



Published in final edited form as:

Curr HIV/AIDS Rep. 2018 December ; 15(6): 414–422. doi:10.1007/s11904-018-0416-x.

A Missing Link: HIV-/AIDS-Related mHealth Interventions for Health Workers in Low- and Middle-Income Countries

Sarah Gimbel^{1,2,3}, Nami Kawakyu^{2,3}, Hallie Dau^{2,3}, Jennifer A. Unger^{2,4}

¹Department of Family and Child Nursing, University of Washington, Seattle, WA 98105, USA

²Department of Global Health, University of Washington, Seattle, WA 98105, USA

³Center for Global Health Nursing, School of Nursing, University of Washington, Seattle, WA 98105, USA

⁴Department of Obstetrics and Gynecology, University of Washington, Seattle, WA 98105, USA

Abstract

Purpose of Review—Through a review of the peer-reviewed and gray literature on HIV mobile health (mHealth) tools for health workers and in-depth interviews with mHealth leaders in the field, we provide a synthesis of current work and propose mHealth research priorities for HIV prevention, care, and treatment.

Recent Findings—Significant investment in implementation research and bringing together researchers capable of identifying drivers of successful implementation and industry leaders capable of bringing efficacious tools to scale are needed to move this area forward.

Summary—Effective and appropriate technologies to support health systems in the prevention and treatment of HIV/AIDS in low and middle-income countries are needed to improve the efficiency and quality of health service delivery and ultimately improve health outcomes. Although a growing number of HIV mHealth tools have been developed to support health workers, few of these tools have been rigorously evaluated and even fewer have been brought to scale.

Keywords

mHealth; Health workforce; LMIC; HIV; AIDS

Background

Despite significant investments by the international community, the HIV/AIDS epidemic continues to have devastating effects globally, with over 36 million people infected and millions newly infected each year [1]. Sub-Saharan Africa (sSA) has been especially hard hit, with over 25 million individuals living with HIV in 2016 [1]. Of those infected in sSA,

*Sarah Gimbel sgimbel@uw.edu.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

less than 40% are accessing treatment, due, in large part, to structural and capacity limitations of health services [1, 2].

Health systems to prevent and treat HIV/AIDS in low- and middle-income countries (LMIC) require innovative strategies to facilitate and evaluate improved efficiency and quality of service delivery and ultimately improve health outcomes. Specifically, the use of digital communication technology to support health and healthcare delivery (eHealth) in LMIC is an evolving strategy and represents a potentially important solution within the context of the HIV/AIDS crisis [3].

eHealth broadly focuses on information and communication technologies, and encompasses mobile health (mHealth) which refers to the use of mobile communication tools to support public health and clinical care [4]. Mobile phone subscription rates in developing countries have grown significantly from one quarter of the global market in 2000 to three-quarters by 2009 [5]. Since mobile phone penetration has exceeded other advancements in infrastructure development in LMICs and virtually 100% of the world's population lives within reach of a cell phone signal, mHealth is seen as a promising approach to promote health [6]. mHealth applications specifically targeting patients with HIV have been shown to be effective in promoting patient-level adherence, resulting in improved clinical outcomes in multiple patient populations and contexts [7, 8]. Improvements in service efficiency as a result of mHealth tools have also been shown, including decreases in patient expenditure and faster delivery of HIV services [9]. Other studies have demonstrated improvements in quality of HIV care provision as a result of patient-oriented applications, expressly through lessening stigma (via greater confidentiality) [10]. mHealth, rather than eHealth, is the focus of this paper, as frontline health care workers (HCW) and managers as well as community health workers (CHW) are more likely to access mobile devices than other digital technologies in LMIC.

The rise in mHealth technologies in HIV care as well as in maternal, neonatal, and child health (MNCH) promoted the gradual movement toward developing national-level digital health systems in many LMIC, further necessitating meaningful investment in improving monitoring and evaluation, data literacy, outcome collection, and use of these technologies.

Of the 14 WHO mHealth common use categories, six are directed toward the HCW as the end user (Table 1) [11].

mHealth applications have been built to support HCW as job aids, for clinical decision support, for data collection, and as evaluation tools [11]. There has been particular interest in the development of tools to improve both frontline and CHW capacity to report and use reliable data, rationalize resource allocation, and ensure quality of care. While mobile technologies cannot physically carry drugs, health workers, and equipment between locations, they can carry and process information in many forms, making them an attractive and viable strategy [12]. Despite their widespread small-scale deployment, very few HCW-directed mHealth strategies have been rigorously evaluated and almost none have been implemented at scale.

In this paper, we provide a state-of-the-science review of mHealth interventions specifically geared toward HCW and CHWs promoting HIV prevention and care in LMIC. Through a review of the peer-reviewed and gray literature, HIV conference abstracts and currently funded projects via NIH and larger foundations, and in-depth interviews with leaders in the mHealth field, we provide insight into current and future mHealth priorities within the field of HIV prevention, care, and treatment in LMIC contexts.

Methods

The literature review targeted peer-reviewed and gray literature, and included four systematic review articles related to HIV mHealth and CHW mHealth, and four mHealth landscape analysis reports to identify mHealth programs that matched the search criteria. For the search, mHealth was defined as “medical and public health practice supported by mobile devices” [11]. Searches were conducted on Google, Google Scholar, PubMed, NIH reporter, as well as gray literature sources such as conference materials and mHealth websites. The following search terms were used in a variety of combinations “mHealth,” “eHealth,” “digital health,” “mLearning,” “HIV,” “health care worker,” “nurse,” “community health workers,” “health system,” “WHO,” “alliance,” “expert,” and “strategic plan”.

The following inclusion criteria was used in the literature search: (i) written in a journal, report, conference presentation, project brief, and/or website (ii) included research on persons at risk for and with HIV (iii) focused on an LMIC (iv) mHealth activities targeted HCWs and/ or CHWs as end users, and (v) written on or after January 1, 2013.

Literature was excluded from the review if (i) it was not specific to mHealth, but rather the broader categories of eHealth, eLearning, and/or distance learning, (ii) the article was not specific to HIV, or (iii) the tool had an exclusively patient-focused design.

In addition to the literature review, semi-structured interviews were conducted remotely via Skype with leading experts in the mHealth field by the authors. Experts were initially identified by the authors via personal contacts and then expanded with recommendations by leaders in the field and literature reviews. Four of the five experts contacted agreed to be interviewed. Respondents included academic researchers (2) and experts from non-profit organizations (2) who develop mHealth tools. All individuals interviewed were men and nationals of the USA, Canada, or the UK. Efforts to recruit female or LMIC experts were unsuccessful.

Interviewees were asked a series of six questions related to mHealth innovations targeting HCW and/or CHW working in HIV in LMIC setting. The main goals of the interviews were to (i) gather perspectives on the current state of mHealth for HCWs and CHWs working in HIV in LMIC, (ii) highlight the most compelling examples of mHealth innovations, (iii) determine the gaps in mHealth, and (iv) identify top priorities for research in mHealth for HCWs and CHWs in LMIC. Five interviews were conducted between December 2017 and January 2018. All were audiotaped and transcribed verbatim, with duration ranging from 17 to 27 min (average 20.17 min). A preliminary coding structure was derived deductively from the interview guide. Data were coded by all authors independently and analyzed using

applied thematic analysis [13]. Subsequently, the authors met to review and discuss code assignments, and any discrepancies were discussed and reconciled. Themes related to the a priori research questions were extracted. All authors discussed and analyzed themes from key informants and triangulated impressions to determine the implications of the data.

Results

Literature Review on the Current State of HIV mHealth for Health Care Workers

Our literature search and key informant interviews identified illustrative examples of mHealth programs for each of the WHO HCW categories, but is not an exhaustive summary of the findings (Table 2).

Cross-Cutting Programs

Our literature search indicated that many digital tools for HCWs working in HIV had multiple uses, with a particular convergence of programs that increased HCW access to informational resources, including knowledge development through mLearning, connectivity to other CHWs and HCWs through mobile telehealth, and clinical guidance through clinical decision support systems [17, 18, 24]. This is consistent with changes in the greater mHealth field, where the highest growth category in recent years has been in information access at the point-of-care [11]. *CHN on the Go*, launched in Ghana for nurse-use in 2014, is one example of a cross-cutting app with multiple features. The application includes mLearning courses which nurses can take for credit, access clinical guidelines, a planner to organize work flow, and a WhatsApp network whereby nurses can communicate with other nurses in other parts of the country [25]. Currently, over 300 nurses and supervisors across five districts in Ghana are using *CHN on the Go* with support from the international non-governmental agency, Concern. The effect, as one participating nurse reported on the Concern website “you can just click on it and everything is there. Your confidence is boosted up” [25].

mLearning Programs

Though the literature on eLearning and distance learning is prolific [16], there is little evidence on the acceptability or effectiveness of mLearning programs. The two mLearning projects we located in the search, one with interactive 3D case-based simulations and another where educational text messages were sent, were small-scale pilot projects of 20 and 30 participants, respectively [15, 26]. The case-based simulation training tool introduced in Peru, did not report on effectiveness or acceptability, although they did conclude that implementation was hindered due to more interoperability on Android smart phones [26]. The educational text message study in India reported improved knowledge of HIV and decreased stigma among users [15].

Mobile Telehealth and Communication and Informational Exchange Programs

WhatsApp and SMS as platforms to connect HCWs and CHWs with each other and their supervisors have been tested in Kenya and Malawi with high acceptability [17, 18]. The *mCHW-WhatsApp* project in Kenya found that CHWs used WhatsApp as a tool to communicate one-on-one and as a group with and without their supervisors. One CHW participant explained that WhatsApp worked well as a knowledge exchange platform, “The

person I am chatting with educates me, and also I educate her or him so it helps me. You know, some send photos and explain about them; therefore, I learn” [16]. WhatsApp was also used for CHWs to document and share their work with the network, generating motivation among CHWs to perform well. A similar project in Malawi found that SMS was four times less expensive and at least 134 times more efficient than traveling to communicate in-person with supervisors [17].

Clinical Decision Support Programs

Mobile-based clinical decision support tools for HIV were available for specialized HIV topics and sought to make typically complex tasks more accessible to those with less training. For example, *NeuroScreen* launched in South Africa for CHW use is a mobile-based tool to screen for neurocognitive impairment (NCI), one of the most common consequences and comorbidities of HIV infection. NCI is difficult to diagnose and screen for as its presentation is varied and complex. Given the user-friendly and automated nature of *NeuroScreen*, the tool can be used by CHWs to screen and test for NCIs without substantial investments in training. Findings show that the tool has 81% sensitivity and 85% specificity when used by CHWs, demonstrating similar or better results than other computerized and paper-and pencil screening tests for HIV-associated NCI which are typically administered by higher level HCWs in clinical settings [27].

Similarly, *Health Scout* supports CHWs in Uganda to conduct HIV screening, triage, and counseling among community residents, guided by the information, motivation, and behavioral skills (IMB) model [24]. The intervention was found to be feasible to implement, with 771 residents counseled and CHWs observed with adequate performance. A randomized control trial (RCT) is currently underway to assess impact on HIV care outcomes.

Another mHealth tool simplifying more complex processes is the *mobile pMTCT Cascade Analysis Tool (pCAT)*. The *pCAT*, initially an Excel-based tool, was tested in Côte d’Ivoire, Kenya, and Mozambique with site managers and illustrates and quantifies the site’s pMTCT cascade steps using routine data sources to inform site-level quality improvement projects. Preliminary findings showed high acceptability of the tool when it was used improvement strategy, and demonstrated a four- to fivefold increase in maternal anti-retroviral therapy (ART) coverage and HIV-exposed infant screening [28]. The original Excel tool has been adapted and feasibility and usability tested as an mHealth application for use in Kenya and Mozambique, and is being scaled for use in a broader province-wide systems analysis and improvement trial, managed by the Ministry of Health with limited non-governmental organization support [21].

Electronic Patient Information Programs

Mobile electronic patient information programs seek to improve HCW access to patient records for increased effectiveness, efficiency, and quality of care. One such example is an early infant HIV diagnosis program implemented in Kenya, Nigeria, Uganda, and Zambia, where infant HIV test results are sent from the lab to the health facility via SMS. Given that only a limited number of laboratories in these countries have the resources to test for HIV in

infants, most health facilities must send test samples to central laboratories where results are mailed back, with time from testing to results notification taking several months [19, 20, 29]. These delays mean that nearly half of infants in these countries (and similar countries within sSA) tested for HIV do not receive their test results which delays initiation of lifesaving treatment [28]. With results returning by SMS, facilities and patients reliably receive their results sooner; in Kenya and Uganda, results are returned in less than 30 days compared to months [29], facilities in Nigeria reduced turnaround time by 21 days [20], and Zambia observed a 50% reduction in turnaround time [19]. Additionally, in Nigeria where small battery-operated SMS printers print the test results, costs were 4.6 times less expensive than the traditional paper-based method [28].

Patient Monitoring Programs

Few examples of patient monitoring programs were identified, and some were more than 10 years old [12, 30]. For the purposes of this review we have defined patient monitoring programs as those which store patient data and which is available for clinical/frontline staff to use to monitor patient care. The explanation for the limited number of identified patient monitoring programs may be related to the low proportion of LMIC countries reporting having a patient monitoring mHealth program in the South East Asia and Africa regions (20% and 38%, respectively) [11, 31] and the absence of a national electronic health record (EHR) system in general, although increasingly LMIC Ministries of Health are moving toward EHR adoption. In identified programs, HCWs enter patient HIV/AIDS care and treatment data on mobile phones which are stored in a central database and can be used to track and manage patients [12, 22, 23]. CHW track patients and are able to remind them of appointments and treatment [10].

Additional HIV mHealth Programs for Health Systems Strengthening

Two additional mHealth programs for HCWs were identified that did not fit into the WHO categories. One is the DekiReader, a mobile diagnostic device which can read rapid tests for various infections including HIV, conduct quality checks to assess for misprocessed samples, and provide interpretation of the result. Several publications on the success of its use with malaria are available; no data on acceptability or effectiveness for its use with HIV testing is available [32].

Another health systems strengthening mHealth program is the Early Warning System implemented in Ghana, where HCWs report weekly by SMS the stock of tracer commodities, including HIV/AIDS commodities. These data are available online to HCWs and managers to provide real-time status of commodities and flag any declines in supplies. Pilot study findings showed high participation and acceptability by HCW in reporting, though low participation among managers in using the reported data [33]. The program has been scaled to 783 public and community health facilities in Ghana, including all ART facilities.

A number of mHealth interventions for MNCH providers have demonstrated effectiveness in improving service delivery [34–36]; however, simple adaptation to HIV is not straightforward due to HIV/AIDS complexity as a chronic illness which requires lifelong

adherence and support. Overall, the literature highlights a weakness in that HIV patient-focused mHealth tools often do not assess provider's perceptions of acceptability and feasibility of the technology, despite their direct or indirect involvement [37], resulting in less informed guidance to take these applications to scale.

mHealth Expert Interview Findings

The main goals of the mHealth expert interviews were to (i) gather perspectives on the current state of mHealth for HCWs and CHWs working in HIV in LMIC, (ii) highlight the most compelling examples of mHealth innovations, (iii) determine gaps in mHealth and (iv) identify top priorities for research in mHealth for HCWs and CHWs in LMICs. Our key informants noted few HIV mHealth projects targeted HCW/CHW as end users. Most projects mentioned were developed as small pilots and were not brought to scale and relatedly, limited evidence was disseminated on their effectiveness and efficiency. Finally, more studies are needed to identify drivers and barriers to implementation success in order to move the field forward.

Few HIV + mHealth + HCW/ CHW Projects

Our interviewees pointed out that many current HIV mHealth interventions target patients, not HCWs, as the end user [38–40]. “There are cases where people are using mHealth project tools to find and help register new patients. But generally, the management by health care workers is carried out by more traditional like systems like EHR (electronic health records) registries. There is less use in mobile technologies in the daily management of patients.”

Interviewees noted that most mHealth technologies targeting providers focused on improving maternal, newborn and child health (MNCH), and immunization programs, rather than HIV. One respondent noted that the continuing and expanding support critical for HIV patients bolstered development of more provider-directed mHealth tools in order to improve efficiency of ongoing health system delivery. According to key respondents, efficiency can be achieved by designing tools that enable provision of improved care with existing resources, ensuring more rapid delivery of quality care, and/or by decreasing the costs associated with care. Provider-directed tools have the potential to complement patient-focused mHealth interventions which generally promote adherence to care and treatment.

“One of the areas we’re looking at is improving, with frontline health workers, the provi[sion] of support to patients via digital needs, [so we] can reduce the number of clinic visits that are required for one patient, for instance. And that allows for improved efficiency.”

Many Small Pilot Projects, Few Scaled Projects

Most examples of HW-targeted mHealth tools for HIV mentioned by interviewees were small scale pilots which had yet to be successfully and sustainably scaled-up. Thus, there is limited guidance on the pathway to ensuring sustainability of HIV-specific mHealth products. Defining what is sustainable and scalable is evolving in this field. One respondent noted that previously a tool with 2000 HW users was viewed as a “large” mHealth

intervention whereas currently a growing number of mHealth technologies have been adopted by 5000– 10,000 provider end-users. It was mentioned by multiple respondents that mHealth interventions have a broader history in MNCH where utilization is growing and some lessons may be applicable across disciplines. The WHO offers guidance for innovators working in the space of MNCH [41]. As a practical example, Dimagi, a mHealth organization, has developed a tool in India with over 85,000 users. This tool targets MNCH services provided by CHW. Through bringing it to scale two critical implementation issues were noted. One, the most important characteristic of a successful tool at scale is its ability to be nimble across multiple environments. Second, the developers, one of who was interviewed, noted that what worked at scale was not always apparent when tested in multiple, smaller pilots.

Finally, key informants reported that development and use of mHealth tools for providers, although a priority area of growth in HIV care and treatment in LMIC settings, has been hampered by weak engagement of governments and frontline health workers, which is so essential for initial and sustained success. To combat this perennial challenge, mHealth tool development should ensure that these technologies sync with the overall health sector and existing data management systems in whichever country or setting where they are introduced.

Limited Implementation Science and Impact Evaluations

Nearly all projects mentioned by the interviewees were pilot or small scale in implementation and thus evaluations were largely limited to usability and acceptability testing, with little research on feasibility, implementation research of scale-up, and impact such as effectiveness, efficiency, and quality.

“There are very few things that have been designed for scale or implemented at scale. In terms of, there is still a huge opportunity to provide additional tools. I think some of the evidence is still, there’s evidence that’s emerging, but it’s also lacking. There’s more evidence that needs to be generated“

To bridge this gap from piloting to scale-up, research priorities need to pivot to be more implementation oriented and bring together academia and industry. One respondent described the current situation.

“..It’s just that it’s just academics, it’s either academics or companies, there isn’t enough of a coordination between them”

Engaging both researchers and industry in implementation research holds promise according to the respondents.

“The number one priority is better utilization, adoption and scaling of stuff that works today that has not been productized or fully rolled out, “give some data on the interview e.g., one female HIV provider administrate in Kenya ...

Successful implementation of mHealth tools for HIV care providers will also require cost effectiveness studies and policy reviews which could inform development of guidelines to expedite licensing approaches to move mHealth interventions from concept to real world application.

Discussion and Future Directions

Through our review of the literature on HIV mHealth for HCWs and interviews with global mHealth experts, a number of key themes emerged. First, there was consensus that the field is suffering from “pilotitis,” with an ever-increasing number of small pilot studies (funded through donors, governments and foundation sources as well as the private sector). However, the results of these pilots are disseminated unevenly in peer-reviewed literature and elsewhere. Additionally, the time from implementation to reporting often lags while technology is rapidly advancing. As a result, many small pilots continue to be funded and merely “reinvent the wheel” by developing and piloting similar technology projects, rather than prioritizing development of effective implementation models to bring successful mHealth technologies to a broader audience [42].

In addition, efforts to demonstrate effectiveness of mHealth have been weak. Despite large investments in mHealth technologies in LMIC, only 14% ($n = 16$) of WHO priority countries reported an evaluation of a government-sponsored mHealth program [14], demonstrating that although mHealth interventions are being developed very few projects are integrating with the governments where they are implemented and dissemination of these evaluations is limited to implementers and donors. This is consistent with our literature search where only 60% of the identified HIV mHealth for HCW projects had peer-reviewed publications and among those, the median time from implementation to publication was 2 years. Furthermore, nearly all projects were pilot or small-scale implementation and thus evaluations were largely limited to usability and acceptability testing, with little research on feasibility, implementation research of scale-up, and impact such as effectiveness, efficiency, and quality. These findings were confirmed by interviewed implementers who recognize this limitation as a top priority for the field.

Conclusions

In order to overcome this bottleneck in bringing efficacious HIV mHealth technologies and tools for providers to scale, academics, market entrepreneurs, donors, and governments need to work more synergistically from development, through testing, and expansion. Bringing researcher, donors, implementing countries, and industry together will ensure that both clinical needs and programming knowledge will be considered throughout the design and scaling processes. Evidence needs to be generated with support from researchers, but academic structures can be limiting in their ability to provide services at scale and over the longer term.

MHealth continues to be a growing field and many remain optimistic that these technologies can support individual patients as well as strengthen human resource and health system capacity. However, as demonstrated in this review and by the expert interviews, the field continues to be challenged with its own exponential growth without sufficient maturity. Although many innovations have been developed and tested, there has been little evidence for health care worker focused HIV-specific tools working at scale. Limited information on implementation and best practices have been generated as most studies have focused on piloting technologies in limited settings. However many researchers and implementers have

recognized this challenge and are transforming their approach to project design and evaluation. This reframing includes envisioning a sustainable and scalable product from inception and involving and pursuing input and buy in from end users and governments in the design phase. Our review highlights the need for both industry and academic researchers to work together to implement and evaluate mHealth tools across a broader, more heterogeneous group of settings, and specifically examine the drivers and facilitators of successful implementation. More and more, the field, including donors, is trying to remedy the “pilotitis” and develop collaborative, community designed products with a focus on sustainability and scale and this approach is needed to understand the potential of mHealth tools to improve HIV care delivery.

References

1. UNAIDS. Fact sheet - Latest statistics on the status of the AIDS epidemic: UNAIDS; 2017.
2. Wagner E, Austin B, Davis C, Hindmarsh M, Sachaefer J, Bonomi A. Improving chronic illness care: translating evidence into action. *Health Aff.* 2001;20(6):64–78.
3. Chiasson MA, Hirshfield S, Rietmeijer C. HIV prevention and care in the digital age. *J Acquir Immune Defic Syndr.* 2010;55(Suppl 2): S94–7. [PubMed: 21406996]
4. Kahn JG, Yang JS, Kahn JS. “Mobile” health needs and opportunities in developing countries. *Health Aff (Millwood).* 2010;29(2): 252–8. [PubMed: 20348069]
5. World Bank. Mobile cellular subscriptions 2016 <https://data.worldbank.org/indicator/IT.CEL.SETS?end=2016&start=1960&view=map>. Accessed 8 Feb 2018.
6. Labrique AB, Vasudevan L, Kochi E, Fabricant R, Mehl G. mHealth innovations as health system strengthening tools: 12 common applications and a visual framework. *GI Health Sci Pract.* 2013;1(2):160–71.
7. Lester RT, Ritvo P, Mills EJ, Kariri A, Karanja S, Chung MH, et al. Effects of a mobile phone short message service on antiretroviral treatment adherence in Kenya (WelTel Kenya1): a randomised trial. *Lancet.* 2010;376(9755):1838–45. [PubMed: 21071074]
8. Horvath T, Azman H, Kennedy GE, Rutherford GW. Mobile phone text messaging for promoting adherence to antiretroviral therapy in patients with HIV infection. *Cochrane Database Syst Rev.* 2012;3
9. Swendeman D, Rotheram-Borus MJ. Innovation in sexually transmitted disease and HIV prevention: internet and mobile phone delivery vehicles for global diffusion. *Curr Opin Psychiatry.* 2010;23(2):139–44. [PubMed: 20087189]
10. Hirsch-Moverman Y, Daftary A, Yuengling KA, Saito S, Ntoane M, Frederix K, et al. Using mHealth for HIV/TB treatment support in Lesotho: enhancing patient–provider communication in the START study. *JAIDS.* 2017;74:S37–43. [PubMed: 27930610]
11. World Health Organization. mHealth new horizons for health through mobile technologies. Geneva: World Health Organization; 2011.
12. Zhenwei Qiang C, Yamamichi M, Hausman V, Altman D. Mobile applications for the health sector. Washington, DC: World Bank; 2011.
13. Guest GMK, Namey EE. Applied thematic analysis. Washington DC: Sage Publications; 2011.
14. World Health Organization. eHealth Survey. 2016.
15. Sucharitha ST, Rajagopal J, Siriki R. mLearning- a cost effective initiative for stigma reduction in health care settings. *BMC Infect Dis.* 2014;14(3):E46.
16. Al-Shorbaji N, Atun R, Car J, Majeed A, Wheeler E. eLearning for undergraduate health professional education. Geneva: World Health Organization; 2015.
17. Lemay NV, Sullivan T, Jumbe B, Perry CP. Reaching remote health workers in Malawi: baseline assessment of a pilot mHealth intervention. *J Health Commun.* 2012;17(sup1):105–17.

18. Henry JV, Winters N, Lakati A, Oliver M, Geniets A, Mbae SM, et al. Enhancing the supervision of community health workers with WhatsApp mobile messaging: qualitative findings from 2 lowresource settings in Kenya. *Glob Health Sci Pract*. 2016;4(2):311–25. [PubMed: 27353623]
19. UNICEF. Project Mwana: Using mobile technology to improve early infant diagnosis of HIV. In: Zambia U, editor.: UNICEF; 2012.
20. Mendoza G, Okoko L, Konopka S, Jonas E. *mHealth Compendium, Volume Three* Arlington, VA: African strategies for health project, management sciences for health 2013 p. 66–7.
21. Gimbel S, Nduati R, Kawakyu N, Coutinho J, Zunt A, Aburri N, et al. Usability and feasibility of a provider decision support smartphone application for frontline health workers in Kenya and Mozambique. Fifth Global Symposium on Health Systems Research Abstract 2143. October 8–12, 2018 Liverpool, UK
22. United Nations. Innovation for sustainable development : local case studies from Africa. United Nations. Department of E, Social A, editors. [New York]: United Nations; 2008.
23. Cishahayo S. GIS Applied to HIV & AIDS program monitoring: Case of TRACNet System.
24. Long A, Mbabali I, Hutton HE, Thomas AG, Bugos E, Mulamba J, et al. Design and implementation of a community health worker HIV treatment and prevention intervention in an HIV hot spot fishing community in Rakai, Uganda. *J Int Assoc Provid AIDS Care (JIAPAC)*. 2017;16(5):499–505. [PubMed: 28528560]
25. Concern Worldwide U.S. CHN ON THE GO: Concern Worldwide U.S; 2016 <https://www.concernusa.org/story/chn-on-the-go/>. Accessed 8 Feb 2018.
26. Zolfo M, Iglesias D, Kiyani C, Echevarria J, Fucay L, Llacsahuanga E, et al. Mobile learning for HIV/AIDS healthcare worker training in resource-limited settings. *AIDS Res Ther*. 2010;7(1):35. [PubMed: 20825677]
27. Robbins RN, Gouse H, Brown HG, Ehlers A, Scott TM, Leu C-S, et al. A mobile app to screen for neurocognitive impairment: preliminary validation of NeuroScreen among HIV-infected south African adults. *JMIR Mhealth Uhealth*. 2018;6(1):e5.
28. Rustagi AS, Gimbel S, Nduati R, de Fatima Cuembelo M, Wasserheit JN, Farquhar C, et al. Impact of a systems engineering intervention on PMTCT service delivery in Côte d'Ivoire, Kenya, Mozambique: a cluster randomized trial. *JAIDS*. 2016;72(3):e68–76. [PubMed: 27082507]
29. HP Development Company. Early infant diagnosis project: HP Development Company, L.P. <http://www8.hp.com/us/en/hpinformation/social-innovation/kenya.html#.WnyyoLbMxZ1>. Accessed 8 Feb 2018.
30. Kizito K, Adeline K, Baptiste KJ, Anita A, Agnes B, Johnson P, et al. TRACnet: a national phone-based and web-based tool for the timely integrated disease surveillance and response in Rwanda. *Online J Public Health Inform*. 2013;5(1):e202.
31. Nascimento ND, Cannon M, Perales N, Chariyeva Z. Assessment of an mHealth initiative to improve patient retention 2014.
32. Agarwal S, Rosenblum L, Goldschmidt T, Carras M, Goal N, Labrique A. Mobile technology in support of frontline health workers. Johns Hopkins University; 2016.
33. Dimagi Inc. Early warning System7 2 2018 <http://www.dimagi.com/wp-content/uploads/2015/01/CommCare-Supply-EWS-casestudy.pdf>. Accessed 8 Feb 2018.
34. Atnafu A, Otto K, Herbst CH. The role of mHealth intervention on maternal and child health service delivery: findings from a randomized controlled field trial in rural Ethiopia. *mHealth*. 2017;3(9):39. [PubMed: 29184891]
35. Litterbach E-K, Russell CG, Taki S, Denney-Wilson E, Campbell KJ, Laws RA. Factors influencing engagement and behavioral determinants of infant feeding in an mHealth program: qualitative evaluation of the growing healthy program. *JMIR Mhealth Uhealth*. 2017;5(12):e196. [PubMed: 29254908]
36. Balakrishnan R, Gopichandran V, Chaturvedi S, Chatterjee R, Mahapatra T, Chaudhuri I. Continuum of care services for maternal and child health using mobile technology – a health system strengthening strategy in low and middle income countries. *BMC Med Inform Decis Mak*. 2016;16(1):84. [PubMed: 27387548]

37. Murray MCM, O'Shaughnessy S, Smillie K, Van Borek N, Graham R, Maan EJ, et al. Health care providers' perspectives on a weekly text-messaging intervention to engage HIV-positive persons in care (WelTel BC1). *AIDS Behav.* 2015;19(10):1875–87. [PubMed: 26297567]
38. Catalani C, Philbrick W, Fraser H, Mechael P, Israelski DM. mHealth for HIV Treatment & Prevention: a systematic review of the literature. *Open AIDS J.* 2013;7:17–41. [PubMed: 24133558]
39. Devi BR, Syed-Abdul S, Kumar A, Iqbal U, Nguyen P-A, Li Y-C, et al. mHealth: an updated systematic review with a focus on HIV/ AIDS and tuberculosis long term management using mobile phones. *Comput Methods Prog Biomed.* 2015;122(2):257–65.
40. Muessig KE, Pike EC, LeGrand S, Hightow-Weidman LB. Mobile phone applications for the care and prevention of HIV and other sexually transmitted diseases: a review. *J Med Internet Res.* 2013;15(1):e1.
41. World Health Organization. A practical guide for engaging with mobile operators in mHealth for RMNCH. 2015.
42. Simoni JM, Aunon FM, Kemp CG, Kutner BA, Ramaiya MK, Velloza J, Yang JP. Implementation research on HIVadherence interventions: no time to wait. [commentary on “Effectiveness and cost-effectiveness of a nurse-delivered intervention to improve adherence to treatment for HIV: a pragmatic, multicentre, openlabel, randomised clinical trial.” by Bruin M, Oberjé EJM, Viechtbauer W, et al.]. *The lancet infectious diseases* 2017.

Table 1

WHO mHealth use categories

mHealth use categories	Target user
Emergency management systems	Health system
Health surveys	Health system
Surveillance	Health system
Access to information, resources, databases, and tools	HCW + patient
mLearning	HCW
Mobile telehealth	HCW
Clinical decision support systems	HCW
Electronic patient information	HCW
Patient monitoring	HCW
Emergency toll-free telephone services	Patient
Community mobilization/health promotion campaigns	Patient
Health call centers/health care telephone helplines	Patient
Reminder to attend appointments	Patient
Treatment adherence	Patient

Table 2
Illustrative examples of mHealth programs for WHO mHealth HCW use categories

Program type, examples, country (year)	Health focus (target user)	Program description	Acceptability data	Effectiveness data
Cross-cutting				
CHN on the Go [14] Ghana, 2014	Maternal and child health, including HIV (nurse)	App with multiple features including mLearning courses, access to guidelines to inform diagnosis and treatment, planner to organize work flow, activity tracking by supervisors, and a WhatsApp peer network.	Unavailable	Unavailable
mLearning				
ITM and IMTAVH [15] Peru, 2009	HIV (HCWs)	Continuing medical education program with interactive 3D case-based simulations of HIV care available on mobile phones.	Unavailable	Unavailable
Tagore WAY2SMS [16] India, 2013	HIV (medical students)	30 SMS sent to medical students on HIV to increase knowledge and reduce stigma among HCWs.	Unavailable	Change in knowledge and attitude among participants.
Mobile telehealth and access to information resources				
K4Health SMS network [13] Malawi, 2010	HIV and reproductive health (CHWs)	SMS CHW network to exchange HIV/AIDS and reproductive health information.	High; increased contact with supervisor initiated by CHW	Increased quality of care.
mCHW-WhatsApp [17] Kenya, 2014	Broad health topics, including HIV (CHWs)	WhatsApp CHW network to receive supervision including quality assurance, connecting with peers, and gain access to information and training.	High	Unavailable.
Clinical decision support systems				
Health scout [18] Uganda, 2015	HIV (CHWs)	Decision support tool guiding CHWs through situated Information, Motivation, and behavioral-model counseling session with screening, triaging, and counseling prompts.	Unavailable	Unavailable. Randomized control trial currently underway.
Mobile pMTCT cascade analysis tool [28] Cote d'Ivoire, Kenya, Mozambique, 2013	HIV (HCWs)	Mobile-based tool for pMTCT site managers to quantify patient flows to identify clinic-level interventions.	High	3–4 fold increase in maternal ARV coverage and 17-fold increase in HIV-exposed infant screening
NeuroScreen [27] South Africa, 2015	HIV (CHWs)	A mobile and tablet-based automated tool to screen for neurocognitive impairment due to HIV infection.	High	81% sensitivity and 85% specificity in preliminary findings
Electronic patient information				
Early infant diagnosis: EID project [19], Program Mwana [20], SMART [21] Kenya (2012), Nigeria (2010), Uganda (2012), Zambia (2010)	HIV (HCWs)	Laboratories and caregivers can receive infants' HIV test results by SMS. Some laboratories have battery-operated printers to print results from phones.	High	Decreased time, by up to 50%, between testing and results notification. [12]
Patient monitoring				

Program type, examples, country (year)	Health focus (target user)	Program description	Acceptability data	Effectiveness data
Phones for for Health [12] Rwanda 2007	HIV (HCWs)	HCWs enter and upload data on all patients receiving ARTs on mobile phones. Data can be accessed online by health authorities.	Unavailable	Unavailable
TRACnet [22, 23] Rwanda, 2005	HIV (HCWs)	HIV/AIDS care and treatment health information system to manage patients and drug distribution through the use of solar powered mobile phones.	High coverage. Data on acceptability unavailable	98% timeliness and 100% completeness of reporting
Other				
DektReader [23] Global	Multiple diseases including HIV (HCWs)	Mobile diagnostic device which can analyze rapid HIV tests, conduct quality checks to assess for misprocessed samples, and provide interpretation of the result.	Unavailable for HIV	Unavailable for HIV. High effectiveness for malaria diagnosis
Early warning system (EWS) [12] [†] Ghana, 2011	HIV and other tracer commodities (HCWs)	HCWs report stock of tracer commodities including HIV weekly by SMS. Data can be accessed online by participating managers and providers.	High	Reduced stock out rates on tracer commodities by 25%