mHealth Interventions to Counter Noncommunicable Diseases in Developing Countries

Still an Uncertain Promise

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KEYWORDS

• Low- and middle-income countries • mHealth • Chronic disease

KEY POINTS

- High population coverage by the mobile telephone network increased the possibilities of mHealth interventions in LMICs.
- Short text messages are the most common type of mHealth intervention used in LMICs.
- Results from randomized controlled trials showed a positive but modest effect of mHealth on NCDs outcomes.

THE PROMISE OF mHEALTH

Low- and middle-income countries (LMICs) carry a disproportionate burden of chronic diseases.[1] Health systems in these countries are facing a critical shortage of health professionals and resources making health services for persons with chronic diseases unavailable or low quality, which results in decreased life expectancy and quality of life.[2]

Mobile health (mHealth) interventions constitute a promise for health care delivery especially in resource-constrained settings in developing countries where mobile technology has a high penetration. In fact, cell phones and plans are lowering their cost, and cell devices are getting easier to use and are offering now more functionalities (eg, multimedia messaging service, bluetooth, Internet access, applications, GPS, camera and video) allowing the implementation of low-cost interventions.

In many places in LMICs, people have better access to mobile phones services than to basic services, such as water, electricity, sewerage, and sanitation.[3] In recent years, mHealth has yielded positive health outcomes because of improvements in the supply side of health care systems.[4] In terms of effectiveness, extensive reviews and meta-analyses in high-income countries have shown that mHealth increased access to medical services for vulnerable and hard-to-reach populations, enhanced communication flows and coordination among health care organizations, allowed timely data collection, improved education and training of health care workers, spread information

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among the community, and improved health care delivery.[5–12]

Mobile technologies represent a potential tool for improving health care services and clinical outcomes for chronic diseases, especially in the developing world. High population coverage by the mobile phone network, with 91.8% penetration, was reported in LMICs by the International Telecommunications Union in 2015; however, Internet coverage is still low and only 34.1% of the population is online, compared with 81.3% in the developed world.[13] In this regard, affordable smartphones and a growth of mobile broadband will increase access and the possibilities of mHealth interventions in LMICs.

However, there is still limited evidence of the effectiveness of mHealth in relation to its impact and long-term effects on prevention and control of chronic diseases in the developing world.[14] This article assesses the impact of mHealth on noncommunicable diseases (NCDs) in adults in LMICs. It differs from a previous published systematic review[14] because it includes other mHealth interventions, such as mobile applications and e-health registries, in addition to voice communication and text messages. The period covered is between 2012 and 2016.

EVIDENCE OF MHEALTH TO COUNTER NONCOMMUNICABLE DISEASES IN LOW- AND MIDDLE-INCOME COUNTRIES

Method

Search strategy

Systematic literature searches were performed from February to May 2016 using the following electronic bibliographic databases: Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, and the Latin American and Caribbean Health Science Literature Database according to MOOSE and PRISMA guidelines. Key words used in these searches included the following: telecommunication, cellular phone, cell phone, mobile phone, short text message, multimedia message, mobile applications, e-health registries, lifestyle, reminder system, risk reduction, patient education, self-management, patient compliance, primary prevention, outcome assessment, developing countries, underserved areas, and the specific LMIC.

Studies were included if they (1) were randomized controlled trials (RCTs) or systematic reviews and meta-analyses of RCTs with original data, conducted in an LMIC as defined by the World Bank published between January 2012 and April 2016[15]; (2) included subjects older than 18 years of age; (3) addressed the impact of mobile interventions on a chronic disease (asthma, diabetes, hypertension, tobacco use, cardiovascular disease, chronic respiratory disease, and cancer); and (4) measured outcomes including morbidity, mortality, hospitalization rates, behavioral or lifestyle changes, process of care improvements, clinical outcomes, costs, and self-reported outcomes, such as patient, compliance, knowledge, self-efficacy and health-related quality of life. Only articles published in English language were included. Data were limited to published studies from the aforementioned databases.

Randomly assigned pairs of reviewers independently evaluated selected abstracts. Articles whose abstracts met the inclusion criteria were reviewed by a separate, randomly assigned pair of reviewers. If the article met the inclusion criteria, these reviewers extracted pertinent data and assessed methodologic quality using the Cochrane Risk of Bias Assessment Tool.[16] Discrepancies in article inclusion, data extraction, and bias assessment were solved by team consensus. Early Reviewer Organizer Software version 2.0 was used by reviewers' for full text evaluations of articles, data abstraction, and quality assessment.[17]

Results

We retrieved 1274 abstracts using the search terms and 108 articles were selected for full review, 36 of which were excluded because they were conducted in upper-income countries; did not address mHealth (n = 11); were not RCTs, systematic reviews, or meta-analyses (n = 24); did not focus on chronic disease (n = 2); were not published in English (n = 1); and (n = 14) were provisional abstracts (**Fig. 1**). Included studies (n = 20) came from 14 LMICs: Malaysia (n = 1); India (n = 5); China (n = 2); Iran (n = 3); Pakistan (n = 2); Philippines (n = 1); Thailand (n = 1); South Africa (n = 2); Mexico (n = 2); Honduras (n = 1); Argentina, Guatemala, and Peru (n = 1); and Bolivia (n = 1). We finally included 20 studies (see **Fig. 1**).

Most of the studies evaluated more than one outcome and included chronic diseases, such as asthma (n = 1), diabetes (n = 11), hypertension (n = 4), prehypertension (n = 1), and cardiovascular disease (n = 4) (**Table 1**).

Fifteen studies addressed clinical outcomes, which included intermediate outcomes or markers of disease severity, such as forced expiratory volume, blood pressure, body mass index, cholesterol, glycosylated hemoglobin, hospitalization, and adherence to medication.[18–32] Only one study addressed process of care measures, such as

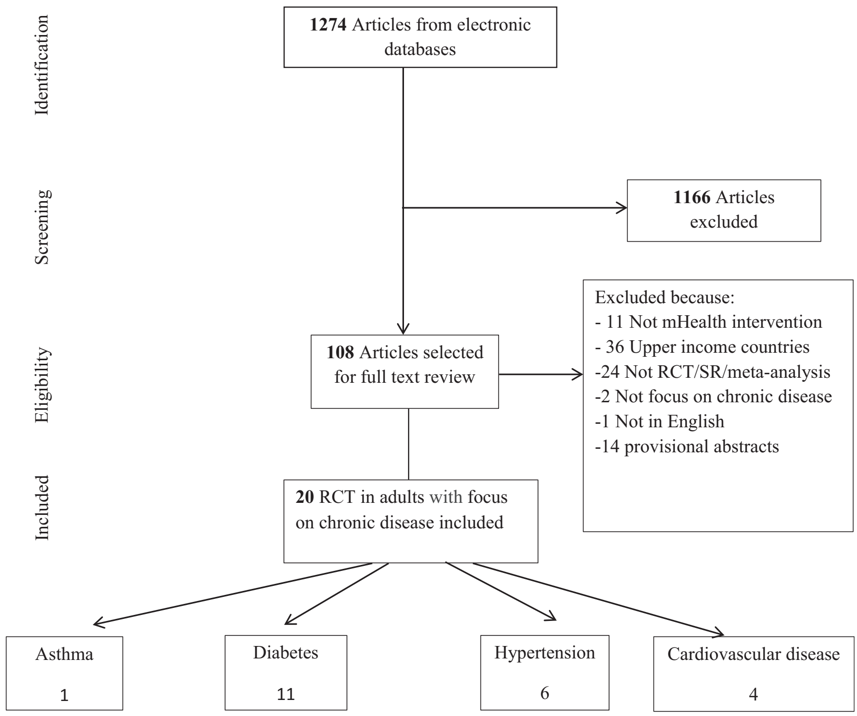

Fig. 1. Flow of information through the systematic review (SR).

follow-up for a definitive test in persons with an initial positive screening test as its main outcome.[33] Four studies examined patient compliance with diet, physical activity, and chronic medication[18,23,29,32]; four included, as an additional outcome, health-related quality of life measures[19,26,27,30]; and most evaluated changes in behaviors.[18,20,23–26,29–32,34–37] None of the evaluated studies included costs (see Table 1).

ASTHMA

Lv and colleagues[19] conducted a three-arm trial to evaluate in subjects with asthma whether daily short text messages about how to manage asthma in addition to in-person asthma education from a physician at the initial visit (SMS group) improved perceived control of asthma symptoms, forced expiratory volume in 1 second, and quality of life compared with receiving asthma education plus a free peak expiratory flow meter and training to use it (traditional group) or receiving asthma education at the initial visit (control group). The content of SMS included introduction to asthma, medication, asthma exacerbation triggers and strategies to avoid them, how to handle asthma acute attacks, and how to make an action plan. In this study, no differences were observed in the forced expiratory volume in 1 second among those who received the intervention but the SMS group show improvements in the perceived asthma symptoms and in the quality of life. However, a high proportion of subjects withdrew from the study; only 71 (47.3%) completed the follow-up visit (30 in the SMS group, 27 in the traditional group, and 14 in the control group) representing a risk to study validity.

DIABETES

Most of the included studies focused on diabetes management and education. Only one study focused on diabetes prevention. Tamban and colleagues[23] evaluated whether the use of SMS improved adherence to management prescriptions and clinical outcomes in type 2 diabetes compared with standard care. In this study, no significant differences were found in terms of adherence to diet and physical activity but significant changes were observed in glycosilated hemoglobin (HbA_{1c}) in the intervention group compared with usual care.

Peimani and colleagues[24] compared in a three-arm RCT the effect of tailored SMS-based education and nontailored SMS-based education versus usual care to support and educate patients with type 2 diabetes in an outpatient diabetes clinic in Iran. In the tailored SMS-based education group, 75% of the SMS were customized to the two top barriers to adherence assessed during the

Table 1
Details of included studies

Study (Year)	Country	NCD	Study Design/Intervention	Outcomes
Lv et al,[19] 2012	China	Asthma	RCT. SMS about how to manage asthma every day + education control (n = 50) vs traditional group who received asthma information, a free PEF meter and training on its proper use (n = 50) vs CG who received only verbal asthma education information at the initial visit (n = 50). Follow-up 3 mo.	PCAQ-6 score (mean changes in the score) from baseline to 3 mo: SMS group 7.07 ± 4.44 vs 4.78 ± 5.77 traditional group and 3.00 ± 5.31 in CG, *P* = .046. Forced expiratory flow in 1 s (% predicted): no differences were detected between the groups. AQLQ(S) score (mean changes) from baseline to 3 mo: SMS 31.40 ± 30.42 vs traditional 16.52 ± 21.10 vs CF 4.21 ± 30.98, *P* = .008. The follow-up adherence rates were 60% in the SMS group, 54% in the traditional group, and 28% in CG; *P* = .003
Goodarzi et al,[20] 2012	Iran	Diabetes	RCT. Educational SMS (n = 50) vs usual care (n = 50) in clinical parameters among T2DP. Follow-up 4 mo.	At baseline HbA_{1c} (%) 7.91 ± 1.24 in IG vs 7.83 ± 1.12 in CG, *P* = NS; and at 4 mo HbA_{1c} 7.02 ± 1.02 in IG vs 7.48 ± 1.26 in CG, *P* = .024. Cholesterol at baseline IG 180 ± 44.47 mg/dL vs CG 176.9 ± 31.15 mg/dL; and at 4 mo IG 165.95 ± 38.18 vs CG 187.2 ± 38.6, *P* = .002. Mean percentage of change in the score: Knowledge, IG 53.9% compared with CG 10.3%, *P*<.001; Practice, IG 38.5% compared with CG 10.4%, *P*<.001; and Self-efficacy, IG 13.19% compared with CG −3.10, *P*<.001.
Ramachandran et al,[22] 2013	India	Diabetes	RCT. Tailored SMS encouraging lifestyle change (n = 271) compared with standard lifestyle advice (n = 266) to reduce incident T2DP in men with impaired glucose tolerance. Follow-up 24 mo.	In the IG, 50 (18%) men developed T2DM over the 2 y compared with 73 (27%) men in the CG. Hazard ratio of 0.64 (95% CI, 0.45–0.92), *P* = .015. Number needed to treat to prevent one case of T2DM was 11 (95% CI, 6–55).

Tamban et al,[23] 2013	Philippines	Diabetes	RCT. SMS as an adjunct to the standard care (n = 52) vs standard care (n = 52) to improve adherence to diet and exercise and clinical parameters among T2DP. Follow-up 6 mo.	Adherence to diet and exercise was arbitrarily defined by the authors. Adherence to diet was defined as adhering to the dietary recommendation at least 4 d in a week and also eating 2–3 main meals in a day as recommended. Adherence to exercise was defined as adhering to the exercise recommendation of at least 5 d in a week and also having 30 min of exercise or more in a day. At 6 mo, significant differences were seen in mean number of meals/day, IG 2.61 $\pm$ 0.63 vs CG 2.29 $\pm$ 0.72 (P = .018) and mean number of minutes/exercise IG 37.40 $\pm$ 14.87 vs CG 31.44 $\pm$ 10.82 (P = .021), but not in the number of days patient complied with diet and exercise. At baseline HbA_{1c} (%) IG 7.81 $\pm$ 1.40–6.99 $\pm$ 0.86 at 6 mo and in CG 7.86 $\pm$ 1.14–7.34 $\pm$ 0.90 at 6 mo, P = .0452.
Kumar et al,[33] 2015	India	Diabetes	RCT. Mobile reminders (n = 135) vs control (n = 133) on follow-up for definitive tests and screening yield for diabetes to outpatients in a primary care setting. Follow-up 3 working days.	85.7% of outpatients in IG returned for a definitive test vs 53.3% in CG. RR = 1.61 (95% CI, 1.35–1.91), P<.001. Number of patients who were diagnosed with diabetes in IG and CG arm were 27.1% and 14.8%, respectively. Number of patients who were diagnosed with prediabetes in IG and CG were 36.1% and 23%, respectively.

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Study (Year)	Country	NCD	Study Design/Intervention	Outcomes
Peimani et al,[24] 2015	Iran	Diabetes	RCT. T-SMS (n = 50) vs non-T-SMS (n = 50) vs control (n = 50) on education of basic self-care skills among T2DP. Follow-up 3 mo.	HbA_{1c} and lipid profile were not affected by the intervention. A reduction in BMI was observed in both SMS groups, BMI at baseline 27.71 ± 5.29 in T-SMS and 27.14 ± 5.51 at 3 mo, BMI at baseline 27.40 ± 4.73 in non T-SMS and 26.90 ± 4.57 at 3 mo vs BMI at baseline 27.92 ± 4.97 in CG and 28.21 ± 5.15 at 3 mo, *P* <.001. FBS at baseline 172.44 ± 70.74 mg/dL in T-SMS and 152.54 ± 81.09 mg/dL at 3 mo, non T-SMS: FBS at baseline 169.54 ± 70.87 mg/dL and 147.82 ± 47.27 mg/dL at 3 mo. CG: FBS at baseline 166.94 ± 67.52 mg/dL and 165.32 ± 57.85 mg/dL at 3 mo, *P* = .003. Self-care inventory: at baseline 55.41 ± 10.54 in T-SMS and. 65.37 ± 10.26 at 3 mo, non-T-SMS at baseline 55.43 ± 10.67 and 65.79 ± 9.99 at 3 mo, CG at baseline 54.57 ± 9.13 and 49.98 ± 11.15 at 3 mo, *P*<.001. Diabetes self-care barriers: T-SMS at baseline 45.6 ± 11.06 and 31.42 ± 11.8 at 3 mo, non T-SMS at baseline 42.98 ± 10.20 and 29.24 ± 11.55 at 3 mo, CG at baseline 49.78 ± 10.62 and 57.56 ± 12.50 at 3 mo, *P*<.001. Diabetes management self-efficacy: T-SMS at baseline 57.40 ± 12.9 and 43.77 ± 11.50 at 3 mo, non T-SMS at baseline 53.63 ± 12.39 and 39.78 ± 8.67 at 3 mo vs CG at baseline 58.95 ± 11.86 vs 66.95 ± 11.38 at 3 mo, *P*<.001.

Wongrochananan et al,[26] 2015	Thailand	Diabetes	Cluster RCT. Interactive multimodality technology intervention in the intervention offices included email, SMS, and Web site with four main functions (self-regulation, self-monitoring and assessment, social support, and reminder system; linked to email and SMS) (n = 78) vs usual care (n = 48) in improving HbA_{1c} and self-management behaviors among T2DP patients. Follow-up 3 mo.	55 T2DP patients (70.5%) in the IG have a follow-up visit and 30 (62.5%) in the CG. A reduction in HbA_{1c} was observed, mean change in HbA_{1c} (%) in the IG: −0.28 (1.18) compared with +5.86 (1.00) in the CG, $P = .001$. No differences were observed in cholesterol, triglyceride, LDL-c, SBP, DBP, and BMI. No differences were found in diabetes self-efficacy and in diabetes quality of life but changes were observed in the self-care score. Mean change in the score in the IG +7.73 (11.86) compared with CG +1.84 (4.84), $P < .05$.
Shahid et al,[29] 2015	Pakistan	Diabetes	RCT. Mobile phone calls every 15 d (IG) (n = 220) vs usual care (CG) (n = 220) to improve HbA_{1c} and LDL-c among T2DP living in rural areas with poor glycemic control ($HbA_{1c} \geq 8\%$) and no chronic complications. Follow-up 4 mo.	Mean difference from baseline to 4 mo: HbA_{1c} (%) was −1.46 (0.07) in the IG vs −0.48 (0.04) in the CG at 4 mo, $P < .001$. LDL-c mean reduction was −23 (1.4) mg/dL in the IG compared with −9.04 (0.77) mg/dL in the CG, $P < .001$. Self-reported outcomes: adherence to a diet plan and the proportion of physically active patients have a greater increased in the IG at 4 mo compared with usual care.
Patnaik et al,[28,35] 2016	India	Diabetes	RCT. Intense lifestyle education using printed materials and computers + telephone calls + weekly SMS with educational tips (n = 50) vs control who received printed materials (n = 50) to decrease perceived stress among patients with diabetes. Follow-up 3 mo.	After 3 mo, total 55 patients (51%) (CG = 21; IG = 34) had a follow-up visit. No changes were observed between the groups in coronary heart disease risk factor and in clinical outcomes: BMI, waist-hip ratio, TC, FBS. Mean Cohen Perceived Stress Scale scores obtained were (18.9) at baseline for both groups. At 3-mo follow-up, the scores reduced to 17.05 in the IG and increased to 20.7 in the CG.

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Study (Year)	Country	NCD	Study Design/Intervention	Outcomes
Anzaldo-Campos et al,[30] 2016	Mexico	Diabetes	RCT. PDI (n = 99) vs PD-TEI, which include a cell phone app + USB glucose meter (n = 102) vs CG (n = 100) among T2DP with poor glycemic control (HbA_{1c} ≥8%). Follow-up 4 and 10 mo.	Mean difference from baseline to 10 mo: HbA_{1c} (%) in PDI was -2.63 (3.73), −3.02 (2.83) in the PD-TEI, and −1.3 (3.29); *P*<.001. No differences were observed between PDI and PD-TEI. No changes were observed over time in TC, triglycerides, LDL-c, high-density lipoprotein cholesterol, and SBP, DBP. Self-reported outcomes: PDI and PD-TEI reported changes in the Diabetes Knowledge Questionnaire 24, 3.20 (3.28) and 3.24 (4.15) compared with CG 1.15 (4.05). No changes were observed in self-efficacy, depression, self-reported behaviors, and quality of life.
Piette et al,[21] 2012	Honduras and Mexico	Hypertension	RCT. Mobile monitoring and behavior-change calls plus home blood pressure monitoring and email alerts for health workers (n = 99) vs usual care (n = 101) on SBP among patients with hypertension. Follow-up 6 wk.	Mean difference in SBP was -4.2 mm Hg (95% CI, -9.1 to 0.7; *P* = .09) lower in the IG but not statistically significant. IG have fewer depressive symptoms in the Scale compared with CG mean difference -2.5 in the score 10-item Center for Epidemiologic Studies-Depression (95% CI, -4.1 to -0.8; *P* = 0.04). Improvements were observed in medication-related problems, perceived health status, and treatment satisfaction.

Rubinstein et al,[25] 2015	Argentina, Guatemala, and Peru	Prehypertension	RCT. mHealth counseling calls on lifestyle modification (reduction of dietary sodium intake, reduction of simple sugars and saturated fat intake, increase of fruit and vegetable intake, and promotion of physical activity) + SMS (n = 316) vs usual care (n = 321) in reducing blood pressure, body weight, and eating behaviors among prehypertensive patients. Follow-up 12 mo.	266 (84%) participants in the IG and 287 (89%) in the CG were assessed at 12 mo. The intervention did not result in a change in blood pressure compared with usual care. However, the study showed a significant net reduction in body weight (−0.66 kg; *P* = .04) and intake of high-fat and high-sugar foods/ number of servings (−0.75; *P* = .008) in the IG vs the CG. Participants in IG who received more than 75% of the calls (≥9 calls) had a much higher reduction of their body weight −4.85 kg (95% CI, −8.21 to −1.48) and waist circumference −3.31 cm (95% CI, −5.95 to −0.67) and greater improvement in some eating behaviors.
Bobrow et al,[27] 2016	South Africa	Hypertension	RCT. SMS information-only (n = 457) vs SMS + interactive adherence support system (n = 458) vs usual care (n = 457) in maintaining and improving treatment adherence and blood pressure control among patients with hypertension. Follow-up 12 mo.	Mean adjusted difference in SBP at 12 mo for the SMS information-only compared with usual care was −2.2 mm Hg (95% CI, −4.4 to −0.04; *P* = .046) and for the SMS interactive compared with usual care was −1.6 mm Hg (95% CI, −3.7 to 0.6; *P* = .16). The adjusted OR for controlled blood pressure (<140/90 mm Hg) at 12 mo was 1.4 (95% CI, 1.0–1.9; *P* = .04) and 1.4 (95% CI 1.0–1.9; *P* = .04) for SMS information and SMS interactive, respectively, compared with usual care. The adjusted OR for improved availability of dispensed medicine was 1.86 (95% CI, 1.39–2.49; *P*<.0001) for SMS information compared with usual care and 1.60 (95% CI, 1.20–2.16; *P* = .002) for SMS interactive with usual care. EuroQol 5-D, Self-Report Questionnaire score, attendance at clinic appointments, retention in clinical care, treatment and clinic satisfaction, hypertension knowledge, self-reported adherence, hospital admissions, and differences in medication changes did not differ between groups.

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Study (Year)	Country	NCD	Study Design/Intervention	Outcomes
Hacking et al,[36] 2016	South Africa	Hypertension	RCT. SMS information (n = 109) vs control (n = 114) to improve health knowledge and self-reported health-related behaviors among patients with hypertension. Follow-up 17 wk.	69.7% in IG and 61.4% in CG had a follow-up visit. Knowledge: no significant changes were observed. Positive self-reported behavior change was reported by participants in the SMS intervention.
Piette et al,[37] 2016	Bolivia	Hypertension and diabetes	RCT. Standard m-health (tailored IVR calls) (n = 27) vs m-health + CP (tailored IVR calls + feedback to the care partner through IVR summaries and suggestions for supporting the patient's self-care) (n = 45) in completion of IVR calls and in health self- report among patients with hypertension and diabetes. Follow-up 4 mo.	mHealth + CP patients completed significantly more IVR calls than standard mHealth patients (62.0% vs 44.9%; *P*<.047) mHealth + CP patients were significantly more likely than standard mHealth patients to report excellent health during their IVR calls (adjusted OR, 2.60; 95% CI, 1.07–6.32).
Khonsari et al,[18] 2014	Malaysia	CVD	RCT. SMS-based reminders on medication adherence (n = 31) vs usual care (n = 31) for medication adherence among patients after hospital discharge following acute coronary syndrome. Follow-up 8 wk postdischarge.	97% of the patients had a follow-up visit. MMAS-8 was measured at 8 wk postdischarge: high adherence (score of 8) IG 64.5% vs 12.9% for CG, medium adherence (score of 6 to <8) IG 19.4% vs 29% for CG, and low adherence (scores of <6) IG 16.1% vs 58.1% for CG. RR of being low adherent among CG was 4.09 (95% CI, 1.82–9.18) compared with IG, *P*<.0001. No statistically significant changes in New York Heart Association classification, death, and hospital readmissions rate were observed between study groups.

Kamal et al,[32] 2015	Pakistan	CVD	RCT. SMS with reminders customized to their individual prescription + SMS with health information (n = 100) vs usual care (n = 100) for medication adherence in patients with >1 mo since last episode of stroke. Follow-up 2 mo.	Mean MMAS-8 score was measured at baseline IG 6.6 (0.7) vs 6.6 (0.16) in CG and at 2 mo in IG 7.4 (0.93) vs 6.7 (1.32), *P*<.01. No major effect was observed on SBP after the intervention. Mean DBP in IG was −2.6 mm Hg (95% CI, −5.5 to 0.15) lower compared with CG.
Boroumand et al,[34] 2015	Iran	CVD	RCT. SMS + follow-up telephone calls related to cardiac self-efficacy assessment (n = 35) vs telephone calls not related to cardiac self-efficacy assessment (n = 35) among participants hospitalized with coronary artery disease. Follow-up 4 mo.	Mean cardiac self-efficacy score: IG at baseline 30.5 compared with at 3 mo 53.1 and 59.1 at 4 mo; in CG the mean score obtained was 29.9 at baseline compared with 30.7 at 3 mo and 30.1 at 4 mo; *P*<.001.
Tian et al,[31] 2015	China and India	High risk of CVD	Cluster RCT. 23 villages (n = 1095 high-risk CVD participants) were assigned to CHWs monthly visits + smartphone for CHWs with an electronic decision support system with prompts to deliver the intervention + performance feedback and incentives or usual care, 24 villages (n = 991 high-risk CVD participants). Follow-up 12 mo.	Net pre-post difference in the proportion of patient-reported antihypertensive medication between the two groups was of 25.5%, *P*<.001. SBP reduction in the mean SBP between the groups (−2.7 mm Hg; *P* = .04). Net pre-post difference in the use of aspirin 17.1% (*P*<.001) and receiving monthly follow-up, 16% (*P*<.001). No differences were observed in tobacco use and salt awareness.

Abbreviations: AQLQ(s), Standard Asthma-Specific Quality of Life Questionnaire; BMI, body mass index; CG, control group; CHW, community health worker; CI, confidence interval; CP, care partners; CVD, cardiovascular disease; DBP, diastolic blood pressure; FBS, fasting blood sugar; HbA_{1c}, glycosylated hemoglobin; IG, intervention group; IVR, interactive voice response; LDL-c, low-density lipoprotein cholesterol; MMAS-8, Morisky Medication Adherence Scales−8 item; non-T-SMS, nontailored SMS-based education; OR, odds ratio; PCQ-6, perceived control asthma questionnaire; PD-TEI, Project Dulce technology-enhanced intervention; PDI, Project Dulce–only intervention; RR, relative risk; SBP, systolic blood pressure; T2DP, type 2 diabetes patients; TC, total cholesterol; T-SMS, tailored SMS-based education.

baseline visit using the Diabetes Self-Care Barriers assessment scale for older adults. In the nontailored SMS-based education group, random messages were sent. In both groups, participants received seven SMS per week during 3 months. No significant changes were observed in HbA_{1c} and lipid profile. However, a reduction of mean body mass index and fasting blood glucose were observed in both intervention groups.

Goodarzi and colleagues[20] evaluated at 3 months the impact of one-way educational messages (SMS) with information about exercise, diet, medication, and self-monitoring blood glucose levels on improving HbA_{1c}, lipid profile and knowledge, attitude, practice, and self-efficacy toward diabetes. Results showed an improvement in HbA_{1c} and cholesterol levels and in knowledge practice toward diabetes and self-efficacy in the intervention group.

Shahid and colleagues[29] compared in a two-arm RCT the effect of mobile phone calls on HbA_{1c} and low-density lipoprotein cholesterol values compared with usual care at 4 months in patients with type 2 diabetes with poor glycemic control and no chronic complications living in rural areas of Pakistan. The intervention included mobile phone calls every 15 days were patients were asked about self blood glucose monitoring, medication intake, healthy eating, and physical activity and received feedback from the investigator. Reductions were observed in HbA_{1c}, low-density lipoprotein cholesterol, and systolic blood pressure (SBP) in both groups; however, more pronounced reductions were found in the intervention group. Anzaldo-Campos and coworkers[30] evaluated the effect of a diabetes care and education program led by trained clinicians, nurses, and peers with mobile tools (Project Dulce technology-enhanced intervention/PD-TEI) and without them (Project Dulce/PDI) compared with usual clinical care on clinical and self-reported outcomes in patients with type 2 diabetes in Mexico. Patients with type 2 diabetes in the PD-TEI group received a cell phone where they have accessed to educational videos and materials and received interactive surveys (once a day during the first month and twice a week the second month) with questions regarding glucose measurements, carbohydrate intake, physical activity, and medication adherence. Providers also received alerts when patients reported out of range glucose values or missed their appointments. Clinical outcomes and self-reported outcomes were assessed at baseline, 4 months, and 10 months. Improvements in HbA_{1c} and in diabetes knowledge were reported in the intervention groups compared with usual care but no differences were observed between PD-TEI and PDI.

Two studies assessed the effect of mobile interventions to encourage lifestyle changes.[22,35] Ramachandran and colleagues[22] evaluated in Indian men with impaired glucose tolerance whether tailored SMS encouraging lifestyle changes reduced the incidence of type 2 diabetes at 24 months. The mobile phone message content was based on the transtheoretical model of behavioral change, which was assessed at baseline and at follow-up visits.[38] The investigators also took into account participants' preferences regarding timing and frequency of messaging to tailored SMS. Results of this study showed a significant reduction in the incidence of type 2 diabetes in the group who received tailored messages (18%) compared with the group who received standard lifestyle advice (27%), hazard ratio of 0.64 (95% confidence interval, 0.45–0.92; $P = .015$).

Patnaik and colleagues[28,35] evaluated the effect of a multicomponent intervention to reduce coronary heart disease risk factors and perceived stress among patients with diabetes. The intervention group received printed materials, telephone counseling calls every 3 weeks, and weekly SMS with lifestyle messages about healthy diet, physical activity, adherence to medication, and tips to manage stress during 3 months. Forty-five percent of the patients did not have a follow-up visit at 3 months and reported results were obtained from 21 patients in the control group (42%) and from 34 patients in the intervention group (68%). Substantial losses to follow-up were observed in both groups, with a greater tendency to loose subjects in the control group, which might affect the validity of the study.

Despite frequent diabetes screening and appropriate targeting of patients with high-risk, follow-up of those with abnormal results is uncommon and the yield of screening is low.[39] Kumar and colleagues[33] evaluated the effect of mobile reminder to improve screening yield during opportunistic screening for diabetes in outpatients attending primary care centers in India. This study showed positive results with improvement in follow-up for definitive test and outpatients in the intervention arm had 1.6 times more chances of returning for definitive test than control subjects.

A cluster randomized trial led by Wongrochananan and colleagues[26] evaluated whether a multicomponent intervention that included an mHealth component (SMS) improved HbA_{1c} and self-management behaviors at 3 months, compared with usual care. The intervention included emailing, SMS, and a Web site that addressed self-regulation, self-monitoring and assessment, social support, and a reminder system linked to the patient's email and mobile phone. Subjects enrolled were encouraged to log onto the Web site and set their personal goals for improving self-management behaviors. SMS and emails were sent to help them comply with the planned activities. Although the intervention showed improvements in HbA_{1c} levels and quality of life, the main limitation was its incomplete compliance with study procedures, and high drop-out rates.

HYPERTENSION

Four of the included studies focused on hypertension management and one on hypertension prevention. Piette and colleagues[21] assessed whether a multifaceted intervention that included a mobile intervention through automated calls for patients with hypertension plus home blood pressure monitoring and alerts via email for health care workers improved SBP. Patients with hypertension received automated calls during 6 weeks reminding them to measure blood pressure regularly and asking them about their SBP values, medication adherence, and salt intake. The system processed these responses and generated alerts when the patient reported that at least half of the time in the prior week he/she had had high SBP values or had been rarely or never taking their blood pressure medication. No effect was found on SBP; however, some improvements were observed in medication-related problems (eg, experiencing medication side effects, being confused by the complexity of the regimen, not being sure that the medication is important to get better) and in perceived health status.

Bobrow and colleagues[27] evaluated whether adherence support delivered via SMS with information only (one-way SMS) versus interactive text messaging (two-way SMS) improved treatment adherence and blood pressure control among patients with hypertension. In the group that received information only, SMS were one-way and encouraged patients to take their hypertensive medication, provided education about hypertension and its management, and reminders for scheduled appointments and prescription drugs refill at the clinic. In addition, in the interactive text messaging group, participants received the same messages plus a free service to reply to messages. Both interventions produced modest reductions on SBP. Medication changes, clinical appointments, hypertension knowledge, and self-reported adherence did not differ between the two groups.

Other studies assessed the effect of mHealth on self-reported health among hypertensives.[36,37] Piette and colleagues[37] evaluated the effect of tailored interactive voice response (IVR) calls to patients with hypertension plus an automated feedback to a care partner with summaries and suggestions for supporting the patient's self-care compared with noninteractive IVR calls in patients with hypertension. This study included patients with diabetes and hypertension and self-reported health was assessed at 4 months. Participants whose care partners received feedback were more likely to report excellent health than those who received IVR only.

Hacking and colleagues[36] used SMS to improve knowledge and self-reported health behaviors. Positive self-reported behavior change was reported but no improvement in knowledge was observed. A limitation of this study was its incomplete compliance with the follow-up interview.

Another study conducted by Rubinstein and colleagues[25] in Latin America evaluated the effect of mobile counseling plus tailored SMS to promote adoption of healthy lifestyles (healthy eating and physical activity) compared with usual care among prehypertensive subjects. Counseling calls were conducted on a monthly basis by nutritionists and the content of the calls and of the SMS focused on lifestyle modification. One-way SMS were sent on a weekly basis and content was based on the transtheoretical model of behavioral change, which was assessed in every monthly call.[38] Target behaviors treated in the calls were reduction of sodium intake, reduction of high fat and high sugar intake, increase in fruit and vegetable intake, and promotion of physical activity. The intervention did not result in a reduction of blood pressure values at 12 months; however, participants in the intervention group had a significant although modest reduction in weight and reported lower intake of high-fat and high-sugar foods.

CARDIOVASCULAR DISEASE

Two studies were conducted in patients with coronary artery disease, one in patients with stroke, and one in persons with high cardiovascular risk.[18,31,32,34] Two of them included SMS-based reminders to improve medication adherence.[18,32] In the study conducted by Kamal and colleagues[32] SMS were customized according to the patients' medical information and drug profile and sent during 8 weeks. Reminders were customized to the patient's prescription and participants were asked to respond stating if they were taking medication. In addition, two health information SMS were sent weekly.

Khonsari and colleagues[18] included patients who were discharged from hospital after an acute coronary syndrome. Patients received SMS reminders before every medication intake and also messages reminding patients to come to the hospital and have their prescribed medication refilled. Both studies showed improvement in the eight-item Morisky Medication Adherence Scale compared with usual care at 2 months of follow-up.[40]

Cardiac self-efficacy is related to adoption of healthy behaviors in patients with coronary disease. Boroumand and Moeini[34] evaluated the effect at 4 months of tailored SMS plus telephone calls versus telephone calls among patients hospitalized with coronary heart disease. In the intervention group, telephone calls were made twice a week during the first month and once a week during the second and third months. During telephone calls, cardiac self-efficacy was assessed and included such domains as maintenance of performance, management of disease symptoms, and regulation of cardiac risk factors.[41] The information provided was used to tailor SMS. Six messages per week, a total of 72 SMS, were sent during the study period. Results showed improvement in self-efficacy score in patients with coronary heart disease.

Tian and colleagues[31] evaluated in a cluster randomized trial the effect of a multicomponent intervention delivered by community health workers (CHWs) to improve cardiovascular management in persons with high cardiovascular risk living in rural villages in China and India. CHWs conducted monthly follow-up visits with the assistance of a mobile application that include an electronic decision support system to guide the implementation of two therapeutic lifestyle modifications (smoking cessation and salt reduction) and the appropriate prescription of hypertensive medication and aspirin. CHWs in the intervention group also received performance feedback and a financial incentive. Forty-seven villages were included, 23 in the intervention group with 1095 high cardiovascular risk participants and 24 villages with 991 participants in the control group. The net pre-post difference in the proportion of patient-reported antihypertensive medication was the main outcome.

In China, the intervention group had 24.4% higher net increase in the proportion of patient-reported antihypertensive medication compared with the control group and in India this net increase was 26.6%, both statistically significant. Use of aspirin was also more frequent in the intervention group at the end of the follow-up. A reduction in the SBP was observed in the intervention group with a mean difference pre-post between both arms of −2.7 mm Hg (P = .04). No changes were seen in tobacco use and in salt awareness.

DISCUSSION

According to the World Bank Classification, half of the studies included in this review correspond to upper-middle-income countries and half to LMICs. To date, low-income countries are not represented.

Labrique and colleagues[42] have developed a framework for 12 common mHealth and information and communication technology (ICT) applications that serve to map and catalog mHealth services and identify gaps to innovation, solutions, and implementation activity. The most represented domain in the reviewed articles was client education and behavior change in communication. In the included studies, mHealth was used as a channel to deliver education, increase patients' and care partners' knowledge, modify attitudes, and improve health-seeking behaviors and health-related lifestyle decisions. Three studies included an electronic decision support system for health workers as an additional component of the intervention. In two studies, the system generated alerts for health workers when it was detected that patients were not taking their chronic medication or were not under control,[21,30] and in another study the system generated prompts and guided CHWs to deliver lifestyle interventions and support the appropriate prescription of medication in persons with high cardiovascular risk during monthly visits[31]

Electronic data capture using mobile devices with easy user interfaces and offline data store have been implemented in many developed countries; however, no RCT have been conducted to evaluate if this mHealth intervention improves NCDs management.

One-way SMS was the most common used mobile function to deliver health education and health information. Only two studies used the IVR function.[21,37] This mobile function is easy to use and serves as a channel to deliver health information, especially in people with low health literacy levels.[43]

The impact of the proposed mHealth interventions on clinical outcomes was modest. One out of four included studies related to hypertension and prehypertension showed a small positive effect in blood pressure values.[27] Two of the four studies found modest reductions in weight; one was conducted in subjects with diabetes and was focused on diabetes education and the other implemented lifestyle modification strategies through mobile counseling calls and tailored SMS in prehypertensive patients.[24,25]

Five out of six studies showed a modest reduction in HbA_{1c} values compared with usual care.[20,23,26,29,30] As regards medication adherence, two out of three studies showed improvement in the Morisky Medication Adherence Scales.[18,32] Finally, five studies evaluated the long-term impact of mHealth to prevent or control NCDs.[22,25,27,30,31] Five studies reported loss to follow-up of more than 20% undermining of the reported results.[19,26,28,35,36]

There is an important gap between the scientific production of research and public health priorities in LMICs. In this sense, diabetes was the most represented chronic disease with the 11 studies. We found five studies addressing hypertension despite its much higher disease burden in our countries.[44] No mHealth studies on cancer screening or management were identified from LMICs.

Evidence-based information to guide policy-makers is scarce in our countries and research does not fully match LMICs health priorities. Potential to inform policy makers depends on the level of evidence, adequacy among publications, burden of diseases covered, presence of recommendations, or actionable messages and information for adoption and scaling-up.

In regard to the quality of the evidence reported in the reviewed articles, we only included individual randomized controlled trials, randomized cluster trials, systematic reviews, and meta-analysis in our search strategy to strengthen the quality of the evidence; however, eight of the included studies had a small sample size.[18–20,23,24,34,35,37] Furthermore, the analysis of some of the studies was not based on an intention-to-treat approach, leading to biased results that may have overestimated the effects of the mHealth interventions. Only two studies included insightful messages and information that might be useful for scaling-up these interventions.[22,27]

Evidence is still scarce regarding the effectiveness of different types of mHealth interventions to counter chronic diseases. The implementation of other mHealth interventions and ICT applications (eg, for data collection and reporting, electronic decision support, electronic health records) depends on access to other mobile functions, such as multimedia messaging service, videos, and apps, which are available in smartphones and depend on access to mobile broadband.

In LMICs, there are several limitations regarding technology use and implementation of mHealth interventions, which include but are not limited to technological literacy, health workers' resistance to new technology, different patterns of cell phone usage among underserved populations, shared or lack of mobile phones for personal use, lost or stolen phones, limited connectivity, limited infrastructure, access to smartphones, and lack of standardized data security protocols to ensure interoperability and to maximize the full capabilities of mHealth and ICT applications.[45]

mHealth studies conducted require methodologic rigor to provide high quality of evidence and influence practice and policies. The strength of the evidence depends on the study design, the methodologic quality and the statistical precision, the magnitude of the measured effects, and the relevance of these effects to the implementation context.[46,47] Many mHealth studies in LMICs fail to apply rigorous criteria in this review.

Research regarding adoption and ownership of mHealth is still needed. Few studies reported process indicators related to delivery of the intervention and reach of the target population. Rubinstein and colleagues[25] reported process indicators regarding delivery of the intervention (dose, reach, and implementation fidelity), such as the number of participants who were reached by the nutritionist, mean number of counseling calls received, and median number of attempts to contact a participant. It also showed SMS sent, SMS received, and attrition rate of participants. Bobrow and coworkers[27] also reported the number of messages sent, SMS that had a failed delivery response, and technical errors related to the delivery of SMS.

As per cost-effectiveness, no studies were found. This constitutes an underresearched area because cost-effectiveness evaluations of these interventions are critical to inform and guide policy makers' investments.

When interpreting the results of this study, some limitations should be taken into consideration. Our review was restricted to studies with rigorous design, such as RCT, meta-analysis, or systematic reviews of clinical trials. This strategy may have excluded studies with less strong designs. However, because the evidence of beneficial effects is at best modest, the inclusion of quasiexperimental studies more prone to different type of biases could have overestimated their true effects.

Another limitation was the exclusion of gray literature in the search strategy. Although the chance of finding an RCT not indexed in the most common electronic databases is low, this possibility cannot be excluded.

Although in this review the number of RCTs using mHealth to address chronic diseases in LMIC has been duplicated compared with a previous systematic review,[14] at least half of the studies found have small sample size or were proof of concept trials, which makes it difficult to extrapolate the study results to larger LMIC populations.

SUMMARY

We found few studies addressing the impact of mHealth interventions on chronic disease outcomes in LMICs. mHealth was found to have positive impact on processes of care and clinical outcomes. Yet, the effect was modest. In addition, the evidence is still scarce with respect to the effectiveness of different types of mobile interventions to reduce chronic diseases. Further research is needed to assess the effectiveness and cost-effectiveness of mHealth strategies, particularly to address hypertension, cancer, and chronic respiratory diseases.

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