Title: **Assessment of design and implementation attributes of mHealth interventions: A systematic review**

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1. Introduction

The public health sector in Sub-Saharan Africa (SSA) is beseeched by a multitude of problems cumulating into inadequate reach of healthcare services to the population (Afriyie et al., 2019; Ahmat et al., 2022). The region shoulders the highest burden of disease (Abbafati et al., 2020). Communicable diseases in SSA are still a major public health concern while non-communicable diseases are on the rise (Bygbjerg, 2012; Modjadji, 2021; Peer, 2015). Considering this, achieving the Sustainable Development Goal no. 3 of ensuring healthy lives and promoting well-being for all by 2030 (United Nations, 2016) remains a tall order for SSA. This highlights the need for innovations in healthcare delivery systems in SSA.

mHealth, defined by the WHO as "the use of mobile and wireless devices to support the achievement of health objectives (Rehman et al., 2017) presents a vital tool for health promotion. mHealth interventions have been shown to improve the reach and quality of healthcare services around the world (Gleason, 2015). In SSA, there are many examples of both effective mHealth interventions which have been scaled-up to national levels (Hopkins, 2015; Levine et al., 2015) and others which have not delivered as expected (Betjeman et al., 2013). These mHealth interventions have provided valuable insight into feasibility and effectiveness of mHealth interventions in resource poor settings.

While feasibility and effectiveness of mHealth interventions are being analysed through experimental, reviews and analysis studies (Hall et al., 2015), the authors' preliminary literature search found no systematic review (SR) or meta-analysis that examined design attributes and implementation strategies of mHealth interventions. This lack of research in this area was best exposed by Hall et al. (2015,) who commented that "we found limited evidence across the population of studies and reviews to inform recommended intervention characteristics" (Hall et al., 2015, para. 1). They recommend that "research is needed to …..... identify recommended intervention characteristics" (Hall et al., 2015, para. 1).

This SR therefore, assessed intervention designs and implementation strategies of mHealth interventions and their effects on interventions' outcomes.

2. Objectives and Significance of the SR

2.1 Objectives of the SR

The SR was aimed at identifying design and implementation variables of mHealth interventions and infer their effects on interventions' outcomes.

2.2 Significance of the SR

This SR helped pool together design and implementation attributes of mHealth interventions which are critical for success. By referring to these attributes, mHealth intervention designers will be informed by attributes that have been shown to be effective. It is hoped that this will help them in designing effective mHealth interventions.

3. Methods

This SR was conducted and is reported following the Preferred Reporting Items for Systematic Reviews and Meta–Analyses (PRISMA) guidelines (Liberati et al., 2009).

3.1 Literature Search Strategy and Study Inclusion Criteria

To identify all relevant literature, a systematic search was conducted in three stages. The first stage involved searching for relevant published studies in eight electronic databases (CINAHL, PubMed, Web of Science, mHealth evidence, Google scholar, Global Index Medicus, ClinicalTrial.gov and African Journals Online). Main search terms used were 'mHealth' and 'Africa'. The search was

expanded using MeSH and thesaurus terms of the main search terms and directed by Boolean operators 'OR' and 'AND'. Table 1 below shows the full search input used in the databases.

Table 1: Search Input

mHealth OR m-Health OR eHealth OR e-Health OR telemedicine OR tele-medicine OR (mobile health) OR sms OR (short message service*) OR (text messag*) OR telehealth OR tele-health OR (mobile phon*) or cellphon*	AND	Africa OR (Sub-Saharan Africa) OR (Sub Saharan Africa) OR (low income countr*) OR (low in-come countr*) OR (developing countr*)

Second stage of literature search involved searching for grey literature on WHO and K4Health websites. In addition, clinicaltrials.gov was searched for recently completed unpublished trials.

Third stage of literature search involved manual screening of reference lists of all potential papers which were reviewed in full. All papers which cited these potential papers were also screened for relevancy.

After every stage of literature search, the results were imported into RefWorks bibliography citation software for duplicates exclusion. To avoid selection bias, two authors screened all identified studies against the full inclusion criteria. Any differences were discussed by all the two authors and decision taken accordingly. Table 2 shows inclusion and exclusion criteria and figure 1 presents a flow diagram of the literature search and screening process

Table 2. Inclusion & Exclusion criteria

Parameter	**Inclusion criteria**	**Exclusion criteria**
Language	English only	Not in English
Time	2010 – 2020	Before 2010
Mode of communication	Non internet-based communication services available on mobile phones such as text messaging, voice messaging and voice calling	Internet based communication services such as social media and multimedia Messaging Services (MMS)
ICT equipment used in trials	-Cell phones / Mobile phones -Smart phones	-Tablet, Laptop and desktop computers -Personal Digital Assistants (PDA) -Patient monitoring devices
Study designs	-Randomised controlled trials (RCT) -Controlled experimental trials -Effectiveness evaluation trials	All other experimental and non-experimental study designs such as, SRs, cohort studies, case control studies, controlled before-after studies and literature, narrative and critical reviews
Type of study	-Intervention's effectiveness evaluation studies only	All other study types like descriptive studies looking at technology and population demographics of mHealth services users
Type of intervention	HP interventions only	Clinical and other types of mHealth interventions
Location of interventions	Sub-Saharan Africa	Any other region of the world

4 Results

A total of 3,249 studies were identified during the literature search. After title and abstract review, 51 studies were selected for full paper review. Eleven studies met the full inclusion criteria and were included in this SR. Ten of the eleven studies were RCTs and one Crawford et al. (2014) was a pilot project evaluation. The studies were published between 2010 and 2016. Study interventions were

conducted in seven SSA countries as follows; three in Kenya and one each in Cameroon, Ghana, Malawi, Nigeria, South Africa and Uganda and one trial Barnabas et al. (2016) was conducted concurrently in South Africa and Uganda.

All eleven studies ultimately aimed at finding the most efficient way of implementing an mHealth intervention and assessing whether an mHealth approach is effective for a particular health promotion activity. Six of eleven included studies aimed at assessing effectiveness of text message reminders on promotion of medication adherence and clinical appointments attendance. Among the remaining five studies, four were on promotion of maternal and child health services while one was on promotion of Voluntary Medical Male Circumcision (VMMC) uptake.

The eleven included studies had a combined total of 13,235 participants. Crawford et al. (2014) with 5,000 and Mbuagbaw et al. (2012) with 200 had the highest and lowest number of participants respectively. Participants of nine trials had to periodically attend health facilities for various healthcare services. Two trials were wholly community-based. All interventions studies recruited adults aged at least 16 years old. Table 4 shows details and design characteristics of included studies.

5 Discussion

5.1 Summary

Among all eleven included studies only one (Mbuagbaw et al., 2012) did not report significant difference in primary study outcome between intervention and control groups. This shows that mHealth interventions in SSA are mostly effective. Similar finding is shown in SRs by Aranda-Jan et al. (2014) and Betjeman et al. (2013).

5.2 Communication Interactivity

Among all eleven included studies, six deployed interactive communications while five used one-way communication systems. Five of the six interactive interventions reported significant improvements in primary study outcomes. All five interventions which deployed one-way communication systems reported significant improvement in primary study outcomes among intervention groups as compared to control groups.

5.3 Message content

Among all eleven included studies, two (Pop-Eleches et al., 2011; Raifman et al., 2014) tested the effect of varying the content of text messages on study outcomes. Both studies found that short text message medication reminders with no additional information were significantly more effective than medication reminders with additional motivational or health education information.

5.4 Use of BCTs

Among all eleven included studies, only three (Bobrow et al., 2016; Mbuagbaw et al., 2012; Odeny et al., 2014) used BCTs to inform on interventions' design. Two of the three studies (Mbuagbaw et al., 2012; Odeny et al., 2014) reported significant improvement in primary study outcomes in intervention groups. Only (Odeny et al., 2014) acknowledged the positive effective of BCT used on study outcomes. BCTs are conspicuously underutilised in mHealth interventions in SSA and where they have been used, results have not been consistently positive.

5.5 Use of Incentives

Among all eleven included studies, only three (Lund et al., 2014; Pop-Eleches et al., 2011; Siedner et al., 2015) made use of incentives in interventions' implementation. All three interventions reported significant improvement in primary study outcomes in intervention groups. None of the three studies acknowledged the effect of incentives used on either study outcomes or conduct of interventions.

5.6 Frequency of Communication

Only one study (Pop-Eleches et al., 2011) assessed the effect of varying frequency of sending text messages on final study outcome. Pop-Eleches et al. (2011) found that weekly short text messages were

significantly more effective in promoting ART adherence compared to control (68% against 47% adherence, P=0.01). Comparatively, daily short text message reminders were not significantly more effective compared to control group (49% against 47% adherence, P=0.80). This finding is similar to those of Finitsis et al. (2014), Head et al. (2013) and Horvath et al. (2012) whose findings showed that less frequent text message reminders were more effective.

5.7 Message tailoring

Among all eleven included studies only three (Crawford et al., 2014; Lund et al., 2014; Odeny et al., 2014) tailored content of messages sent to particular situation of participants. All three interventions reported significant improvement in primary study outcomes. None of the three interventions acknowledged any effect of tailoring message content on final study outcomes.

5.8 Messaging automation

Nine of eleven included studies utilised automated messaging systems and all reported significant improved outcomes. It is difficult to make a link between messaging automation and the final study outcomes in the presented SR. However, a meta-analysis by Head et al. (2013) found no difference in effect between interventions based on messaging automation or not.

6 Implication of the study

As the findings of this SR have shown that some design and implementation attributes of effective mHealth interventions may not be the most obvious or what are considered logical. There is a need for further research on health promotion interventions that pool together effective design attributes. The authors believe that there is a need to go beyond conducting SRs or meta-analyses which show effectiveness of mHealth interventions. Assessing design and implementation attributes which have made the interventions to be effective is very important as it would aid health promoters and project designers to be informed by practice which have been shown empirically to be effective.

7 Conclusions

The presented SR aimed at identifying design and implementation attributes of mHealth health promotion interventions critical for success of the interventions in SSA. Overall, this review found that mHealth interventions in SSA are mostly effective. In medication adherence interventions, mHealth implementers should consider use of weekly short SMS reminders without any additional motivational or health education information, as they have been shown to be more effective. Tailored and personalised messages have also been shown to be more effective, therefore, mHealth project implementers should consider adopting them. Interactivity and messaging automation have not been shown to be more effective therefore project designers can choose the system which best suits their situation; however, messaging automation has been shown to have many other advantages. BCTs which are currently underutilised in mHealth interventions in SSA should be considered in predominantly behaviour change interventions like smoking cessation. Finally, mHealth implementers should consider involving a wide variety of stakeholders in designing and implementing interventions.