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A scoping review assessing the evidence used to support the adoption of mobile health (mHealth) technologies for the education and training of community health workers (CHWs) in low- and middle-income countries

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KEYWORDS: mHealth, Global Health, Community Health Worker, Education and Training, Scoping Review

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ABSTRACT

Objectives

Undertake a systematic scoping review to determine how a research evidence base, in the form of existing systematic reviews in the field of mobile health (mHealth), constitutes education and training for community health workers who use mobile technologies in everyday work. The review was informed by the following research questions: Does educational theory inform the design of the education and training component of mobile health (mHealth) interventions? How is education and training with mobile technology by CHWs in low- and middle-income countries categorised by existing systematic reviews? What is the basis for this categorisation?

Setting

The review explored the literature from 2000 to 2017 to investigate how mHealth interventions have been positioned within the available evidence base in relation to their use of formal theories of learning.

Results

The scoping review found 24 primary studies that were categorised by 16 systematic reviews as supporting CHWs' education and training using mobile technologies. However, when formal theories of learning from educational research were used to re-categorise these 24 primary studies, only four could be coded as such. This identifies a problem with how CHWs' education and training using mobile technologies is understood and categorised within the existing evidence base. This is because there is no agreed upon, theoretically informed understanding of what counts as learning.

Conclusion

The claims made by mHealth researchers and practitioners regarding the learning benefits of mobile technology are not based on research results that are underpinned by formal theories of learning. mHealth suffers from a reductionist view of learning that underestimates the complexities of the relationship between pedagogy and technology. This has resulted in miscategorisations of what constitutes CHWs' education and training within the existing evidence base. This can be overcome by informed collaboration between the health and education communities.

Strengths and limitations of this study

- The study applied an innovative three-step scoping review methodology to unpack the evidence on mobile technology's contribution to the education and training of CHWs.
- In-depth primary analysis determined if theories of learning were used to conceptualise and categorise education and training in mHealth.
- The study details if these theories were used to design and implement the education and training component of mHealth interventions for CHWs.
- The in-depth primary analysis of theories of learning is limited to programmatic information reported in the identified primary studies.

- The review is limited to papers included in systematic reviews published between 2000-2017.

INTRODUCTION

The popularity of mobile phones in low- and middle-income countries (LMICs) has motivated their use in healthcare, particularly as a tool to support primary health care outreach by community health workers (CHWs) to those with little or no access to health care. While the role, level of training and expertise of CHWs differs across LMICs (see [1] for a discussion of their role in Kenya), they are a vital part of strategies to overcome weakness in health systems. Mobile technology is increasingly viewed as essential to the work of CHWs.

The field of mobile health (mHealth) investigates the role mobile technologies can play in healthcare. mHealth has many functionalities [2-3], one of which is to provide education and training for CHWs. Delivering individual access to educational material is the primary means of achieving this [4], particularly in contexts where face-to-face training is limited. Yet, such information dissemination models of education are well known to miss the wider social and cultural aspects of learning inherent to healthcare practice [5] and more relevant educational theories, including inquiry learning, experiential learning and situated learning, are used in other areas of healthcare practice [6–8].

Educational researchers have built on these foundational theories to develop concepts of workplace-based learning and mobile learning [9, 10] which are designed to support learners to produce new knowledge using technology while working. However, it is unclear if or how workplace-based learning and mobile learning research has been incorporated into mHealth platforms. Preliminary indicators suggest this is not the case. For example, in Labrique et al.'s [11] widely regarded mHealth framework, none of the example interventions in the category 'provider training and education' are informed by formal theories of workplace-based or mobile learning [11: 164]. Other categories, such as 'electronic decision-support' could be considered workplace-based learning. The problem is further complicated by the fact that in two systematic reviews [3, 12] of mHealth interventions, the same underlying mechanisms of information dissemination and increased communication are applied to two very different challenges: (a) patient education for behaviour change and (b) CHWs' continuous professional development. Yet, from an educational perspective, it is challenging to equate mHealth interventions that provide health-related information with interventions trying to change CHW's practice and support professional development; the underlying pedagogical mechanisms required for both types of interventions differ significantly in nature and scale.

Consequently, there is a pressing need to understand: 1) If and how educational theories are being incorporated into mHealth platforms currently? 2) How the adoption of a novel educational lens can inform the future development of mHealth technology for use by CHWs?

While multiple reviews of mHealth in LMICs have recently been published, this systematic scoping review is the first to combine theories of workplace-based learning and mobile learning and apply them to mHealth research on education and training for CHWs in LMICs. The focus of the review is not on measurable endpoints of education and training but rather on how the educational components have been conceptualised within existing mHealth research.

METHODS

Review approach:

We conducted a systematic scoping review of the research evidence on the use of mobile technologies to facilitate CHWs' education and training in LMICs. A scoping review is defined as "a form of knowledge synthesis that addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting, and synthesizing existing knowledge" [13: 1292]. Scoping reviews are part of the family of research synthesis methods, but compared to systematic reviews address broader research questions. They aim to provide an overview and organisation of existing knowledge rather than a narrow synthesis of a predefined research question [14, 15]. Usually, this different synthesis approach is conducted over a shorter timeframe than systematic reviews, using more targeted search terms and focuses less on the critical appraisal of the included evidence.

A scoping review approach was chosen for this study because we wanted to explore how existing literature has conceptualised and operationalised the use of mobile technologies to support CHWs' learning practices. The focus is on the diversity of understandings and definitions of CHWs' education and training in the existing literature and what patterns and gaps might emerge from a systematic analysis of this body of knowledge[1]. In order to capture the conceptualisation and positioning of mHealth interventions that have an education or training component, our scoping review targeted existing systematic reviews of mHealth interventions rather than primary studies as a first level of analysis. Unlike primary studies, these reviews require an explicit conceptual framework—including Labrique's framework—in order to group mHealth interventions for analysis. Consequently, we can derive the positioning and categorisation of different mHealth interventions with respect to their support for CHWs' education and training from these systematic reviews.

Our scoping review followed explicit and transparent research steps to explore the research evidence on mHealth and CHWs' education and training. A review protocol was not published and the study was not registered with PROSPERO, as these mechanisms are not applied to scoping reviews [13, 14].

We followed a novel three-step approach in our scoping review that combined secondary research methods with a primary re-analysis of the included studies. In the first step, existing systematic reviews investigating CHWs' education and training when using mobile technologies were sought. As outlined above, this novel approach was necessary to allow us to investigate how different mHealth interventions were categorised in relation to education and training within the evidence base. In the second step, we then extracted the primary studies included in these reviews in order to provide a descriptive account of the included mHealth interventions and the wider characteristics of the evidence base. In the third step, we conducted a primary re-analysis of the included mHealth interventions, which were recoded with respect to their education or training component. That is, we used two coding frameworks inspired by different theories of learning—workplace-based learning [9] and mobile learning [10]—and applied these coding frameworks to the primary studies included in the systematic review. As a result, we obtained two different set of results on how mHealth interventions were categorised regarding their support for CHWs' education and training: (i) the categorisation of interventions in the systematic reviews themselves and (ii) our re-categorisation of the same interventions using explicit learning

[1] We were not concerned with whether mobile technologies are effective in increasing learning outcomes or how CHWs perceive the use of mobile technologies. These types of research questions lend themselves to full systematic reviews.

from educational research. These two sets of categorisations allowed us to juxtapose the prevailing positioning and understanding of education and training in mHealth with a more pedagogically grounded understanding. A more traditional review approach, without this re-analysis of primary studies, would not have allowed us to juxtapose these different understandings. The same applies had we followed a systematic review approach that only included primary studies and not the existing reviews themselves. We elaborate on the methods employed in each step below.

Step 1: Review of existing systematic reviews

Search methods:
We designed an exhaustive and sensitive search strategy to identify all relevant reviews of mHealth interventions that included CHWs' education and training facilitated by mobile technologies in LMICs. The search strategy was deliberately designed to be over-inclusive. Search terms were formulated to identify any mHealth review covering LMICs and we manually filtered down the reviews relevant to CHWs' education and training. Likewise, despite being focused on CHWs in our review, our search strategy did not specify terms related to CHWs. Both decisions ensured that no relevant reviews were excluded during the search. The full search terms therefore only included key words for the concepts 'mHealth', 'systematic review', and 'LMICs'. Concepts were combined using the AND boolean operator to develop a master search string (Supplementary Material 1).

The full search string was then applied to a range of academic databases in the health and social sciences: CINAHL; Pubmed; Medline; PsychInfo; ERIC; Education Full-text; and ISI web of science. Database searches covered the period 2000 to 2017. The year 2000 as a cut-off date was chosen as mobile technologies did not see widespread application to support health care in LMICs before then. In addition, we also searched the Grey literature for reviews relevant for inclusion. Grey literature sources included Google and Google Scholar searches as well as specialized systematic review databases, i.e. Cochrane Library of Systematic Reviews, Campbell Library, and the 3ie database of international development reviews. Lastly, reference lists of includes reviews were used as an additional source for snowball searching for additional reviews. A full record of the conducted search is provided in Supplementary Material 2.

Inclusion criteria:
We formulated explicit inclusion criteria that determined what reviews were eligible for inclusion in our scoping review. Conceptually, this referred to existing systematic reviews of mHealth interventions that support CHWs' education and training in LMICs. To operationalise this into transparent inclusion criteria, the following definitions were applied.

Population: CHWs were defined broadly in line with the WHO's 2007 definition of lay health workers as applied in Lewin et al. [16]:

> "Community health workers should be members of the communities where they work, should be selected by the communities, should be answerable to the communities for their activities, should be supported by the health system but not necessarily a part of its organization, and have shorter training than professional workers."

This definition allows for different types of health care workers to be classified as CHWs in different contexts. Reviews were included as long as they covered mHealth interventions applied by or for CHWs regardless of whether CHWs were the main focus of the review. LMICs were defined using the World Bank classification of economies [17]. To be

included, reviews had to focus on LMICs and for reviews that had no regional scope, at least 50 per cent of the included studies had to be from LMICs in order for the review to be featured in our scoping review.

Intervention: Reviews had to include mHealth interventions that used mobile technology to facilitate CHWs' education and training. This excludes reviews that focus on fixed ICT infrastructure such as desktop PCs and fixed diagnostic ICTs only. Education and training was defined broadly and we followed the reviews' positioning of interventions as to how they facilitated learning. In addition, we included the following categories used in reviews based on Labrique et al's framework to ensure no relevant interventions were missed: Decision-support; provider-provider communication; provider work planning and scheduling; data collection and reporting. A systematic review covering any of the above categories was thus included in our scoping review. This was because each of these categories could potentially be framed as supporting the CHWs' education and training using conceptualisations of workplace-based learning and mobile learning. For example, improved communication between CHWs could support collaboration and social learning. Likewise, following explicit decision-making algorithms could lead to the learning and acquisition of new and improved practices by CHWs. Again, we aimed to be over-inclusive at this stage so as not to miss any relevant reviews.

Research design: To be included, studies had to qualify as a 'systematic review' which was defined broadly for this scoping review. Any type of research synthesis was included as long as a structured and transparent review approach was applied. Indicators of a structured review approach referred to: reporting of (i) a systematic search; (ii) pre-defined inclusion criteria; and (iii) a stated method of synthesis. Indicators of a transparent review approach referred to: reporting of (i) numbers of searched and included studies; (ii) a summary table of included studies; and (iii) a discussion of the strengths of the evidence in the synthesis.

Outcomes: No studies were excluded on the basis of measured outcomes or applied outcome measures because intervention effectiveness was not of concern in this scoping review.

Screening and coding of reviews:
Two reviewers screened all search hits for potentially relevant systematic reviews at title and abstract. Full-texts of potentially relevant reviews were then sought and screened again against our inclusion criteria. A sub-set of 10 per cent of the citations eligible of full-text screening were double-screened to assess inter-reviewer reliability. Disagreements between reviewers were resolved by joint discussion with a third reviewer acting as an arbitrator. Following the screening, included systematic reviews were then coded for two high-level characteristics: (i) applied framework to categorise interventions and (ii) included mHealth interventions.

Critical appraisal:
As this is a scoping review, no critical appraisal of either included reviews or primary studies was conducted.

Step 2: Extraction of primary studies from the included reviews

Identification of primary studies:
Having identified eligible reviews, we then extracted the primary studies included in each review for further analysis. That is, the included systematic reviews served as the data

source for primary studies. We only searched the relevant systematic reviews under the intervention categories that could potentially relate to education and training. Extracting only primary studies that existing systematic reviews had coded and categorised as related to education and training allows us to unpack and examine this positioning.

We did not conduct an independent scientific search for relevant primary studies in addition to the search for systematic reviews. Including primary studies that were not found in existing systematic reviews would not have revealed any new information regarding how the primary studies were categorised. As a result, primary studies of mHealth interventions and CHWs that were not included in any of the systematic reviews were excluded from our scoping review. In practice, this refers mainly to primary studies published after the included systematic reviews were conducted[2].

Inclusion criteria for primary studies:
In terms of population, intervention, and outcome the inclusion criteria of the primary studies were identical to the criteria for systematic reviews. In terms of study design, however, primary studies could be of any empirical research design that investigated an applied mHealth intervention. This included both quantitative and qualitative research designs but excluded design that assessed interventions in a lab setting and/or assessed perceptions and feasibility of a future intervention implementation [e.g. 20, 21].

Screening and coding of primary studies:
All primary studies allocated to the eligible intervention categories explained above were screened at full-text by two reviewers. The same quality assurance processes as used for the screening of the systematic reviews were implemented. We designed an explicit coding tool to capture key characteristics related to the type of CHWs, the type of mHealth intervention and technology applied, the context in which it was applied, as well as the educational event or process facilitated by the technology.

Step 3: Primary analysis of study's categorisation as supporting the education and training of CHWs
Two well-established coding frameworks from educational research feature the key pedagogical attributes of workplace-based and mobile learning: Eraut and Hirsh [9] for workplace-based learning and Kearney et al [10] for mobile learning. Applying these two frameworks as our coding tool allowed us to re-code the primary studies in order to investigate whether their claim to facilitate CHWs' education and training did hold true from a pedagogical perspective. In this last step, we thus can compare the outcomes of this pedagogically-informed coding tool with the reported codes in the reviews. Again, two independent reviewers applied the coding tool with a third reviewer acting as an arbitrator in case of disagreement.

Review limitations
There are three key limitations to this review. First, only English-language articles were considered for inclusion. Second, systematic reviews published up to 2017 only cover primary studies published up to 2015. Studies published after this date were not identified by the systematic reviews and by extension are not covered by our scoping review. Third, only a partial range of grey literature was searched and mHealth conferences were not covered.

FINDINGS

[2] The searches undertaken by the authors of the two most up-to-date systematic reviews [18, 19] included in our scoping review were finalised in December 2015.

Search results:

Searches were run between March and May 2016 and updated in June 2017. They yielded a total of 5,379 citations from twelve different sources (Figure 1). After screening these citations on title and abstract, the large majority of citations were not relevant (n=5,281)—a result of our deliberately over-inclusive search strategy. We identified 98 existing reviews that on title and abstract met our inclusion criteria. Full-texts of these reviews were then sought and reviews screened for inclusion in more detail. This in-depth screening excluded a further 82 reviews leaving only 16 reviews that met the predefined inclusion criteria. Reasons for exclusion at full-text screening referred to: reviews not including studies from LMICs (n=33); not including studies that focus on CHWs as a population (n=22); not classified as following a structured and transparent review method (n=13); not including studies that focus on mobile technologies to facilitate training and learning (n=12); and; not including studies that focus on mobile technologies (n=2). As a result, we were left with 16 reviews that included research evidence on the application of mobile technologies to facilitate learning CHWs' education and training in LMICs.

In a second step, we then extracted the primary studies included in the 16 systematic reviews. We only extracted primary studies that were coded in the reviews to fit intervention categories associated with CHWs' education and training. As explained above, this referred to: provider training and education; decision-support; provider-provider communication; provider work planning and scheduling; data collection and reporting. Controlling for duplicates, we identified 24 studies that were included in the systematic reviews. Supplementary Material 3 provides a list of all systematic reviews and primary studies that were included in our scoping review.

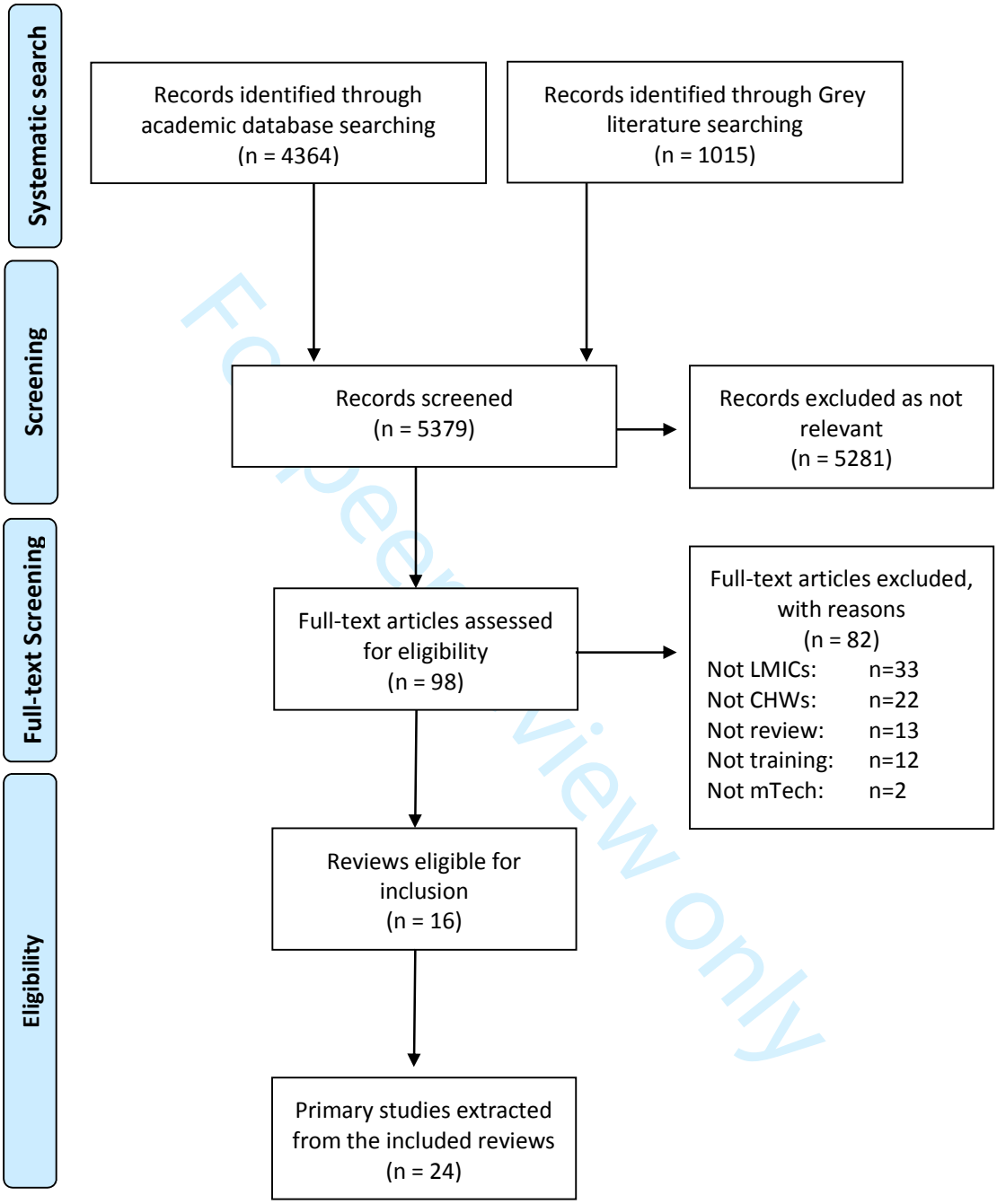

Figure 1 PRISMA flow chart of identification and inclusion of studies

Description of mHealth interventions: how did they facilitate CHWs' education and training?

We extracted descriptive information from all 24 included primary studies using a structured coding tool. A summary table of the extracted data per study is presented in Supplementary Material 4. Of the 24 primary studies extracted from the 16 systematic reviews, three were undertaken in Kenya, three in Malawi, three in Tanzania, two in Ghana, two in Rwanda, and two in South Africa. One study was undertaken in: Bangladesh, Ethiopia, Guatemala, Nigeria, Liberia, Uganda, India and Pakistan respectively. One study was conducted in multiple countries (Mexico and Guatemala). Seventeen studies were undertaken in a rural setting, one in both urban and rural, one peri-urban, and four urban, with one setting undetermined. SMS was used in eight of the studies (including RapidSMS and FrontlineSMS), CommCare in five studies, MoTECH in one, Java Applets in three, customised designs in three, and standard voice calls in two. One tool was undetermined and one used a Palm Pilot PDA.

Intervention participants were described as CHWs in 13 studies while two studies referred to traditional birth attendants. In nine studies, different terms were used to describe health care workers fitting the above definition of CHWs. Examples of these include: village elders, community health volunteer, health surveillance assistant, and accredited social health activist. The number of CHWs involved in the mHealth interventions ranged from 5 to 638 with a median of 75. Only seven studies reached more than 100 CHWs[3].

The 24 studies included in the 16 systematic reviews reported a range of mHealth interventions that were positioned to facilitate CHWs' education and training. Of the 24 extracted primary studies, a majority were grouped by the systematic reviews to provide direct training and education to CHWs (n=16) (Figure 2). This could refer, for example, to using mobiles to facilitate continued professional development (CPD). A similar number of studies used mobile devices to enhance the communication between CHWs as well as with their supervisors (n=14). For instance, through use of SMS feedback and rapid response services in order to enhance CHWs' access to information and support learning. Other common intervention categories referred to the application of mobiles to train CHWs to collect and manage medical data (n=13); the use of technology-supported decision-making tools (n=11); and the facilitation of supervision of CHWs (n=8).

Methodological approaches

A variety of methodological approaches with a range of research methods and designs were used: case study (n=7), pilot study (n= 6), mixed methods (n=4), quasi-experimental designs (n=4). There were only two RCTs and one technical evaluation, and one study where the methods used could not be determined.

Discrepancies in categorisation

The same studies reported by different reviews were not consistently categorised in their relation to CHWs' education and training. For example, a study that reported on mobile phone text-message reminders to support Kenyan health workers' adherence

[3] In all but one study [22], the CHWs involved in the mHealth intervention are synonymous with the research sample.

to malaria treatment guidelines [23], was included in five reviews but was alternatively categorised as a decision-support tool, a monitoring and compliance device, or as a training and education intervention (Supplementary Material 5). This pattern characterises the entire sample, where there is a large overlap between the primary studies included in the systematic reviews, but little overlap in their allocation to intervention categories. On average, each primary study is allocated to three different intervention categories across different or within reviews. Of the primary studies allocated to multiple categories (n=14), only four studies are consistently allocated to the same intervention category across reviews (see Supplementary Material 5, column 1). As a result, there seems to be little agreement between reviews regarding what type of interventions can directly facilitate CHWs' education and training and how such learning can be defined.

This is not surprising given that the challenges of categorisation are well known [24]. However, given the large variance in the allocation of interventions, there is a need for mHealth researchers to develop a clearer understanding of what counts as education and training for CHWs. To overcome the seemingly *ad hoc* manner of categorisation, we used educational research to develop a refined coding tool (see Supplementary Material 5 and 6) This tool is based on pedagogical frameworks for workplace and mobile learning [9, 10], and is applied to assess the exact nature of education and training that was supported by the mHealth interventions.

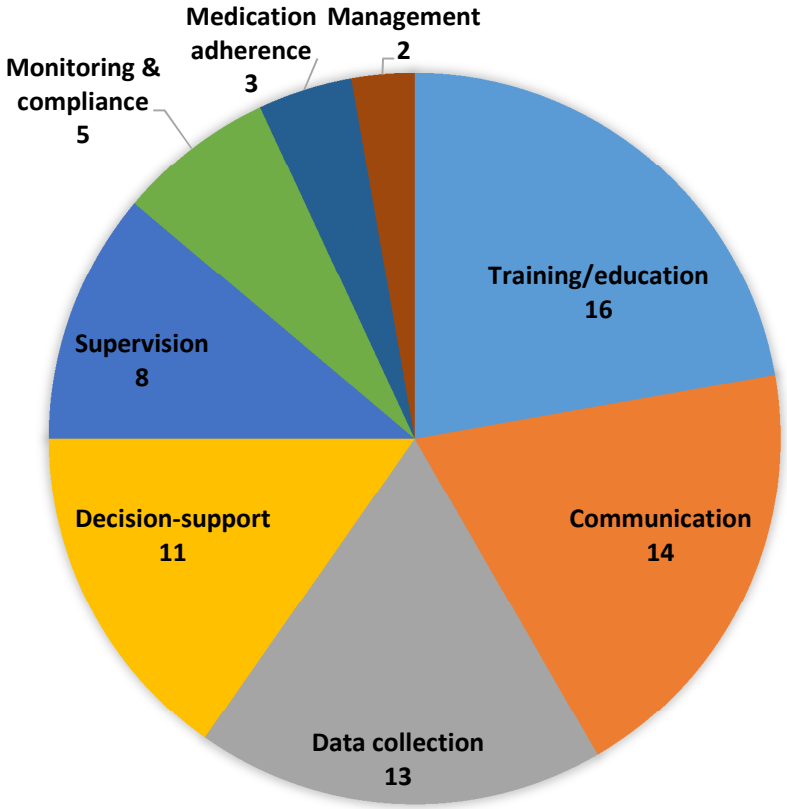

Figure 2 Overview of mHealth intervention categories featured in the included systematic review

Step 3: Recoding of mHealth interventions using educational frameworks

The results of our re-analysis of the included primary studies and whether the reported mHealth interventions could indeed be positioned to facilitate CHWs' education and training through the use of mobiles are presented in Supplementary Material 5.

In Supplementary Material 5, columns 2 and 3 show the findings of our recoding of whether the interventions can be classified as workplace learning (column 2) or mobile learning (column 3). From recoding the primary studies using the educational frameworks, we find that only four mHealth interventions [23, 25–27] could be positioned as facilitating CHWs' education and training through the use of mobile technology. That is, of the 24 studies that are allocated in the systematic reviews to categories associated with a potential educational use of technology, the allocation of 20 studies cannot be confirmed from a pedagogic perspective.

Discussion

Of the four studies that remained after recoding, all exhibited elements of workplace-based and mobile learning (see Supplementary Material 6). However, the ways in which these elements were implemented was weak from an educational research perspective. The need to produce evidence on how mobile technology can support reflective and interactive forms of CHWs' education and training, particularly coaching, supervision and mentoring, remain critically neglected overall. mHealth interventions are not building effectively enough on previous global health research which has evidenced how good quality supervision "is one the key approaches to improving the quality of health care"[28: 3]. This is particularly true when it is backed up by regular support and feedback [29–34]

Instead, priority seemed to be given to easily scalable basic technologies that use an information dissemination model of learning to ensure CHW adherence to standardised practice (e.g. simplified guidelines on protocols sent via text messages). Learner agency was not a core priority. In three out of the four studies [23, 25, 26], agency was trumped by the need for CHWs to be held accountable to managerial oversight. Simplistic approaches, which focus on measuring the volume of information that CHWs are exposed to as a proxy for education and training have their limitations. It is unclear how they can empower CHWs, and there is a danger that the drive for improved efficiency through mobile technology could have the adverse effect of deprofessionalisation [35], potentially leading to a weakening of community-based health structures in the longer term.

Decision-support tools offer a means by which to generate insights into CHW practice and could be used as a medium to improve learning. However, the ways in which this could be implemented were not explored in detail. Svoronos et al [26] chose to focus on the details of system implementation. While in Blaschke et al, CHWs "stated that they felt empowered" [25: 24] by the automatic provision of a patient's weight for height calculation, but how this impacted on changes in practice through improved learning was not provided.

Instead of focusing on the developmental needs of CHWs, mHealth interventions in the main concentrate on providing CHWs with tools to support activities for which

they may not know the wider significance due to lack of training. Jones et al. [36] (the qualitative evaluation of the Zurovac et al [23] RCT) are open in the weaknesses of this aspect of their work: “it was clear that many of the participants believed that the type of training they received did not provide them with an adequate understanding of the importance of the new knowledge, or of the positive outcomes that a change in practice could bring” [36: 4]. They also noted that “few participants mentioned the messages in terms of ‘support supervision’, rather that they were made to feel somewhat guilty for not employing proper practice”. This is not surprising as using mobile technology for such a nuanced task as supportive supervision is challenging. Our previous work has demonstrated how CHWs and their supervisors used mobile messaging platforms (e.g. Whatsapp) to engage in virtual one-to-one, group, and peer-to-peer forms of supportive supervision [37]. Additional research is needed to investigate how technology can be embedded within successful supportive supervisory systems.

The one study that matched most closely what is known about mobile and workplace learning was Martínez-Fernández et al. [27]. In this study, mobile phones were used by 125 CHWs “to make consultations regarding issues about which they are unsure; send full epidemiological and clinical information related to the cases they attend; receive continuous training, and perform community health promotion and prevention activities through distance learning sessions” [27: 284]. After being given some technical training on phone use and data collection, they were provided with basic initial training in vital signs monitoring, and in the identification of signs of distress in children and pregnant women. The CHWs could use their phones for tele-consultations with medical staff (gynaecologists, paediatricians, internists and surgeons). Quarterly face-to-face training was augmented by tele-training. It is very clear that this intervention had a much stronger focus on ‘work processes as a by-product of learning’ including ‘consultation’ and ‘embedding on-going training within the intervention design’, a fact overlooked by the other interventions.

Conclusion

The findings from this scoping review suggest the mHealth literature is in danger of overclaiming regarding its ability to promote CHWs’ education and training within a work context. Studies claiming to have an educational component to their mHealth intervention were not often informed by educational theory nor was the educational approach taken well documented. The review has highlighted the need for more evidence on the precise nature of CHWs’ education and training that can be supported by mHealth interventions. This needs to start with improved categorisation, building on educational frameworks and richer accounts of learning [38]. The mechanisms for achieving educational outcomes are still unknown and educational theory should be embedded in the design of an intervention as well its evaluation – for which further cross-disciplinary work between global health and education is needed. Appropriate models of technology-enhanced learning (e.g. [39–41]) and extended use of educational theories will enable the development of much needed robust evidence on the role of technology in supporting CHWs’ education and training in mHealth.

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Competing interests
None declared

Data Sharing
All relevant data are within the paper and supporting material.

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Supplementary Material 1: Search terms

Search terms:

Mhealth terms: (mhealth OR m-health OR “mobile health” OR ((mobile technolog* OR “mobile phone” OR “mobile device” OR phone OR tablet OR PDA OR “personal digital assistant” OR iPAD OR iPOD OR “smart phone” OR “feature phone” OR app OR “mobile application”) AND Health) OR ((“Text messag*” OR “short messag*” OR SMS OR “social media” OR “mobile communication”) AND health)

Review terms: (“systematic review” OR “literature review” OR “meta-analysis” OR “review of reviews” OR “systematic map” OR “evidence map” OR “evidence gap map” OR “evidence synthesis” OR “research synthesis”)

Developing country term: (“developing countr*” OR LMICs OR “low- and middle-income countr*” OR “low and middle income countr*” OR Africa OR Asia OR “Latin America” OR “East* Europe” OR “majority world” OR “global south”)

Supplementary Material 2: Systematic search records

Source	*Terms*	*Results*
Google Scholar	("mobile health" OR mHealth) AND review AND ("developing countries" OR LMICs OR Africa OR Asia OR Latin America")	500: 51
	Update 30 May 2017 (August 2016-May 2017)	500: 14
Google	(Mhealth OR "mobile health") AND review	500: 34 Dups 18
	Update 30 May 2017 (August 2016-May 2017)	500: 10 Dups: 7
3ie	(Mhealth OR "mobile health")	1:1
	Update 30 May 2017 (August 2016-May 2017)	7:3 Dups: 4
Cochrane	(Mhealth OR "mobile health")	4: 0
	Update 30 May 2017 (August 2016-May 2017)	3: 0
Campbell	(Mhealth OR "mobile health")	0
	Update 30 May 2017 (August 2016-May 2017)	0
CINAHL	Master string	1247*: 64
	Update 30 May 2017 (August 2016-May 2017	5: 2 Dups: 2
Pubmed	(Mhealth OR "mobile health") OR ("mobile technology*" AND health) AND ("systematic review" OR "literature review")	1008: 41
	Update 30 May 2017 (August 2016-May 2017)	46: 5 Dups: 4
Medline	Master string	1247*: 64
	Update 30 May 2017 (August 2016-May 2017	11: 7 Dups: 7
PsychInfo	(Mhealth OR "mobile health")	211*: 12
	Update 30 May 2017 (August 2016-May 2017)	13
ERIC	(Mhealth OR "mobile health")	211*: 12
	Update 30 May 2017 (August 2016-May 2017)	13
Education Full-text	(Mhealth OR "mobile health")	211*: 12
	Update 30 May 2017 (August 2016-May 2017)	13
Isl web of science	(Mhealth OR "mobile health") OR ("mobile technology*" AND health) AND ("systematic review" OR "literature review")	465: 82
	Update 30 May 2017 (August 2016-May 2017)	111: 14 Dups: 12

Supplementary material 3: List of included systematic reviews and primary studies

Systematic reviews included in the scoping review

1. Hall, C.S., Fottrell, E., Wilkinson, S. and Byass, P., 2014. Assessing the impact of mHealth interventions in low-and middle-income countries–what has been shown to work?. *Global health action*, *7*(1), p.25606.
2. Peiris, D., Praveen, D., Johnson, C. and Mogulluru, K., 2014. Use of mHealth systems and tools for non-communicable diseases in low-and middle-income countries: a systematic review. *Journal of cardiovascular translational research*, *7*(8), pp.677-691.
3. Aranda-Jan, C.B., Mohutsiwa-Dibe, N. and Loukanova, S., 2014. Systematic review on what works, what does not work and why of implementation of mobile health (mHealth) projects in Africa. *BMC public health*, *14*(1), p.188.
4. Agarwal, S., Perry, H.B., Long, L.A. and Labrique, A.B., 2015. Evidence on feasibility and effective use of mHealth strategies by frontline health workers in developing countries: systematic review. *Tropical medicine & international health*, *20*(8), pp.1003-1014.
5. Källander, K., Tibenderana, J.K., Akpogheneta, O.J., Strachan, D.L., Hill, Z., ten Asbroek, A.H., Conteh, L., Kirkwood, B.R. and Meek, S.R., 2013. Mobile health (mHealth) approaches and lessons for increased performance and retention of community health workers in low-and middle-income countries: a review. *Journal of medical Internet research*, *15*(1).
6. Braun, R., Catalani, C., Wimbush, J. and Israelski, D., 2013. Community health workers and mobile technology: a systematic review of the literature. *PloS one*, *8*(6), p.e65772.
7. Hurt, K., Walker, R.J., Campbell, J.A. and Egede, L.E., 2016. mHealth interventions in low and middle-income countries: a systematic review. *Global journal of health science*, *8*(9), p.183.
8. Bloomfield, G.S., Vedanthan, R., Vasudevan, L., Kithei, A., Were, M. and Velazquez, E.J., 2014. Mobile health for non-communicable diseases in Sub-Saharan Africa: a systematic review of the literature and strategic framework for research. *Globalization and health*, *10*(1), p.49.
9. Goel, S., Bhatnagar, N., Sharma, D. and Singh, A., 2013. Bridging the human resource gap in primary health care delivery systems of developing countries with mhealth: narrative literature review. *JMIR mHealth and uHealth*, *1*(2).
10. O'Donovan, J., Bersin, A. and O'Donovan, C., 2015. The effectiveness of mobile health (mHealth) technologies to train healthcare professionals in developing countries: a review of the literature. *BMJ Innovations*, *1*(1), pp.33-36.
11. Chib, A., van Velthoven, M.H. and Car, J., 2015. mHealth adoption in low-resource environments: a review of the use of mobile healthcare in developing countries. *Journal of health communication*, *20*(1), pp.4-34.
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13. Adepoju, I.O.O., Albersen, B.J.A., De Brouwere, V., van Roosmalen, J. and Zweekhorst, M., 2017. mHealth for Clinical Decision-Making in Sub-Saharan Africa: A Scoping Review. *JMIR mHealth and uHealth*, *5*(3).

14. Colaci, D., Chaudhri, S. and Vasan, A., 2016. mHealth Interventions in Low-Income Countries to Address Maternal Health: A Systematic Review. *Annals of Global Health*, *82*(5), pp.922-935.
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Primary studies extracted from the systematic reviews and included in the scoping review

1. Alam, M., Khanam, T. and Khan, R., 2010, December. Assessing the scope for use of mobile based solution to improve maternal and child health in Bangladesh: A case study. In *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development* (p. 3). ACM.
2. Andreatta, P., Debpuur, D., Danquah, A. and Perosky, J., 2011. Using cell phones to collect postpartum hemorrhage outcome data in rural Ghana. *International Journal of Gynecology & Obstetrics*, *113*(2), pp.148-151.
3. Barrington, J., Wereko-Brobby, O., Ward, P., Mwafongo, W. and Kungulwe, S., 2010. SMS for Life: a pilot project to improve anti-malarial drug supply management in rural Tanzania using standard technology. *Malaria journal*, *9*(1), p.298.
4. Chang, L.W., Kagaayi, J., Arem, H., Nakigozi, G., Ssempijja, V., Serwadda, D., Quinn, T.C., Gray, R.H., Bollinger, R.C. and Reynolds, S.J., 2011. Impact of a mHealth intervention for peer health workers on AIDS care in rural Uganda: a mixed methods evaluation of a cluster-randomized trial. *AIDS and Behavior*, *15*(8), p.1776.
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13. Mahmud, N., Rodriguez, J. and Nesbit, J., 2010. A text message-based intervention to bridge the healthcare communication gap in the rural developing world. *Technology and Health Care*, *18*(2), pp.137-144.
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15. Palazuelos, D., Diallo, A.B., Palazuelos, L., Carlile, N., Payne, J.D. and Franke, M.F., 2013. User perceptions of an mHealth medicine dosing tool for community health workers. *JMIR mHealth and uHealth*, *1*(1).
16. Ramachandran, D., Goswami, V. and Canny, J., 2010, December. Research and reality: using mobile messages to promote maternal health in rural India. In *Proceedings of the 4th ACM/IEEE international conference on information and communication technologies and development* (p. 35). ACM.
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Lori, J.R., Munro, M.L., Boyd, C.J. and Andreatta, P., 2012. Cell phones to collect pregnancy data from remote areas in Liberia. *Journal of Nursing Scholarship*, *44*(3), pp.294-301.

21. McNabb, M., Chukwu, E., Ojo, O., Shekhar, N., Gill, C.J., Salami, H. and Jega, F., 2015. Assessment of the quality of antenatal care services provided by health workers using a mobile phone decision support application in northern Nigeria: a pre/post-intervention study. *PLOS one*, *10*(5), p.e0123940.
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23. Little, A., Medhanyie, A., Yebyo, H., Spigt, M., Dinant, G.J. and Blanco, R., 2013. Meeting community health worker needs for maternal health care service delivery using appropriate mobile technologies in Ethiopia. *PloS one*, *8*(10), p.e77563.

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24. Surka, S., Edirippulige, S., Steyn, K., Gaziano, T., Puoane, T. and Levitt, N., 2014. Evaluating the use of mobile phone technology to enhance cardiovascular disease screening by community health workers. *International journal of medical informatics*, *83*(9), pp.648-654.

Supplementary Material 4: Summary of the included primary studies

Primary study	Country	Area	Tool	Methodology	Number of participants / sample (n)[1]
Alam (2010)	Bangladesh (urban)	MCH	Custom design	Case study	27 CHWs, 6 supervisors
Andreatta (2011)	Ghana (rural)	MCH	SMS	Case study	8 traditional birth attendants, 2 midwifes
Barrington (2010)	Tanzania (rural)	Malaria	SMS	Pilot study	Health facility workers at 129 rural clinics
Chang (2011)	Uganda (rural)	AIDS	SMS	Mixed methods: RCT and qualitative process evaluation	29 Peer health care workers
Derenzi (2012)	Tanzania (rural and urban)	Chronic care (esp. HIV)	CommCare	Quasi-experimental: multiple experiments and designs	87 CHWs n=30
Diero (2006)	Kenya (rural)	Respiratory	Palm Pilot PDA	Case study	CHWs, unclear
Zurovac (2011)	Kenya (rural)	Malaria	SMS	Cluster RCT	119 CHWs

[1] Where not explicitly stated to the contrary, the number of intervention participants and the research sample was synonymous.

Gisore (2012)	Kenya (rural)	MCH	Phone and weighting scales	Case study	474 village elders
JSI (2013)	Rwanda (unclear)	Supply chain Management	Mobile phone	N/A (grey lit)	371 CHWs
Khan (2012)	Pakistan (urban)	TB	Custom design	Quasi-experimental: retrospective controlled	Community laypeople as TB screeners, unclear
Lemay (2012)	Malawi (rural)	Family planning/reproductive health/ HIV/AIDS knowledge	Frontline SMS	Mixed methods	638 CHWs
MacLeod (2012)	Ghana (rural)	MCH	MoTECH	Technical evaluation study	Community health volunteer, unclear
Mahmud (2010)	Malawi (rural)	Communication		Pilot study	75 CHWs
Ngabo (2012)	Rwanda (rural)	MCH	RapidSMS	Pilot study	432 CHWs
Palazeus (2013)	Mexico & Guatemala (rural)	Dosing	CommCare	Descriptive survey and qualitative interviews	17 CHWs
Ramachandran (2010)	India (rural)	MCH	Java applet	Case study	7 rural health workers

Svoronos (2010)	Tanzania (rural)	MCH	CommCare	Pilot study	5 CHWs
Tomlinson (2009)	South Africa (peri-urban)	Data collection	Java applet	Pilot study	24 CHWs
Blaschke (2009)	Malawi (rural)	Child nutrition	RapidSMS	Pilot study	Health surveillance assistant, unclear
Munro (2014)	Liberia (rural)	MCH	SMS	Quasi-experimental: Before/after design	99 traditional birth attendees
McNabb (2015)	Nigeria (urban)	MCH (ANC)	CommCare	Quasi-experimental Before/after design	152 CHWs, 20 supervisors
Martínez-Fernández (2015)	Guatemala (rural)	Infant mortality	Custom design	Case study	125 Community facilitators
Little (2013)	Ethiopia (rural)	Maternal health	Custom design	Case study	20 Health extension workers
Surka (2015)	South Africa (urban)	CVD screening	CommCare	Mixed methods pilot study	24 CHWs

Supplementary Material 5: Categorisation and re-analysis of included studies

COLUMN 1			COLUMN 2				COLUMN 3			
Primary study	**Intervention allocation**	**Agreement in allocation**	**Reclassification of intervention as WPL?**				**Reclassification of intervention as ML?**			
			Learning by-product of work	*Learning within work*	*Learning for work*	*Reclassification: fits WPL?*	*Personalisation*	*Authenticity*	*Collaboration*	*Reclassification: fits ML?*
Alam (2010)	(1) Supervision & monitoring[c]; (2) Data collection[ab]	2 different allocations	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Andreatta (2011)	(1) Data collection[b]; (2) Training & education[ad]; Training; (3) Medication adherence[e]	4 different allocations	No evidence	No evidence	Training in the use of a data reporting protocol.	No	No evidence	No evidence	No evidence	No
Barrington (2010)	(1) Data collection[b]; (2) Training & education[a]; (3) Management[e]	2 different allocations	No evidence	No evidence	Training in the use of a mobile phone.	No	No evidence	No evidence	No evidence	No
Chang (2011)	(1) Communication[f] (2) Training & education[e]; (3) Monitoring & compliance[eg];);	4 different allocations	No evidence	• Asking questions • Getting informatio • Locating resource people	No evidence	Secondary	No evidence	No evidence	No evidence	No
DeRenzi (2012)	(1) Managament[f] (2) Communication[ab]	4 different allocations	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No

	(3) Monitoring & compliance[g] (4) Health system support[d]									
Diero (2006)	(1) Standards and guidelines[d]	Single review	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Zurovac (2011)	(1) Decision-support[af] (2) Monitoring & compliance[edg] (3) Training & education[ad]	3 different allocations		• Giving and receiving feedback • Use of mediating artefacts	Being supervised	Yes		Contextualisation of knowledge in practice contexts		Yes
Gisore (2012)	(1) Data collection[f] (2) Training & education[d]	2 different allocations	No evidence	No evidence	Training on tool usage	No	No evidence	No evidence	No evidence	No
JSI (2013)	(1) Supervision[a] (2) Communication[a]	Single review	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Khan (2011)	(1) Decision-support[f]	Single review	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Lemay (2012)	(1) Communication[abd]	Agreement	No evidence	• Asking questions	No evidence	No	No evidence	No evidence	Communication	No
McLeold (2012)	(1) Supervision[a] (2) Communication[a]	Single review	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Mahmud (2010)	(1) Training & education[de] (2) Communication[af] (3) Data collection[a]	3 different allocations	No evidence	No evidence	Training on tool usage	No	No evidence	No evidence	No evidence	No
Ngabo (2012)	(1) Communication[af] (2) Supervision[a] (3) Medication	3 different allocations	No evidence	No evidence	Training on tool usage	No	No evidence	No evidence	Communication	No

	adherence[e]									
Palazuelos (2013)	(1) Training & education[ai] (2) Medicine adherence[ai]	Agreement	No evidence	No evidence	Training on tool usage	No	No evidence	No evidence	No evidence	No
Ramachandran (2010)	(1) Education & training[ad]	Agreement	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Svoronos (2010)	(1) Training & education[a] (2) Decision support[a] (3) Monitoring & compliance[d] (4) Supervision & management[d] (5) Data collection[b]	5 different allocations	• Tackling challenging tasks and roles • Problem solving • Standardisation of practice	• Giving and receiving feedback • Use of mediating artefacts	• Being supervised • Training on tool usage	Yes	No evidence	Contextualised feedback & practice support	No evidence	Yes
Tomlinson (2009)	(1) Supervision and management[ad] (2) Communication[a] (3) Data collection[ef]	3 different allocations	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Blaschke (2009)	(1) Decision-support[f] (2) Data collection[g]	2 different allocations	No evidence	• Learning from mistakes • Giving and receiving feedback	• Being supervised • Training on tool usage	Yes	No evidence	Contextualised feedback & practice support	No evidence	Yes
McNabb (2015)	(1) Decision-support[m] (2) Data collection[l]	2 different allocations	Tool forces practice decisions	No evidence	No evidence	Secondary	No evidence	No evidence	No evidence	No
Martı´nez-Ferna´ndez (2015)	(1) Decision-support[l] (2) Data collection[l] (3) Training[l]	Single review	No evidence	Consultation and logistical support.	Using phones for CPD	Yes	Distance learning using mobile tools			Yes

Little (2013)	(1) (2)	Data collection[alno] Provider-Provider Communication[n]	2 different allocations	Tool forces practice decisions	No evidence	No evidence	Secondary	No evidence	No evidence	No evidence	No
Munro (2014)	(1)	Data collection[lo]	Agreement			Learning to use and implement data collection Training or tool usage	Secondary	No evidence	No evidence	No evidence	No
Surka (2014)	(1)	Data collection[n]	Single review	Tool forces practice decisions	No evidence	Training or tool usage	Secondary	No evidence	No evidence	No evidence	No

a=Agrawal (2015); b=Chib (2015); c=Goel (2013); d=Braun (2015); e=Aranda-jan (2014); f=Hall (2014); g=Kallander (2014); h=Hurt (2014); i=O'Donovan; j=Peiris (2014); k=Bloomfield (2014); l=Colaci (2016); m=Adepoju (2017); n=White (2016); o=Amoakoh (2016); q=Tian (2017)

Supplementary Material 6

Theory of learning	Learning processes		Studies coded to constitute workplace and mobile learning			
			Zurovac (2011)	Svoronos (2010)	Blaschke (2009)	Martinez-Fernandez (2015)
Workplace based learning	**Work Processes** with learning as a by-product	Participation in group processes				
		Working alongside others				
		Consultation				YES
		Tackling challenging tasks and roles				
		Problem solving				
		Trying things out				
		Consolidating, extending and refining skills	YES			YES
		Working with				YES

		clients				
	Learning Activities located **within** work or learning processes	Asking questions				
		Getting information	YES	YES	YES	YES
		Locating resource people				YES
		Listening & observing				
		Reflecting				
		Learning from mistakes				
		Giving and receiving feedback				
		Use of mediating artefacts				
	Learning Processes at or near the workplace	Being supervised		YES (see our previous table for details)		YES
		Being coached				YES

		Being mentored				
		Shadowing				
		Visiting other sites				
		Conferences				
		Short courses				YES
		Working for a qualification				
		Independent study				
Mobile learning	Personalisation	Agency	Medium: improved participants' ability to treat	Low: re-enforce target behaviour		High: able to call for help as needed
		Customisation				
	Authenticity	Situatedness	High: messages received at work (but in the linked paper noted that it was not linked to	High: phones used at work	Medium: feedback loops for the HSA	High: phones used at work

			training)			
		Contextualisation				
	Collaboration	Data sharing				
		Conversation				High: based on communication

BMJ Open

A scoping review assessing the evidence used to support the adoption of mobile health (mHealth) technologies for the education and training of community health workers (CHWs) in low- and middle-income countries

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A scoping review assessing the evidence used to support the adoption of mobile health (mHealth) technologies for the education and training of community health workers (CHWs) in low- and middle-income countries

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Contributor Statement: Activities undertaken by the authors were as follows: Establishment of research question/s and development of search strategy: NW and LL. Background framing: NW & AG. Database search and record screening: LL. Extraction of primary studies from the included reviews: LL and NW. Recoding: NW and LL. Discussion & Conclusion: NW, LL and AG.

KEYWORDS: mHealth, Global Health, Community Health Worker, Education and Training, Scoping Review

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ABSTRACT

Objectives

Undertake a systematic scoping review to determine how a research evidence base, in the form of existing systematic reviews in the field of mobile health (mHealth), constitutes education and training for community health workers who use mobile technologies in everyday work. The review was informed by the following research questions: Does educational theory inform the design of the education and training component of mHealth interventions? How is education and training with mobile technology by CHWs in low- and middle-income countries categorised by existing systematic reviews? What is the basis for this categorisation?

Setting

The review explored the literature from 2000 to 2017 to investigate how mHealth interventions have been positioned within the available evidence base in relation to their use of formal theories of learning.

Results

The scoping review found 24 primary studies that were categorised by 16 systematic reviews as supporting CHWs' education and training using mobile technologies. However, when formal theories of learning from educational research were used to re-categorise these 24 primary studies, only four could be coded as such. This identifies a problem with how CHWs' education and training using mobile technologies is understood and categorised within the existing evidence base. This is because there is no agreed upon, theoretically informed understanding of what counts as learning.

Conclusion

The claims made by mHealth researchers and practitioners regarding the learning benefits of mobile technology are not based on research results that are underpinned by formal theories of learning. mHealth suffers from a reductionist view of learning that underestimates the complexities of the relationship between pedagogy and technology. This has resulted in miscategorisations of what constitutes CHWs' education and training within the existing evidence base. This can be overcome by informed collaboration between the health and education communities.

Strengths and limitations of this study

- The study applied an innovative three-step scoping review methodology to unpack the evidence on mobile technology's contribution to the education and training of CHWs.
- In-depth primary analysis determined if theories of learning were used to conceptualise and categorise education and training in mHealth.
- The study details if these theories were used to design and implement the education and training component of mHealth interventions for CHWs.
- The in-depth primary analysis of theories of learning is limited to programmatic information reported in the identified primary studies.

- The review is limited to papers included in systematic reviews published in English between 2000-2017.

INTRODUCTION

The popularity of mobile phones in low- and middle-income countries (LMICs) has motivated their use in healthcare, particularly as a tool to support primary health care outreach by community health workers (CHWs) to those with little or no access to health care. CHWs usually receive limited but focused training on key health priorities in LMICs and they play a vital role in supporting communities to better engage with the formal health system. While the precise scope of their role differs across LMICs (Oliver et al. discuss their role in Kenya[1]), they have become a vital part of strategies to address weaknesses in health systems. Mobile technology is increasingly viewed as essential to the work of CHWs.

The field of mobile health (mHealth) investigates the role mobile technologies can play in healthcare. mHealth has many functionalities,[2-3] one of which is to provide education and training for CHWs. Delivering individual access to educational material is the primary means of achieving this,[4] particularly in contexts where face-to-face training is limited. Yet, such information dissemination models of education are well known to miss the wider social and cultural aspects of learning inherent to healthcare practice,[5] and more relevant educational theories, including inquiry learning, experiential learning and situated learning, are used in other areas of healthcare practice.[6-8]

Educational researchers have built on these foundational theories to develop concepts of workplace-based learning and mobile learning,[9,10] which are designed to support learners to produce new knowledge using technology while working. However, it is unclear if or how workplace-based learning and mobile learning research has been incorporated into mHealth platforms. Preliminary indicators suggest that almost all 'education theory' is ignored. For example, in Labrique et al.'s widely regarded mHealth framework,[11] none of the example interventions in the category 'provider training and education' (p. 164) are informed by formal theories of workplace-based or mobile learning. Other categories, such as 'electronic decision-support' could be considered workplace-based learning. The problem is further complicated by the fact that in two systematic reviews of mHealth interventions,[3,12] the same underlying mechanisms of information dissemination and increased communication are applied to two very different challenges: (a) patient education for behaviour change and (b) CHWs' continuous professional development. Yet, from an educational perspective, it is challenging to equate mHealth interventions that provide health-related information with interventions trying to change CHW's practice and support professional development; the underlying pedagogical mechanisms required for both types of interventions differ significantly in nature and scale.

Consequently, there is a pressing need to understand: 1) If and how educational theories are being incorporated into mHealth platforms currently? 2) How the adoption of a novel educational lens can inform the future development of mHealth technology for use by CHWs?

While multiple reviews of mHealth in LMICs have recently been published, this systematic scoping review is the first to combine theories of workplace-based learning and mobile learning and apply them to mHealth research on education and training for CHWs in LMICs. The focus of the review is not on measurable endpoints of education and training

but rather on how the educational components have been conceptualised within existing mHealth research.

METHODS

Review approach:

We conducted a systematic scoping review of the research evidence on the use of mobile technologies to facilitate CHWs' education and training in LMICs. A scoping review is defined[13] as "a form of knowledge synthesis that addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting, and synthesizing existing knowledge" (p. 1292). Scoping reviews are part of the family of research synthesis methods, but compared to systematic reviews address broader research questions. They aim to provide an overview and organisation of existing knowledge rather than a narrow synthesis of a predefined research question.[14-15] Usually, this different synthesis approach is conducted over a shorter timeframe than systematic reviews, using more targeted search terms and focuses less on the critical appraisal of the included evidence.

A scoping review approach was chosen for this study because we wanted to explore how existing literature has conceptualised and operationalised the use of mobile technologies to support CHWs' learning practices. The focus is on the diversity of understandings and definitions of CHWs' education and training in the existing literature and what patterns and gaps might emerge from a systematic analysis of this body of knowledge[i]. In order to capture the conceptualisation and positioning of mHealth interventions that have an education or training component, our scoping review targeted existing systematic reviews of mHealth interventions rather than primary studies as a first level of analysis. Unlike primary studies, these reviews require an explicit conceptual framework—including Labrique's framework—in order to group mHealth interventions for analysis. Consequently, we can derive the positioning and categorisation of different mHealth interventions with respect to their support for CHWs' education and training from these systematic reviews.

Our scoping review followed explicit and transparent research steps to explore the research evidence on mHealth and CHWs' education and training. A review protocol was not published and the study was not registered with PROSPERO, as these mechanisms are not applied to scoping reviews.[13-14]

We followed a novel three-step approach in our scoping review that combined secondary research methods with a primary re-analysis of the included studies. In the first step, existing systematic reviews investigating CHWs' education and training when using mobile technologies were sought. As outlined above, this novel approach was necessary to allow us to investigate how different mHealth interventions were categorised in relation to education and training within the evidence base. In the second step, we then extracted the primary studies included in these reviews in order to provide a descriptive account of the included mHealth interventions and the wider characteristics of the evidence base. In the third step, we conducted a primary re-analysis of the included mHealth interventions, which were recoded with respect to their education or training component. That is, we used two coding frameworks inspired by different theories of learning—workplace-based learning and mobile learning.[9,10] These two theories of were selected because they are both well-developed, proven and have been applied in multiple projects in the education

[i] We were not concerned with whether mobile technologies are effective in increasing learning outcomes or how CHWs perceive the use of mobile technologies. These types of research questions lend themselves to full systematic reviews.

literature. Each builds on over a decade of research, and draws together key conceptual points into practically applicable frameworks.

The chosen coding frameworks were then applied to the primary studies included in the systematic review. As a result, we obtained two different set of results on how mHealth interventions were categorised regarding their support for CHWs' education and training: (i) the categorisation of interventions in the systematic reviews themselves and (ii) our re-categorisation of the same interventions using explicit learning from educational research. These two sets of categorisations allowed us to juxtapose the prevailing positioning and understanding of education and training in mHealth with a more pedagogically grounded understanding. A more traditional review approach, without this re-analysis of primary studies, would not have allowed us to juxtapose these different understandings. The same applies had we followed a systematic review approach that only included primary studies and not the existing reviews themselves. We elaborate on the methods employed in each step below.

Step 1: Review of existing systematic reviews

Search methods:
We designed an exhaustive and sensitive search strategy to identify all relevant reviews of mHealth interventions that included CHWs' education and training facilitated by mobile technologies in LMICs. The search strategy was deliberately designed to be over-inclusive. Search terms were formulated to identify any mHealth review covering LMICs and we manually filtered down the reviews relevant to CHWs' education and training. Likewise, despite being focused on CHWs in our review, our search strategy did not specify terms related to CHWs. Both decisions ensured that no relevant reviews were excluded during the search. The full search terms therefore only included key words for the concepts 'mHealth', 'systematic review', and 'LMICs'. Concepts were combined using the AND boolean operator to develop a master search string (Supplementary Material 1).

The full search string was then applied to a range of academic databases in the health and social sciences: CINAHL; Pubmed; Medline; PsychInfo; ERIC; Education Full-text; and ISI web of science. Database searches covered the period 2000 to 2017. The year 2000 as a cut-off date was chosen as mobile technologies did not see widespread application to support health care in LMICs before then. In addition, we also searched the Grey literature for reviews relevant for inclusion. Grey literature sources included Google and Google Scholar searches as well as specialized systematic review databases, i.e. Cochrane Library of Systematic Reviews, Campbell Library, and the 3ie database of international development reviews. Lastly, reference lists of included reviews were used as an additional source for snowball searching for additional reviews. A full record of the conducted search is provided in Supplementary Material 2.

Inclusion criteria:
We formulated explicit inclusion criteria that determined what reviews were eligible for inclusion in our scoping review. Conceptually, this referred to existing systematic reviews of mHealth interventions that support CHWs' education and training in LMICs. To operationalise this into transparent inclusion criteria, the following definitions were applied.

Population: CHWs were defined broadly in line with the WHO's 2007 definition of lay health workers as applied in Lewin et al.[16]:

> "Community health workers should be members of the communities where they work, should be selected by the communities, should be answerable to the communities for their activities, should be supported by the health system but not necessarily a part of its organization, and have shorter training than professional workers." (p.3)

This definition allows for different types of health care workers to be classified as CHWs in different contexts. Reviews were included as long as they covered mHealth interventions applied by or for CHWs regardless of whether CHWs were the main focus of the review. LMICs were defined using the World Bank classification of economies.[17] To be included, reviews had to focus on LMICs and for reviews that had no regional scope, at least 50 per cent of the included studies had to be from LMICs in order for the review to be featured in our scoping review.

Intervention: Reviews had to include mHealth interventions that used mobile technology to facilitate CHWs' education and training. This excludes reviews that focus on fixed ICT infrastructure such as desktop PCs and fixed diagnostic ICTs only. Education and training was defined broadly and we followed the reviews' positioning of interventions as to how they facilitated learning. In addition, we included the following categories used in reviews based on Labrique et al's framework to ensure no relevant interventions were missed: Decision-support; provider-provider communication; provider work planning and scheduling; data collection and reporting. A systematic review covering any of the above categories was thus included in our scoping review. This was because each of these categories could potentially be framed as supporting the CHWs' education and training using conceptualisations of workplace-based learning and mobile learning. For example, improved communication between CHWs could support collaboration and social learning. Likewise, following explicit decision-making algorithms could lead to the learning and acquisition of new and improved practices by CHWs. Both 'provider work planning and scheduling' and 'data collection and reporting' can offer CHWs with opportunities for reflective practice, for example by providing insights into the relationship between data capture and decision-making. Reviewing cohort data could offer supervisors the opportunity to support peer learning. Again, we aimed to be over-inclusive at this stage so as not to miss any relevant reviews.

Research design: To be included, studies had to qualify as a 'systematic review' which was defined broadly for this scoping review. Any type of research synthesis was included as long as a structured and transparent review approach was applied. Indicators of a structured review approach referred to: reporting of (i) a systematic search; (ii) pre-defined inclusion criteria; and (iii) a stated method of synthesis. Indicators of a transparent review approach referred to: reporting of (i) numbers of searched and included studies; (ii) a summary table of included studies; and (iii) a discussion of the strengths of the evidence in the synthesis.

Outcomes: No studies were excluded on the basis of measured outcomes or applied outcome measures because intervention effectiveness was not of concern in this scoping review.

Screening and coding of reviews:

Two reviewers screened all search hits for potentially relevant systematic reviews at title and abstract. Full-texts of potentially relevant reviews were then sought and screened again against our inclusion criteria. A sub-set of 10 per cent of the citations eligible of full-text screening were double-screened to assess inter-reviewer reliability. Disagreements between reviewers were resolved by joint discussion with a third reviewer acting as an

arbitrator. Following the screening, included systematic reviews were then coded for two high-level characteristics: (i) applied framework to categorise interventions and (ii) included mHealth interventions.

Critical appraisal:
As this is a scoping review, no critical appraisal of either included reviews or primary studies was conducted.

Step 2: Extraction of primary studies from the included reviews

Identification of primary studies:
Having identified eligible reviews, we then extracted the primary studies included in each review for further analysis. That is, the included systematic reviews served as the data source for primary studies. We only searched the relevant systematic reviews under the intervention categories that could potentially relate to education and training. Extracting only primary studies that existing systematic reviews had coded and categorised as related to education and training allows us to unpack and examine this positioning.

We did not conduct an independent scientific search for relevant primary studies in addition to the search for systematic reviews. Including primary studies that were not found in existing systematic reviews would not have revealed any new information regarding how the primary studies were categorised. As a result, primary studies of mHealth interventions and CHWs that were not included in any of the systematic reviews were excluded from our scoping review. In practice, this refers mainly to primary studies published after the included systematic reviews were conducted. (Searches for the two most up-to-date systematic reviews[18-19] included in our scoping review were completed in December 2015.)

Inclusion criteria for primary studies:
In terms of population, intervention, and outcome the inclusion criteria of the primary studies were identical to the criteria for systematic reviews. In terms of study design, however, primary studies could be of any empirical research design that investigated an applied mHealth intervention. This included both quantitative and qualitative research designs but excluded designs that assessed interventions in a lab setting and/or assessed perceptions and feasibility of a future intervention implementation.[20,21]

Screening and coding of primary studies:
All primary studies allocated to the eligible intervention categories explained above were screened at full-text by two reviewers. The same quality assurance processes as used for the screening of the systematic reviews were implemented. We designed an explicit coding tool to capture key characteristics related to the type of CHWs, the type of mHealth intervention and technology applied, the context in which it was applied, as well as the educational event or process facilitated by the technology.

Step 3: Primary analysis of study's categorisation as supporting the education and training of CHWs
Two well-established coding frameworks from educational research feature the key pedagogical attributes of workplace-based and mobile learning: Eraut and Hirsh[9] for workplace-based learning and Kearney et al.[10] for mobile learning. Applying these two frameworks as our coding tool allowed us to re-code the primary studies in order to investigate whether their claim to facilitate CHWs' education and training did hold true from a pedagogical perspective. In this last step, we thus can compare the outcomes of this pedagogically-informed coding tool with the reported codes in the reviews. Again, two

independent reviewers applied the coding tool with a third reviewer acting as an arbitrator in case of disagreement.

Review limitations

There are three key limitations to this review. First, only English-language articles were considered for inclusion. Second, systematic reviews published up to 2017 only cover primary studies published up to 2015. Studies published after this date were not identified by the systematic reviews and by extension are not covered by our scoping review. In general, relying on systematic reviews as an identification strategy entails the risk that our review is subject to a limitation in scope because we can only re-produce the scope of the included systematic reviews in our own review[ii]. Third, only a partial range of grey literature was searched and mHealth conferences were not covered.

Patient and Public Involvement

Patients or the public were not involved in this research.

FINDINGS

Search results:

Searches were run between March and May 2016 and updated in June 2017. They yielded a total of 5,379 citations from twelve different sources (Figure 1). After screening these citations on title and abstract, the large majority of citations were not relevant (n=5,281)—a result of our deliberately over-inclusive search strategy. We identified 98 existing reviews that on title and abstract met our inclusion criteria. Full-texts of these reviews were then sought and reviews screened for inclusion in more detail. This in-depth screening excluded a further 82 reviews leaving only 16 reviews that met the predefined inclusion criteria. Reasons for exclusion at full-text screening referred to: reviews not including studies from LMICs (n=33); not including studies that focus on CHWs as a population (n=22); not classified as following a structured and transparent review method (n=13); not including studies that focus on mobile technologies to facilitate training and learning (n=12); and, not including studies that focus on mobile technologies (n=2). As a result, we were left with 16 reviews that included research evidence on the application of mobile technologies to facilitate CHWs' education and training in LMICs.

In a second step, we then extracted the primary studies included in the 16 systematic reviews. We only extracted primary studies that were coded in the reviews to fit intervention categories associated with CHWs' education and training. As explained above, this referred to: provider training and education; decision-support; provider-provider communication; provider work planning and scheduling; data collection and reporting. Controlling for duplicates, we identified 24 studies that were included in the systematic reviews. Supplementary Material 3 provides a list of all systematic reviews and primary studies that were included in our scoping review.

[Figure 1 goes approximately here.]

[ii] However, this limitation is mitigated by the large number of identified systematic reviews (n=16), which provide large depth and breadth in the scope of included systematic reviews and thus in our own scoping review.

Description of mHealth interventions: how did they facilitate CHWs' education and training?

We extracted descriptive information from all 24 included primary studies using a structured coding tool. A summary table of the extracted data per study is presented in Supplementary Material 4. Of the 24 primary studies extracted from the 16 systematic reviews, three were undertaken in Kenya, three in Malawi, three in Tanzania, two in Ghana, two in Rwanda, and two in South Africa. One study was undertaken in: Bangladesh, Ethiopia, Guatemala, Nigeria, Liberia, Uganda, India and Pakistan respectively. One study was conducted in multiple countries (Mexico and Guatemala). Seventeen studies were undertaken in a rural setting, one in both urban and rural, one peri-urban, and four urban, with one setting undetermined. SMS was used in eight of the studies (including RapidSMS and FrontlineSMS), CommCare in five studies, MoTECH in one, Java Applets in three, customised designs in three, and standard voice calls in two. One tool was undetermined and one used a Palm Pilot PDA.

Intervention participants were described as CHWs in 13 studies while two studies referred to traditional birth attendants. In nine studies, different terms were used to describe health care workers fitting the above definition of CHWs. Examples of these include: village elders, community health volunteer, health surveillance assistant, and accredited social health activist. The number of CHWs involved in the mHealth interventions ranged from 5 to 638 with a median of 75. Only seven studies reached more than 100 CHWs. In all but one study,[22] the CHWs involved in the mHealth intervention were synonymous with the research sample.

The 24 studies included in the 16 systematic reviews reported a range of mHealth interventions that were positioned to facilitate CHWs' education and training. Of the 24 extracted primary studies, a majority were grouped by the systematic reviews to provide direct training and education to CHWs (n=16) (Figure 2). This could refer, for example, to using mobiles to facilitate continued professional development (CPD). A similar number of studies used mobile devices to enhance the communication between CHWs as well as with their supervisors (n=14). For instance, through use of SMS feedback and rapid response services in order to enhance CHWs' access to information and support learning. Other common intervention categories referred to the application of mobiles to train CHWs to collect and manage medical data (n=13); the use of technology-supported decision-making tools (n=11); and the facilitation of supervision of CHWs (n=8).

Methodological approaches

A variety of methodological approaches with a range of research methods and designs were used: case study (n=7), pilot study (n= 6), mixed methods (n=4), quasi-experimental designs (n=4). There were only two RCTs and one technical evaluation, and one study where the methods used could not be determined.

Discrepancies in categorisation

The same studies reported by different reviews were not consistently categorised in their relation to CHWs' education and training. For example, a study that reported on mobile phone text-message reminders to support Kenyan health workers' adherence to malaria treatment guidelines,[23] was included in five reviews but was alternatively categorised as a decision-support tool, a monitoring and compliance device, or as a training and education intervention (Supplementary Material 5). This pattern characterises the entire sample, where there is a large overlap between the primary studies included in the systematic reviews, but little overlap in their allocation to intervention categories. On average, each primary study is allocated to three different intervention categories across different or within reviews. Of the primary studies allocated to multiple categories (n=14), only four studies are consistently allocated to the same intervention category across reviews (see Supplementary Material 5, column 1). As a result, there seems to be little agreement between reviews regarding what type of interventions can directly facilitate CHWs' education and training and how such learning can be defined.

This is not surprising given that the challenges of categorisation are well known.[24] However, given the large variance in the allocation of interventions, there is a need for mHealth researchers to develop a clearer understanding of what counts as education and training for CHWs. To overcome the seemingly *ad hoc* manner of categorisation, we used educational research to develop a refined coding tool (see Supplementary Material 5 and 6) This tool is based on pedagogical frameworks for workplace and mobile learning,[9,10] and is applied to assess the exact nature of education and training that was supported by the mHealth interventions.

[Figure 2 goes approximately here.]

Recoding of mHealth interventions using educational frameworks

The results of our re-analysis of the included primary studies and whether the reported mHealth interventions could indeed be positioned to facilitate CHWs' education and training through the use of mobiles are presented in Supplementary Material 5.

In Supplementary Material 5, columns 2 and 3 show the findings of our recoding of whether the interventions can be classified as workplace learning (column 2) or mobile learning (column 3). The key criterion to determine if an intervention supports practice-based mobile learning was that at least one aspect of workplace-based learning *and* one aspect of mobile learning were addressed (see Supplementary Material 6 for the coding tool). From recoding the primary studies using the educational frameworks, we find that only four mHealth interventions[23, 25-27] could be positioned as facilitating CHWs' education and training through the use of mobile technology. That is, of the 24 studies that are allocated in the systematic reviews to categories associated with a potential educational use of technology, the allocation of 20 studies cannot be confirmed from a pedagogic perspective. The only four studies where the allocation can be confirmed are highlighted in green in Supplementary Material 5.

Discussion

Of the four studies that remained after recoding,[23, 25-27] all exhibited elements of workplace-based and mobile learning (see Supplementary Material 6). However, the ways in which these elements were implemented was weak from an educational research perspective. The need to produce evidence on how mobile technology can support reflective and interactive forms of CHWs' education and training, particularly coaching, supervision and mentoring, remain critically neglected overall. mHealth interventions are not building effectively enough on previous global health research,[28] which has evidenced how good quality supervision "is one the key approaches to improving the quality of health care" (p.3). This is particularly true when it is backed up by regular support and feedback.[29-34]

Instead, priority seemed to be given to easily scalable basic technologies that use an information dissemination model of learning to ensure CHW adherence to standardised practice (e.g. simplified guidelines on protocols sent via text messages). Learner agency was not a core priority. In three out of the four studies,[23,25,26] agency was trumped by the need for CHWs to be held accountable to managerial oversight. Simplistic approaches, which focus on measuring the volume of information that CHWs are exposed to as a proxy for education and training have their limitations. It is unclear how they can empower CHWs, and there is a danger that the drive for improved efficiency through mobile technology could have the adverse effect of deprofessionalisation,[35] potentially leading to a weakening of community-based health structures in the longer term. Instead, mHealth training interventions need to be seen as part of a wider learning health systems approach[36] to support the training of CHWs, and as such cannot be considered in isolation.

Decision-support tools offer a means by which to generate insights into CHW practice and could be used as a medium to improve learning. However, the ways in which this could be implemented were not explored in detail. Svoronos et al.[26] chose to focus on the details of system implementation. While in Blaschke et al.,[25] CHWs "stated that they felt empowered" (p. 24) by the automatic provision of a patient's weight for height calculation, but how this impacted on changes in practice through improved learning was not provided.

Instead of focusing on the developmental needs of CHWs, mHealth interventions in the main concentrate on providing CHWs with tools to support activities for which they may not know the wider significance due to lack of training. Jones et al.[37] (the qualitative evaluation of the Zurovac et al.[23] RCT) are open in the weaknesses of this aspect of their work: "it was clear that many of the participants believed that the type of training they received did not provide them with an adequate understanding of the importance of the new knowledge, or of the positive outcomes that a change in practice could bring" (p.4). They also noted that "few participants mentioned the messages in terms of 'support supervision', rather that they were made to feel somewhat guilty for not employing proper practice".[37] This is not surprising as using mobile technology for such a nuanced task as supportive supervision is challenging. Our previous work has demonstrated how CHWs and their supervisors used mobile messaging platforms (e.g. Whatsapp) to engage in virtual one-to-one, group, and peer-to-peer forms of supportive supervision.[38] Additional research is needed to investigate how technology can be embedded within successful supportive supervisory systems.

The one study that matched most closely what is known about mobile and workplace learning was Martínez-Fernández et al.[28] In this study, mobile phones were used by 125 CHWs "to make consultations regarding issues about which they are unsure; send full epidemiological and clinical information related to the cases they attend; receive continuous training, and perform community health promotion and prevention activities through distance learning sessions" (p. 284). After being given some technical training on phone use and data collection, they were provided with basic initial training in vital signs monitoring, and in the identification of signs of distress in children and pregnant women. The CHWs could use their phones for tele-consultations with medical staff (gynaecologists, paediatricians, internists and surgeons). Quarterly face-to-face training was augmented by tele-training. It is very clear that this intervention had a much stronger focus on 'work processes as a by-product of learning' including 'consultation' and 'embedding on-going training within the intervention design', a fact overlooked by the other interventions. The key findings are summarised in Table 1.

Key discussion points	**Implications**
There is a large overlap between the primary studies included in the systematic reviews, but little overlap in their allocation to intervention categories.	Potential for misclassification and further research is required to determine more robust classification categories.
As a result, there seems to be little agreement between reviews regarding what type of interventions can directly facilitate CHWs' education and training and how such learning can be defined.	There is not a coherent evidence base due to a lack of primary studies explicitly detailing the role of their interventions in learning and training.
We used educational research to develop a refined coding tool	The coding tool we used is available in Supplementary Material 6. Details of the theories it is based on is available in Supplementary Material 7. The tool was designed to be refined as the evidence base develops.
The need to produce evidence on how mobile technology can support reflective and interactive forms of CHWs' education and training, particularly coaching, supervision and mentoring, remain critically neglected overall.	A new interdisciplinary research agenda on training and education in mHealth, that builds on existing global health research and moves away from information dissemination model of learning is needed.
Focus on the developmental needs of CHWs to improve their practice	Targeted training approaches that use new technologies in innovative ways to promote CHWs' CPD are required. In particular, theories of work-based learning need to be better implemented.
The review has highlighted the need for	CHWs' decision-support tools would

more evidence on the precise nature of CHWs' education and training that can be supported by mHealth interventions.	have the means to offer insights into CHWs' learning, but studies generally do not explore learning aspects of these tools. At most, learning is seen as a positive by-product. We argue that this should include better documentation of learning practices in primary studies.

Table 1: Summary of the implications of our key discussion points.

Limitations

Our scoping review only covers systematic reviews published up to 2017, which means that only primary studies published up to 2015 were included. Our work is open to the biases inherent in relying on existing systematic reviews. However, the scoping review seems well designed to deal with these: First, we included a large number of systematic reviews (n=16), ensuring a wide coverage of primary studies included in these reviews. Second, we further re-analyse the studies included in these reviews to mitigate any quality concerns regarding the included systematic reviews themselves. In targeting secondary literature, we rely on education researchers' interpretation of mobile learning and workplace-based learning in order to unpack patterns in categorisations and conceptualisations. We have made this process transparent through inclusion of our coding tool (see Supplementary Material 6) and references.[9,10,38-49] Other researchers may take an alternative perspective on this literature.

Conclusion

The findings from this scoping review suggest the mHealth literature is in danger of overclaiming regarding its ability to promote CHWs' education and training within a community work context. Studies claiming to have an educational component to their mHealth intervention were not often informed by educational theory nor was the educational approach taken well documented. The review has highlighted the need for more evidence on the precise nature of CHWs' education and training that can be supported by mHealth interventions. This needs to start with improved categorisation, building on educational frameworks and richer accounts of learning.[39] The mechanisms for achieving educational outcomes are still unknown and educational theory should be embedded in the design of an intervention as well as in its evaluation – for which further cross-disciplinary work between global health and education is needed. Appropriate models of technology-enhanced learning[40-42] and extended use of educational theories will enable the development of much needed robust evidence on the role of technology in supporting CHWs' education and training in mHealth. Achieving this will be challenging, given the complex realities of using mHealth in low-income settings. Nevertheless, we promote[50] the use of training tools which employ empirically proven equitable pedagogic strategies to maximise learning as a continual process of 'participation',[43] within a social justice approach to global health.[51]

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Competing interests
None declared

Data Sharing
All relevant data are within the paper and supporting material.

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Figure legends

Figure 1 PRISMA flow chart of identification and inclusion of studies

Figure 2 Overview of mHealth intervention categories taken directly from the 16 included systematic reviews. The primary studies were often characterised differently by different systematic reviews.

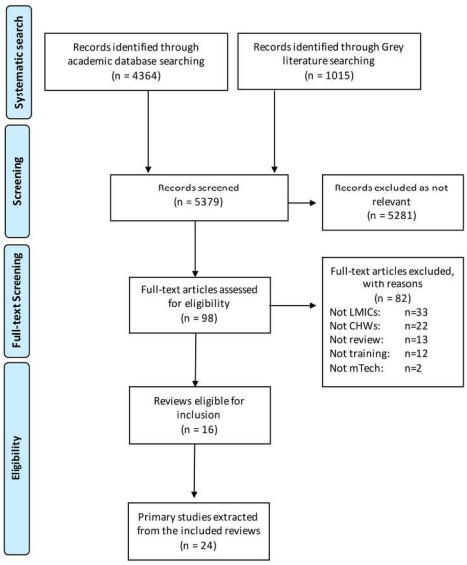

Figure 1 PRISMA flow chart of identification and inclusion of studies

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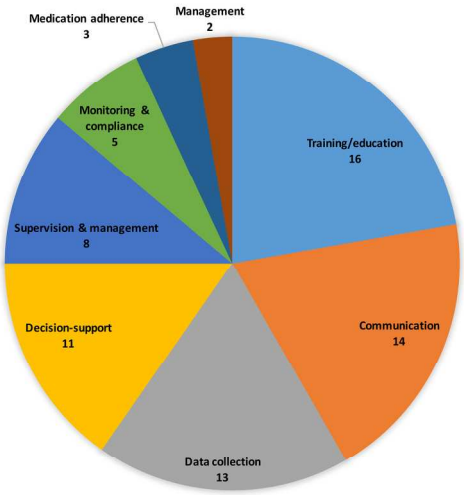

Figure 2 Overview of mHealth intervention categories taken directly from the 16 included systematic reviews. The primary studies were often characterised differently by different systematic reviews.

190x107mm (300 x 300 DPI)

Supplementary Material 1: Search terms

Search terms:

Mhealth terms: (mhealth OR m-health OR “mobile health” OR ((mobile technolog* OR “mobile phone” OR “mobile device” OR phone OR tablet OR PDA OR “personal digital assistant” OR iPAD OR iPOD OR “smart phone” OR “feature phone” OR app OR “mobile application”) AND Health) OR ((“Text messag*” OR “short messag*” OR SMS OR “social media” OR “mobile communication”) AND health)

Review terms: (“systematic review” OR “literature review” OR “meta-analysis” OR “review of reviews” OR “systematic map” OR “evidence map” OR “evidence gap map” OR “evidence synthesis” OR “research synthesis”)

Developing country term: (“developing countr*” OR LMICs OR “low- and middle-income countr*” OR “low and middle income countr*” OR Africa OR Asia OR “Latin America” OR “East* Europe” OR “majority world” OR “global south”)

Supplementary Material 2: Systematic search records

Source	*Terms*	*Results*
Google Scholar	("mobile health" OR mHealth) AND review AND ("developing countries" OR LMICs OR Africa OR Asia OR Latin America")	500: 51
	Update 30 May 2017 (August 2016-May 2017)	500: 14
Google	(Mhealth OR "mobile health") AND review	500: 34 Dups 18
	Update 30 May 2017 (August 2016-May 2017)	500: 10 Dups: 7
3ie	(Mhealth OR "mobile health")	1:1
	Update 30 May 2017 (August 2016-May 2017)	7:3 Dups: 4
Cochrane	(Mhealth OR "mobile health")	4: 0
	Update 30 May 2017 (August 2016-May 2017)	3: 0
Campbell	(Mhealth OR "mobile health")	0
	Update 30 May 2017 (August 2016-May 2017)	0
CINAHL	Master string	1247*: 64
	Update 30 May 2017 (August 2016-May 2017	5: 2 Dups: 2
Pubmed	(Mhealth OR "mobile health") OR ("mobile technology*" AND health) AND ("systematic review" OR "literature review")	1008: 41
	Update 30 May 2017 (August 2016-May 2017)	46: 5 Dups: 4
Medline	Master string	1247*: 64
	Update 30 May 2017 (August 2016-May 2017	11: 7 Dups: 7
PsychInfo	(Mhealth OR "mobile health")	211*: 12
	Update 30 May 2017 (August 2016-May 2017)	13
ERIC	(Mhealth OR "mobile health")	211*: 12
	Update 30 May 2017 (August 2016-May 2017)	13
Education Full-text	(Mhealth OR "mobile health")	211*: 12
	Update 30 May 2017 (August 2016-May 2017)	13
Isl web of science	(Mhealth OR "mobile health") OR ("mobile technology*" AND health) AND ("systematic review" OR "literature review")	465: 82
	Update 30 May 2017 (August 2016-May 2017)	111: 14 Dups: 12

Supplementary material 3: List of included systematic reviews and primary studies

Systematic reviews included in the scoping review

1. Hall, C.S., Fottrell, E., Wilkinson, S. and Byass, P., 2014. Assessing the impact of mHealth interventions in low-and middle-income countries–what has been shown to work?. *Global health action*, *7*(1), p.25606.
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Supplementary Material 4: Summary of the included primary studies

Primary study	Country	Area	Tool	Methodology	Number of participants / sample (n)[1]
Alam (2010)	Bangladesh (urban)	MCH	Custom design	Case study	27 CHWs, 6 supervisors
Andreatta (2011)	Ghana (rural)	MCH	SMS	Case study	8 traditional birth attendants, 2 midwifes
Barrington (2010)	Tanzania (rural)	Malaria	SMS	Pilot study	Health facility workers at 129 rural clinics
Chang (2011)	Uganda (rural)	AIDS	SMS	Mixed methods: RCT and qualitative process evaluation	29 Peer health care workers
Derenzi (2012)	Tanzania (rural and urban)	Chronic care (esp. HIV)	CommCare	Quasi-experimental: multiple experiments and designs	87 CHWs n=30
Diero (2006)	Kenya (rural)	Respiratory	Palm Pilot PDA	Case study	CHWs, unclear
Zurovac (2011)	Kenya (rural)	Malaria	SMS	Cluster RCT	119 CHWs

[1] Where not explicitly stated to the contrary, the number of intervention participants and the research sample was synonymous.

Gisore (2012)	Kenya (rural)	MCH	Phone and weighting scales	Case study	474 village elders
JSI (2013)	Rwanda (unclear)	Supply chain Management	Mobile phone	N/A (grey lit)	371 CHWs
Khan (2012)	Pakistan (urban)	TB	Custom design	Quasi-experimental: retrospective controlled	Community laypeople as TB screeners, unclear
Lemay (2012)	Malawi (rural)	Family planning/reproductive health/ HIV/AIDS knowledge	Frontline SMS	Mixed methods	638 CHWs
MacLeod (2012)	Ghana (rural)	MCH	MoTECH	Technical evaluation study	Community health volunteer, unclear
Mahmud (2010)	Malawi (rural)	Communication		Pilot study	75 CHWs
Ngabo (2012)	Rwanda (rural)	MCH	RapidSMS	Pilot study	432 CHWs
Palazeus (2013)	Mexico & Guatemala (rural)	Dosing	CommCare	Descriptive survey and qualitative interviews	17 CHWs
Ramachandran (2010)	India (rural)	MCH	Java applet	Case study	7 rural health workers

Svoronos (2010)	Tanzania (rural)	MCH	CommCare	Pilot study	5 CHWs
Tomlinson (2009)	South Africa (peri-urban)	Data collection	Java applet	Pilot study	24 CHWs
Blaschke (2009)	Malawi (rural)	Child nutrition	RapidSMS	Pilot study	Health surveillance assistant, unclear
Munro (2014)	Liberia (rural)	MCH	SMS	Quasi-experimental: Before/after design	99 traditional birth attendees
McNabb (2015)	Nigeria (urban)	MCH (ANC)	CommCare	Quasi-experimental Before/after design	152 CHWs, 20 supervisors
Martínez-Fernández (2015)	Guatemala (rural)	Infant mortality	Custom design	Case study	125 Community facilitators
Little (2013)	Ethiopia (rural)	Maternal health	Custom design	Case study	20 Health extension workers
Surka (2015)	South Africa (urban)	CVD screening	CommCare	Mixed methods pilot study	24 CHWs

Supplementary Material 5: Categorisation and re-analysis of included studies

COLUMN 1			COLUMN 2				COLUMN 3			
Primary study	**Intervention allocation**	**Agreement in allocation between systematic review**	**Reclassification of intervention as WPL?**				**Reclassification of intervention as ML?**			
			Learning by-product of work	*Learning within work*	*Learning for work*	*Reclassification: fits WPL?*[2]	*Personalisation*	*Authenticity*	*Collaboration*	*Reclassification: fits ML?*
Alam (2010)	(1) Supervision & monitoring[c]; (2) Data collection[ab]	2 different allocations	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Andreatta (2011)	(1) Data collection[b]; (2) Training & education[ad]; Training; (3) Medication adherence[e]	4 different allocations	No evidence	No evidence	Training in the use of a data reporting protocol.	No	No evidence	No evidence	No evidence	No
Barrington (2010)	(1) Data collection[b]; (2) Training & education[a]; (3) Management[e]	2 different allocations	No evidence	No evidence	Training in the use of a mobile phone.	No	No evidence	No evidence	No evidence	No
Chang (2011)	(1) Communication[f] (2) Training &	4 different allocations	No evidence	• Asking questions	No evidence	Secondary	No evidence	No evidence	No evidence	No

[2] Secondary refers to a study relating to workplace-based and/or mobile learning only superficially. This can be caused by a lack of detailed reporting of intervention design and implementation or by workplace-based and/or mobile learning only being a minor aspect of the applied intervention that is not fully developed.

	education[e]; (3) Monitoring & compliance[eg]);			• Getting information • Locating resource people						
DeRenzi (2012)	(1) Managament[f] (2) Communication[ab] (3) Monitoring & compliance[g] (4) Health system support[d]	4 different allocations	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Diero (2006)	(1) Standards and guidelines[d]	Single review	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Zurovac (2011)	(1) Decision-support[af] (2) Monitoring & compliance[edg] (3) Training & education[ad]	3 different allocations		• Giving and receiving feedback • Use of mediating artefacts	Being supervised	Yes		Contextualisation of knowledge in practice contexts		Yes
Gisore (2012)	(1) Data collection[f] (2) Training & education[d]	2 different allocations	No evidence	No evidence	Training on tool usage	No	No evidence	No evidence	No evidence	No
JSI (2013)	(1) Supervision[a] (2) Communication[a]	Single review	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Khan (2011)	(1) Decision-support[f]	Single review	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Lemay (2012)	(1) Communication[abd]	Agreement	No evidence	• Asking questions	No evidence	No	No evidence	No evidence	No evidence	No
McLeold (2012)	(1) Supervision[a] (2) Communication[a]	Single review	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Mahmud (2010)	(1) Training & education[de] (2) Communication	3 different allocations	No evidence	No evidence	Training on tool usage	No	No evidence	No evidence	No evidence	No

	(3) Data collection[a] [af]									
Ngabo (2012)	(1) Communication [af] (2) Supervision[a] (3) Medication adherence[e]	3 different allocations	No evidence	No evidence	Training on tool usage	No	No evidence	No evidence	Communication	No
Palazuelos (2013)	(1) Training & education[ai] (2) Medicine adherence[ai]	Agreement	No evidence	No evidence	Training on tool usage	No	No evidence	No evidence	No evidence	No
Ramachandran (2010)	(1) Education & training[ad]	Agreement	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Svoronos (2010)	(1) Training & education[a] (2) Decision support[a] (3) Monitoring & compliance[d] (4) Supervision & management[d] (5) Data collection[b]	5 different allocations	• Tackling challenging tasks and roles • Problem solving • Standardisation of practice	• Giving and receiving feedback • Use of mediating artefacts	• Being supervise • Training on tool usage	Yes	No evidence	Contextualised feedback & practice support	No evidence	Yes
Tomlinson (2009)	(1) Supervision and management[ad] (2) Communication [a] (3) Data collection[ef]	3 different allocations	No evidence	No evidence	No evidence	No	No evidence	No evidence	No evidence	No
Blaschke (2009)	(1) Decision-support[f] (2) Data collection[g]	2 different allocations	No evidence	• Learning from mistakes • Giving and receiving feedback	• Being supervised • Training on tool usage	Yes	No evidence	Contextualised feedback & practice support	No evidence	Yes
McNabb (2015)	(1) Decision-support[m] (2) Data collection[l]	2 different allocations	Tool forces practice decisions	No evidence	No evidence	Secondary	No evidence	No evidence	No evidence	No

Martı´nez-Ferna´ndez (2015)	(1) Decision-support[l] (2) Data collection[l] (3) Training[l]	Single review	No evidence	Consultation and logistical support.	Using phones for CPD	Yes	Distance learning using mobile tools			Yes
Little (2013)	(1) Data collection[alno] (2) Provider-Provider Communication[n]	2 different allocations	Tool forces practice decisions	No evidence	No evidence	Secondary	No evidence	No evidence	No evidence	No
Munro (2014)	(1) Data collection[lo]	Agreement			Learning to use and implement data collection Training on tool usage	Secondary	No evidence	No evidence	No evidence	No
Surka (2014)	(1) Data collection[n]	Single review	Tool forces practice decisions	No evidence	Training on tool usage	Secondary	No evidence	No evidence	No evidence	No

a=Agrawal (2015); b=Chib (2015); c=Goel (2013); d=Braun (2015); e=Aranda-jan (2014); f=Hall (2014); g=Kallander (2014); h=Hurt (2014); i=O'Donovan; j=Peiris (2014); k=Bloomfield (2014); l=Colaci (2016); m=Adepoju (2017); n=White (2016); o=Amoakoh (2016); p=Tian (2017)

The superscripts a–o above refer to the systematic reviews in which this study has been included. None of these primary studies were covered by Tian (2017).

Supplementary Material 6: Coding tool

Theory of learning	Learning processes		Studies coded to constitute workplace and mobile learning			
			Zurovac (2011)	Svoronos (2010)	Blaschke (2009)	Martinez-Fernandez (2015)
Workplace based learning	**Work Processes** with learning as a by-product	Participation in group processes				
		Working alongside others				
		Consultation				YES
		Tackling challenging tasks and roles				
		Problem solving				
		Trying things out				
		Consolidating, extending and refining skills	YES			YES
		Working with				YES

		clients				
	Learning Activities located **within** work or learning processes	Asking questions				
		Getting information	YES	YES	YES	YES
		Locating resource people				YES
		Listening & observing				
		Reflecting				
		Learning from mistakes				
		Giving and receiving feedback				
		Use of mediating artefacts				
	Learning Processes at or near the workplace	Being supervised		YES (see our previous table for details)		YES
		Being coached				YES

		Being mentored				
		Shadowing				
		Visiting other sites				
		Conferences				
		Short courses				YES
		Working for a qualification				
		Independent study				
Mobile learning	Personalisation	Agency	Medium: improved participants' ability to treat	Low: re-enforce target behaviour		High: able to call for help as needed
		Customisation				
	Authenticity	Situatedness	High: messages received at work (but in the linked paper noted that it was not linked to	High: phones used at work	Medium: feedback loops for the HSA	High: phones used at work

			training)			
		Contextualisation				
	Collaboration	Data sharing				
		Conversation				High: based on communication

Supplementary Material 7: Background on Education Research

We briefly summarise the most salient and relevant ideas from Eraut & Hirsh [9] on workplace-based learning and Kearney et al. [10] on mobile learning.

Workplace-based learning

Research in workplace-based learning allows for the categorisation of the varied nature of training in the workplace. Three categories are relevant to understand how CHWs can be engaged in training while working in their communities: (i) a work practice *within which* learning occurs (e.g. problem solving); (ii) a stand-alone *learning process* during work (e.g. being supervised); and (iii) a time-limited *learning activity* (e.g. giving/receiving feedback or engaging in reflection) on aspects of work practice. Each way in which work practices can support CHW learning were reviewed for each primary study.

Mobile learning

Research in mobile learning has critiqued simplistic conceptualisations of mobile learning as the ability to support anytime, anywhere learning. This ways of framing the use of mobile technologies is seen as particularly out-of-date as technology has developed to a point where authenticity, collaboration and personalisation can provide new insights into mobile learning practices [10]. The ways in which each of these three aspects supported CHW learning were reviewed for each primary study. As such, our framing draws on education researchers' commonly held view of mobile learning a as a socio-cultural form of learning [45-48]. The key point is a focus on how technology supports the learner to produce new knowledge while interacting, often with others, within their environmental context. This way of thinking about the use of technology has aligns strongly with calls by medical educators for the implementation of socio-cultural theories [49] as they "offer a best-fit exploration and explanation" [50: 150] of learning and training for the workplace context. It is important to determine how this line of thinking is relevant for mHealth and CHWs.

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Page 1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Page 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	Page 3-4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	Page 2
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	Page 4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	Page 5-6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	Page 5; Supplementary material 2
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supplementary material 1 and 2
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	Page 6-7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	Page 7-8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Supplementary material 4,5,6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	Page 7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	Not applicable

PRISMA 2009 Checklist

			as no formal synthesis of study results
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	Not applicable as no formal synthesis of study results

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	Page 8; 13
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	Not applicable as no formal synthesis of study results
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Page 8
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Supplementary material 4,5,6
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Not applicable as no risk of bias conducted
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Not applicable as no formal synthesis of study results
Synthesis of results	21	Present the main results of the review. If meta-analyses are done, include for each, confidence intervals and measures of consistency	Page 8-13 Supplementary material 5
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Page 8; 13

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Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Not applicable as no formal synthesis of study results
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	Not applicable as no formal synthesis of study results
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	Page 8; 13
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	Page 11-13
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	Page 14

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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