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REVIEW

The use and impact of mHealth by community health workers in developing and least developed countries: a systematic review

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Abstract

Purpose In places without adequate health facilities, community health workers (CHWs) are employed by local governments to help families with health promotion activities. However, amidst the difficulties, mobile health applications (mHealth) are being increasingly developed in order to facilitate the work of the CHW. This work is a systematic review (SR) of the use of mHealth and the impact it has had so far in improving the health system and service delivery by the CHWs.

Method This SR was based on the 27 PRISMA recommendations. We used the PICOS tool to specify the components of this review (eligibility criteria, keywords, etc.) and the StArt software to organize and control the articles exported from digital databases (PubMed, SciELO, etc.) from 2009 to 2019. The studies accepted for reading in their entirety underwent an analysis of their risk of bias, through the Cochrane risk of bias tool.

Results The studies showed that mobile health intervention has a strong link with health care, mainly in the provision of community care services, maternal and child health care, sexual diseases, and infectious diseases, among others. This happens especially in rural or other areas of difficult access, such as countries in Africa, which occupies 61% of selected articles. However, it is believed that these applications have great potential and could help CHWs provide better disease prevention care.

Conclusion The use of mHealth by CHWs has become typical in many regions of the world and is believed to have the potential to improve health service delivery in hard-to-reach or resource-limited settings.

Keywords mHealth · Community health worker · Systematic review · Mobile applications · eHealth · Health promotion · Primary health care · Mobile health · Agent health · Volunteer health worker · Community health assistant · Family health · Prevention of diseases

Introduction

Primary health care (PHC) has been highlighted as a health organization strategy that responds in an assertive and systematized way to the health needs of a region or population, besides enabling preventive and curative actions and guiding families and communities (Oliveira and Pereira 2013).

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In this context, there are multidisciplinary teams composed of doctors, nurses, auxiliaries or technicians, and community health workers (WHO 1978). In the literature, the importance of the CHW is highlighted, due to the elevated level of information exchange about popular health, medical, and scientific knowledge between them and the community they serve. Usually, CHWs are people that belong to the community, and when hired by the municipality, they work in the same community in which they live. Another highlight of the PHC system is the health system improvement and the cost reduction due to the reduction in the number of doctors and nurses required (Buss 2000; Cipriano and Ferreira 2011; Duarte et al. 2007).

Despite their importance, CHWs do not need any specific academic qualification, and they are subject to the training or education carried out by the municipality (Nascimento and Correa 2008). Because of this, systemic barriers arise, such as lack of training and adequate supervision, which lead to the poor use of resources of the health unit and the poor quality of service rendered to the community. This lack of quality manifests as missing or incorrect data in data collection, duplication of work, difficulties in transmitting information to families and health teams, disorganized scheduling, or nonuse of the available mobile applications by CHWs (Duarte et al. 2007; Nascimento and Correa 2008; Wai and Carvalho 2009).Different instruments that use technology to support CHWs were found during the study, especially the mobile devices for data collection, education, visit scheduling, and health notifications. Some SRs about these technologies were found, which demonstrated the positive impacts on the community and the CHW, who were able to act outside the clinical setting, in remote areas or difficult-to-reach communities, making life easier for those patients who have difficulty attending hospitals (Aranda-Jan et al. 2014; Braun et al. 2013; Labrique et al. 2013; White et al. 2016).

However, these SRs do not mention risk study bias, leaving the quality of these mobile technologies and how much they represent in the daily work of the CHW in doubt. According to the PRISMA statement (Galvão et al. 2015), in items 12 and 15, it is recommended that the quality of these studies be assessed individually and/or together, specifying the method used and the results achieved.

In this SR, we chose the Cochrane Collaboration tool to assess the risk of study bias (Higgins et al. 2011; Sterne et al. 2016), the PICOS tool (Participants, Interventions, Comparators, Results, and Study Design) to support eligibility criteria and data extraction from studies (Santos et al. 2007), and the World Health Organization's (WHO) "Digital Health Intervention Classification V.1.0" to categorize the technologies found. The systematic review protocol was published in the PROSPERO under record CRD42018085427.

The objective of this SR was to locate interventions made on community health workers in the literature, based on mHealth and the kind of benefits that were generated for these professionals in their community. Another objective of the review was to assess the quality of these mobile technologies and how they can improve planning in primary health care.

Method

The present study followed the 27 recommendations of the PRISMA statement, mainly the 5th item, which recommends the registration of the review protocol (Galvão et al. 2015) (see Appendix A). This protocol was registered under the number CRD42018085427 in PROSPERO (International Prospective Record of Systematic Reviews) and can be accessed at http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42018085427.

Search strategy and selecting studies

Systematic searches were performed on PUBMED, SCIELO, ESBCO, DOAJ, Periodic CAPES, ACM Digital Library, IEEE Xplore Digital Library, ScienceDirect (SD), Web of Science (WS), One File, Wiley, and Sage databases. The search was performed with the combination of categories, mobile health (mHealth), and CHW. The terms were *mhealth apps*, *mobile internet*, *geo location apps*, *smartphone*, *cellular*, *community health workers*, *CHW*, *agent health*, *health promotion*, *family health*, or *prevention of diseases*. No restrictions were imposed regarding language or publication date. The last search was performed on August 4, 2020.

The PICO tool (Santos et al. 2007) was used to specify the components related to the identified problem, that is, to define the eligibility criteria, search keywords, and variables for extraction and to structure the research question. How the PICO tool was used in this SR is provided below:

- (P) Community health workers (CHW) or volunteer health worker (VHW) or community health advisors or agent (CHA)
- (I) Mobile application native or web
- (C) Other applications or no comparison
- (O) Increased productivity to the health system, reduction of CHW performance errors, especially in data collection

After filling the PICO tool, it was possible to determine the main questions (Q) of this SR. Q1 – Can mobile applications increase and/or improve the health care professionals' performance in your community? Q2 – Do the data obtained by these technologies allow better planning in the health area?

Eligibility criteria

The selection of the articles was based on the identification of the titles and abstracts of interest, defined in the PICOS tool. The selected articles were then filtered using the eligibility criteria:

- Inclusion criteria: Only studies that were published in complete texts and publications of the last 10 years (2009–2019) and relating the variables defined in the PICO tool were included.
- Exclusion criteria: Hypothetical models, books, systematic review, congress proceedings, theses, dissertation, and articles with incomplete text were excluded.

Data selection and extraction

This study included articles that mentioned the use of mobile devices by CHWs for improving health service quality, meaning any intervention using cell phones, personal digital assistants (PDA), smartphones, tablets, phablets, and hybrid laptops. The interventions that met the inclusion criteria were organized and categorized into two groups: (1) carried out by health workers or (2) involving communication between health services and the population. In each of the groups cited above, there are subcategories: group 1, education, diagnosis and management, communication and information gathering, and group 2, medical advice notices and medical examination results (see Appendix B).

Primary outcomes were defined as any measure that improved the delivery of health services. Secondary outcomes were defined as any measure related to the behavior of the health agent in the health care system. The results are important to distinguish the type of technique or usability questionnaire that was applied on the CHW and on the families during these interventions. The StArt v3.0.3 software was used in this study for the systematic review (Fabbri et al. 2010). The StArt software helps the construction of systematic reviews and meta-analysis in three phases:

1. Planning – Determination of rules and characteristics of the review, i.e., eligibility criteria, PICO, researched databases, keywords, and data extraction fields, among others.
2. Execution – There are three stages in the execution phase: The first stage was to identify the studies in the databases, that is, within the StArt, the search sessions were recreated to allow the import of the articles; the second stage dealt with the selection of these articles using the eligibility criteria; and the last stage performed the data extraction.
3. Summarization – The extracted data were transformed into graphs and exported to the CSV format.

Firstly some extraction data were defined in the StArt including the type of study, the number of participants, target audience, region/country, health issue addressed, the type of device, the type of operating system, the form that this technology uses to communicate, the purpose of the technology, the interoperability involved, the tools used for development, if any usability testing had been done, whether it had been shared in open source tools, if the results offer any modification in the CHW routine, families, and/or health programs (see Appendix C).

The data extraction and evaluations were performed by a single rater and verified by an independent reviewer, who then met to discuss the findings. No divergences of opinion were found between the rater and the independent reviewer.

Data analyses

The experimental and nonexperimental studies that met the inclusion criteria underwent a careful individual evaluation of the methodological quality through the Cochrane RoB tool and Cochrane ROBINS-I (Higgins et al. 2011; Sterne et al. 2016). Each tool is divided into two parts, and they are composed of seven domains. For experimental studies, the following were evaluated: random sequence generation, allocation concealment, and blinding of participants and professionals. In nonexperimental studies, the following were evaluated: bias due to confounding and the bias in the selection of participants into the study. The bias in the measurement of interventions was evaluated as follows: bias due to departure from intended intervention, bias due to missing data, bias in the measurement of outcomes, and bias selection of reported results.

The first part of each tool refers to the description of what was reported in the evaluated study and needs to have enough details and information for a good judgment. The second part is the bias risk judgment for each of the domains analyzed, which can be classified into three categories in the Cochrane RoB tool (low risk of bias, high risk of bias, or risk of uncertain bias) and five categories in the ROBINS-I (low, moderate, severe, critical risk of bias, or no information to assess the risk of bias). For the judgment of each domain, a summary was made available by each Cochrane tool, which helps in the decision-making, making the judgment more transparent in all domains.

In this data analysis, a retrospective was conducted on the main tools related to the CHW, focusing on mobile technologies and how they could be used to improve performance, education, awareness, and access to data for the strengthening of health information systems. It was also considered how mHealth could support patient monitoring, clinical decision-making, and drug and supplies tracking. “Classification of Digital Intervention in Health V.1.0” of the World Health Organization (WHO 2018) was used to categorize the technologies that strengthen the health system.

Results

Characteristics of included studies

In six search sessions (from July 2019 to July 2020), we obtained 3255 documents: 1725 from PubMed, 335 from ScienceDirect, 325 from OneFile, and 870 from EBSCO, DOAJ, Scopus, and IEEE. These documents were exported to StArt for better control and definition of article status (accepted, rejected, or duplicated). There was a reduction to 2673 documents due to the publication date filter (2009–2019) and articles that were duplicates. Most studies were excluded because they were not based on mobile technologies for CHWs, either because they did not provide any description about the results achieved or because they were conference summaries. Only 582 articles passed the eligibility criteria through a complete reading. Finally, 62 articles were included in the SR. Figure 1 illustrates the stages of this systematic review and Table 1 the characteristics of included studies.

These 62 publications reported mobile health projects for CHW in 23 countries. A majority of the projects (52%) took place in developing countries, 38% were in underdeveloped countries, and 10% were in developed countries. It was observed that most of these projects were from Africa (61%), followed by the Americas (20%) and Asia (18%). Moreover, most of these projects were based in rural areas (76.2%), followed by urban/rural (14.3%) and urban (9.5%) areas. Figure 2 illustrates the number of publications by country.

Quality assessment

The analysis revealed that the assessment related to CHWs and mobile health presented substantial variations in research design and methods used. Many studies used mixed methodologies (quantitative and qualitative analysis together), while others preferred to use only qualitative or quantitative results. A total of 36 studies were considered nonexperimental, because they demonstrated the validation of a mobile health technology or application without any evaluation of results or impacts. Moreover, 10 studies were considered quasi-experimental, because they presented a control group and compared the intervention based on mobile technology to a paper intervention but without randomization of the participants. Finally, 17 experimental studies were designed with a random selection of control and intervention groups. Table 2 illustrates the sample size and the intervention time for each study design.

The 36 nonexperimental studies presented a median sample size of 33 CHWs (min = 3, max = 432). The average intervention time was 160 days (min = 1, max = 1095).

The 10 quasi-experimental studies presented a median of 94.5 CHWs (min = 3, max = 474). The average intervention time was 122 days (min = 7, max = 547).

The 17 experimental studies presented a median of 124 CHWs (min = 3, max = 3775). The average intervention time was 243.5 days (min = 3, max = 1004).

The 62 studies presented a median of 42.5 CHWs (min = 3, max = 3775). The average intervention time was 160 days (min = 1, max = 1096).

Experimental and quasi-experimental studies were categorized and judged by the Cochrane RoB tool. Nonexperimental studies were categorized and judged using ROBINS-I. Appendix D shows the bias risk summary of RoB and ROBINS-I.

Figure 3 illustrates the percentage of study quality for experimental and quasi-experimental studies.

Nonexperimental studies were categorized and judged using ROBINS-I. Figure 4 illustrates the percentage of study quality for nonexperimental studies.

Devices and technologies used to CHW

This review revealed that there is a great technological variety in the devices and systems used in CHW intervention in the last 10 years. The first appearance of mHealth for CHW was in 2010 by Haberer et al. The highest index of publications was in 2015 with 11 articles. In 2019, there were 5 articles with the same goal, with the last one being in September 2019 by Hackett et al.

All the studies unanimously aimed to improve the delivery of health services provided by CHWs using mHealth. However, in this study, considering that only the functions most used by them have been reported, it was decided to categorize them through the "Classification of Digital Intervention in Health V.1.0" of the WHO. Figure 5 illustrates this classification; 71% of the studies presented a health system challenge (HSC) related to the lack of access to information or data, 23% in communication obstacles, and 6% in healthcare provider's poor adherence to clinical guidelines.

All studies related HSC to some health issue. Figure 6 illustrates an infographic related to HSC and health problems.

In 36 of the studies (58.1%), the projects were focused on a specific disease or treatment, mainly in the areas of maternal/child health care (24%), sexual diseases (11.3%), infectious diseases (8.1%), and others. In 26 of the studies (41.9%), health promotion and disease prevention stood out; that is, these surveys involved all health issues cited to inform professionals or collect population data.

Regarding the digital intervention in related health (DHI) used in the HSC, 71% of the studies presented some type of health management information system (HMIS) or electronic medical record, with the objective of "routine collection and management of health indicator data" or "storage and aggregation." 23% used telemedicine to "provide prompts and alerts based according to protocol" or "communication and performance feedback to healthcare provider(s)." 6% used learning and training system to "learning and training system healthcare provider(s)" or "assess capacity of healthcare provider(s)." Figure 7 illustrates an infographic regarding the types of technologies or devices related to DHI in CHW

In 60% of the studies, a basic cell phone (which only supports voice calls and/or text messages) was used, while the other 40% used some device with an operational system (Android, iOS, Windows, etc.).

In 37.7% of the studies, SMS/MMS technology was the most used on their devices to send and/or receive text, audio, or video messages. On the other hand, 23% of the studies featured a mobile app for Android smartphones. Finally, in 16.4% of the studies, the type of technology applied was not reported.

Table 1 Characteristics of included studies

Author (year)	Objective	Country and region	Health issues	Study design	Participants (type and no.)	Key findings
Haberer et al. 2010	Notification or Alerts	Uganda (rural)	Maternal health	Nonexperimental (qualitative)	Health care-givers = 19	Participant interest and participation rates were high; however, weekly completion rates for adherence queries were low (0–33%), most commonly due to a misunderstanding of personal identification
Ramachandran et al. 2010	Library media	India (rural)	Maternal health	Quasiexperimental (quantity/-quality)	Health worker = 52	The dialogic messages significantly improve the quality of counseling sessions and increase discussion between health workers and clients.
Hoffman et al. 2010	Library media	Kenya (urban)	Respiratory diseases	Quasiexperimental (quantity/-quality)	Agent health =3	The health professionals appear empowered by the ability to communicate with each other and appear receptive to remote MDOT and health messaging over mobile. Further research should be conducted to test the MDOT
Lim et al. 2011	Data collect	Singapore (rural)	Promotion health	Nonexperimental (quality/-quantity)	Voluntary health = 175	Using mobile phones to seek health information was found to be complementary to online health information seeking and can be regarded as an alternative source to the internet for seeking health information
Andreatta et al. 2011	Data collect	Ghana (rural)	Maternal health	Nonexperimental (quantitative)	Health assistant = 10	The results indicate that it is possible to train professional and traditional birth attendants to use cell phones to report health-related outcome data via a speci-fied protocol
Zurovac et al. 2011	Notification or alerts	Kenya (rural)	Malaria	Experimental (quantitative)	Agent health = 119	In resource-limited settings, malaria control programmers should consider the use of text messaging to improve health workers' case management practices
Rotheram-Borus et al. 2011	Data collect	South Africa (rural)	HIV/AIDS	Experimental (quantitative)	Health care-givers = 1200	Data collection with cellular phones are innovative and effective in low-resource settings
Florez-Arango et al. 2011	Data collect	Colombia (urban)	Maternal health	Experimental (quantitative)	CHW=50	The development of digital content on medical guidelines and distributed on cell phones can improve the performance of community health workers, especially in the quality of care (33.1%)
Chang et al. 2011	Data collect	Uganda (rural)	HIV/AIDS	Experimental (quantity/-quality)	CHW =29	Qualitative analyses found improvements in patient care and logistics and broad support for the mHealth intervention among patients, clinic staff, and PHWs. Key challenges identified included
Rajput et al. 2012	Data collect	Kenya (rural)	HIV/AIDS	nonexperimental (quantity/-quality)	CHW = 57	Variable patient phone access, privacy concerns, and phone maintenance. Users of the system felt it was easy to use and facilitated their work. The system was also more cost-effective than pen and paper alternatives
Jones et al. 2012	Notification or alerts	Kenya (rural)	Malaria	Nonexperimental (quantitative)	CHW=24	The results suggest a high uptake of all CHWs during the intervention, especially in receiving text messages about key health information or news
Gisore et al. 2012	Data collect	Kenya (rural)	Maternal health	Quasiexperimental (qualitative)		

Table 1 (continued)

Author (year)	Objective	Country and region	Health issues	Study design	Participants (type and no.)	Key findings
					Voluntary health = 474	Data collection through cell phones allowed the discovery of pregnancy cases in the community
Ngabo et al. 2012	Notification or alerts	Rwanda (rural)	HIV/AIDS	Nonexperimental (qualitative)	CHW = 432	A total of 35,734 SMS was sent by 432 CHW from May 2010 to April 2011. A total of 11,502 pregnancies were monitored. A total of 362 SMS alerts for urgent and life-threatening events were registered
Chang et al. 2013	Data collect	Uganda (Rural)	HIV/AIDS	Nonexperimental (quantity/-quality)	CHW = 27	Qualitative results included desired mHealth features to verify completion of CHA tasks, clinical decision support tools, and simple access to voice calls. Quantitative results found that 26 (96%) had no Internet access at home; however, only 2 (7.4%) did not have a cell phone
Lozano-Fuentes et al. 2013	Data collect	Mexico	Malaria	Quasiexperimental (qualitative)	CHW = 10	The cost-effectiveness of using the Chaak system will depend largely on the upfront cost of purchasing cell phones and the re-curring cost of data transfer over a cellular network
Palazuelos et al. 2013	Data collect	Mexico (rural)	Promotion health	Nonexperimental (quantity/-quality)	CHW = 17	82% of the 17 CHWs chose the mHealth tool for at least 1 of 7 questions compared to 53% (9/17) who chose to use the paper-based tool. 93% (13/14) rated the phone as being easy or very easy to use, and 56% (5/9) who used the paper-based tool rated it as easy or very easy
Schoenberger et al. 2013	Communication P2P	USA	Promotion health	Nonexperimental (quantity/-quality)	CHW = 114	The benefits of a text messaging system mentioned by focus group participants included an alternative form of communication, quick method for disseminating information, and privacy of communication
Jennings et al. 2013	Notification or alerts	Kenya	Maternal health	Nonexperimental (qualitative)	CHW = 12	The perceived benefits of mobile phones for PMTCT included linking with health workers, protecting confidentiality, and receiving information and reminders
Shishido et al. 2014	Data collect	Brazil	Cardiovascular diseases	Nonexperimental (qualitative)	CHW =4	The system has reduced the use of paper; centered and organized data; and allowed quick data recovery and standardization to improve the readability of data input
Tumusiime et al. 2014	Notification or alerts	Uganda (rural)	Maternal health	Nonexperimental (qualitative)	CHW = 96	A robust cell phone-based system that can be expected to contribute to the efficient de-livery of iCCM by volunteer CHWs trained in rural settings in Uganda, pri-marily for data collection
Campbell et al. 2014	Notification or alerts	Malawi (rural)	Promotion health	Experimental (qualitative)	CHW = 638	The qualitative results were reinforced by research that showed reductions in the lack of essential drugs, lower communication costs, greater service coverage, and more efficient referrals. As an innovative and participative way of analyzing social networks, Net-Map pro-duced important visual, quantitative and qualitative information at a reasonable cost

Table 1 (continued)

Author (year)	Objective	Country and region	Health issues	Study design	Participants (type and no.)	Key findings
Surka et al. 2014	Data collect	South Africa (rural)	Cardiovascular diseases	Experimental (quantity/qualirt)	CHW = 24	The training time was 12.3 h for the paper-based chart tool and 3 h for the mobile phone application. A total of 537 people were screened. The mean screening time was 36 min (SD=12.6) using the paper-based chart tool and 21 min (SD= 8.71) using the mobile phone application, p=<0.0001
Chen et al. 2014	Notification or alerts	China (rural)	Promotion health	Experimental (qualitative)	CHW = 490	Health workers' knowledge of the recommendations increased significantly in the intervention group, both individually (0.17 points; 95% confidence interval, CI: 0.168–0.172) and at the cluster level (0.16 points; 95% CI: 0.157–0.163)
Hamainza et al. 2014	Notification or alerts	Zambia (rural)	Malaria	Nonexperimental (quantity/-quality)	CHW=45	Slightly more RDT-detected malaria infections were recorded in extracted participant registers than were reported in weekly mobile phone summaries, but the difference was equivalent to only 19.2% (31,665 versus 25,583)
Schuttner et al. 2014	Data collect	Zambia (rural)	HIV/AIDS	Nonexperimental (quantity/-quality)	CHW=24	CHWs completed all planned aspects of surveillance and outreach, demonstrating feasibility. Components of this pilot project may aid clinical care in rural settings and have the potential for epidemiologic and health system
Neupane et al. 2014	Data collect	South Africa (rural)	Promotion health	Nonexperimental (quantitative)	CHW=10	Compared to the mHealth system where data accuracy was assured, 40% of the CHWs showed a consistently high level (>90% correspondence) of data transfer accuracy on paper. Overall, there was an improvement over time, and by the fifth month, all CHWs achieved a correspondence of 90% or above between phone and paper data
Ginsburg et al. 2014	Data collect	Bangladesh (urban/-rural)	Promotion health	Experimental (quantitative)	CHW=30	In 4 months, 22,337 women were interviewed; <1% declined participation, and 556 women had an abnormal CBE. Control group CHWs completed fewer interviews, had inferior data quality, and identified significantly fewer women with abnormal breast exams compared with CHWs in arms A and B. Arm B had the highest adherence
Cherrington et al. 2015	Data collect	USA (urban)	Diabetes	Nonexperimental (quantitative)	CHW -34	Implementation of the system in real time with continual feedback from end users allowed for refinement of the tool and ultimately resulted in an application that is easy to use and meets the CHWs needs
Kallander et al. 2015	Data collect	Uganda and Mozambique	Promotion health	Experimental (quantitative)	CHW = 3775	Study strengths include a user-centered design to the innovations, while weaknesses include the lack of a robust measurement of coverage of appropriate treatment. Evidence of cost-effective innovations that increase motivation and performance of CHWs can potentially increase sustainable coverage of iCCM at scale

Table 1 (continued)

Author (year)	Objective	Country and region	Health issues	Study design	Participants (type and no.)	Key findings
Medhanyie et al. 2015	Data collect	Ethiopia (rural)	Maternal health	Nonexperimental (qualitative)	CHW=14	All health workers had never had previous exposure to smartphones and electronic forms, but they got used to them easily. Over 6 months, all health workers completed a total of 952 patient records using the forms on smartphones. Health workers' acceptability and demand for the application
Gatuha and Jiang 2015	Data collect	Kenya (urban/-rural)	Promotion health	Nonexperimental (qualitative)	CHW=33	The benefits of this system are to assist in the control and registration of children's vaccinations. The usability test was applied between the CHA
Stanton et al. 2015	Notification or alerts	Unavailable (rural)	Malaria	Nonexperimental (quantity/-quality)	CHW = 32	CHWs successfully reported 360 unique cases by SMS from 33 communities (169 hydrocoele, 185 lymphoedema, 6 with both), resulting in an estimated adult prevalence of 76.9 per 10,000 and 70.5 per 10,000 adults for lymphoedema and hydrocoele. respectively
Modi et al. 2015	Data collect	India (rural)	Maternal health	Nonexperimental (quantity/-quality)	CHW=69	During the pilot, the intervention and its delivery were found to be largely acceptable, feasible, and useful. A few changes were made to the intervention and its delivery, including (1) a new helpline for ASHAs and (2) further simplification of processes within the ImTeCHO incentive management system
Bastawrous et al. 2015	Data collect	Kenya (rural)	Promotion health	Experimental (quantitative)	Volunteer health = 300	The local Kenyan community healthcare workers readily accepted the peek acuity smartphone test; it required minimal training and took no longer than the Snellen test (77 s vs 82 s; 95% CI, 71–84 seconds vs 73–91 s, respectively; P=.13)
Fotso et al. 2015	Data collect	Malawi (rural)	Maternal health	Quasiexperimental (quantity/-quality)	CHW = ND	The project provides insights on mHealth and community-based programming to improve newborn and child healthcare delivery
Zimmerman et al. 2015	Data collect	Nigeria (rural)	Promotion health	Nonexperimental (quantity/-quality)	CHW=40	First is the rapidity of data collection; data collection lasted 6 weeks from mapping/listing to final collection – and, since completed surveys are uploaded to a cloud-based server, identification of errors can occur in near real time
Kaphle et al. 2015	Data collect	India (rural)	Maternal health	Nonexperimental (quantity/-quality)	CHW=15	mHealth technology adoption by frontline workers can positively impact the quality and experience of the care they provide. Individual characteristics, especially literacy and age, can be important elements affecting technology adoption and the way users leverage the technology for their work
Mushamiri et al. 2015	Data collect	Kenya (rural)	Promotion health	Nonexperimental (quantity/-quality)	CHW = 109	All CHWs interviewed agreed that APAS helped them track pregnant woman efficiently, compared to paper-based tracking forms. Women registered in APAS reported that CHWs reminded them of appointments more regularly than before its inception.

Table 1 (continued)

Author (year)	Objective	Country and region	Health issues	Study design	Participants (type and no.)	Key findings
Kabakyenga et al. 2016	Notification or alerts	Uganda (rural)	Maternal health	Nonexperimental (quantity/-quality)	CHW = 196	CHWs in targeted sites improved child healthcare through mobile phone use coupled with iCCM. Qualitative evaluation showed gains in treatment planning, supply management
Maleka et al. 2016	Data collect	South Africa (rural)	Promotion health	Quasiexperimental (quantitative)	CHW = 207	High positive (100%) and negative correspondence (96%) was found between the paper-based PEDS tools and the smartphone application PEDS tools and between the SLP and CHW. Almost perfect (Cohen's Kappa) inter-rater agreement between conditions was demonstrated
Sa et al. 2016	Data collect	Brazil (urban/-rural)	Promotion health	Nonexperimental (quantity/-quality)	CHW = 194	"We deployed the system at six primary care units involving more than 28,000 families or 96,000 inhabitants. The proposed system has the potential to improve the efficiency of primary care data collection. The solution is cost-effective
Rajan et al. 2016	Data collect	Brazil (urban/-rural)	Promotion health	Nonexperimental (quantity/-quality)	CHW=14	A large percentage (85.7%) of participants had at least a high school education. Internet (92.8%), computer (85.7%) and cell phone (71.4%) use rates were high. Data entry error rates were also high, particularly in free text fields, ranging from 92.3 to 100%. Error rates were comparable across device type
Varma et al. 2016	Notification or alerts	USA (urban/-rural)	Promotion health	Experimental (quantity/-quality)	CHW=81	There were 2710 cases of diarrhea and 373 cases of acute respiratory infection reported by community health workers during the 1-year study period. The data collected by community health workers on cell phones can be a possible complement to other sources of data related to the community and health for the surveillance of such conditions
Meyers et al. 2016	Data collect	Nepal (rural)	Respiratory diseases	Nonexperimental (qualitative)	CHW = 300	This field report provides an example of an mHealth program that had the potential to impact the efficiency of a community health program in rural
Joos et al. 2016	Notification or alerts	Malawi (rural)	Maternal health	Experimental (quantity/-quality)	CHW=60	Study results show that the mHealth intervention improved the documentation of matched pregnancies in both the treatment (OR 1.31, 95% CI: 1.10–1.55, $p<0.01$) and control (OR 1.46, 95% CI: 1.11–1.91, $p=0.01$) groups relative to the baseline period, despite differences in SMS content between groups
Biemba et al. 2017	Data collect	Zambia (rural)	Promotion health	Experimental (quantitative)	CHW=57	CHWs were able to use the mobile app to send weekly reports to health center supervisors about loads of disease cases and medical products consumed, order medicines and supplies, and send pre-referral notices to health centers
Braun et al. 2016	Data collect	Tanzania (rural)	Promotion health	Nonexperimental (qualitative)	CHW =25	CHWs and their customers reported that mobile job assistance was a highly acceptable PF support tool. CHWs perceive benefits for the quality of service,

Table 1 (continued)

Author (year)	Objective	Country and region	Health issues	Study design	Participants (type and no.)	Key findings
						including more timely and more convenient service; better quality of information; greater choice of methods; and greater privacy, confidentiality, and trust with customers
Vallieres et al. 2016	Data collect	Sierra Leone (rural)	Promotion health	Quasiexperimental (quantity/-quality)	CHW=27	The results of this unused study are available to support or use mobile technology or mobile health applications for agents involved in CHW programs and applications
Ramirez et al. 2017	Data collect	USA (rural)	Cardiovascular diseases	Nonexperimental (qualitative)	CHW=3	For CHA, CMT allowed electronic collection of clinical assessment data, providing decision support and remote access to patients' risk factor values
Schoen et al. 2017	Data collect	Kenya (urban/ru	HIV/AIDS	Nonexperimental (quantitative)	CHW =57	CHWs described key benefits of using GeoHealth as helping them save time with bureaucratic paperwork, organizing the data that they needed to collect, and by replacing sheaves of paper, reducing the weight that they carried in the field
Bonnell et al. 2018	Data collect	Dominican Republic (rural)	Maternal health	Nonexperimental (quantity/-quality)	CHW=5	Preliminary data suggest that CHWs using mobile health technology are viable, linking formal and poorly attended health systems to the provision of primary care in mothers' homes
Ilozumba et al. 2018	Data collect	India (rural)	India (rural)	Nonexperimental (quantity/-quality)	CHW=36	The general response of the CHA and community members to the intervention was positive. However, contextual factors such as the relationship between CHWs and their respective communities, the decision-making power of pregnant women, and the lack of access due to fi-nancing influenced the results observed
Mannik et al. 2018	Data collect	Kenya (rural)	Promotion health	Nonexperimental (quantity/-quality)	CHW=1	Five CHAs examined 2865 individuals in remote rural communities in Kenya over a 22-month period (2015–2017). Through data collection it was identified that the risk of cardiovascular diseases among pa-tients was <10% in 2778 (97%), from 10% to <20% in 65 (2.3%), from 20% to <30% in 12 (0.4%) and≥30% in 10 (0.2%)
Musabyimana et al. 2018	Notification or alerts	Rwanda (rural)	Maternal health	Nonexperimental (quantity/-quality)	CHW=ND	RapidSMS was generally accepted by both CHWs and parents. Participants identified insufficient training, a lack of equipment, and low CHW motivation as the main challenges facing RapidSMS
Sonderman et al. 2018	Data collect	Rwanda (rural)	Maternal health	Experimental (quantitative)	CHW=129	The greatest strength is that this is a prospective randomized controlled trial to most effectively evaluate the impact of a mobile health and community health worker (CHW) intervention on return to care following surgery
Laktabai et al. 2018	Data collect	South Africa (rural)	Promotion health	Nonexperimental (quantity/quality	CHW=50	A single case study was conducted, mapping the CHWs workflow and investigating where and when CHWs can be supported by mHealth services

Table 1 (continued)

Author (year)	Objective	Country and region	Health issues	Study design	Participants (type and no.)	Key findings
O'Donovan et al. 2018	Education and training	Uganda (rural)	Promotion health	Experimental (quantitative)	CHW = 129	There was a statistically significant positive correlation (r=0.26, p = 0.03) of positive Pearson correlation between the years of schooling and the improvement in test scores in the control group, which was not present in the intervention group. Most CHWs expressed satisfaction with the use of pills as a training tool; however, some reported technical problems (n=9)
Birur et al. 2019	Education and trainning	India (rural)	Dental health	Quasiexperimental (quantity/-quality)	CHW=50	Trained CHAs can assist in the identification of potentially malignant oral disorders and can be used effectively in the mHealth oral cancer screening program
Zakus et al. 2019	Data collect	Niger (rural)	Promotion health	Experimental (quantitative)	CHW = 50	The results suggest that the use of the mHealth app led to modest improvement through better assessment of sick children and better decisions
Mc Kenna et al. 2019	Data collect	India (rural)	Promotion health	Nonexperimental (qualitative)	CHW=66	mHealth interventions targeting CHWs and beneficiaries have the potential to improve the performance of CHWs, reduce barriers to information and potentially change the behaviors of beneficiaries
Hackett et al. 2019	Data collect	Tanzania (rural)	Promotion health	Experimental (quantitative)	CHW=32	A smartphone application positively influenced community perceptions of health system services and client expectations of health workers; policymakers and implementers must ensure these expectations are met
Schaeffer et al. 2019	Data collect	Bangladesh (urban/-rural)	Maternal health	Nonexperimental (qualitative)	CHW =57	A total of 207 CHA assessments were completed on 101 enrolled children. The app facilitated calculations of respiratory rate, temperature, and gestational age. CHWs were more likely to provide counseling as needed in 4 out of 7 case management recommendations evaluated, including care for the kangaroo mother

In 11.3% of the studies, the acceptability and feasibility questionnaire was used, which is provided in ISO/IEC 25010 (2011) and Nielsen's ten heuristics (2013) to define essential characteristics in quality and usability in software and applications. In 3.2% of the studies, they mentioned the white and black box tests of software engineering, with the purpose of finding bugs and flaws before carrying out the intervention with CHW. Finally, 100% of the studies did not make the source code available on code versioning repositories (GitHub, Bitbucket, etc.), making them limited in terms of evolution or expansion of the study into other similar projects.

Discussions

This systematic review revealed that the number of mHealth assessments for CHW has increased in the past 6 years, mainly in rural or difficult to access areas, such as countries in Africa, which occupies 61% of selected studies.

Through WHO "Classification of Digital Health Intervention V.1.0," it was possible to determine that 71% of the studies used a health management information system (HMIS) or electronic medical record to standardize data entry (Lozano-Fuentes et al. 2013; Schoen et al. 2017; Shishido et al. 2014) and allow real-time analysis of health problems in a community (Shishido et al. 2014), besides decreasing the

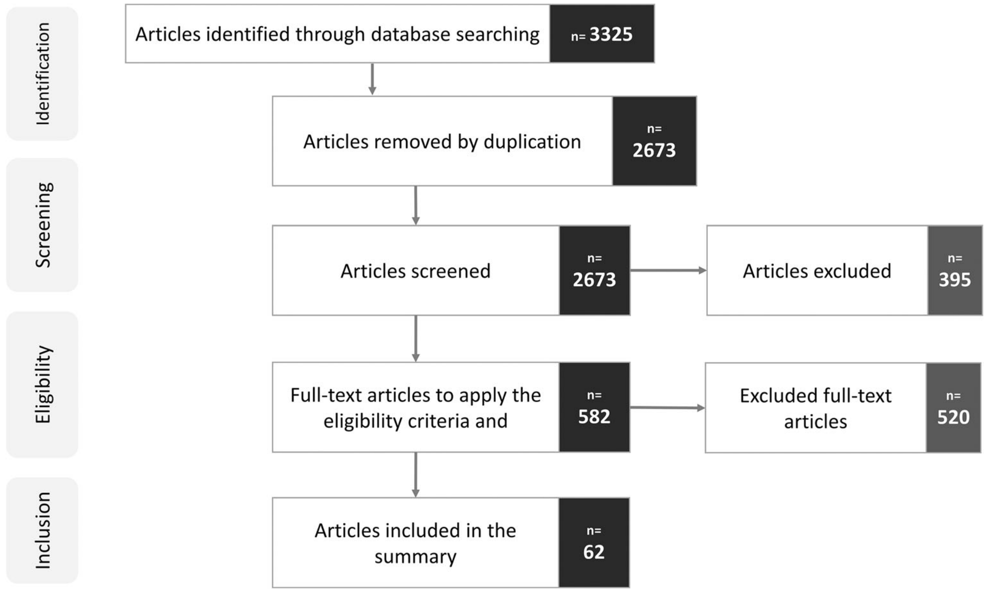

Fig. 1 Stages of the systematic review

loss of data for residents or patients. 23% used telemedicine to facilitate communication between CHW and their supervisors, providing medical advice or medical help support instantly (Chang et al. 2013; Chen et al. 2014; Mushamiri et al. 2015). Finally, 6% used the learning and training system to assess CHWs' ability and reduce healthcare problems with low adherence by these professionals to clinical guidelines (Hoffman et al. 2010; Lim et al. 2011; Ramachandran et al. 2010).

In 58.1% of the studies, they justified their digital intervention through specific health problems related to a community or region, such as sexual, respiratory, infectious, cardiovascular, maternal and child diseases, and others. In 41.9%, they preferred to include all the diseases involved in health promotion and disease prevention to carry out the intervention.

The type of device and technology employed has shown a great variety and evolution in the last 10 years (2009–2019). In 60% of the studies, they used a basic cell phone to send simple text messages and SMS reminders in order to notify

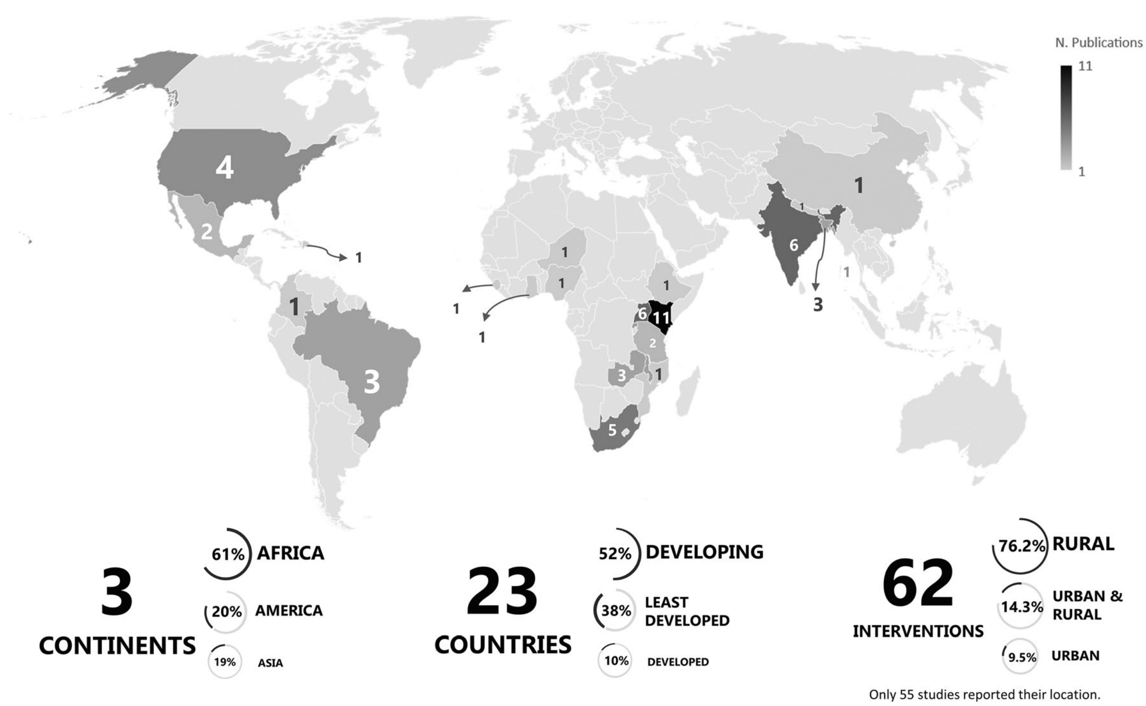

Fig. 2 Number of publications by country

Table 2 Characteristics of included studies

Type of studies	No of studies	Study sample				Intervention time (days)			
		M_d	M_e	min	max	M_d	M_e	min	max
Nonexperimental[1]	36	33	65.2	3	432	160	216.7	1	1095
Quasi-experimental[1]	10	50	94.5	3	474	122	187.6	7	574
Experimental	17	124	457.9	3	3775	243.5	298.7	3	1004
All studies	62	42.5	174.3	3	3775	160	235.0	1	1095

[1] One study did not provide data on population size or intervention time

CHW of family visits, healthy behaviors and/or vaccination in health posts. 40% adhered to smartphones (36%) or tablets (4%) to create native applications on the Android, iOS, and Windows mobile system or web applications for the purpose of collecting health data or for CHW to communicate in real time (P2P) with supervisors or patients via wireless network or mobile networks (3G/4G). The reason for the great use of these basic phones with SMS technology is due to the type of technology available at that time, i.e., many of them occurred from 2010 until 2016, and the rise in the use of smartphones and Tablets in the world market began in 2014. In 2015, the first applications for CHW on Android smartphones appeared. Already in 2019, the use of basic cell phones with SMS was becoming obsolete, and the choice of smartphones was more frequent among studies.

The selected articles presented a great level of heterogeneity in the design and type of study. Approximately 56.4% adopted a nonexperimental model with qualitative results to evaluate mHealth's performance in solving health problems in that region or community, a median sample of 40 CHW, and a median intervention period of 160 days. 43.6% quasi-experimental or experimental results were defined with qualitative and quantitative results to compare the efficiency of those who use the smartphone with an application with those who use the printed form and pen, through two groups (experimental group and control group) with median samples of 50 CHW for quasi-experimental studies and 124 CHW for experimental studies. The median intervention times were, respectively, 122 days and 160 days. Through Cochrane's RoB and ROBINS-I tools, 47 out of 62 studies were classified with low bias risk.

Through this systematic review, it was possible to eliminate the existing doubt regarding the improvement of the performance of health professionals who use mobile applications.

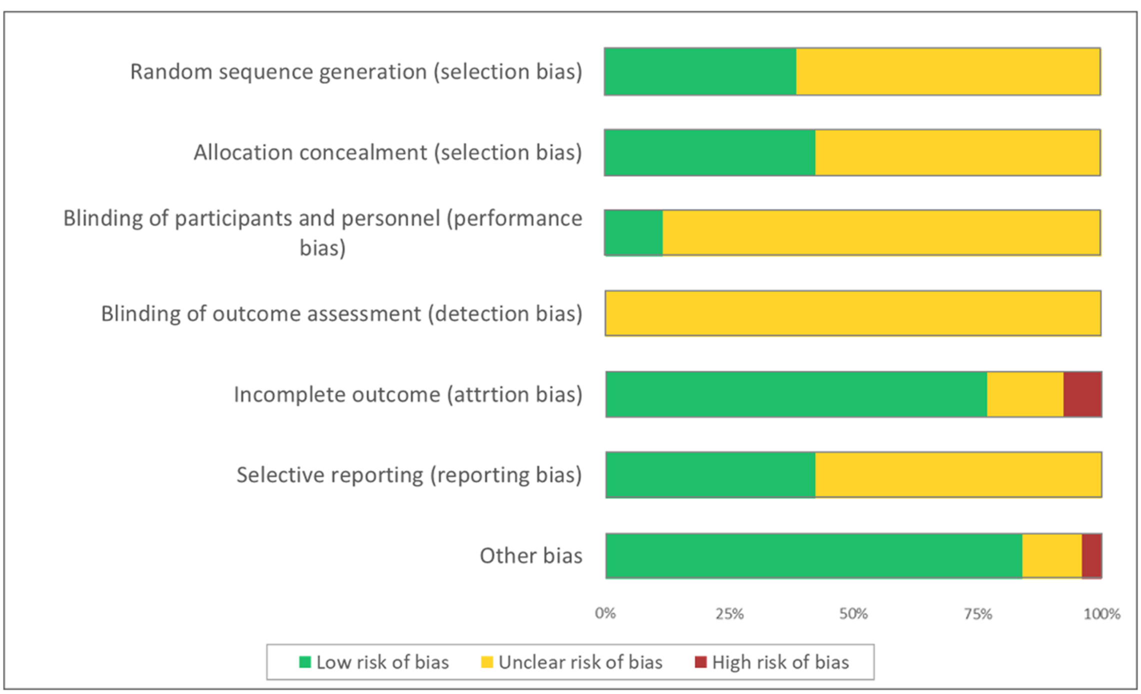

Fig. 3 Risk of bias for experimental and quasi-experimental studies

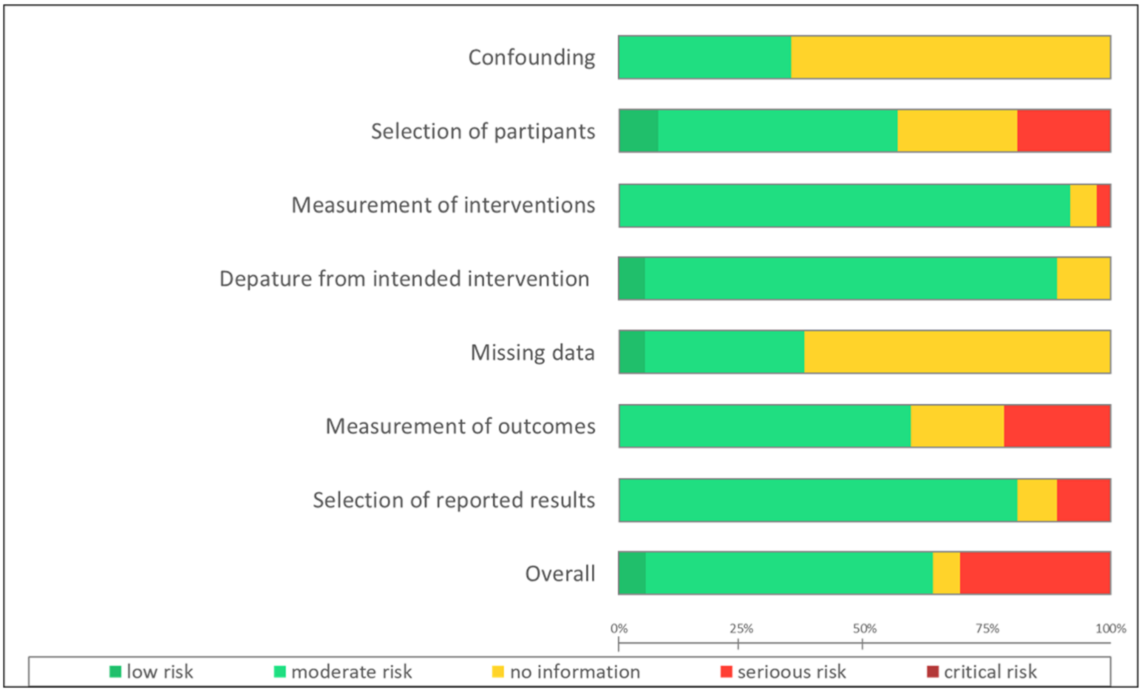

Fig. 4 Risk of bias for nonexperimental studies

Studies show unanimously that using mHealth on smartphones has made CHWs more efficient and effective in their data collection services for patients and individuals in communities.

Such results corroborate with previous reviews (International Organization for Standardization 2011; Nielsen and Budiu 2013); however, this new review brought a more in-depth analysis on this topic, mainly through the use of the Cochrane Collaboration tool to assess the risk of study bias (Higgins et al. 2011; Sterne et al. 2016), which reduces the possibility of risk of bias. Of the experimental studies, 88% were considered representative and had a low risk of bias. In addition, the use of the WHO "Classification of Digital Intervention in Health V.1.0" (WHO 2018) classified

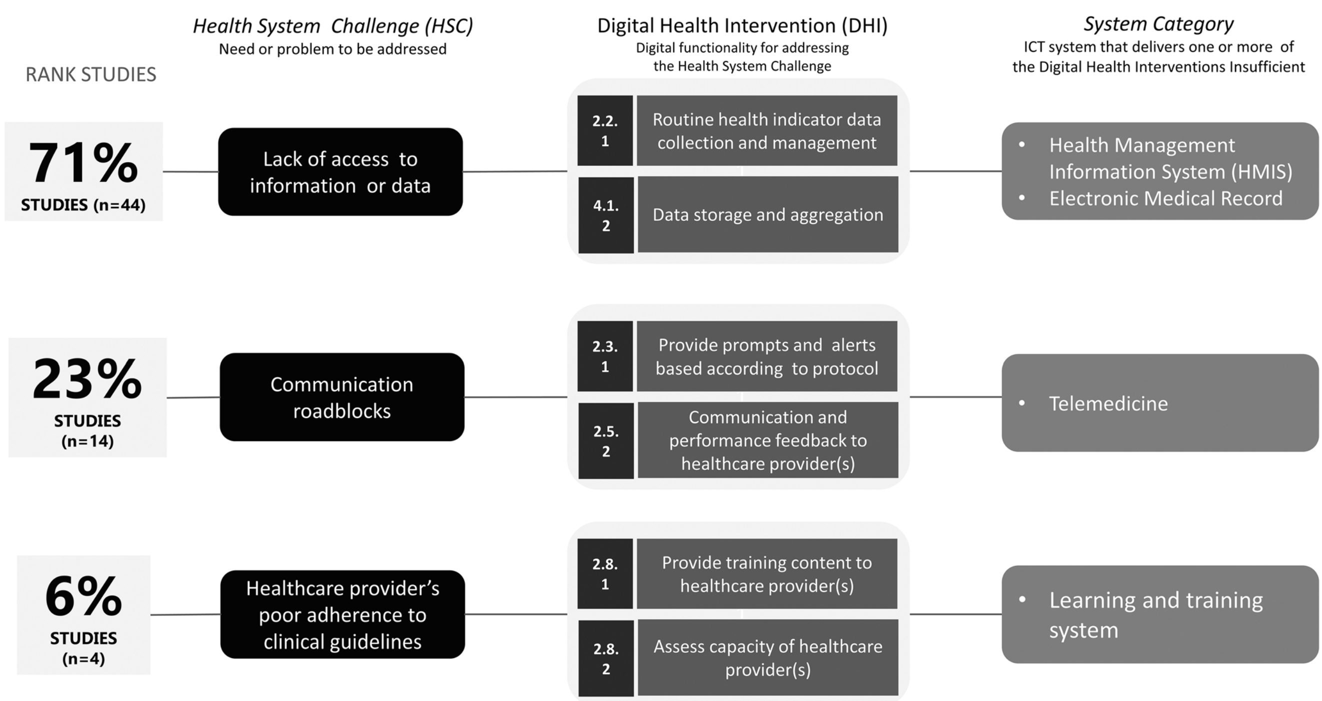

Fig. 5 Infographic "Classification of Digital Intervention in Health V.1.0" of the WHO

Fig. 6 Infographic on HSC related to health issues

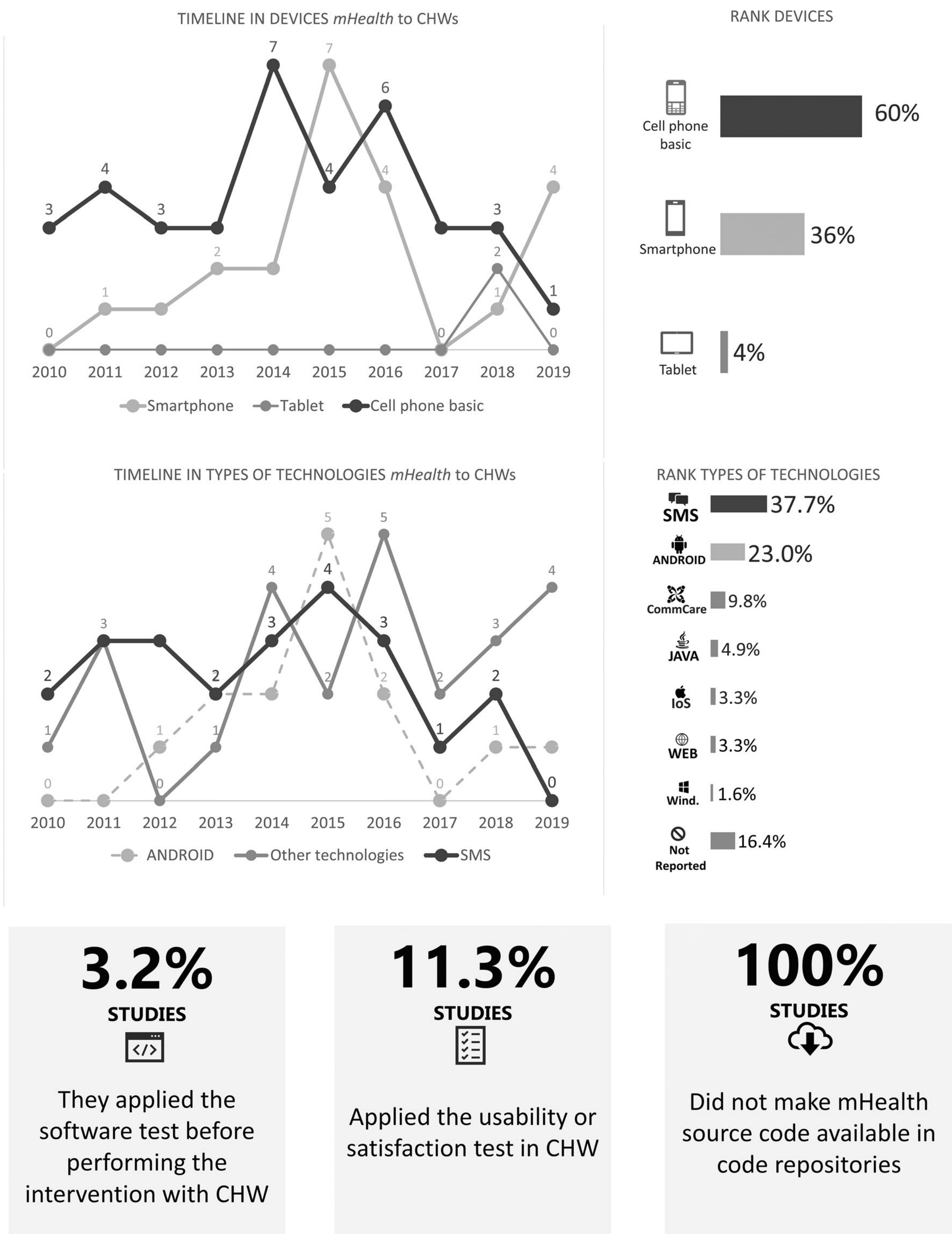

Fig. 7 Infographic regarding the types of technologies or devices related to DHI in CHW

71% of the studies as "management information in health system" with the purpose of analyzing in real time the data captured by the CHWs of that community or region to make the best decision or solution on disease prevention and health promotion problems. Finally, 11.3% of the studies used the acceptability and feasibility questionnaire to ascertain the level of satisfaction of CHW in relation to the use of mHealth. The application of this questionnaire is foreseen in ISO/IEC 25010 (2011) and Nielsen's ten usability heuristics (2013) and is considered essential to reach the level of quality in the usability of software and applications. Therefore, the use of these tools in the study emphasizes quality and reaffirms the use of mHealth in the daily lives of CHWs.

It cannot be said for certain whether the data obtained by these technologies allow better planning in primary health care, due to the variability of studies and technologies used over the past 10 years, for example, the PDA that has become obsolete. Therefore, it was observed that at the beginning of the implementation of these studies or applications, that is, from 2010 to 2013, numerous technological and infrastructure challenges, such as poor access to the telephone network, unavailability of the electrical network, and the lack of cell phones to CHWs were very mentioned in the studies (Florez-Arango et al. 2011; Hoffman et al. 2010; Zurovac et al. 2011) and reviews (Gurman et al. 2012; Marcolino et al. 2018; Stephani et al. 2016). However, it is noticeable that the scenario about these problems has been decreasing in recent years, mainly in the evolution of cell phones to smartphones and the expansion of mobile Internet (Hackett et al. 2019; Schaeffer et al. 2019).

Finally, more studies are still needed to make decisions on primary healthcare planning to be effective and efficient, as most samples showed very limited variability in health data and sample size interviewed by CHW. For this, it is necessary that new studies begin to use the resources available in cloud computing to achieve these characteristics, because through it, it is possible to have a great variety, speed, truthfulness, value, and volume on the data captured.

Limitations

Our review was limited by the scope of our literature search, which included articles in English through indexed digital databases and removed those that were part of conferences and/or collections of monographs, dissertations, and theses. It was noted that most projects are focused on developing mHealth to improve health promotion and that CHW are well connected to these technological projects. However, the scientific gains of these projects were difficult to evaluate, especially in the nonexperimental studies. However, the positive results are almost unanimous, making the negative results less likely to be published. In addition, due to the heterogeneity of methods, it was not possible to make a meta-analysis.

Conclusion

Given the results, we can conclude that the use of mHealth by CHWs has become typical in many regions of the world. In fact, many of these projects showed similarities in their purpose, especially regarding the effectiveness of CHWs in health systems. The health sector has been most successful in smartphone data collection activities in rural areas of developing and underdeveloped countries, particularly in Africa. However, it is believed that upcoming research should include or emphasize software engineering techniques or better qualitative analysis, to understand how these tools can be designed or even replicated in countries that do not use this technology. Similarly, the exploration of usability tests for experimental studies, which would allow a better evaluation of the impact of these studies, would increase or improve the evidence base in this area. Ultimately, it is believed that these mobile applications have the potential to improve the delivery of health services in hard-to-reach or resource-constrained environments and that new projects will strengthen and guide the area of health-focused public policy.

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