

Review

Theories Applied to m-Health Interventions for Behavior Change in Low- and Middle-Income Countries: A Systematic Review

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Abstract

Background: Recently there has been dramatic increase in the use of mobile technologies for health (m-Health) in both high and low- and middle-income countries (LMICs). However, little is known whether m-Health interventions in LMICs are based on relevant theories critical for effective implementation of such interventions. This review aimed to systematically identify m-Health studies on health behavioral changes in LMICs and to examine how each study applied behavior change theories. **Materials and Methods:** A systematic review was conducted using the standard method from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline. By searching electronic databases (MEDLINE, EMBASE, and Cochrane Central Register of Controlled Trials [CENTRAL]), we identified eligible studies published in English from inception to June 30, 2017. For the identified m-Health studies in LMICs, we examined their theoretical bases, use of behavior change techniques (BCTs), and modes of delivery.

Results: A total of 14 m-Health studies on behavioral changes were identified and, among them, only 5 studies adopted behavior change theory. The most frequently cited theory was the health belief model, which was adopted in three studies. Likewise, studies have applied only a limited number of BCTs.

Among the seven BCTs identified, the most frequently used one was the social support (practical) technique for medication reminder and medical appointment. m-Health studies in LMICs most commonly used short messaging services and phone calls as modes of delivery for behavior change interventions.

Conclusions: m-Health studies in LMICs are suboptimally based on behavior change theory yet. To maximize effectiveness of m-Health, rigorous delivery methods as well as theory-based intervention designs will be needed.

Keywords: m-Health, behavioral health, e-health, telehealth, telemedicine

Background

Rapid development of Information and Communication Technologies (ICTs) has influenced many aspects of life. Among ICTs, mobile technology has been considered as a promising tool in multiple areas and has become a necessity in modern life. Particularly, the application of mobile technology in healthcare has drawn wide attention and has been commonly called mobile health (m-Health). More specifically, m-Health is defined as health intervention using mobile technologies such as mobile phones, wearable devices, personal digital assistants, tablet PCs, and so on.¹

The application of m-Health intervention has been expanded from healthcare support (e.g., clinical decision support and electronic medical records) to health prevention, promotion, diagnosis, and monitoring.² In terms of target diseases, m-Health has particularly focused on chronic diseases. In managing chronic conditions, there has been a consensus that the essential services providing frequent and timely services for consultation, prescription, and medical advice can be more crucial than the intensive care or cutting-edge medical equipment. In this light, m-Health has been considered as an effective tool to deliver such essential services for managing chronic diseases.³

The application of m-Health has been increasing in both developed and developing country settings. Recently, m-Health

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is drawing an attention for its potential to improve health in low- and middle-income countries (LMICs) that suffer from inadequate health delivery systems due to insufficient resources. Generally, the ICT penetration rate is very low in LMICs, but that of mobile technology is exceptionally high. For example, in 2015, the global mobile subscription rate and the average mobile subscription rate for LMICs reached 63% and 59%, respectively.^{4,5} Such high coverage of mobile devices may facilitate m-Health implementation in these countries. Therefore, the implementation of m-Health will likely be feasible in LMICs as a solution for better health delivery systems. Also, given that the burden of noncommunicable diseases currently outweighs that of communicable diseases even in most LMICs,⁶ m-Health can contribute to reducing the current global burden of diseases through effective management of chronic diseases.

Although m-Health is gaining popularity in the health sector, there has been concern on its effectiveness. While the evidence-based m-Health intervention has been emphasized, the value and scientific evidence of m-Health have been constantly challenged due to methodological issues.⁷ For example, systematic reviews on diabetes management using m-Health reported a positive association between m-Health and the reduction of risky behaviors among diabetic patients, while others argue that the results have critical limitations such as methodological flaws leading to risk of bias or insufficient sample size.^{8,9} Similar issues have been raised for m-Health studies in LMICs, emphasizing the need for rigorous study design, such as randomized controlled trials (RCTs).¹⁰⁻¹²

Another critical issue for the effective implementation of m-Health is whether m-Health intervention is based on relevant theories or not. Applying relevant theories to an m-Health project is particularly important because it can lead to well-developed intervention strategies and therefore, better health outcomes.^{9,13} Behavior change theory is a group of theories that aims to explain and structuralize the determinants of health behavior. It has been widely used for studies related to behavior change or interventions for health promotion. However, the usefulness and value of behavior change theory often depend on the context and relevance for an intervention study.¹⁴ Therefore, an m-Health program for behavior change should carefully incorporate a behavior change theory that would be most appropriate for the specific intervention strategies.

Considering the limited availability of resources in LMICs, effective, well-designed m-Health interventions based on a theory can be a viable option for these countries. However, little is known about whether m-Health interventions in LMICs are based on relevant theories, which is critical for effective implementation of such interventions. To fill this knowledge gap, this review aimed to systematically identify m-Health studies on health behavioral

changes in LMICs and to examine whether each study was based on any behavior change theories. Ultimately, this systematic review is expected to provide insight for future m-Health studies to maximize their effectiveness in the LMICs context.

Methods

We conducted a systematic review following the standard method of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline.¹⁵ A systematic search using the following electronic bibliographic databases was conducted: Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, and EMBASE. In addition, snowballing search was performed using the reference lists of the selected literature. The search protocol including keywords and the search strings is presented in the *Appendix Tables A1-A3*.

Two authors (Y.-M.C. and S.L.) independently assessed the eligibility of studies throughout the entire selection process. The reviewers first screened the titles and abstracts of the studies identified from the databases, and then conducted a full-text assessment of potentially eligible studies for final inclusion. If there was any discrepancy, two reviewers discussed and reached an agreement through intervention by a senior author (S.-Y.K.). Data extraction was conducted following a similar process and using a template adapted from the Cochrane Consumers and Communication Review Group's template for data extraction.¹⁶

INCLUSION CRITERIA

This review was restricted to studies published in English, but it did not restrict the date of publication, and included studies published through June 30, 2017. The target populations were confined to individuals in LMICs (below \$3,955 gross national income [GNI] per capita, based on the 2016 cutoff by the World Bank).¹⁷ Upper-middle income countries were excluded, due to the high heterogeneity in socioeconomic status between the two groups (lower-middle vs. upper-middle) of middle-income countries. (A full list of countries considered LMICs is provided in *Appendix Table A4*.)

Study types were limited to intervention studies, such as RCTs, case-control studies, quasi-experimental studies, and pre-post design studies. In this review, an intervention for behavior modification was defined as any strategy (e.g., self-management for diseases, education for health knowledge, and medication reminder) to change or maintain people's behavior or attitude to improve health. We included studies on interventions that used mobile devices (wireless and portable electronics including cellular phones, wearable devices, laptop, personal assistance devices, and tablet PC) or mobile technologies (any technologies that enable communication with

remote areas, such as phone call, video call, short messaging service [SMS], multimedia messaging service, online-chat, and e-mail) to promote health behavior change.

DATA EXTRACTION AND ANALYSIS

For the final set of studies included, the following information on the general study characteristics were extracted: study identities (title, authors, and publication year), study methods and setting, participants, type of intervention, and outcomes. To extract data regarding interventions and theories related to behavior, we developed a working framework, adopting the framework used in Webb et al.'s systematic review of behavior changes using the Internet.¹⁸ Their framework consists of three components: (1) theoretical bases, (2) behavior change techniques (BCTs), and (3) modes of delivery. We used their framework as the basis of our own working framework, but modified each component, as follows. First, for the theoretical bases, we introduced the assessment tool developed by Michie and Prestwich¹⁹ to identify the extent to which the intervention designs were theory-based. Second, for BCTs, we adopted the most up-to-date taxonomy on behavior change interventions established by Michie et al.,²⁰ which contains more detailed classification systems (16 groups clustering 93 BCTs) than the older version of taxonomy used by Webb et al.¹⁸ Lastly, we categorized the modes of delivery into three types (SMS; phone calls; and applications for smartphone), based on the frequently used types of delivery methods from the published literature.

Results

A total of 380 studies were identified as a result of the original search using the study protocol. After removing duplicates and screening the title and abstract, 51 studies were selected for full-text screening. The final number of studies selected based on full-text assessment was 14. *Figure 1* presents a flow chart illustrating the entire screening process.

The 14 studies that met the eligibility criteria consisted of 11 RCTs,²¹⁻³¹ 2 pre-post studies,^{32,33} and 1 quasi-experimental study.³⁴ The studies were conducted in various settings, including Bangladesh, Bolivia, Cameroon, Honduras, India, Kenya, Pakistan, and Swaziland. The selected studies included

interventions for diabetes, HIV/AIDS, cardiovascular diseases, and tuberculosis. *Table 1* presents the detailed characteristics of the identified studies.

INTERVENTIONS AND THEORETICAL BASES

Among the 14 studies, 5 studies^{21,23,25,30,33} were supported by a behavior change theory. Five different types of theories were used in the studies: (1) behavior learning theory,³⁵ (2) health belief model,³⁶ (3) integrated theory of behavior change,³⁷ (4) social cognitive theory,³⁸ and (5) transtheoretical model³⁹ (*Table 2* for a brief description of each of the five theories). *Table 3* summarizes the detailed aspects of each of the five theory-based studies based on the six categories of the assessment tool for theoretical bases.

The most frequently cited theory was the health belief model, which was adopted in three studies.^{23,25,30} The transtheoretical model for behavior change was applied to two studies^{21,30} and the behavior learning theory, social cognitive

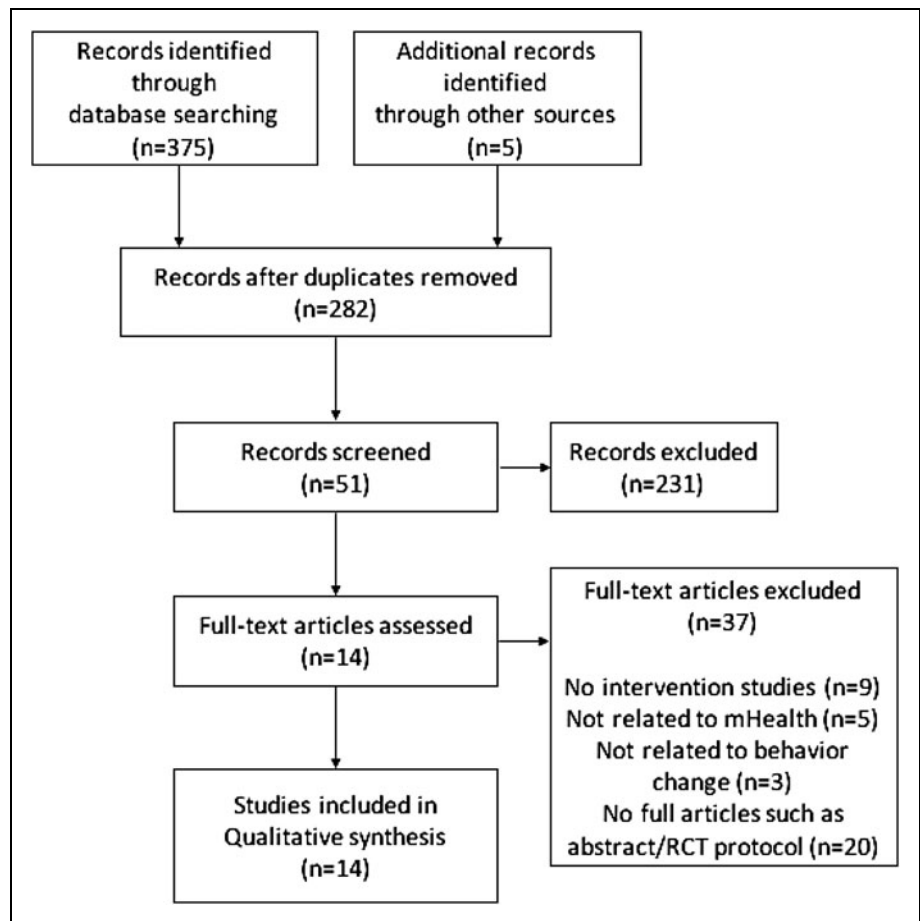


Fig. 1. Flow diagram of the study selection process. This graph provides information on the numbers of studies identified, included and excluded, through the phases of the systematic review following the PRISMA guidelines. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Table 1. Characteristics and Interventions of the Included Studies

STUDY	COUNTRY	STUDY DESIGN	TARGET DISEASE/ SECTOR	BEHAVIOR CHANGE TECHNIQUE	INTERVENTION	MODE OF DELIVERY	OUTCOME MEASURE
Islam et al. ²¹	Bangladesh	RCT	Diabetes	Social support (practical)	Automated SMS to improve medication adherence	SMS	Difference of HbA1c
							Medication adherence score
Johnson et al. ²²	Kenya	RCT	Reproductive health	Instruction on how to perform a behavior	Free text message containing information of family planning methods such as contraception	SMS	Level of knowledge of family planning
							Use of contraception
Kamal et al. ²³	Pakistan	RCT	Stroke	Feedback on behavior	SMS reminders to improve medication adherence	SMS	Medication adherence
				Social support (practical)			Blood pressure
Kliner et al. ³²	Swaziland	Pre-post study	HIV/AIDS	Social support (practical)	Mobile phone call to reminder medical appointment	Phone call	Attendance for follow-up consultation
Lester et al. ²⁴	Kenya	RCT	HIV/AIDS	Social support (practical)	Reminder to improve medication	SMS	Medication adherence
							Suppression of plasma HIV-1 viral load
Mbuagbaw et al. ²⁵	Cameroon	RCT	HIV/AIDS	Social support (practical)	Motivational mobile phone text messages	SMS	Medication adherence
Mohammed et al. ²⁶	Pakistan	RCT	Pulmonary tuberculosis	Social support (practical)	Reminder to take medication through SMS or missed call	SMS/ phone call	Treatment success
Piette et al. ³³	Honduras	Pre-post study	Diabetes	Feedback on behavior	IVR calls with diabetes management information	Phone call	Self-management (glycemic control/foot care)
				Instruction on how to perform a behavior			HbA1c
Piette et al. ²⁷	Honduras (Mexico) ^a	RCT	Hypertension	Self-monitoring of behavior	Automated blood pressure monitoring	Phone call	Blood pressure
					Provided self-care information		
				Self-monitoring of outcomes of behavior	Provided tailored advice		
				Feedback on outcomes of behavior			
Piette et al. ²⁸	Bolivia	RCT	Diabetes	Self-monitoring of behavior	Health and behavior monitoring with tailored feedback through IVR	Phone call	Health literacy
			Hypertension	Self-monitoring of outcomes of behavior			Medication adherence
				Feedback on outcomes of behavior			Perceived health
Pop-Eleches et al. ²⁹	Kenya	RCT	HIV/AIDS	Social support (practical)	Reminder to improve medication adherence	SMS	Medication adherence
Rodrigues et al. ³⁴	India	Quasi-experimental study	HIV/AIDS	Social support (practical)	IVR or SMS reminder for medication	SMS/ phone call	Medication adherence

continued →

Table 1. Characteristics and Interventions of the Included Studies *continued*

STUDY	COUNTRY	STUDY DESIGN	TARGET DISEASE/ SECTOR	BEHAVIOR CHANGE TECHNIQUE	INTERVENTION	MODE OF DELIVERY	OUTCOME MEASURE
Rubinstein et al. ³⁰	Guatemala (Argentina, Peru) ^b	RCT	Hypertension	Goal setting (behavior)	Phone call and text messages for support to change behavior	SMS/ phone call	Blood pressure
				Self-monitoring of behavior			Body weight
				Self-monitoring of outcomes of behavior			Intake of high-fat/high sugar foods
				Feedback on outcomes of behavior			
Shetty et al. ³¹	India	RCT	Diabetes	Social support (practical)	SMS including instructions on medical nutrition therapy, physical activity, reminders on following drug prescription	SMS	Frequency of visit
				Instruction on how to perform a behavior			Physical activity score
							Dietary adherence
							Medication adherence
							Fasting plasma glucose
							HbA1c

^{a,b}Upper middle income countries.

AIDS, acquired immuno-deficiency syndrome; HbA1c, glycated hemoglobin; HIV, human immuno-deficiency virus; IVR, interactive voice response; RCT, randomized controlled trials; SMS, short messaging service.

theory, and integrated theory of health behavior were applied once. Kamal et al.²³ conducted an RCT to improve medication adherence in stroke patients, employing the social cognitive theory and the health belief model. In the RCT, contents of SMS were designed to inform participants of the benefits and/or harms that resulted from their health behavior. Mbuagbaw et al.²⁵ provided the intervention group with reminders and messages for motivation, which were developed through the focus group interview as well as the health belief model. In their intervention, “cues to action,” one of the components in the health belief model, was adopted as a trigger for behavior change through sending a medication reminder. Rubinstein et al.³⁰ assessed the effectiveness of m-Health for cardiovascular diseases. The distinctive feature of their study was a well-designed intervention based on both the health belief model and the transtheoretical model to enhance physical activities and better diet in LMICs. Tailored counseling calls and SMS in accordance to the participants’ readiness of behavior change were provided at five sequential stages of the transtheoretical models. Another theory-based study by Islam et al.²¹ was an RCT that used both of the behavior learning theory and the transtheoretical model. The study’s intervention aimed to modify behaviors and life-style by using SMS as

stimuli for medication adherence and patient support, and the study compared outcomes between standard care and the addition of automated SMS to standard diabetes care. Lastly, the study by Piette et al.³³ applied the integrated theory of behavior change for diabetes care management through interactive voice response.

In all of the five theory-based studies, m-Health interventions were integrated with one or more constructs of theory. Two studies^{23,30} measured a construct of theory, and one study³⁰ provided individual-tailored intervention based on a theory. However, none of the studies used a theory in assessing the mediation effect of theory.

The remaining nine studies^{22,24,26–29,31,32,34} did not mention any application of theories. In terms of intervention type, most of the studies used an SMS reminder to track medication schedule and ultimately to increase medication compliance. Some of the studies^{24,26,29,31,34} also provided interventions such as a social message, physical activity, and diet care depending on the purpose of each study.

BEHAVIOR CHANGE TECHNIQUES

A total of 7 BCTs were identified in the included studies. Six studies employed more than one BCT. The most

Table 2. Descriptions of the Behavior Change Theories Used in the Included Studies

THEORIES	DESCRIPTIONS
BLT ³⁵	Theory that highlights the stimulus and response on behaviors and views that behavior learning occurs when reinforcing the behavior by stimuli
HBM ³⁶	Theory to explain behavior changes with a view that engagements in healthy behavior result from individuals' beliefs about severity of health problems, perceived benefits, perceived barriers or costs of action, and can also be influenced by modifying factors such as self-efficacy and cues to action
ITHB ³⁷	Theory based on the idea that knowledge and beliefs, self-regulation skills such as goal setting and self-monitoring, and social facilitation lead to engagements of self-management
SCT ³⁸	Theory that states that human behavior is produced through personal and environmental interactions and people learn by observing others, with two key components of outcome expectancies and self-efficacy
TTMBH ³⁹	Theory that provides strategies to make decisions for healthy behavior as assessed by individuals' readiness to act, and suggests that the decision of behavior change occurs through five stages including precontemplation, contemplation, preparation, action, and maintenance

BLT, behavioral learning theory; HBM, health belief model; ITHB, integrated theory of health behavior; SCT, social cognitive theory; TTMBH, transtheoretical model of behavior change.

frequently used BCT was the social support (practical) technique, which is the taxonomy used by Michie et al.²⁰ It refers to the access to technical advice and assistance for health behaviors from friends, relatives, colleagues, and staff. All nine studies^{21,23–26,29,31,32,34} using the social support (practical)

technique were intended to encourage medication intake or to remind of a medical appointment by phone call from research staff or via automated SMS.

The second most frequently applied BCTs belonged to the “Feedback and Monitoring” category, and included a total of four techniques: feedback on behavior, self-monitoring of behavior, self-monitoring of outcomes of behavior, and feedback on outcomes of behavior.^{23,27,28,30,33} For example, Piette et al.’s study²⁷ for hypertension management employed self-monitoring BCT. In their study, investigators provided home monitoring equipment to check blood pressure periodically, and gave feedback based on the monitored data.

The remaining two BCTs identified were the “instruction on how to perform a behavior” technique (belonging to the “Shaping Knowledge” group) and the “goal setting of behavior” technique. The former refers to the delivery of information, health behavior management, and dissemination of best practices through mobile functions, and were used in three of the 14 studies.^{22,31,33} The “goal setting of behavior” technique was used in Rubinstein et al.’s study,³⁰ in which participants chose one of the four target behaviors: reduction of sodium intake, reduction of high-fat/high-sugar intake, increase in fruit/vegetable intake, and encouragement of physical activity.

MODES OF DELIVERY

The most commonly used mode of delivery was SMS, which was adopted in 10 out of the 14 studies.^{21–26,29–31,34} Particularly, a reminder service was the most frequently used strategy, followed by the transmission of information on health behavior and consultation through text messages. Phone calls were used in seven selected studies.^{26–28,30,32–34} In these

Table 3. Assessment of the Theoretical Bases of the Theory-Based Studies Identified

STUDY	REFERENCE TO UNDERPINNING THEORY	TARGETING OF RELEVANT THEORETICAL CONSTRUCTS	USING THEORY TO SELECT RECIPIENTS OR TAILOR INTERVENTIONS	MEASUREMENT OF CONSTRUCTS	TESTING OF MEDIATION EFFECTS	REFINEMENT OF THEORY
	IS THEORY MENTIONED?	ARE THE RELEVANT THEORETICAL CONSTRUCTS TARGETED?	IS THEORY USED TO SELECT RECIPIENTS OR TAILOR INTERVENTIONS?	ARE THE RELEVANT THEORETICAL CONSTRUCTS MEASURED?	IS THEORY TESTED?	IS THEORY REFINED?
Islam et al. ²¹	BLT and TTMBH	✓				
Kamal et al. ²³	SCT and HBM	✓		✓		
Mbuagbaw et al. ²⁵	HBM	✓				
Piette et al. ³³	ITHB	✓				
Rubinstein et al. ³⁰	HBM and TTMBH	✓	✓	✓		

Based on the theory coding scheme by Michie and Prestwich.¹⁹

studies, the patients' behavior was monitored and the information on health and disease management was delivered via phone calls. No study used a smartphone as a delivery mode.

Discussion

m-Health has attracted attention as a potentially cost-effective means to improve healthcare in LMICs through its potential to lower geographic barriers to healthcare. m-Health can be a particularly useful tool in managing chronic diseases that require behavior change. To ensure the effectiveness of m-Health interventions in LMICs, it is crucial to base the study design on relevant theories. Our review explored behavior change studies using mobile devices in LMICs, focused on the application of behavior change theory.

Overall, the findings of our review suggest that m-Health studies in LMICs are suboptimally based on behavior change theory. Specifically, in terms of each of the three components (theoretical bases, BCTs, and modes of delivery) of the assessment framework, our review highlights the following: First, the application of theory-based design of an m-Health intervention for behavior changes appear to be insufficient. Among the 14 studies included in our review, only a minor proportion (36%) was found to be based on behavior change theories. Given the fact that theory-based research appeared to be more effective than the studies that do not employ a theory,^{13,18,40} the application of behavior change theory should be an essential step for m-Health research design in the future,⁴¹ particularly for LMICs with relatively poor healthcare environments.

Second, only limited types of BCTs have been applied in m-Health studies for behavior change. Even the 5 theory-based studies identified in our review, have used a very limited number/range of BCTs (7 out of 93 techniques classified). One possible reason for such limited application might be that mobile technology has strengths in monitoring a patient's status or sending reminders and thus BCTs related to this nature tend to be more often used. Another potential reason might be that studies have repeatedly applied proven techniques from previous studies rather than adopting alternative new BCTs. For future m-Health interventions, it would be desirable to attempt to apply more diverse types of BCTs that can benefit from the mobile platform.

Third, as for the modes of delivery, basic delivery modes such as SMS or a phone call, rather than high-end mode such as smartphone or wearable devices, are dominantly used in LMICs. This might be due to the low accessibility to high-end mobile technology in the setting. Another barrier to m-Health implementation in LMICs might be a service fee for users although the fee is not very costly.³² Future m-Health studies in

LMICs should consider that the use of m-Health in LMICs seems to be influenced by accessibility and affordability of technology based on socioeconomic situations specific to each country.⁴²

Based on our analysis of the identified theory-based studies using the assessment framework, our review also suggests that the studies share the following aspects and thus there is room for improvement for the way theories are applied. First of all, interventions were often supported by only a selected set of constructs, rather than by the whole theory. It is suboptimal to apply a partial set of constructs of a theory since behavioral change is a complicated process and thus might require more than a single step of a given process. Next, the effectiveness of the model constructs linked to an intervention was rarely assessed. Only 2 out of the 14 studies measured the constructs of models.^{23,30} The constructs of a model should be measured to explain the effects of the interventions for behavior change based on the theoretical explanations. Lastly, none of the studies except Rubinstein et al.'s applied theories in developing a tailored intervention or selecting participants. Since the preconditions for the promotion of healthier behavior vary among individuals, it is crucial to design an appropriate design and to select a suitable study population based on a theory.

Our study has limitations. First, due to the heterogeneity in study setting, target diseases, populations, and study design of the included studies, it was not appropriate to conduct any quantitative comparison of the study outcomes between the theory-based and nontheory-based studies. Second, our review mainly concerns with the extracted data on the application of theory for m-Health interventions. The limited data extracted from the articles were not sufficient to understand how theories were incorporated within each individual study. For this reason, we conducted an additional search for the original study protocols of the studies and provided more details when available.

Despite the limitations, our review provides a comprehensive summary of the trend and current status of the application of behavioral theories in m-Health interventions in resource-poor settings. Additionally, it provides insights into the crucial aspects of m-Health intervention designs for future efforts to utilize m-Health for health improvement in LMICs.

Conclusions

Our review shows that m-Health studies in LMICs are suboptimally based on behavior change theory yet and the way theories are applied could be further improved. Considering the significant role of behavior change theory in public health, the application of established theories for health promotion

would be a feasible approach to evidence-based m-Health interventions in LMICs. Future m-Health studies on behavior change in LMICs should consider the application of relevant behavior theories, use of BCTs when applicable, as well as the most appropriate modes of delivery.

Authors' Contributions

Y.-M.C. and S.-Y.K. conceptualized and designed the study. Y.-M.C. took the lead role in development of study protocol, data collection, interpretation of results, and drafted the article. S.L. was involved in data collection, interpretation of results, and critical revision of the article. S.M.S.I. provided a critical viewpoint in interpretation of results and critical revision of the article. S.-Y.K. contributed to interpretation of the results and critical revision of the article and provided technical support. All authors reviewed and approved the final version of the article.

Disclosure Statement

No competing financial interests exist.

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(Appendix follows →)

Appendix Table A1. Search Protocol (EMBASE)

		SEARCH WORDS	RESULTS
Population	1	LMIC	990
	2	"low and middle income"	6,346
	3	("low income" OR "middle income") AND (countr* OR setting)	16,332
	4	"developing country" OR "developing countries"	70,593
	5	"resource poor" OR "poor resource" OR "resource limited" OR "resource constrained" OR "low-resource"	15,471
Population total	6	#1 OR #2 OR #3 OR #4 OR #5	96,595
Intervention 1	7	m-Health OR "mobile health" OR (mobile NEXT/2 health)	2,034
	8	"mobile phone"/exp OR "mobile phone" OR "cell phone"/exp OR "cell phone" OR "cellular phone"/exp OR "cellular phone" OR "smart phone"/exp OR "smart phone"	12,741
	9	"mobile device" OR "wearable device" OR "tablet"/exp OR "tablet" OR pda OR laptop OR ipad OR iphone	72,512
	10	sms OR "short message service" OR mms OR "multimedia message service"	12,550
	11	"text messag*" OR "instant messag*" OR "voice messag*" OR "phone call" OR "e mail":ab,ti	11,915
	12	(mobile OR smartphone OR phone) NEXT/2 (app OR apps OR application OR applications)	4,872
	13	(mobile OR smartphone OR phone) NEXT/2 (technolog* OR intervention)	2,109
Intervention 1	14	#7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13	109,040
Intervention 2	15	"model"/exp OR model	2,787,259
	16	"theory"/exp OR theory	351,449
	17	"theoretical model"/exp OR "theoretical model"	23,853
	18	"behavior"/exp OR behavior	2,642,677
	19	(#15 OR #16 OR #17) AND #18	443,094
	20	"behavior change"/exp OR "behavior change"	27,784
	21	"medication compliance" OR "medication adherence" OR "treatment compliance" OR diet:ab,ti OR exercise:ab,ti OR "physical activity":ab,ti OR "weight control":ab,ti OR "self-monitoring" OR smoking:ab,ti OR "alcohol consumption":ab,ti	778,625
	22	"health behavior" OR "health behaviour" OR behavior OR behaviour AND (model OR theory OR theories)	230,294
	23	"social learning" OR "social cognitive" OR "reasoned action" OR "planned behavior" OR "social support" OR "community organization model" OR "ecological approach" OR "organizational change" OR "diffusion of innovation" AND (model OR theory)	13,245
Intervention 2	24	#19 OR #20 OR #21 OR #22 OR #23	1,202,490
P&I1&I2	25	#6 AND #14 AND #24	221
	26	#25 AND [humans]/lim	208
Total			208

LMIC, low- and middle-income country; P&I1&I2, P, population, I1 intervention 1, I2, intervention 2.

Appendix Table A2. Search Protocol (MEDLINE)			
		SEARCH WORDS	RESULTS
Population	1	LMIC OR "low and middle income"	7,291
	2	("low income" OR "middle income") AND (countr* OR setting)	18,411
	3	"developing country" OR "developing countries"	110,547
	4	"resource poor" OR "poor resource" OR "resource limited" OR "resource constrained" OR "low-resource"	14,274
Population total	5	#1 OR #2 OR #3 OR #4	133,766
Intervention 1	6	m-Health OR "mobile health"	29,243
	7	"mobile phone" OR "cell phone" OR "cellular phone" OR "smart phone"	6,135
	8	"mobile device*" OR "wearable device*" OR tablet* OR pda OR laptop OR ipad OR iphone	63,852
	9	SMS OR "short message service" OR MMS OR "multimedia message service"	9,868
	10	"text messaging" OR "text message" OR "instant message" OR "voice message" OR "phone call" OR e-mail[tiab]	8,951
	11	(Mobile OR smartphone OR phone) NEAR (app OR apps OR application OR applications)	269
	12	(Mobile OR smartphone OR phone OR "mobile phone") NEAR (technolog* OR intervention)	363
Intervention 1	13	#6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12	113,734
Intervention 2	14	Model theoretical[MeSH] AND (behavior OR behaviour)	181,246
	15	"behavior change" OR "behaviour change" OR "behavioral change" OR "behavioural change" OR "health behavior" OR "health behaviour"	61,649
	16	"Medication Compliance" OR "Medication adherence" OR "Treatment compliance" OR Diet[tiab] OR Exercise[tiab] OR "physical activity"[tiab] OR "Weight control"[tiab] OR self-monitoring OR smoking[tiab] OR "alcohol consumption"	747,519
	17	("health behavior" OR "health behaviour" OR behavior OR behaviour) AND (model OR theory OR theories)	258,831
	18	("social learning" OR "behavioural learning" OR "behavioral learning" OR "transtheoretical" OR "social cognitive" OR "reasoned action" OR "planned behavior" OR "social support" OR "community organization model" OR "ecological approach" OR "organizational change" OR "diffusion of innovation") AND (model OR theory)	20,442
Intervention 2	19	#14 OR #15 OR #16 OR #17 OR #18	1,104,274
P&I1&I2	20	#5 AND #13 AND #19	145
		Filter: Human	105
Total			105

LMIC, low- and middle-income country; P&I1&I2, P, population, I1 intervention 1, I2, intervention 2.

Appendix Table A3. Search Protocol (CENTRAL)			
		SEARCH WORDS	RESULTS
Population	1	LMIC OR "low and middle income"	358
	2	("low income" OR "middle income") AND (countr* OR setting)	1,117
	3	"developing country" OR "developing countries"	3,962
	4	"resource poor" OR "poor resource" OR "resource limited" OR "resource constrained" OR "low-resource"	1,119
Population total	5	#1 OR #2 OR #3 OR #4	4,329
Intervention 1	6	m-Health OR "mobile health"	353
	7	"mobile phone" OR "cell phone" OR "cellular phone" OR "smart phone"	1,074
	8	"mobile device**" OR "wearable device**" OR tablet* OR pda OR laptop OR ipad OR iphone	18,911
	9	SMS OR "short message service" OR MMS OR "multimedia message service"	1,168
	10	"text messaging" OR "text message" OR "instant message" OR "voice message" OR "phone call" OR e-mail[tiab]	2,284
	11	(Mobile OR smartphone OR phone) NEAR (app OR apps OR application OR applications)	662
	12	(Mobile OR smartphone OR phone OR "mobile phone") NEAR (technolog* OR intervention)	888
Intervention 1	13	#6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12	22,795
Intervention 2	14	MeSH descriptor: [Models, Theoretical] explode all trees	181,246
	15	Behavior OR Behaviour	21,971
	16	#14 AND #15	2,072
	17	"behavior change" OR "behaviour change" OR "behavioral change" OR "behavioural change" OR "health behavior" OR "health behaviour"	7,519
	18	"Medication Compliance" OR "Medication adherence" OR "Treatment compliance" OR Diet[tiab] OR Exercise[tiab] OR "physical activity"[tiab] OR "Weight control"[tiab] OR self-monitoring OR smoking[tiab] OR "alcohol consumption"	90,781
	19	("health behavior" OR "health behaviour" OR behavior OR behaviour) AND (model OR theory OR theories)	7,117
	20	("social learning" OR "behavioural learning" OR "behavioral learning" OR "transtheoretical" OR "social cognitive" OR "reasoned action" OR "planned behavior" OR "social support" OR "community organization model" OR "ecological approach" OR "organizational change" OR "diffusion of innovation") AND (model OR theory)	1,866
Intervention 2	21	#16 OR #17 OR #18 OR #19 OR #20	100,507
P&I1&I2	22	#5 AND #13 AND #21	62
Total			62

CENTRAL, Cochrane Central Register of Controlled Trials; P&I1&I2, P, population, I1 intervention 1, I2, intervention 2.

Appendix Table A4. List of Countries Considered as Low- and Middle-Income Countries

INCOME GROUP	REGION	COUNTRIES	GNI PER CAPITA (2016 CURRENT US DOLLARS)	REMARKS	
Low-income (GNI per capita of \$1,005 or less in 2016)	East Asia and Pacific	Democratic People's Republic of Korea	–	Data not available	
	Latin America and Caribbean	Haiti	780		
	South Asia	Afghanistan	580		
			Nepal	730	
	Sub-Saharan Africa	Benin	820		
			Burkina Faso	640	
			Burundi	280	
			Central African Republic	370	
			Chad	720	Value in 2011 current dollars (2011 cutoff: below \$1,025)
			Comoros	760	
			Democratic Republic of the Congo	420	
			Eritrea	520	
			Ethiopia	660	
			The Gambia	440	
			Guinea	490	
			Guinea-Bissau	620	
			Liberia	370	
			Madagascar	400	
			Malawi	320	
			Mali	750	
			Mozambique	480	
			Niger	370	
			Rwanda	700	
			Senegal	950	
			Sierra Leone	490	
			Somalia	–	Data not available
			South Sudan	820	Value in 2015 current dollars (2015 cutoff: below \$1,025)
			Tanzania	900	
			Togo	540	
			Uganda	660	
			Zimbabwe	940	

continued →

Appendix Table A4. List of Countries Considered as Low- and Middle-Income Countries *continued*

INCOME GROUP	REGION	COUNTRIES	GNI PER CAPITA (2016 CURRENT US DOLLARS)	REMARKS	
Lower middle-income (GNI per capita between \$1,006 and \$3,955 in 2016)	East Asia and Pacific	Cambodia	1,140		
		Indonesia	3,400		
		Kiribati	2,380		
		Lao PDR	2,150		
		Federated States of Micronesia	3,680		
		Mongolia	3,550		
		Myanmar	1,190	Value in 2015 current dollars (2015 cutoff: \$1,026 to \$4,035)	
		Papua New Guinea	2,160	Value in 2014 current dollars (cutoff: \$1,046 to \$4,125)	
		Philippines	3,580		
		Solomon Islands	1,880		
		Timor-Leste	2,180	Value in 2015 current dollars (2015 cutoff: \$1,026 to \$4,035)	
		Vanuatu	3,170	Value in 2014 current dollars (2014 cutoff: \$1,046 to \$4,125)	
		Vietnam	2,050		
		Europe and Central Asia	Armenia	3,760	
			Georgia	3,810	
			Kosovo	3,850	
			Kyrgyz Republic	1,100	
			Moldova	2,120	
			Tajikistan	1,110	
			Ukraine	2,310	
Uzbekistan	2,220				
Latin America and Caribbean	Bolivia	3,070			
	El Salvador	3,920			
	Guatemala	3,790			
	Honduras	2,150			
	Nicaragua	2,050			
	Djibouti	1,030	Value in 2005 current dollars (2005 cutoff: \$906 to \$3,595)		
	Arab Republic of Egypt	3,460			
	Jordan	3,920			
	Morocco	2,850			
	Syrian Arab Republic	1,840	Value in 2007 current dollars (2007 cutoff: \$936 to \$3,855)		

continued →

Appendix Table A4. List of Countries Considered as Low- and Middle-Income Countries *continued*

INCOME GROUP	REGION	COUNTRIES	GNI PER CAPITA (2016 CURRENT US DOLLARS)	REMARKS
		Tunisia	3,690	
		West Bank and Gaza	3,230	
		Republic of Yemen	1,040	
	South Asia	Bangladesh	1,330	
		Bhutan	2,510	
		India	1,680	
		Pakistan	1,510	
		Sri Lanka	3,780	
	Sub-Saharan Africa	Angola	3,440	
		Cabo Verde	2,970	
		Cameroon	1,200	
		Republic of the Congo	1,710	
		Côte d'Ivoire	1,520	
		Ghana	1,380	
		Kenya	1,380	
		Lesotho	1,210	
		Mauritania	1,120	
		Nigeria	2,450	
		São Tomé and Príncipe	1,730	
		Sudan	2,140	
		Swaziland	2,830	
		Zambia	1,300	

Countries included in this review is highlighted in bold.

GNI, gross national income.