Explaining the impact of mHealth on maternal and child health care in low- and middle-income countries: A realist synthesis

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Abstract

Background: Despite the growing global application of mobile health (mHealth) technology in maternal and child health, contextual factors, and mechanisms by which interventional outcomes are generated, have not been subjected to a systematic examination. In this study, we sought to uncover context, mechanisms, and outcome elements of various mHealth interventions based on implementation and evaluation studies to formulate theories or models explicating how mHealth interventions work (or not) both for health care providers and for pregnant women and mothers.

Method: We undertook a realist synthesis. An electronic search of six online databases (Medline, PubMed, Google Scholar, Scopus, Academic Search Premier, and Health Systems Evidence) was performed. Using appropriate Boolean phrases terms and selection procedures, 32 articles were identified. A theory-driven approach, narrative synthesis, was applied to synthesize the data. Thematic content analysis was used to delineate elements of the intervention, including its context, actors, mechanisms, and outcomes. Abduction and retroduction were applied using a realist evaluation heuristic tool to formulate generative theories.

Results: We formulated two configurational models illustrating how and why mHealth impacts the implementation and uptake of maternal and child care services. Implementation-related mechanisms include buy-in from health care providers, perceived support of health care providers’ motivation, and perceived ease of use and usefulness. These mechanisms were influenced by adaptive health system conditions including organization, resource availability, policy implementation dynamics, experience with technology, network infrastructure, and connectivity. For pregnant women and mothers, mechanisms that trigger mHealth use and consequently uptake of maternal and child health care include perceived satisfaction, motivation, and positive psychological support. Information overload was identified as a potential negative mechanism impacting the uptake of maternal and child health care. These mechanisms were influenced by health system conditions, socio-cultural characteristics, socio-economic and demographics characteristics, network infrastructure and connectivity, and awareness.

Conclusion: Models developed in this study provide a detailed understanding of the implementation and uptake of mHealth interventions and how and why they impact maternal and child health care in low- and middle-income countries. These models provide a foundation for the ‘white box’ of theory-driven evaluation of mHealth interventions and can improve rollout and implementation where required.

Background

The potential for mobile health (mHealth) to enhance healthcare utilisation, promote affordability and support accountability of health care in low-and middle-income countries (LMICs) is supported by the near-universal availability of mobile phones, with increasing coverage in many LMICs [1, 2]. Hence, there is increasing attention for the use of information and communication technologies (ICT) such as mobile phones to improve the provision and quality of healthcare. mHealth offers a personalised and interactive tool aimed at promoting healthcare access and awareness [3, 4]. mHealth has the potential to strengthen public sector care delivery for optimal management of chronic conditions and improvement of maternal and child health (MCH) care [5–7]. In addition to promoting health education among patients and reducing waiting times and cost of healthcare, mHealth enhances patient support, providing a system for emergency response and monitoring [6].

The potential challenges faced by mHealth interventions have been highlighted in previous studies [8, 9]. One-way mobile phone messaging is the most common type of mHealth communication used in LMICs [8]. However, the limitation of this approach is that patients only receive messages and cannot interact with health care providers in real-time. Factors influencing mHealth interventions at the individual level include users’ intentions, skills, attitudes, perceived norms, self-efficacy, literacy levels and proficiency in the use of mobile devices such as smartphones [8]. Systems-related factors affecting the use of mHealth interventions include unsuitable implementation context, poor internet infrastructure, unreliable power supplies and frequent power outages [9]. Other resource-related factors such as poor internet connectivity and cell phone networks are identified as challenges experienced by health care providers (HCPs) and patients using mHealth interventions.

Systematic reviews support the value of mHealth applications as an effective tool to improve MCH related outcomes as a key step towards achieving the Sustainable Development Goals (SDGs), in particular, SDG 3 [10, 11] mHealth has shown to improve health education, facilitate utilisation, increase clinic attendance, and promote health-seeking behaviour [12]. mHealth also supports regular immunisation and exclusive breastfeeding by targeting behavioural change [10, 13].

mHealth is an important ICT tool for MCH information and can influence healthcare-seeking behaviour, positively or negatively [14]. Hackett et al., [15] established that mHealth is significantly associated with MCH outcomes. While outcomes-based evaluation of mHealth interventions can offer insight into their performance, replicating findings across socio-demographic and geographical boundaries becomes challenging because mHealth interventions take on different forms. Having a functional understanding of how and why these interventions work (or not) can offer better implementation prospects. We sought to respond to this need by exploring and conceptualising contextual elements and mechanisms that interact to explain the observed effects of mHealth interventions on the uptake of MCH care in LMICs. We aimed to formulate models explicating how mHealth interventions work for health care providers and pregnant women and mothers by uncovering the context, mechanisms and outcome elements in implementation and evaluation studies of mHealth interventions used in MCH in LMICs [16].

Materials And Methods

Our study was informed by the realist understanding of generative causality as conceptualised by Pawson and Tilley [17]. They proposed the formula mechanism (M) (resource + reasoning) + Context (C) = Outcome (O), to express the relationship between context, mechanism and outcomes to explicate how interventions “cause” behaviour. According to this formula, O is a product of M in a specific C [17]and theories or models can be formulated, tested, confirmed and modified using a context-mechanism-outcome configuration (CMOc) [18]. Some implementation scientists have suggested modifications of the CMOc
heuristic to improve the explanatory power of the generative causality principle [19, 20]. Marchal et al. [21] and Mukumbang et al. [22] proposed adding “intervention” (I) modalities and relevant “actors” (A) to the CMO configuration based on the fact that an intervention (I) can only work when adopted by actors (A). Based on this modification, the generative understanding postulates that “outcome” (O) is produced by a mechanism (M) activated in context (C) through actors (A) when interventions (I) are executed” [16, 23]. The models developed in this study were achieved by formulating Intervention-Context-Actors-Mechanism-Outcome (ICAMO) configurations (Table 1).

Figure 1 shows a tentative conceptual model developed a priori based on existing literature on mHealth and MCH. This was achieved through abductive thinking – the inventive thinking required to imagine the existence of such mechanisms to ‘suggest’ the likeliest possible explanation. The model suggests that when HCPs (A) are educated on mHealth interventions and trained on how to use programme resources (I), their perceived support will motivate (M), encourage (M) and improve their self-efficacy (M), in turn improving the delivery of MCH care (O). With regards to programme users, the framework proposes that health educational and reminder messages of MCH (I) will sensitise, motivate (M) and encourage (M) pregnant women and mothers (A) to routinely use MCH care, such as emergency obstetrical care, facility deliveries (O) and early initiation of antiretroviral therapy for HIV positive women (O). We adopted a realist synthesis approach based on Pawson's practical steps for conducting a realist review [24], which includes five stages.

1. Clarifying the scope of the review,
2. Searching for relevant evidence
3. Appraising the quality of evidence
4. Extracting and organising data
5. Synthesising the evidence

**Stage 1: Clarifying the scope of the review**

The purpose of the review is to determine how, why, for whom and under which conditions mHealth supports MCH care in LMICs. The initial scan of literature and expertise of the research team helped to define the research questions: 1) What mechanisms and contextual factors lead to the implementation and uptake of MCH care? 2) How do those mechanisms and contextual factors interact to explain the implementation and uptake of MCH care?

**Stage 2: Searching for relevant evidence**

Five electronic databases (Medline, Google Scholar, Scopus, Academic Search Premier and Health Systems Evidence) were searched between June 2008 and December 2018 using the following Boolean combinations: [“mHealth” AND “maternal health”], [“mHealth” AND “maternal health” AND “child health”], [“mHealth” AND “maternal health services”], [mHealth PRE/15 maternal] and [mHealth PRE/15 maternal AND child AND health]. A total of 813 records were identified.

The following criteria were considered for inclusion: peer-reviewed, published in English, published between January 2008 and June 2018; studies conducted in LMICs; and studies targeting pregnant women, mothers with new babies and healthcare professionals (HCPs), including community health workers (CHWs). We considered cross-sectional, cohort, case-control and experimental studies, as well as RCTs.

Non-full text papers, technical reports, brief communications, presentation of scenarios or training workshops, editorial discussions, non mHealth applications, telemedicine and other eHealth programme applications were excluded. Studies published before 2008 were excluded as mHealth interventions were not common before that time.

**Stage 3: Study selection and appraising quality of evidence**

From 813 records identified in the database searches, 747 duplicates and non-relevant titles and abstracts were removed. Of the remaining 66 articles, 14 systematic reviews were also excluded. Fifty-two (n=52) full-text articles were screened for potential inclusion and twenty (n=20) were excluded for various reasons, yielding 32 articles (Figure 2).

A quality assessment was performed for each article using a research evidence appraisal tool [25] (Additional file 1). Eight of the 32 articles were of high quality, and 24 were classified as having good or moderate quality. Results from these studies could thus provide relevant and credible information towards challenging or enhancing the initial theory.

**Stage 4: Extracting the data**

Data were extracted and organised through a process of note-taking, annotation and conceptualization using the following headings: name of authors, year of publication and study setting or country; summary of the study aim; intervention, context, actors, Mechanisms, and outcomes (Additional file 2).

**Stage 5: Synthesising the evidence and concluding a process of reasoning**

The narrative synthesis (NS) approach proposed by Popay et al. [26] informed the process of collating, summarizing and reporting the results. NS proposes a theory-driven approach to data synthesis and is compatible with the philosophical assumptions guiding theory formulation in realist evaluation [27]. NS relies on the application of various methods of inference making through the use of words and text [26]. To this end, NS is applied in reviews addressing several questions, with research evidence in the context of studies that strive to inform policy and practice [26]. Four interrelated steps are involved in NS: (i) Theory
Step 1. Theory development of how interventions work

According to Arial et al. [28], a thinking framework herein referred to as initial programme theory, is required as a first step to continuously test and revise our understanding of how mHealth interventions could improve MCH health outcomes [29]. This initial programme theory – an assumption of how the programme should work – guides the process of operationalising mechanisms into theories or models at the end of synthesis (see Figure 1).

Step 2. Development of preliminary synthesis of results

We applied a deductive thematic analysis to extract data [30, 31] based on the concepts outlined in the ICAMO heuristic tool [32] and used an inductive approach to code constructs within each concept (Additional file 2). We identified relevant aspects of the intervention (I), context factors (C), mechanisms (M) and outcomes (O) related to the delivery of mHealth programmes for community health care workers (CHWs) and health care providers (HCPs), and pregnant women and mothers.

Step 3. Exploring associations in the data

The realist evaluation approach [18, 33] informed the process of constructing the explanatory model. Three different methods were employed to establish associations of the extracted ICAMO themes: retroductive inferencing, counterfactual thinking and configuration mapping. We applied retroductive inferencing to explore the relationship between the themes of the ICAMO heuristic tool. Retroductive inferencing is a mechanism-focused analytical approach used to reconstruct the basic conditions of phenomena, based on available data (abductive reasoning). Counterfactual thinking was applied to argue towards transfactual conditions – the existence of powers, potentials and liabilities which cause the outcomes [30]. We then mapped possible explanations based on the data through the process of configurational mapping – a process of organising and representing knowledge by linking and specifying relationships between variables.

Step 4. Assessment of the rigour of the synthesis

To assess robustness, we applied the TAPUPAS criteria (Table 2), an appraisal tool developed by Pawson et al. [34] to appraise the articles for relevance and to add more strength to the appraisal tool used to assess the quality of the study (see Additional file 1). Two study authors (EMK and FCM) applied judgmental rationality – the ability to evaluate different positions as being better or worse – to map ICAMO elements using Vensim® software. This was achieved through discursive and iterative consultation among the researchers until consensus was reached.

Results

Thirty-two (32) studies from different geographic areas were identified: sub-Sahara Africa (21), Asia Pacific (10) and Latin America (1), (Addition file 2). Following the initial programme theory (Figure 1), findings are presented for HCPs and pregnant women and mothers. Out of the 32 studies, 20 contributed to the development of a model for HCPs, while 29 contributed to the model for pregnant women and mothers. We used the Additional file 2 to extract data from the selected articles and the thematic analysis of the extracted data are presented in Table 3 and 4.

For more details on the thematic analysis (see Additional file 2, Table 3 and 4).

Implementation of mHealth by community health workers and health care providers

Table 3 presents the themes used to map the HCPs ICAMO (Figure 3), which shows an explanatory model of how and why HCPs implement mHealth interventions (or not).

The first aspect of mHealth interventions is that it offers a ‘communication platform’ (I) [35–42]. This is influenced by health system organisation(C) [4, 42, 43], their ‘experience with technology’(C) [40, 43], HCPs’ socio-demographic characteristics (C) [37], and availability of internet infrastructure (C) [44]. Having a functional ‘communication platform’ motivates (M+) [36] HCPs to ‘improve their performance of health care’ (O+) [36, 44], which increases the quality of MCH care delivery (O+)[36]. Also, the communication platform improves ‘perceived ease of use and usefulness of mHealth’(M+)[45, 46], which also improves their performance of health care (O+)[46].

The second relevant aspect of mHealth interventions relates to their ability to offer a ‘data management platform’ (I) [15, 42, 45, 47, 48]. The importance of data management platform is influenced by health system organisation (C) [15, 42] and experience with technology (C) [40]. Having a functional data management platform improves the perceived support of HCPs (M+)[47], resulting in improved HCPs’ performance of health care (O+)[47]. Also, the data management platform facilitates the perceived ease of use and usefulness of mHealth (M+)[45, 46], leading to improved HCPs’ performance of health care (O+)[45, 46].

Another important aspect of mHealth interventions for /HCPs is that these offer an environment of ‘decision-making support and guidelines’ (I) [44, 47, 49, 50]. Decision-making support and guidelines are influenced by health system organisation(C) [44, 49] socio-demographic characteristics (C), and ‘availability of internet infrastructure’(C) [44]. Having decision-making support systems and guidelines motivate HCPs (M+) [44, 50], thus improving the performance of health care (O+) [44, 50] and quality of MCH care delivery (O+) [50]. Finally, decision-making support and guidelines improve perceived support (M+) [47] and result in improved performance [47] and hence the quality of MCH care delivery (O+).
Table 4 presents the relevant themes used to develop the ICAMO model for pregnant women and mothers while Figure 4 presents a model illustrating how and why various aspects of mHealth interventions work for pregnant women and mothers.

The first important aspect of the uptake of mHealth interventions by pregnant women and mothers is the ‘reminder messages system’ (I) [43, 44, 49, 51–56]. This aspect is influenced by socioeconomic and demographics characteristics (C) [43, 44, 49, 51–53, 55], health system and political clout [43], and technical aspects of mobile phone services (C) [15, 36, 41, 42, 44, 45, 55, 57], which is influenced by socio-cultural practices, norms (C) [15, 62], socio-economic and demographics characteristics (C) [36, 15, 41, 44, 45, 55, 57, 58, 62], health system and political clout (C) [36, 42, 59–61, 63], and technical aspects of mobile phone services (C) [14, 61, 63]. The communication platform improves ‘positive psychological support’ (M+) [15, 36, 63, 41, 42, 44, 45, 55, 57, 60, 62], thereby improving health-seeking behaviour (O+) [15, 41, 42, 55, 63]. For instance, when users are educated about MCH, their capabilities to make healthy choices are enhanced, which motivates them to seek medical care in time [62]. Nevertheless, ‘perceived information overload’ (M-) can result in decreased visits to health facilities based on perceived desensitisation, as pregnant women and mothers who have access to more information online and on their mobile phone may become complacent about the use of health facilities (O-) [14].

mHealth interventions also offer a ‘consultation platform with HCPs’ (I) [38, 47, 48], which is influenced by socio-cultural practices (C) [47], health system and political clout [38, 48], and technical aspects of mobile phone services (C) [38]. The consultation platform improves the perceived satisfaction of care (M+) [15, 48] and improves health-seeking behaviour (O+) [38, 47].

We combined the tentative programme theory (Figure 1), the HCPs model (Figure 3), and the pregnant women and mothers model (Figure 4) to create a mHealth programme theory, which portrays how the adoption of mHealth programmes by HCPs and pregnant women and mothers influences the performance and quality of health care among HCPs and health-seeking behaviours among pregnant women and mothers (Figure 5). We identified that performance and quality of service delivered by HCPs (O+) were influenced by four different mechanisms: (1) ‘Buy-in from HCPs (M+)’ explaining that HCPs engagement with mHealth impacted their performance. (2) ‘Perceived support of HCPs’, which shows how the perceived support of HCPs such as quality of training, resources, and administrative support help HCPs to perform their task and improve HCPs-community relationship influence. (3) ‘Motivation (M+)’, reflecting how mHealth encourages HCPs to be more active in their task, and how knowledge acquisition and skills improve self-efficacy and confidence. (4) ‘Ease of use and usefulness of mHealth (M+)’, which shows how the quality of training received, resource availability, administrative support, knowledge and skills gained helped to improve their tasks such as data collection and data management.

In addition, four mechanisms explained how the mHealth program influences health-seeking behaviour among pregnant women and mothers were identified including: (1) ‘Perceived satisfaction (M+)’ explaining how perceived privacy, confidentiality and support from HCPs can influence the health-seeking behaviours. (2) ‘Motivation (M+)’ reflection of how the information and education received through the mHealth act as a stimulus of the health-seeking behaviours. (3) ‘Positive psychological support (M+)’ reflecting how knowledge gained improved self-efficacy and confidence and encouraged, empowered, and motivated pregnant women and mothers can impact on health-seeking behaviours among pregnant women and mothers. (4) ‘Information overload and sensitisation (M-)’ reflecting how accessing MCH information has a positive or negative effect as pregnant women and mothers may become complacent to using health facilities once they can access the needed health information through their mobile phones [14].

The model shows that HCPs outcomes such as improved performance quality of health care delivery (O+) have an impact on the mechanisms activated by pregnant women and mothers to produce the outcomes.

Discussion

The present realist synthesis analysed 32 articles describing eight intervention modalities used to implement the mHealth programme for HCPs, pregnant women and mothers in LMICs. namely mHealth programme, training and support of HCPs, a communication platform, data management platform, decision support and guideline (for HCPs) and mHealth message send to HCPs, reminder messages system, a communication platform, consultation platform (for pregnant women and mothers). Our findings are supported by many other studies [45, 48, 55, 64].

Our model suggests that when HCPs (A) are trained and supported in mHealth and its use as a communication platform, data management platform, and tool for decision support and guideline (I), their perceived support and perceived ease of use and usefulness will motivate buy-in and engagement (M), in turn improving the delivery of the mHealth intervention (O+), improved HCPs performance (O+) and quality of health care delivery (O+). Adaptive health system conditions, resource availability, policy implementation dynamics, health system organisation, experience with technology, socio-demographic characteristics, and network infrastructure and connectivity (C) are contextual factors that explain how the adoption of mHealth programme by HCPs (I) activate the mechanisms (M) to produce the outcome (O) [44, 47, 50, 60].

With regards to pregnant women and mothers, the model proposes that mHealth messages sent to HCPs, the reminder messages system used by HCPs to send reminder messages to pregnant women and mothers, the communication platform which provides health education and information to pregnant women and mothers, and the consultation platform (I), improve the perceived satisfaction with care received from HCPs (M+), and provide positive psychological support through motivation, encouragement and empowerment (M+) of pregnant women and mothers (A) to routinely use MCH care, including improved
health-seeking behaviour (O+). The uptake of mHealth interventions (O+) and improved initiative of pregnant HIV positive women on antiretroviral therapy (O+).

A negative mechanism was identified namely information overload (M-) which resulted in decrease health facility visit (O-)[14].

An arrow from HCPs (A) outcomes to the pregnant woman and mothers’ mechanisms (M) explains how improved delivery of mHealth programme, the performance of care, and quality of health care delivery by HCPs (O+) influence the perceived satisfaction, motivation, and psychological support (M+) of pregnant women and mothers (A) that will in turn influence on their overall health-seeking behaviours (O+). We identified six contextual factors influencing the adoption of mHealth by pregnant women and mothers, including aspects of the health system and political clout, socio-cultural characteristics, socio-economic and demographic characteristics, technical aspects of mobile phones, network infrastructure and connectivity, and awareness about mHealth (C). These contextual factors in turn influence how perceived satisfaction with care, motivation, positive psychological support (M+); and information overload and desensitization mechanisms (M-) are activated to trigger health-seeking behaviour outcomes (O+) among pregnant women and mothers (A). Our results concur with that found by Abejirinde et al. [48] which showed that empowerment of health workers explained their competencies and that mHealth empowered HCPs to adopt and use mHealth in contexts where it aligns to their needs, workload, training and skills [48]. Perceived usefulness and ease of use of mHealth encouraged and empowered HCPs with skills and confidence, perceived usefulness related to design and technical concerns, cost, time, privacy, ease of use, security issues, risk-benefit assessment, experience with the technology and contact with others (colleagues and patients) [65, 66].

Our model is supported by a study done Azhar and Dhillon [66] that identified behavioural intent, self-efficacy, social influence, attitude and perceived privacy threat as factors that influenced successful use of mHealth applications for self-care [66]. Moreover, our model explains that perceived satisfaction with care and psychological support are important mechanisms leading to the improvement of health care behaviours among pregnant women and mothers. This finding is supported by a systematic review by Aker et al. that found that users’ perceived platform quality, perceived satisfaction of care, perceived quality and interaction and outcomes were found to influence users’ uptake of mHealth for health care utilisation [67]. They identified other dimensions, such as system reliability, privacy, availability, adaptability, efficiency, assurance, responsiveness, functional and emotional benefits to influence the uptake of mHealth interventions. Our findings are supported by a realist-informed document review that identified empowerment, perceived quality of MCH care, encouragement, motivation, and knowledge acquisition as the main mechanisms driving the implementation and uptake of MCH care through the MomConnect programme [68].

How does our model compare to relevant existing frameworks?

The Fogg Behaviour Model (FBM) [69] is a psychosocial model which proposes that for a targeted behaviour to occur, presence of the following is needed in tandem: Ample motivation, ability and an active trigger [69]. Fogg explained that users with high motivation and abilities are likely to perform the target behaviour. The Fit between Individual, Task and Technology (FITT) framework explains the degree to which technology’s functionality matches task requirements and individuals abilities to use the technology to perform tasks [70]. FITT is influenced by technological characteristics, individual abilities and task performance and users’ adoption of technology [70]. The Technology Acceptance Model (TAM) seeks to explain users’ adoption or rejection of information technology by focusing on two theoretical constructs: perceived ease of use and usefulness [71]. According to TAM, if potential users believe an application is useful, they may at the same time believe that the system is easy or not easy to use, which makes the performance of benefit of usage outweighed by the effort of using the application [71].

We found that FBM, FITT and TAM identified constructs that could be considered by realists as mechanisms to explain how mHealth interventions work. For instance, the FBM model revealed user motivation as central to explaining how mHealth interventions work. The FITT model highlights the perceived ease of use as the central mechanism explicating how mHealth interventions work. The TAM model reveals perceived ease of use and usefulness as the central ingredients to intervention uptake. While using theoretical frameworks in mHealth evaluation has been found beneficial to inform best practices [72], these models are limited in their explanatory power in that they largely ignore the role of contextual elements in triggering the identified mechanisms. Our ICAMO models thus not only identify further mechanisms and relevant contextual elements but also illustrate how contextual factors could impact on intervention modalities provided by the programme to activate the mechanism that produces the outcomes. In this way, our models do not only provide evidence of how and why mHealth interventions work or not, but also context-linked explanatory theories to inform implementation and rollout of mHealth interventions to ensure conducive health systems and programmatic conditions that increase the chances of uptake of the intervention among users.

Strengths and limitations

Understanding the influence of mHealth by focusing on the mechanisms and contextual factors through which outcomes are generated, is relevant because more information can be obtained about why mHealth interventions work or not, and what triggers observed outcomes. Lack of information on how mHealth interventions work may encumber the understanding of challenges and justifications for the implementation of successful mHealth programmes, as well as its limitations.

A limitation of this review is that only six databases were searched and that search terms were restricted to LMICs. The review also relied on articles published in English, which could have resulted in missing important studies on mHealth interventions for MCH. Most articles did not conceptualise notions of context and mechanisms as understood in a realist philosophical sense. Thus, strict identification of these concepts needed further interpretation by the authors. Published studies on MCH-allied mHealth programmes are growing but have been inadequate in evaluating context and mechanisms by which outcomes are generated. More research is needed to evaluate mHealth using realist methods by comparing higher and LMICs.

Conclusion

This review unearthed theoretical models explicating utilisation of mHealth by HCPs and pregnant women and mothers. The models developed in the study provide a detailed understanding of the uptake of mHealth interventions and how they enhance MCH in LMICs. Our findings suggest that mHealth
Programmes can shift the pattern of health care utilisation and can be applied by policymakers to inform implementation strategies for mHealth programmes in LMICs. By making explicit ICAMO configurations that are associated with success and failure of mHealth programmes, policymakers can be informed on critical aspects that can inform the scale-up of mHealth interventions. ICAMO models can yield important insights into potential policy changes that need to be enacted for mHealth interventions to be successful at scale. These models provide a foundation for the 'white box' of theory-driven evaluation of mHealth interventions and hence improve implementation where required.

**Abbreviations**

ANC/PNC – Antenatal and postnatal care  
CHWs – Community Health Workers  
CMOc – context-mechanism-outcome configuration  
FITT – Fit between Individual, Task and Technology  
HCPs – Healthcare providers  
LMICs – Lower- and Middle-Income Countries  
MCH – Mother and Child Health  
mHealth – mobile Health  
NS – Narrative synthesis  
ICAMO – Intervention-Context-Actors-Mechanism-Outcomes  
TAM – Technology Acceptance Model  
RCT – Randomised controlled trials  
SDGs – Sustainable Development Goals  
SBA – Skilled Birth Attendant  
SMS – short messaging services

**Declarations**

**Ethics approval and consent to participate**  
Not applicable

**Consent for publication**  
Not applicable

**Availability of data and material**  
The dataset(s) supporting the conclusions of this article is (are) included within the article (and its additional file(s)).

**Competing interest**  
The authors declare no conflict of interest

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Tables

Table 1: Definition of the concepts in the ICAMO heuristic

| Concepts | Definition/descriptions |
|----------|-------------------------|
| Intervention (I) | Refers to the characteristics of various mHealth interventions such as type of technology, co-interventions, and modalities. In this case, mHealth modality was defined as the use of mobile phones and tablets, making use of text, audio, images, short messaging services (SMS), voice SMS, applications accessible via general packet radio service. |
| Context (C) | Describes conditions required for programme mechanisms to activate or not. Context can be viewed as circumstances that facilitate or constrain mechanisms, including pre-existing individual, organisational, social and cultural conditions, that are external to the interventions [73]. In this case, context is categorised as a) Environmental, which comprises the broad external environment in which interventions are situated, including political, economic, social, technological, legal, and infrastructural environments [2]; and b) Organisational/health systems, which include resources, policies and structures directly related to the unique health facility settings in which the mHealth technology is introduced [2]. |
| Actors (A) | Includes individuals, groups, and institutions that play a role in the implementation and uptake of the intervention [74]. In this study, actors include pregnant women, mothers and healthcare providers (HCPs), including community health workers. |
| Mechanism (M) | A mechanism refers to causal forces, powers, processes or interactions that generate behavioural change. In realist evaluation terms, mechanisms include choices, perceptions, reasoning and decisions that people make as a result of the resources provided by programmes. |
| Outcomes (O) | Defined as the product of mechanisms activated within specific contexts. Outcomes are anticipated and unanticipated (emergent) consequences of interventions [18]. |

Table 2: TAPUPAS criteria

| Criteria | Guiding question |
|----------|-----------------|
| Transparency | Is it to scrutiny? |
| Accuracy | Is it well-grounded? |
| Purposive | Is it fit for purpose? |
| Utility | Is it fit for use? |
| Propriety | Is it legal and ethical? |
| Accessibility | Is it intelligible? |
| Specificity | Does it meet source-specific standards? |

Table 3: Thematic representation of the themes of health care professionals
| Variables | Themes |
|-----------|--------|
| Intervention | Communication platform § Information and education [4, 36, 38-41, 43, 60, 64] |
| | Data management platform § Registration, tracking, data collection and security [15, 42, 45, 46, 48, 59] |
| | Decision support and guideline [44, 47, 49, 50] |
| Context | Health system organisation § HCPs training, supervision, resource availability, support and mobilisation [4, 15, 60, 39, 42, 43, 46-50] § Mobile phone availability and distribution to HCPs [36] § Availability of HCPs [38, 59] § HCPs and CHWs collaboration [38] |
| | Socio-demographic characteristic § Individual, pre-existing HCPs level of education, [37, 40] § The language spoken by HCPs [44, 50] |
| | Experience with technology § Technology adoption [40, 43] |
| | Network infrastructure and connectivity § Availability of network and connectivity [44, 64] |
| Actors | HCPs |
| Mechanism | Perceived support of HCPs § Quality of training, resources, and administrative support impact on respondents’ task [39, 46] § Improved HCP-community relationship [4, 47] |
| | Motivation § Encouragement to be more active in doing the task [36, 40, 41, 44] § Knowledge acquisition and skills improvement improved self-efficacy and confidence [4, 15, 36, 38, 42, 48, 49, 59, 60] |
| | Perceived ease of use and usefulness of mHealth § [45, 46] |
| Outcomes | Improved HCPs performance of care § Improved accuracy in diagnosis, referral and recommendations [48-50] § More procreative [36, 38, 41], improved skills and help to overcome barriers [46] § Increase in rate of care attendance [37, 39] § Data security [47] |
| | Improved quality of health care delivery § Improved MCH care delivery [60] [44] § Improved relation between HCPs and community members [4, 40] |

Table 4: Thematic representation of the element of pregnant women and mothers
| Variables     | Themes                                                                 |
|--------------|------------------------------------------------------------------------|
| Intervention | Reminder messages system ([43, 44, 49, 51–56, 63])                   |
|              | Communication platform                                                 |
|              | § Health information and education ([4, 14, 57–62, 15, 36, 38, 41, 42, 44, 45, 55]) |
|              | Consultation platform with HCPs ([38, 47, 48])                        |
| Context      | Health system aspects and political clout                             |
|              | § Government support ([63])                                            |
|              | § Awareness of intervention ([39, 61])                                |
|              | § Availability of HCPs ([36, 38])                                     |
|              | § Training, support, and supervision of HCPs ([4, 42, 48])            |
|              | § Health system responsiveness ([39, 56, 59, 60])                     |
|              | Socio-cultural characteristics                                        |
|              | § Socio-cultural practices, social structures, and norms ([15, 62, 63]) |
|              | § Community buy-in ([47])                                             |
|              | Socio-economic and demographic characteristics                         |
|              | § Pre-existing individual (education, health literacy) characteristics ([14, 41, 58, 62, 75, 43–45, 49, 52, 53, 55, 57]) |
|              | § Income ([15, 51])                                                   |
|              | § Access to a cell phone ([44, 45, 51, 52, 54, 57, 58, 75])           |
|              | Technical aspects of Mobile phone                                      |
|              | § Access to a working phone ([44, 45, 51, 52, 54, 57, 58, 75])        |
|              | § Network availability and connectivity ([14, 38, 52, 61])             |
|              | § Preferences of language ([54])                                      |
|              | § Lack of trust in technology and face-to-face preference ([63])       |
| Actors       | Pregnant women and mothers                                            |
| Mechanism    | Perceived satisfaction                                                 |
|              | § Satisfaction with care ([48, 52, 56, 61])                            |
|              | § Perceived privacy and confidentiality ([15])                         |
|              | § Perceived support from HCPs ([4, 42])                               |
|              | Information overload and sensitisation ([14])                          |
|              | Positive psychological support                                         |
|              | § Encouragement ([15, 36, 43, 45, 44, 55, 57, 63])                   |
|              | § Empowerment ([41, 62])                                              |
|              | § Motivation ([38, 39, 62, 75, 44, 47, 49, 54–56, 59, 60])            |
|              | § Knowledge gained improved self-efficacy and confidence ([39, 42, 49]) |
| Outcomes     | Improved overall health-seeking behaviour (O+)                         |
|              | § Improved MCH care ([15, 41, 47, 55–57, 62, 63, 75])                 |
|              | § Improved use of ANC and PNC ([4, 36, 60, 39, 42–45, 49, 53, 54])    |
|              | § Improved SBA, facility birth and emergency obstetric care ([4, 15, 36, 38, 42–45, 49]) |
|              | § Increased use of iron tablets and immunization ([52, 54])           |
|              | Decreased visits to health care facilities based on perceived desensitization (O-) ([14]) |
Figure 1

Tentative programme theory of mHealth programmes (source: study author)
Figure 2
PRISMA diagram illustrating the study selection process

Figure 3
HCPs (A) configuration mapping of mHealth ICAMO
Figure 4
ICAMO model of how and why mHealth works for pregnant women and new mothers

Figure 5
Programme theory of mHealth programmes and maternal and child health

Supplementary Files
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• Additionalfile1.docx
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• PRISMA2009checklist.docx