per week for 6 months vs. one thank you message every 2 weeks in control	Yes	Yes	Quitline and nicotine gum subsidies offered to all participants	RCT	Daily smokers in New Zealand who desired to quit, at least 16 years old, and were able to receive text messages on their phones (N = 1,705)	Intervention group was 2.2 times more likely to quit at 6 weeks (28 % vs. 13 %, $p < .01$), but this leveled off at 26 weeks
	Free 2011 [38]	Biochemically verified self-reported abstinence from smoking at 6 months	Five motivational and behavior change messages a day for 5 weeks, and three messages a week for 26 weeks (31 weeks total)	Yes	Yes	Messages encouraged participants to call the QUIT helpline	RCT	Smokers > 16 years old recruited in the UK via public advertising campaign (N = 5,800)	Intervention group was 2.2 times more likely to be continuously abstinent for 6 months, according to self-reported abstinence and verified by salivary cotinine levels (10.7 vs. 4.9 %, $p < .0001$)

Table 3 continued

Topic	Reference (Author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheo-retical model	Other study interventions	Study design	Target population	Findings
	Obermayer 2004 [39]	Smoking cessation at 6 weeks	At least two messages a day based on high craving times; respondents could request additional support	Yes	Yes	Website that logs number of cigarettes smoked and all messages received	Pilot study	College students ages 18–25 who smoke a minimum of 28 cigarettes a week with a desire to quit in the next 30 days	22 % quit for at least seven days (no comparison group)
	Abroms 2012 [40]	Acceptablity of a 4 week text message supported program for quitting smoking	Text messages up to 3 months after participant's quit date, tailored to individual's survey answers to reasons for quitting (0–4 a day)	Yes	Yes	Emails and online tracking of progress	Pilot study	University students (N = 23)	82.3 % rated the program positively at 4 weeks
Substance abuse	Suffoletto 2012 [41]	Decrease in maximum drinks per day and heavy drinking weeks	Weekly text message that asked for the total days that they drank in the previous week and maximum drinks in one sitting only (assessment group), or asked for these measures and provided appropriate feedback (intervention), sent over 4 weeks	Yes	No	None	RCT (in three arms)	Adults aged 18–24 identified in an emergency department as hazardous drinkers without a current psychiatric disorder (N = 45)	Intervention group experienced a small decrease in heavy drinking days in the 4 weeks and maximum drinks per week (−3.4 and −2.1) while the assessment group experienced an increase (1.8 and 1.1) and the control experienced a small decrease (−1.1 and −.6). None of these reached statistical significance

Table 3 continued

Topic	Reference (Author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheo-retical model	Other study interventions	Study design	Target population	Findings
Diabetes	Perez-Ferre 2010 [42]	Comparison of control of gestational diabetes control in standard of care group vs. telemedicine group (as measured by A1c, blood pressure, albumin to creatinine ratio, and weight)	Participants texted weekly glucose measures to their physician, who was able to respond with recommendations	Yes	Yes	Chart created mapping glycemic control for the health providers	Partially randomized control trial (8 most severe were allocated to the intervention group)	Pregnant women in Spain diagnosed with gestational diabetes (N = 100)	No significant difference in outcomes between the two groups in birth outcomes; Intervention group had an average of 15.05 interactions with health personnel vs. 9.11 in the control group, taking 3.8 h versus 4.6 h ($p < .001$); Insulin dependent women had a significant reduction in the number of clinic visits (82 %, $p = .03$)
	Kim 2007 [43]	Improved Hgb A1c	Personalized text messages from endocrinology nurse	Yes	Yes	Patients recorded glucose readings on a website which input them into their chart	RCT	Patients at a South Korean endocrinology hospital with uncontrolled type 2 diabetes without complications (N = 60 randomized, N = 51 analyzed)	Mean decrease of 1.15 in the Hgb A1c in the intervention group; mean increase in Hgb A1c of .07 in the control group ($p < .05$)
	Mulvaney 2012 [44]	Improved Hgb A1c control	8–12 messages a week over 6 months tailored to baseline questionnaire about adherence, customized by participants	Yes	Yes	Website with messages that users could customize	Pilot study	Teenagers aged 13–17 with type 1 diabetes and historical controls matched on age, gender, and Hgb A1c (N = 56)	Mean Hgb A1c at 3 months in the intervention group was the same as baseline Hgb A1c (8.8 %), but historical controls had an increase in A1c to 9.9 % ($p = .006$)

problem), to contemplation (identifying the problem but not being ready to change), to preparation (putting in the necessary pieces to make the change), to action (making the change), to maintenance (sustaining change). The most successful interventions applied these stages most rigorously, moving participants through all known stages [37, 38].

Substance Abuse

One study examined text messaging to reduce substance abuse among patients in an emergency room who screened positive for alcohol abuse [41]. Young adults were recruited from the emergency department and randomized to one of three groups: a control group, who received a reminder to complete a follow-up survey; an assessment group, where participants were asked how much they had drunk in the previous week; and an intervention group, where participants were texted feedback depending on the number of drinks they reported. The study enrolled only 45 participants, and found no statistically significant difference in the number of heavy drinking days. However, there was a trend to fewer heavy drinking days in the control and intervention group, and a slight increase in the assessment group.

Diabetes

Three studies focused on the effective management of diabetes. A semi-randomized trial conducted in Spain targeted women treated for gestational diabetes [42]. Insulin-dependent women were placed in the intervention group and all others were randomized. The intervention group texted their provider weekly glucose measurements, and providers responded with recommendations; the control group received standard care. No significant difference was found between the intervention and control group's diabetic control, but women who were insulin-dependent had a significant reduction in outpatient visits. One study showed an improvement in A1c for those receiving messages from an endocrinology nurse [43]; and one showed stable A1c in those receiving automated messages based on their baseline survey compared to a slight worsening in controls [44]. All three of these studies applied stages of change theories (though not as consistently as the most successful smoking cessation studies), to encourage participants to move from pre-contemplation to action by using the medium to make small changes in glucose control. Only the last study, however, was customized to the participants' particular reasons for taking better control of their diabetes. None of these studies systematically incorporated all stages of change into their models.

Postpartum and Infant Care Period

Weight Loss and Activity

Three RCTs were identified that used text messaging for weight loss in men and women (Table 4). All three studies allocated participants to a control group versus a two-way text message intervention where participants texted their weights to researchers and received feedback. All three found the intervention group lost significantly more weight than the control group participants [45–47]. All three weight loss programs applied lessons from the transtheoretical model, and one study, which showed the largest weight loss in the intervention group, moved participants in a structured manner through all stages of change, similar to the most successful smoking cessation programs [46]. Two studies using text messages to promote exercise found modest increases in weekly exercise, though they were both short-term, one lasting 2 weeks and the other lasting 4 weeks [48, 49].

Depression

Only one study on depression met all inclusion criteria. This study was conducted in New Zealand and provided high school students with text and video messages [50]. In the intervention group, participants received messages based on cognitive behavioral theory, and those in the control received general health promotion messages to control for attention and desirability bias. Those in the intervention group were significantly more likely to believe that the messages helped them to be more positive and get rid of negative thoughts [50].

Vaccinations

In a focus group of 40 pregnant women, only half had received influenza vaccine in the previous year [51]. Participants reported that they did not believe that the text messages would change their behavior, but that they would be more likely to discuss the influenza vaccine with their provider. Two RCTs recruited parents of children at low-income pediatrics clinics to promote childhood vaccines [52, 53]. The first did not show a significant difference in adherence to vaccination schedule, but the authors noted that 40 % of participants experienced a service disruption. The second study showed a small but significant increase in adherence (43.1 % vs. 39 %). This may reflect its larger sample size, with 7,574 participants versus 90 in the first study. A cohort study published in 2011 of parents at five separate pediatric clinics demonstrated that children of parents who received text message reminders were more

Table 4 Studies of text message interventions during postpartum and infancy periods

Topic	Reference (author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheoretical model	Other study interventions	Study design	Target population	Findings
Weight loss and activity	Donaldson 2011 [45]	Reduction in BMI and waist circumference	Participants texted their weight to practitioners twice weekly and received feedback over a 12 week period	Yes	Yes	None	RCT	Adults who had completed a weight loss program (N = 34)	Intervention group had a decrease in BMI and waist circumference while the control group experienced an increase (difference of 3.7 and 1.5, respectively, $p < .05$)
	Haapala 2009 [46]	Weight loss	Daily tailored text messages with goals, step-wise calorie reduction; participants responded with daily weight for 12 weeks	Yes	Yes	Part of a private mobile platform called Weight Balance with individualized recommendations	RCT	Overweight adults ages 25–44 in Finland (N = 125)	4.5 kg weight loss in the intervention group; non-significant change in weight loss in the control group ($p = .0001$)
	Patrick 2009 [47]	Weight loss	3–5 messages daily tailored to time of day, baseline questionnaire, and participant's previous replies for 12 weeks	Yes	Yes	Website that tracked weight; Monthly phone calls with counselors eliciting feedback on the program	RCT	Community members aged 25–55 with BMI 25–39.99 (N = 65)	After adjusting for time, sex, and mean age, intervention group lost 1.97 kg at 4 months ($p = .02$)
	Prestwich 2010 [48]	Increase in walking a minimum of 30 min 3× a week	Reminder created by each participant to walk, sent an average of 3.7 times a week; An average of 5.1 texts per week for 4 weeks	No (but customized throughout the study)	Yes	None	RCT	Adults in Leeds, UK recruited via email that exercised less than 3 times a week, did not have a medical condition, and were able to receive text messages (N = 149)	The text message intervention groups increased the number of days that they met daily recommended exercise by half a day a week ($p < .05$)
	Sirriyeh 2010 [49]	Increased physical activity amongst adolescents	Affective or instrumental messages prompting physical activity sent daily for 2 weeks	No	No	None	RCT	Students 16–18 years old in a Leeds, UK school (N = 128)	Participants increased their activity an average of 31.5 min a week; A post hoc analysis revealed that inactive participants who received affective messages had the greatest increase in physical activity ($p = .018$); Other groups were not significantly different

Table 4 continued

Topic	Reference (author, year, ref#)	Study objective	Text message intervention	Two-way	Application of transtheo-retical model	Other study interventions	Study design	Target population	Findings
Depression	Whittaker 2012 [50]	Satisfaction with a text message based depression intervention	Twice daily text messages based on cognitive behavioral therapy techniques vs. general health promotion messages for 9 weeks	No	No	Access to mobile website	RCT	Students in five New Zealand high schools, aged 13–17 (N = 1,348)	Those in the intervention group thought it helped them to be more positive (66.7 % vs. 50.1 % in the control, $p < .001$) and get rid of negative thoughts (50.2 % vs. 32.4 % $p < .001$)
Vaccination rates	Kharbanda 2011 [51]	Pregnant women's views on vaccination	Informational messages regarding flu vaccine in pregnancy	NA	No	None	Focus group	Pregnant women in New York City (N = 40)	Only half had received influenza vaccine in the previous year. Overall felt that text message would them talk with their provider
	Ahlers-Schmidt 2012 [52]	Effect size of text message immunization reminders on infant immunization schedule adherence	Immunization reminders	No	No	None	RCT	Low income Spanish and English-speaking parents of newborns discharged from a university hospital (N = 90)	No significant difference in adherence to childhood immunization schedule; 40 % of participants experienced a disruption in phone service
	Stockwell 2012 [53]	Increased influenza vaccination	Five weekly text messages in English and Spanish regarding the safety and efficacy of the vaccine [3], and the time and location of vaccination clinics [2]	No	No	None	RCT	Parents in four low-income pediatric clinics in New York (N = 7,574 analyzed)	The intervention group was marginally more likely to receive the influenza vaccine (43.1 % vs. 39.2 %, $p < .05$)
	Kharbanda 2011 [54]	Higher vaccination rates within the scheduled window for second and third HPV vaccine dose	Three weekly reminders about the second and third vaccine to parents who enrolled	No	No	None	Cohort study	Parents of girls ages 9–20 at five pediatric clinics due for the second and third HPV vaccine (N = 432)	51.6 % of those enrolled in the text message intervention received a second HPV vaccine within the recommended window, versus 35.0 % of those who were not ($p < .001$), comparable to historical control (38.1 %)

likely to complete the Human papillomavirus vaccine course than those who did not [54].

Discussion

These studies demonstrate the applicability of text messaging to promoting behaviors identified by governmental agencies and professional societies as important targets for maternal and infant health promotion, particularly amongst the underserved, as well as some areas that need further exploration [55–57]. Several of the interventions reviewed provide compelling preliminary evidence that smoking cessation, diabetes control, appointment reminders, medication adherence, weight loss, and vaccine uptake are amenable to and aided by this technology. Other targets relevant to maternal and infant health, including STI education, vitamin adherence, substance abuse, and depression have not been studied in randomized control trial format, in large sample sizes, and with adequate follow up periods. Moreover, they have not been studied in the populations relevant to maternal and child health. This is largely consistent with a separate review published in 2012, which was limited to articles that studied maternal and infant health directly and returned a total of thirty articles, four of which were quantitative [58].

Based on this literature review, five lessons emerge for researches in this field. First, databases have yet to create a systematic way of classifying these articles, making it difficult to find relevant articles. Databases could help overcome the difficulty of identifying relevant articles by classifying articles with a standard term. We suggest "mhealth"—short for "mobile health"—which is emerging as the most popular term among researchers and has the specificity of comprehensiveness necessary to be a useful research term.

Second, interventions should follow established theoretical models more closely. Those studies discussed with the most compelling evidence for effective behavioral change share a relatively more rigorous application of theories of behavior change, especially the transtheoretical model, also known as the "stages of change" model. Using this theory, the study directors are able to target messages and modify content to established stages of change, especially in several of the smoking interventions [37, 38]. Thus, they incorporate this new technology into what is already known about successful models of intervention. For example, the Agency for Healthcare Research and Quality review of health literacy interventions found that effective interventions were distinguished by "their high intensity, theory basis, pilot testing before full implementation, emphasis on skill building, and delivery of the intervention by a health professional" [59]. Using established theories of behavioral change appears to be as important in text message interventions as it is in other behavioral interventions.

Third, researchers should choose motivational messages over informational messages, and vary message timing and content to maintain engagement. In directly comparing motivational to educational text messages, one study found that motivational messages were effective, while educational messages were not [16]. In the smoking interventions discussed, one study used strictly motivational messages and ultimately had more long-term success than a similar intervention that used a combination of motivational and educational messages [37, 38]. This is a preliminary finding, but indicates that if program designers have a choice, motivational messages are preferable. Researchers should also vary the content and timing of the message, especially in medication adherence interventions. Though medications reminders were effective in the three studies [10, 17, 18], those groups that received the same message at the same time of day did not show an improvement in adherence [9, 17]. Receiving the same message at the same time of day may increase the likelihood that participants will ignore the message over time. Finally, comparing self-reported adherence to electronic monitoring invites caution in interpreting these results and provides evidence that researchers should use other types of technology to improve accuracy in measuring adherence [21].

Fourth, the outcomes of the text messaging programs need to be more closely aligned to the content. This is especially true of programs that send participants messages on various topics, including the comprehensive pregnancy education programs [8, 11, 15, 23, 24]. The lack of a clear outcome precludes effective measurement of the intervention's efficacy, as other authors have noted [58, 60]. Narrowing the intervention to a specific purpose could help researchers to apply theories of behavior change, as well as to measure the effectiveness of their program. Other methodological issues include the fact that many studies were not RCTs, and few accounted for attention bias.

Finally, researchers need to closely examine the reasons for high drop-off rates. Of the nine studies that included more than 200 participants, only four had more than 80 % follow-up: one of these provided cell phones to participants [17]; one had participants text their interest and consent to researchers, demonstrating their interest and comfort with the medium [38]; and one scheduled follow-up interviews with high school students during school hours [50]. The fourth is distinguished in its design by the personalization of messages to participants' baseline information, and the integration of the program into their care [61]. Determining what leads to successful retention in these programs is essential to scaling up interventions. One of the studies of influenza vaccine messages noted that 40 % of participants

experienced a service disruption during the intervention [52]. In populations with high likelihood of service disruption, one solution would be for researchers to pay for cell phone service during participation.

Even in the absence of infrastructure issues, these programs must provide value to participants to prevent drop-off. Those programs that allow two-way messaging and feedback appear to be relatively more successful, such as the three weight-loss RCTs [45–47]. Another way to reinforce the intervention is by integrating multiple platforms, such as website feedback, or the use of the QUIT number in smoking interventions [37, 38, 43]. Providers must see improvement in time, costs, or other relevant measures to invest in these programs. Finally, text message programs should link participants with existing infrastructure to support and sustain behavior change.

There were several limitations of this review. Because of the lack of standardized keywords in this field, some studies may have been inadvertently excluded. Additionally, because of the heterogeneity of the studies that were included, results could not be pooled. While this allowed us to provide an overview of the state of the literature, it prevented us from drawing definitive conclusions about the efficacy of the interventions studied here. Finally, this review is subject to publication bias, as unpublished studies were not included.

The use of text messages to promote maternal health has tremendous potential to reach pregnant women and new mothers, particularly those with fewer resources. As we have shown, these women are more likely to use text messaging and to be at risk for poor birth outcomes that may be modified through appropriate text message interventions [2–6]. These women are traditionally more difficult to outreach to with traditional communication methods, and thus this technology may be particularly valuable for this population. Future studies could add much to the existing literature by focusing on this population, and fleshing out should utilize behavioral theories to guide their interventions, prioritize motivational messages over informational, vary the timing of messaging, incorporate other platforms and resources into the interventions, and align research outcomes more closely to messaging content.

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