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REVIEW

mHealth Interventions in Low-Income Countries to Address Maternal Health: A Systematic Review

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Abstract

BACKGROUND The wide availability and relative simplicity of mobile phones make them a promising instrument for delivering a variety of health-related interventions. Mobile health (mHealth) interventions have been tested in a variety of health delivery areas, but research has been restricted to pilot and small studies with limited generalizability. The aim of this review was to explore the current evidence on the use of mHealth for maternal health interventions in low- and low middle-income countries.

METHODS Peer-reviewed papers were identified from Medline/PubMed, Web of Science, and Cochrane Library via a combination of search terms. Quantitative or mixed-methods papers published in the English language between January 2000 and July 2015 were included.

RESULTS Three hundred and seventy papers were found in the literature search. We assessed the full text of 57 studies, and included 19 in the review. Study designs included were 5 randomized controlled trials, 9 before and after comparisons, 1 study with endline assessment only, 3 postintervention assessments, and 1 cohort study. Quality assessment elucidated 9 low-quality, 5 moderate, and 5 high studies. Five studies supported the use of mobile phones for data collection, 3 for appointment reminders, and 4 for both appointment reminders and health promotion. Six studies supported the use of mHealth for provider-to-provider communication and 1 for clinical management.

CONCLUSIONS Studies demonstrated promise for the use of mHealth in maternal health; however, much of the evidence came from low- and moderate-quality studies. Pilot and small programs require more rigorous testing before allocating resources to scaling up this technology.

KEY WORDS maternal health, mHealth, mobile phone, reproductive health, technology

INTRODUCTION

Despite increasing attention and major global commitments and funding, maternal health remains a significant problem in low-income countries. Although maternal deaths fell by 45% between 1990 and 2013, approximately 800 women die every day due to complications of pregnancies and childbirth.[1] Of all maternal deaths between 2003 and 2009, 73% were due to direct obstetric complications; the top 3 causes were hemorrhage (27.1%), hypertensive disorders (14%), and sepsis

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(10.7%).[2] Nearly all (99%) maternal deaths occur in developing counties, reflecting inequalities in access to quality health services; these inequalities are further reflected in the disparities between high- and low-income women, and those living in rural versus urban areas in low- and middle-income countries (LMICs). Solutions for the prevention and management of complications of pregnancy exist, however, implementation of these solutions is constrained as overall access to quality care is lacking; health systems strengthening is necessary to address this critical context. mHealth has the potential to reduce inequalities in care through a variety of applications that aim to facilitate the communication between clients and providers, promote women's behavioral change, simplify and extend training, and assist in data collection; with the overarching aim to improve access to and quality of obstetric care. It is necessary to implement and evaluate these strategies in order to build the evidence-base that will enable the incorporation of mHealth into health systems and to improve access to quality maternal health care worldwide.

mHealth is defined by the World Health Organization as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices,"[3] and has been evaluated as a useful public health tool, particularly in underserved settings.[4,5] The number of mobile phone subscribers in developing countries increased from 1200 million in 2005 to 5400 million in 2014.[6] The ubiquitous penetration of mobile phones surpasses infrastructure in many LMICs, including paved roads, electricity, and fixed Internet deployment, demonstrating the potential of mHealth to address geographical barriers to access care. It also has potential to address the human resource gap through technology designed to assist in clinical diagnosis and treatment adherence, and improve health care worker training and patient education, among others.[3]

Mobile phone interventions have been tested in different areas including HIV, maternal and child health, family planning, malaria, and tuberculosis.[7-12] A systematic review on the use of mHealth and community health workers (CHWs) reported multiple applications for these technologies, including field data collection, receiving alerts and reminders, facilitating health promotion, and communication between providers.[13]

Although mHealth is a very promising strategy, most of the current evidence comes from small pilot studies with limited scalability.[3,5] Specific mHealth solutions are required for the field of maternal health, where death rates remain high due to limited access to quality care. Given the resource constraints in low-income countries, understanding the true effect of these strategies is essential before funds can be allocated to larger-scale interventions. A few reviews were recently published exploring this topic, but differed from the scope of our study. Poorman's study did not restrict the search to LMICs, and included studies in the "preconception period" loosely related to maternal heath, such as notification of sexually transmitted infections and vitamin supplementation in men and women in high-income countries.[14] Importantly, this review did not assess the quality of the articles included and did not publish its search strategy in detail, as we have done here. Similarly, another systematic review included mHealth interventions targeted at increasing childhood immunization rates and interventions targeted at increasing obstetric care attendance; but not studies evaluating other uses of mHealth such as data collection or provider training in the obstetric setting itself.[15] The present systematic review builds on these efforts in a more rigorous and comprehensive manner by including a clear systematic search strategy and quality assessment of the literature, and by capturing and collating several studies not previously assessed thereby painting a more definitive picture of the state of evidence for mHealth interventions in maternal health care delivery.

MATERIALS AND METHODS

Search Strategy. We included peer-reviewed papers identified via Medline/PubMed, Web of Science, and Cochrane Library. The search employed a combination of terms describing mobile phones, maternal health, and LMICs, as defined by the World Bank development indices (Box 1).[16]

Papers published in English between January 2000 and July 2015 were considered. Included studies reported original data using quantitative or mixed-method designs evaluating the implementation of an mHealth intervention to improve maternal health outcomes. We decided to limit the scope of this review to quantitative research (purely quantitative or mixed methods) and therefore excluded descriptive studies, purely qualitative research, oral presentations, policy briefs, commentaries, and study protocols. Additionally, we excluded papers that described a software or application but did not evaluate its implementation (Table 1). Initial screening

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BOX 1. Search String Imputed into MEDLINE/PubMed

(mHealth*[tiab] or mobile phone*[tiab] or phone*[tiab] or SMS[tiab] or text message*[tiab] or mobile device*[tiab] or telemedicine*[tiab] or cell phone*[tiab] OR mobile health [tiab] OR Mobile Applications[Mesh] OR Cell Phones [Mesh])
AND
(pregnancy*[tiab] OR Pregnancy [Mesh] or maternal health[tiab] OR prenatal care[tiab] OR perinatal care[tiab] OR postnatal care[tiab] OR postpartum [tiab] OR parturition[Mesh] or childbirth[tiab] or obstetrics[tiab] OR Prenatal Care [Mesh] OR "Delivery, Obstetric"[Mesh] OR puerperium [tiab] OR midwife[tiab] OR midwives [tiab] OR nurse* [tiab] OR traditional birth attendant*[tiab] OR provider*[tiab] OR health provider*[tiab] OR Maternal Health Services [Mesh])
AND
(Armenia OR Bhutan OR Bolivia OR Cabo Verde OR Cameroon OR Congo OR Cote d'Ivoire OR Djibouti OR Egypt OR El Salvador OR Georgia OR Ghana OR Guatemala OR Guyana OR Honduras OR India OR Indonesia OR Kiribati OR Kosovo OR Kyrgyz or Lao* OR Lesotho OR Mauritania OR Micronesia OR Moldova OR Mongolia OR Morocco OR Nicaragua OR Nigeria OR Pakistan OR Papua New Guinea OR Paraguay OR Philippines OR Samoa OR Sao Tome OR Senegal OR Solomon OR South Sudan OR Sri Lanka OR Sudan OR Swaziland OR Syria OR Syrian OR Timor OR Ukraine OR Uzbekistan OR Vanautu OR Vietnam OR Gaza OR Yemen OR Zambia OR Afghanistan OR Bangladesh OR Benin OR Burkina Faso OR Burundi OR Cambodia OR Central African Republic OR CAR OR Chad OR Comoros OR Congo OR Eritrea OR Ethiopia OR Gambia OR Guinea OR Haiti OR Kenya OR Korea OR Liberia OR Madagascar OR Malawi OR Mali OR Mozambique OR Myanmar OR Nepal OR Niger OR Rwanda OR Sierra Leone OR Somalia OR Tajikistan OR Tanzania OR Togo OR Uganda OR Zimbabwe)
OR
(Bolivia OR El Salvador OR Guatemala OR Guyana OR Honduras OR Haiti OR Nicaragua OR Paraguay)

of titles and abstracts was followed by full-text assessment of eligible studies. References of included papers were screened for additional sources.

Quality Assessment of Included Papers. Quality assessment of the studies was conducted using an adapted STROBE checklist for observational studies and CONSORT checklist for clinical trials.[17,18] Included papers were assigned a rating of high, moderate, or low quality.[19]

RESULTS

Our search identified 370 papers. We removed 23 duplicates and screened 347 titles and abstracts, of which 290 were excluded after initial screening. Full texts of 57 studies were assessed; 38 were excluded and 19 were included in this review (Fig. 1). Of the 19 papers, 14 described programs in Africa, 4 in Asia, and 1 in Latin America. Two

Table 1. Inclusion and Exclusion Criteria

	Inclusion Criteria	Exclusion Criteria
Topic	Papers evaluating mobile phone interventions addressing maternal health outcomes Papers evaluating mobile phone interventions aimed at improving providers' or lay workers' skills related to maternal health care or maternal health data collection	Papers evaluating other mHealth or eHealth interventions (eg, telecommunications, computer-based, tablet-based etc.) or health outcomes not related to maternal health
Setting	Low- and low middle-income countries	High- and high middle-income countries
Types of studies/designs	Quantitative or mixed-methods design that report outcome data	Descriptive studies. Qualitative research. Papers that described a software or application, but did not evaluate the implementation of those technologies
Type of publications	Papers published in peer-reviewed journals	Oral presentations, policy brief, commentaries, and study protocols. Reports form nongovernmental organization
Language	English	Other than English
Publication date	January 2000-July 2015	Before January 2000 or after July 2015.

papers reported on the same program in Liberia, 2 on the same program in Indonesia, 2 on the same program in Ethiopia, and 3 on the same program in Tanzania; despite this overlap, each reported different outcomes and/or study periods.

Eight papers reported on interventions targeting women; 6 on interventions targeting CHWs, traditional birth attendants (TBAs), or health extension workers (HEWs); 2 targeted midwives; and 3 discussed interventions including both formal and informal health workers. Nine papers were graded low quality, 5 moderate, and 5 high. Nine papers described a before and after design with no control group, whereas 5 reported on randomized controlled trials (RCTs).[20-22] One study used a historic control group.[23] Sample sizes ranged from 10 to 2,550, limiting comparability. Loss to follow-up (LTFU) was a challenge both in before and after studies and in RCTs; the study by Munro et al had an LTFU of 36.3%,[21] the RCT by Ngoc et al had significantly different LTFU in its 2 groups with 0.6% in the phone follow-up group and 8.1% in the clinic follow-up group,[24] and Adanikin et al had an LTFU of 21.3% in their intervention group and 42.8% in their historic control group.[23] The largest proportion of papers was classified as low quality. Of the 9 low-quality papers, 4 reported before and after studies, 1 reported an endline assessment, 3 reported on a postintervention assessment, and 1 reported on a cohort study with a historic control group. The 5 moderate-quality papers were all before and after studies. The remaining 5 high-quality papers were RCTs.

Labrique et al proposed a framework with 12 domains in which mHealth and information and communication technologies are commonly applied.[25] This review found 5 major domains where mHealth was used to address the continuum of care in maternal health: data collection, decision support and provider-to-provider communication, appointment reminder with or without health education, and clinical management. Table 2 describes the aggregated characteristics of the papers included in the analysis and Table 3 describes each study in more detail.

Data Collection. Two papers reported on the same Liberian TBA (N = 99) data collection and pregnancy registration program. Non- and low-literate TBAs were trained to use a mobile phone to send a 10-digit message containing information on pregnant women.[21,22] The early post-training assessment and the 1-year assessment showed significant improvement across a variety of mobile phone use indicators. A similar protocol was used in Ghana to train midwives (n = 2) and TBAs (n = 8) to use mobile phones to report cases of postpartum hemorrhage (PPH). Participants reported 13 cases of PPH during the study period; however, additional data on referral systems and specific health outcomes of those women were not provided. [12]

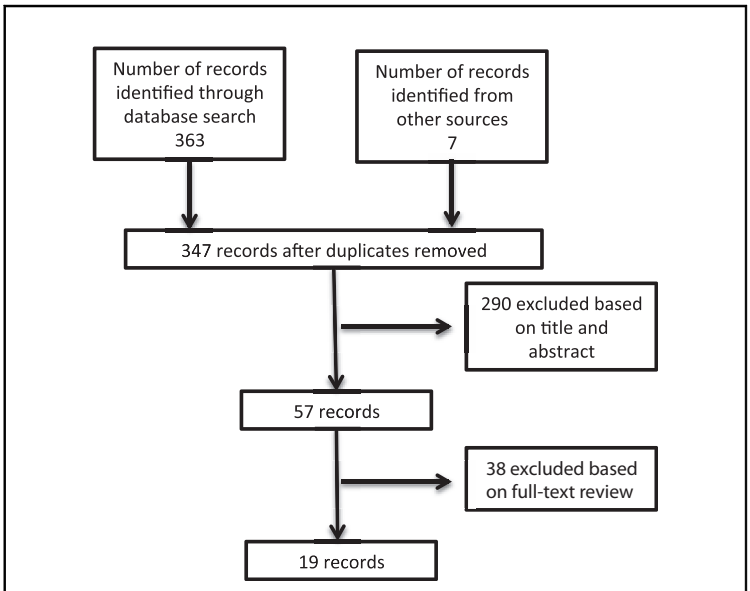

Figure 1. Flow diagram of the systematic review.

Another study trained Ethiopian midwives (n = 18) and HEWs (n = 12) in data collection using smart phones.[26] The study reported that health workers felt confident using the device, required little assistance, and developed a sense of ownership and empowerment with unrestricted phone access; however, this was not quantified in their analysis.

A 6-month study of electronic smartphone forms[27] reported 16 of 25 HEWs (69.6%) cited them as good protocol reminders. Identified barriers of consistent use of electronic forms included problems with username or password settings and freezing or locking up of smart phones.

Decision Support and Provider-to-Provider Communication. Mobile phones were evaluated as means to support health workers in their clinical decisions, facilitate referrals, and promote provider-to-provider communication.

A study conducted in Rwanda used a short message service (SMS) to facilitate real-time reporting and communication between 432 CHWs and the formal health system.[20] Over a 1-year period, 100% of CHWs complied, resulting in >35,000

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Table 2. Characteristics of the Studies Included in the Analysis

Main Goal of Intervention	Number of Records	Country	Target Population
Data collection	5	Ethiopia, Ghana, Liberia	Midwives, HEWs, TBAs, VHWs
Decision support and provider-to-provider communication	6	Rwanda, Gambia, Indonesia, Nigeria, Guatemala	CHWs, midwives
Appointment reminder	3	Kenya, Nigeria, Thailand/Myanmar border	Clients
Appointment reminder and health promotion	4	Tanzania, Ethiopia	Clients
Clinical management	1	Vietnam	Clients

CHW, community health worker; HEW, health extension worker; TBA, traditional birth attendants; VHW, village health workers

reports to the system, including 11,502 pregnancies, 163 SMS alerts associated with danger signs, and 3 maternal deaths. SMS alerts also were sent to CHWs regarding pregnancy management resulting in a 27% increase in facility-based deliveries. The effect on referral processes or CHW facility feedback mechanisms were not described.

Cole-Ceesay et al implemented a package of maternal health interventions in The Gambia, which included a component that used mobile phones to link village health workers and TBAs with health providers and ambulances. The paper reported only the endline assessment without specifying the specific contribution of this component; 109 patients were transferred from communities to hospitals over a 3-year period.[28]

mHealth also was used in Indonesia to facilitate communication among midwives and obstetricians. Midwives showed a significant increase in the confidence to solve difficult problems ($P < .01$) and store patient data ($P < .01$).[11] Mobile phone use was positively associated with access to institutional and peer-network resources ($P < .05$).[29]

An mHealth initiative in Guatemala provided mobile phones to tele-community facilitators that enabled them to ask questions about consultations, send epidemiological and clinical data, and receive training. Between 2008 and 2012, there were 116,275 general consultations, 6,783 women were monitored, and 2014 emergency transfers were coordinated. There was a statistically significant reduction in maternal mortality ($P < .05$) in the intervention communities compared with control communities over the 4-year period. However, there was an overall reduction in maternal mortality in the whole department over the same period. [30]

The m4Change project was designed to support the Nigerian government's initiative to promote the use of mHealth to improve maternal and child health.[31] A mobile phone application, including decision-support algorithms, data collection tools, and recorded health counseling messages, was developed to help CHWs to provide higher-quality antennal care in 10 primary health centers. After 1 year of program implementation, client exit interviews showed a significant increase in the overall score of quality of care received (13.33 at baseline vs. 17.15 at endline; $P < .0001$), and significant improvement in technical aspects such as the provision of HIV test (67.5% vs. 82.2%). Client satisfaction with antenatal care significantly improved after the intervention, 83.3% satisfaction at endline versus 75.4% at baseline ($P = .025$).

Appointment Reminders. Adaniki et al conducted a study in Nigeria where reminders to attend the postpartum visit were sent to women after delivery. Women in the intervention group attended more puerperal visits than a historic control group; failure to attend was 21.3% in the intervention group and 42.8% in the control.[23]

Odeny et al conducted an RCT evaluating the effect of SMS appointment reminders among HIV-positive pregnant women.[32] Women in the intervention group (n = 195) received a text message every 2 weeks starting on week 28 of gestation and weekly during the puerperium; women in the control group received standard care (n = 193). Almost 20% of women in the intervention group attended postpartum visits compared with 12% in the control group (relative risk [RR], 1.66; 95% confidence interval [CI], 1.02-2.70).

A study conducted in the Thailand-Myanmar border equipped health care personnel with smartphones to use in data collection and to send automated text messages to clients.[33] Published results focused on the appointment reminder service; a text message increased the odds of attending the appointment by almost 3 times (odds ratio [OR],

Table 3. Details of the Papers Included in the Systematic Review

Author	Country	Target of Intervention	Goal	Intervention	Design	Key Findings	Quality
Ngabo et al[20]	Rwanda	CHWs	Communication between CHWs and health facilities	• Rapid SMS system: facilitates communication between CHWs and the rest of the health system (health providers, ambulance, etc.) • CHWs trained using cascade approach • 432 CHWs trained; 500 cell phones distributed among them	Before and after with no control group	• 11,502 pregnancies (81% of estimated total in district) registered over 1 y • 163 SMS alerts associated with danger signs • 3 maternal deaths and 137 child deaths registered in system • 100% of CHWs complied with reporting • 27% increase in facility-based deliveries	Low
Cole-Ceesay et al[28]	Gambia	TBAs and CHWs	Communication between CHWs and health facilities	• Complex intervention package • Mobile phone component: phones linked community with emergency ambulance service and hospitals	Endline assessment	• Mobile phone component outcomes not independently addressed • 109 patients transferred from communities to local hospitals over 3 y • Main limitations: lack of call credit and short battery life	Low
Lori et al[22]; Munro et al[21]	Liberia	TBAs	Data collection	• Part of I-ROPE project: mobile phone data collection and training non- or low-literate TBAs (n = 99) • TBAs trained to send real-time SMS for data collection on the total number of pregnant women in the community; asked to send an SMS to local server with personal information and information of identified pregnant woman using a 10-digit code • TBAs provided with mobile phones, call credit, and solar charger	Before and after with no control group	• Mean increase in cell phone knowledge score was 3.67 between pre- and post-test	Moderate
						• Significant improvement in following abilities on 1-y post-test assessment: turn on the mobile without help, make calls without help, identify mobile coverage, identify if mobile is charged, create messages without help, send SMS without help; continued to have difficulty adding minutes to a phone	Moderate
Lund et al[34-36]	Zanzibar (Tanzania)	Clients	Appointment reminders and health education	• Wired Mothers intervention: automated SMS system; women received unidirectional text messages and a mobile phone voucher to enable bidirectional contact with health providers • SMS provided health education and appointment reminders	Cluster RCT Intervention: 12 health facilities, 1311 women Control: 12	*Antenatal care outcomes* • 44% of women in the intervention group received ≥4 ANC visits vs. 31% in the control group (OR, 2.39; 95% CI, 1.03-5.55) • 30% of women in the intervention group called their health providers	High

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Table 3. continued

Author	Country	Target of Intervention	Goal	Intervention	Design	Key Findings	Quality
				• Frequencies of the messages: 2/mo before 36 wk gestation and 2/wk from week 36 until delivery • Women in the control group received standard care (ANC, skilled attendance at delivery, postnatal visit)	health facilities, 1239 women	• 59% of the women in the intervention group said text message influenced their decision to attend the antenatal visit • 71% felt that the educational messages helped them learn about danger signs in pregnancy and to feel that the health system cared for them	
						Skilled birth attendance outcomes • Increased skilled birth attendance in the intervention group (60%) compared with the control group (47%) • Significant increase in skilled delivery attendance in urban areas (OR, 5.73; 95% CI, 1.51-21.81); did not affect women from rural areas • Higher levels of skilled delivery attendance among women who attended secondary school vs. those who had not (OR, 1.33; 95% CI, 1.01-1.77) and who were primigravida vs. those who had multiple pregnancies (OR, 1.86; 95% CI, 1.41-2.46)	High
						Perinatal outcomes • 2482 children were born alive, 54 were stillborn, and 36 died within first 42 d of life • Overall perinatal mortality rate was 27/1000 total births; 19/1000 births in intervention clusters vs. 36/1000 births in control clusters • Intervention associated with a reduction in perinatal mortality (OR, 0.50; 95% CI, 0.27-0.93) • Insignificant changes in stillbirths and deaths within the first 42 d of life	High
Odeny et al[32]	Kenya	Clients	Appointment reminder	• Up to 14 SMS sent to HIV-positive pregnant women; SMS sent every 2 wk starting on week 28 of pregnancy (max 8 depending on gestation); additional messages sent weekly during first 6 wk postpartum • Control group received standard care	RCT Intervention group, n = 195 Control group, n = 193	• 19.6% of intervention women attended a maternal postpartum clinic vs. 11.8% women in control group (RR, 1.66; 95% CI, 1.02-2.70) • 92% of intervention group infants received HIV testing compared with 85% of control group (RR, 1.0.8; 95% CI, 1.00-1.16)	High
Little et al[26]; Medhanyie et al[27]	Ethiopia	MWs and HEWs	Data collection	• MWs (n = 10) and HEWs (n = 15) given smartphones and trained for 3 mo to use a health application • Application provided 4 types of information: performance indicators (ANC, postnatal care, and	Postintervention assessment (Intermediate assessment of ongoing study)	• Most health workers felt comfortable using the device and required little technical assistance • MWs submitted more protocols than HEWs (registration, ANC, lab test, delivery) • Unrestricted use of smartphones generated a	Low

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Table 3. continued

Author	Country	Target of Intervention	Goal	Intervention	Design	Key Findings	Quality
				delivery); deliveries due on the following months; tasks and appointments due the following month; and appointments missed • Study period: 6 mo		sense of ownership and empowerment among health workers • Average of 160 min of voice calls per health worker; low usage of SMS (<3/mo)	
						• 23 health workers (92%) completed and submitted ≥3 electronic records to central server; 2,893 electronic health records corresponding to 1,122 women submitted • 20 workers (87%) believed electronic forms were useful for patient follow-up and appointment keeping, and were good reminders on what to do or ask • 12 workers (52.2%) said electronic forms were comprehensive • 10 workers (43.5%) said electronic forms were helpful to ask questions and assess patients step-by-step • Barriers for not using electronic forms included problems with username and password settings, smartphone freezing or locked up	Low
Martinez-Fernandez et al[30]	Guatemala	CF	Decision support, data collection, training	• CFs are volunteers who perform prevention and promotion of health and are equipped with a kit of essential drugs • Gave mobile phones to 125 CFs providing service to 466 rural communities, allowing them to make consultations, send data, and receive training	Before and after with control group	• 116,275 general consultations, 6783 women monitored, and 2014 emergency transfers coordinated over 4 y • Significant reduction in maternal mortality ($P < .05$) in intervention communities compared with control communities	Low
McNabb et al[31]	Nigeria	CHWs	Decision support and data collection and health education	• M4Change project implemented in 10 PHCs: CHWs given mobile phone/iPad, taught how to use app that contained ANC decision-support algorithms and recorded health counseling messages that were played for clients during visits • First-time ANC clients aged >18 y (N = 266) interviewed at first visit and 1 y later; assessed quality score of technical care services and client health counseling	Before and after with no control group	• Evidence-based total quality score of 25 indicators increased from 13.3 to 17.2 (of 25) ($P < .0001$) • Technical quality score increased from 7.77 to 8.44 (of 12) ($P < .0001$); performance in provision of HIV increased the most, 67.5% to 82.2%; measuring blood pressure increased from 87% to near universal at 97%; health education had the highest quality score increase from 5.45 to 8.67 points ($P < .001$) • Overall client satisfaction (proportion of clients who said they were very satisfied with the ANC services) increased from 75% to 83% ($P < .05$)	Moderate

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Table 3. continued

Author	Country	Target of Intervention	Goal	Intervention	Design	Key Findings	Quality
						• Client satisfaction aspects relating to usefulness of information received, respectful treatment by provider, and client's intention to return to the facility were already high at baseline (>91%) and did not significantly increase at the end of the intervention, but continued to remain high	
Andreatta et al[12]	Ghana	MW and TBAs	Data collection	• Nurse MWs (n = 2) and TBAs (n = 8) trained to use cell phones to report PPH data (occurrence, management, and outcome); TBAs had low literacy levels • Participants trained over 2 d to send text messages using a numeric protocol to report PPH-related events • Measurement over 90 d	Postintervention assessment	• 425 births reported by 9 of 10 birth attendants • 13 cases (3.1%) of PPH and 1 case of neonatal death reported	Low
Tesfaye et al[37]	Ethiopia	Clients	Appointment reminders and health education	• Maternal and Newborn Health in Ethiopia Partnership addressing family planning, behavior change thought IEC, and pregnancy care • Mobile phone intervention included in intervention package: HEWs sent text messages to clients for health promotion and visit reminders	Before and after with no control group Baseline surveys: n = 1027 Endline surveys: n = 1019	• Significant increases in postnatal care, from 5% to 51% and from 15% to 47% in the Amhara and Oromiya regions, respectively • Women with any ANC were 1.7 times more likely to have had a postnatal care visit vs. those who had none (OR, 1.67; 95% CI 1.10-2.54) • Women who had attended ≥2 community meetings with family members and had access to a HEW's mobile phone number were 4.9 times more likely to have received postnatal care than those who did not (OR, 4.86; 95% CI, 2.67-8.86) • Household mobile phone ownership was not significantly associated with attending postnatal care (OR, 1.16; 95% CI, 0.84-1.61)	Moderate
Ngoc et al[24]	Vietnam	Clients	Follow-up	• 1433 women seeking early medical abortion at 4 hospitals in Vietnam were randomized to clinic or phone follow-up • Clinic follow-up: returned to the hospital for confirmation of abortion outcome 2 wk after mifepristone administration • Phone follow-up: completed a semiquantitative pregnancy test at initial visit to determine baseline HCG and again at home 2 wk later. On the initial visit they received drugs to perform a medical abortion Clinic staff called women to review the pregnancy test results and symptom checklist	RCT	• No significant differences in rate of ongoing pregnancies (clinic: 2.7%; phone, 2.5%, RR, 0.9; 95% CI, 0.99-1.02) • 85% of women in the phone group did not need an additional clinic visit • Phone follow-up and home pregnancy test were effective in screening for ongoing pregnancy; sensitivity 92.8% and specificity 90.6%	High

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Table 3. continued

Author	Country	Target of Intervention	Goal	Intervention	Design	Key Findings	Quality
Adanikin et al[23]	Nigeria	Clients	Appointment reminders	• Intervention group (N = 1153): SMS reminders were sent twice, at 2 wk and 5 d before scheduled postnatal care appointment • Historic control group: patients who had delivered in the hospital within the preceding 6 mo of the study and had been given an appointment to attend a postnatal clinic • Intervention period: 6 mo	Cohort with historic control group	• 98% of intervention women received SMS reminders; this group's FTA rate was 21.3% vs. 42.8% in the control group. Absolute reduction was 21.5% • Patients who received an SMS reminder were 50% more likely to attend their postnatal appointment than patients who did not receive reminders (RR of FTA, 0.50; 95% CI, 0.32-0.77) • Total cost of sending 2,252 SMS reminders over 6 mo of study: US $21.12	Low
Kaewkungwal et al[33]	Thailand/ Myanmar border	Clients	Appointment reminders	• Health care personnel equipped with smartphones with text messaging and remote data-capturing capabilities • Intervention: automatically generated lists and messaging reminders of when mothers and children are due for visits, and data collection regarding ANC and child's immunization status • Clients without telephones received home visits according to scheduled reminder of visit dates and type of immunization required, as shown on workers' smartphones	Before and after with no control group.	• 280 pregnant women attended 900 ANC visits during 2-y study period; 58.68% came on time as per scheduled dates after intervention vs. 43.79% before • About 10% of women received appointment message reminders on their cell phones • Sending appointment reminder via cell phone increased odds of being on time for a visit by 2.97 (1.60- 5.54) • After the program was fully functional: 17% of parents received appointment reminders on their cell phones; 45% of the child's immunization information was collected and updated on health care worker smart phones; 44.22% of children received scheduled vaccines on time compared with 34.49% before the program ($P < .001$)	Moderate
Chib[11]; Lee et al[29]	Indonesia	MW	Provider-to-provider communication and access to information	• Simple voice communication to facilitate dialogue between MWs and OB-GYNs, while using mobile phones to do data transfer • Phones provided to MWs, MWCs, and OB-GYNs at the provincial hospital. • Mobile phone project implemented in 15 subdistricts of Aceh Besar with 223 village MWs • 122 MWs in study group received mobile phones and surveyed in initial study • 223 MWs surveyed in follow-up study	Before and after with no control group	• Significant increase in confidence to solve difficult problems ($P < .10$) and confidence to store patients' data ($P < .10$) • Study group more likely to turn to health center personnel for medical information ($P < .10$) • Improvements in searching for numbers in mobile phone lists ($P < .10$) and getting the mobile phone to do what they wanted it to do ($P < .10$)	Low

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Table 3. continued

Author	Country	Target of Intervention	Goal	Intervention	Design	Key Findings	Quality
						Results from follow-up study ● MW cell phone use was positively associated with access to institutional and peer-network resources ($P < .05$) ● Access to institutional resources had a direct positive effect on MW health knowledge ($P < .05$), whereas access to peer resources did not	Low

ANC, antenatal care; CHW, community health care worker; CF, community facilitator; CI, confidence interval; FTA, failure to attend; HCG, human chorionic gonadotropin; HEW, health extension worker; IEC, information education communication; MW, midwife; MWC, midwife coordinators; OB-GYN, obstetrician gynecologist; OR, odds ratio; PHC, primary health center; PPH, postpartum hemorrhage; RCT, randomized control trial; RR, relative risk; SMS, short message service; TBA, traditional birth attendant.

2.97; 95% CI, 1.60-5.54) and increased the odds of attending the visits on time (OR, 1.91; 95% CI, 1.46-2.49). After the program was fully implemented, 44.22% of the children received their immunization on time compared with 34.49% before the program ($P < .001$).

Appointment Reminders and Health Education. Certain studies used the same mHealth platform to send both appointment reminders and health education messages to promote behavioral change in pregnant women. Lund et al conducted a cluster RCT in Zanzibar, Tanzania within the program Wired Mothers.[34] Wired Mothers provided unidirectional text messages with appointment reminders and health education content, and women were given a voucher for bidirectional messaging with health providers. Forty-four percent of women in the intervention group received ≥4 antenatal care visits compared with 31% in the control group (OR, 2.39; 95% CI, 1.03-5.55), and 71% of women felt that the educational messages were useful to learn about pregnancy complication signs. Lund et al also assessed the proportion of skilled birth attendance.[35] In urban areas, 60% of the women in the intervention group had a skilled birth attendant present compared with 47% in the control group (OR, 5.73; 95% CI, 1.51-21.81). Finally, the intervention was associated with a reduction in perinatal mortality (OR, 0.50; 95% CI, 0.27-0.93), but there was no difference among groups in the number of stillbirths and deaths within the first 42 days of life.[35,36]

A study conducted in Ethiopia assessed the use of community meetings and text messages as appointment reminders and to illicit behavioral change.[37] Researchers found an increase in postnatal care in women who attended ≥2 community meetings and had access to HEWs and mobile phones (OR, 4.86; 95% CI, 2.67-8.86). However, household cell phone ownership itself was not associated with attending postnatal care.

Clinical management. Another potential use of mobile phones is to facilitate clinical management or follow-up, however, we only found 1 paper that described it. A Vietnamese study randomized 1,433 women seeking early medical abortion into 2 groups: medical treatment and phone follow-up or medical treatment and clinic follow-up.[24] The rate of ongoing pregnancy did not differ between study groups; phone follow-up and a semiquantitative pregnancy test done at the women's house were highly effective for screening ongoing pregnancy (sensitivity 92.8%; specificity 90.6%).

DISCUSSION

This systematic review found that mobile phone technology in the context of maternal health has been evaluated over a range of service delivery applications, such as data collection, provider-to-provider communication, appointment reminders, health education, and clinical follow-up. Studies showed promising findings for this technology, including health education and appointment reminder messaging significantly increasing postnatal care,[37] and being associated with reducing perinatal mortality[36]; however, a large proportion of the evidence came from low- and moderate-quality studies emphasizing the need for higher-quality research in this field. Four reports described data collection interventions, but they were of low quality, the sample sizes were small, and the effect of the intervention was not rigorously quantified. Two other studies evaluated the use of mobile phones to support lay health workers in their clinical decision-making process and facilitate patient referral to a health facility; the quality of these studies was low, they lacked a control group, and in one case, it was unclear if the reported effect was due to the mobile phone or other components of the intervention. Limited evidence from this systematic review suggested that mobile phone technologies are useful for increasing attendance to clinic appointments and promoting behavior change. Although there is a lot of potential in the use of mHealth for clinical follow-up, we did not find substantial evidence to show the effect or lack thereof of this technology in clinical management as only 1 paper considering this topic met our inclusion criteria.

Another issue relates to challenges intrinsic to this technology. Studies in which part of the intervention was to provide mobile phones to health providers found the additional challenge of mobile phone cost, maintenance, and lack of electricity to maintain charge.[20,21] Other limitations were related to phone sharing, where the fact that a message was delivered did not imply that the woman included in the study read it and her behavior was influenced by the SMS.[23,34,35] Another mHealth dimension that has not been deeply explored in maternal health programs is the delivery of provider training. We found evidence of mHealth used to support decision making and to communicate with other providers, but not specifically to deliver training. Given the global workforce crisis and the widespread deployment of task shifting as a way to address it, it is pertinent to explore the use of mHealth to deliver training to providers in the formal sector as well as to lay health workers.[38]

Our findings are in agreement with previous literature on this topic. A 2012 systematic review on maternal health and mHealth technology agreed with our findings that mHealth has the potential to address maternal health in low-income settings, and that high-quality studies are required to yield stronger conclusions. Future evaluations in this field should address scalability of pilot projects and long-term sustainability of the interventions.[39] This study included 34 papers, 4 of which were quantitative reports and they did not restrict their inclusion criteria to peer-reviewed papers. The present study differs in that the inclusion criteria were more rigorous, focusing on measurable results from peer-reviewed quantitative studies, and included a quality assessment of the literature, which the above review did not.

Other reviews explore this topic, but differed from the present study in the scope and the inclusion and exclusion criteria. Although there is some overlap, this systematic review explores the current evidence on the use of mHealth for maternal health interventions in low-income countries addressing the aspects that were not included in previous reviews and focusing specifically on maternal health interventions. The present review is in agreement with the others regarding the need of higher quality and more robust studies.

This systematic review has its strengths and weaknesses. To ensure a comprehensive search strategy, we used a literature search strategy adding specific terms for the 3 components we were interested in studying (mobile phone + maternal health + low- and low-middle income countries) and used clear inclusion and exclusion criteria. Although we included only papers published in peer-reviewed journals to improve the quality of the review, this may have resulted in the omission of outside reports from nonprofit organizations, white or gray literature, or papers published in technology journals. Another limitation is that we only included papers published in English. It is also worth noting that there is program overlap among some of the reports included in this review. Two of the 4 studies on data collection and 2 of the 4 on decision support corresponded to the same programs in Liberia and Indonesia, respectively. Similarly, 3 of the 4 studies on appointment reminders and health education correspond to the same program in Zanzibar, Tanzania. Increasing the quality of the studies as well as the diversification of programs and research

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groups would contribute to the generalizability of the findings.

This systematic review suggests that mobile phones offer a promising opportunity in the maternal health field to improve access to and quality of prenatal and obstetric health care, both from provider-facing technologies targeting practice behavior and performance and from patient-facing technologies focusing on adherence and education. This former is especially critical to reduce maternal mortality, as suboptimal obstetric care is directly responsible for the majority of maternal deaths, thus emphasizing the need for technologies to enhance provider performance and skills and other dimensions of quality including supply and commodity chains, provider motivation, and patient satisfaction. In general, this review again highlights the need for further higher-quality evidence to reinforce specific mHealth designs and applications to the health care delivery setting for maternal health. Additionally, larger-scale and more rigorous studies are needed to assess external validity across LMIC settings to guide health-sector resource investments into these technologies. Future research should explore new areas of application of mHealth interventions, such as the use of mobile phones to deliver training to health providers, and for supervision and quality improvement for health workers. Despite these research needs, mHealth has significant potential to alter the landscape of maternal health care in LMICs, and is worthy of attention and support.

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