Mobile health applications for HIV prevention and care in Africa

*Jamie I. Forrest[a,b], Matthew Wiens[a,b], Steve Kanters[a,b],
Sabin Nsanzimana[c,d], Richard T. Lester[e], and Edward J. Mills[a,f]*

Purpose of review
More people have mobile phones in Africa than at any point in history. Mobile health (m-health), the use of mobile phones to support the delivery of health services, has expanded in recent years. Several models have been proposed for conceptualizing m-health in the fields of maternal–child health and chronic diseases. We conducted a literature review of m-health interventions for HIV prevention and care in African countries and present the findings in the context of a simplified framework.

Recent findings
Our review identified applications of m-health for HIV prevention and care categorized by the following three themes: patient-care focused applications, such as health behavior change, health system-focused applications, such as reporting and data collection, and population health-focused applications, including HIV awareness and testing campaigns.

Summary
The potential for m-health in Africa is numerous and should not be limited only to direct patient-care focused applications. Although the use of smart phone technology is on the rise in Africa, text messaging remains the primary mode of delivering m-health interventions. The rate at which mobile phone technologies are being adopted may outpace the rate of evaluation. Other methods of evaluation should be considered beyond only randomized-controlled trials.

Keywords
Africa, HIV, m-health, mobile health, SMS

INTRODUCTION

Six billion of the world's seven billion people now have a mobile phone subscription [1]. The global proliferation of mobile phone use in recent years has largely been driven by a rapid uptake in low-income and middle-income countries. In 2002, roughly one-in-ten people in Tanzania, Uganda, Kenya, and Ghana had a mobile phone subscription; today this has risen to over 80% [2]. Mobile phone ownership is now as common in South Africa and Nigeria as it is in the USA [2]. Talking and text messaging (SMS) remains the primary use of mobile technology in many developing countries, but a small yet growing proportion of users are now using mobile devices capable of accessing the Internet.

With substantial growth in the number of mobile phone users, researchers and health practitioners have become increasingly interested in the field of mobile health, or m-health, broadly defined as the use of mobile phone technology to improve the delivery of health services. M-health offers particular promise for delivering interventions to reduce morbidity and mortality and to improve quality of life in resource-constrained settings. There has been considerable interest in m-health to support the delivery of HIV care and prevention services because much of the global burden of HIV exists in settings experiencing a rapid uptake in mobile phone use.

[a]Global Evaluative Sciences, [b]School of Population and Public Health, Faculty of Medicine, University of British Columbia, Vancouver, Canada, [c]Rwanda Biomedical Center, Kigali, Rwanda, [d]Basel Institute for Clinical Epidemiology & Biostatistics and Swiss Tropical and Public Health Institute, University of Basal, Basal, Switzerland, [e]Department of Medicine, University of British Columbia, Vancouver, Canada and [f]School of Public Health and Community Medicine, University of Rwanda, Kigali, Rwanda

Correspondence to Jamie I. Forrest, Global Evaluative Sciences, 302-1505W 2nd Avenue, Vancouver, BC, Canada V6H 3Y4. Tel: +1 604 336 3050; fax: +1 604 608 5583; e-mail: jforrest@geshealth.com

KEY POINTS

- With increased access to mobile technologies, there are more opportunities for the application of mobile health (m-health) strategies in the delivery of HIV prevention and care in Africa.

- Although a primary focus of m-health thus far has been for the benefit of the individual patient, m-health can also be advantageous for health systems and populations.

- SMS remains the primary mode of delivering m-health interventions, but with the rise of smart phone technology, there are new opportunities to consider the role of social media in HIV care and prevention.

- The rate at which mobile phone technologies are being adopted may outpace the rate at which rigorous evaluation of m-health interventions can be performed and consideration should be given to other methodological forms of evaluation beyond only randomized-controlled trials.

There have been several extensive reviews of m-health interventions for all disease areas, including a World Bank report published in 2011 reporting on more than 500 m-health interventions [3]. Many of these interventions, however, are among populations in high-income settings, thereby limiting their applicability to the resource-constrained context. This is not only because the use of mobile phones for voice and data transmission remains limited, but also because important cultural differences exist regarding engagement with the health system. Furthermore, with technology advancing much more rapidly than the field of global health implementation science, many pilot interventions considered only 5 years ago, likely have limited applicability today.

Utilizing existing frameworks proposed in other disease areas for conceptualizing m-health applicability, we aim to review the literature and update a conceptual framework as it applies to m-health interventions to support HIV prevention and care in African countries.

METHODS AND CONCEPTUAL FRAMEWORK

We conducted a literature review using the search terms 'mobile health OR mhealth OR m-health OR SMS' AND 'HIV' AND 'Africa' on the Medline and EMBASE databases from 2005 to July 5, 2015, to identify relevant studies focusing on mobile health interventions for HIV prevention and care in an African setting.

Using two reviews that presented conceptual frameworks for m-health application (one in chronic disease prevention and one in maternal and child health), we developed a framework adaptable to m-health for HIV prevention and care in resource-constrained contexts. Khan *et al.* [4] proposed a social ecological framework that categorizes m-health interventions into three broad levels of application: uses for individual, uses for communities, and uses within large geographical areas. The domains at the community-level and larger geographical areas address interventions that could be used for social and professional networking and in facilitating increased community connectedness. The domain at the individual level, focuses on the use of m-health to facilitate a direct communication between individual mobile phone users and the health system. This includes interventions to promote medication adherence, encourage healthy behaviors, and engage and retain a patient in health services. More recently, Labrique *et al.* [5] developed a more nuanced framework for the classification of m-health interventions for maternal and child health. In this framework, the primary focus is on where the intervention fits within 12 components of the health system (e.g. education, diagnostics, supply chain, electronic health records, vital events tracking, and so on). A second layer then focuses on the 'touch points' of the m-health intervention (e.g. patient, community health worker, nurse, clinic, etc.). Within these layers are specific life stages targeted by the intervention (e.g. before pregnancy, pregnancy, motherhood, infant, child, and so on).

We present a simplified, hybrid form of these frameworks in which to contextualize the findings of our literature review on m-health for HIV prevention and care in Africa. The proposed framework focuses on the domains of influence: patients, health systems, and populations, and similarly to the framework by Labrique *et al.* these domains were further subdivided into functional components, albeit components applicable to HIV care (Fig. 1 and Table 2). With any rapidly growing field of research there can often be duplicate definitions. Table 1 provides explicit definitions for clarity.

PATIENT CARE-FOCUSED M-HEALTH

The first domain is related to patients and the applicability of m-health innovations for the purpose of communicating information related to care. This focus on patient care was among the earliest m-health interventions to be formally evaluated in resource-constrained settings. Specifically, these interventions focus on four subdomains, namely medication adherence, patient engagement and
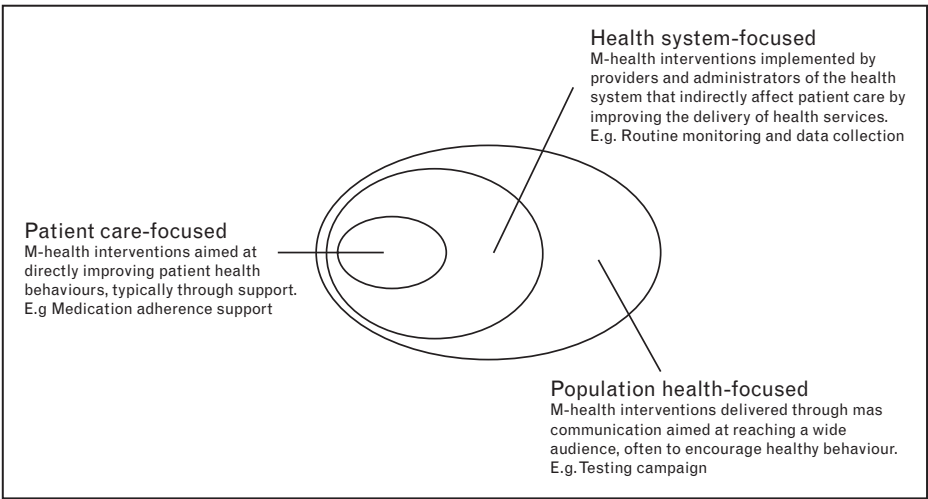
FIGURE 1. Conceptual diagram of m-health interventions for HIV prevention and care in Africa. It depicts concentric overlapping domains of m-health influence. The center refers to paint care-focused interventions aimed at directly improving patient health, embedded within health system-focused interventions that help improve the delivery of health services, and finally population health-focused interventions that use mass communication to reach a wide audience.

retention, support groups, and notification of lab results including diagnoses. Specifically, two prominent randomized controlled trials, conducted in Kenya and Uganda, showed that SMS can improve adherence to antiretroviral therapy (ART), and by doing so, prolong viral suppression [6,7]. Another

Table 1. Definitions in mobile-related technology

SMS
Short message service, allows exchange of short text messages between mobile phone devices
One-way SMS
Delivery of SMS without the expectation of a reply from the user
Two-way SMS
Delivery of SMS with options for the user to reply
Basic phone
Offers basic voice and SMS services
Feature phone
Basic phone with Internet-enabled service and enables the transmission of picture messages
Smart phone
Feature phone plus a graphical interface and touchscreen capability with built-in Wi-Fi and global position system (GPS) technology
Apps
A software application designed to run on mobile devices
WAP
Wireless Application Protocol for accessing information over mobile network

trial in Cameroon found no effect of SMS on adherence to ART [8], whereas a more recent trial in Nigeria found that SMS in combination with counseling was a very effective strategy [9]. A meta-analysis of eight studies found that SMS-based interventions resulted in a nearly 40% higher odds of adherence compared with control conditions, with further advantage for less frequent SMS messaging (i.e. weekly) and bi-directional messaging (i.e. permitting SMS reply) [10■■]. Figure 2 displays a forest plot of the studies conducted in African countries. As can be seen, even when restricted to the African setting, the use of SMS on average improves medication adherence among HIV-positive patients (odds ratio: 1.49; 95% confidence interval: 1.17–1.90).

M-health has also been successfully adapted as an intervention to improve retention of patients in HIV care. Following the success of the WelTel trial for improving adherence to ART, another study in Kenya is seeking to evaluate the efficacy of SMS for patient retention in Nairobi [11]. Qualitative analysis has shown promise for enabling early identification of problems, leading to timely problem solving that may improve retention and engagement in care during the first year of diagnosis [12]. The MORE CARE trial in Cameroon tested the efficacy of reminders on follow-up in care among children exposed or infected with HIV [13■]. The trial found that SMS and phone call was the most effective method of retaining mother–child pairs in care. Another study in Kenya found that SMS significantly improved maternal postpartum visit

Table 2. Summary of evidence on m-health interventions related to HIV prevention and care in Africa

Domain	Sub-domain	Studies	Summary
Patient care-focused	Medication adherence support	Lester *et al.* [6], Pop-Eleches *et al.* [7], Mbuagbaw *et al.* [8], Maduka *et al.* [9]	SMS is shown to be an effective strategy at improving adherence to antiretroviral therapy.
	Patient engagement and retention	van der Kop *et al.* [11], Smillie *et al.* [12], Bigna *et al.* [13■], Odeny *et al.* [14], Mwapasa *et al.* [15■]	SMS has been used successfully to retain patients in care. This has been shown to be particularly useful to engage mother–child pairs in prevention of mother-to-child transmission programs.
	Patient support groups	Dean *et al.* [16]	Support groups via SMS may help overcome stigma and logistical challenges for people living with HIV in rural or remote areas.
	Notification of laboratory results	Dryden-Peterson *et al.* [18■], Siedner *et al.* [19■]	SMS may be an effective strategy for delivering laboratory test results. This may help retain patients in care. More discussion on the ethical and privacy implications is necessary.
Health system-focused	Routine monitoring and evaluation and data collection	Nsanzimana *et al.* [20], Rotheram-Borus *et al.* [22], Mutua *et al.* [23]	SMS can be used to relay information to a centralized system for monitoring evaluation for HIV care delivery programs. Data can also be collected from research participants via SMS.
	Professional networking and clinical support	Chang *et al.* [24], Lemay *et al.* [25]	In rural areas, community health workers can access clinical support and network with peers via m-health.
	Supply chain management	Rivett *et al.* [27]	M-health could be an effective strategy for relaying information regarding medication stock-outs. More evaluation is needed, particularly its application in other African settings.
	Disease surveillance and diagnostics	Rajput *et al.* [28]	Real-time monitoring of disease and the potential for point-of-care diagnostics should be explored further.
Population health-focused	Education and testing campaign	Chib *et al.* [29]	Mass communication by SMS to engage individuals in an HIV awareness and testing campaign may have limited effect on health outcomes. Evaluation poses challenges.
	Research participant recruitment	de Tolly *et al.* [30]	SMS is a successful tool for recruiting participants to a research study.

attendance and high rates of early infant HIV testing were achieved in both trial arms. [14] Finally, the promoting retention among infants and mothers effectively (PRIME) study demonstrating the efficacy of SMS to support the retention of mother–infant pairs for prevention of mother-to-child transmission (PMTCT) in Malawi [15■].

Other m-health interventions that focus on patient behavior in the context of HIV have been evaluated. In South Africa, a pilot SMS support group was shown to help reduce stigma and overcome logistical challenges among women receiving antenatal care at two urban clinics. [16] The potential for m-health applications such as these to integrate more aspects of social networking for peer health support are limitless. More rigorous evaluation of such interventions should, however, be conducted prior to major scaling initiatives [17].

Patient focused m-health interventions addressing education have also been evaluated. The use of SMS for notification of laboratory test results is a more recent example of this kind of m-health strategy for people living with HIV in Africa. A cluster-randomized trial examining the utility of CD4 results delivered by SMS in Botswana found that those randomized to SMS received their results
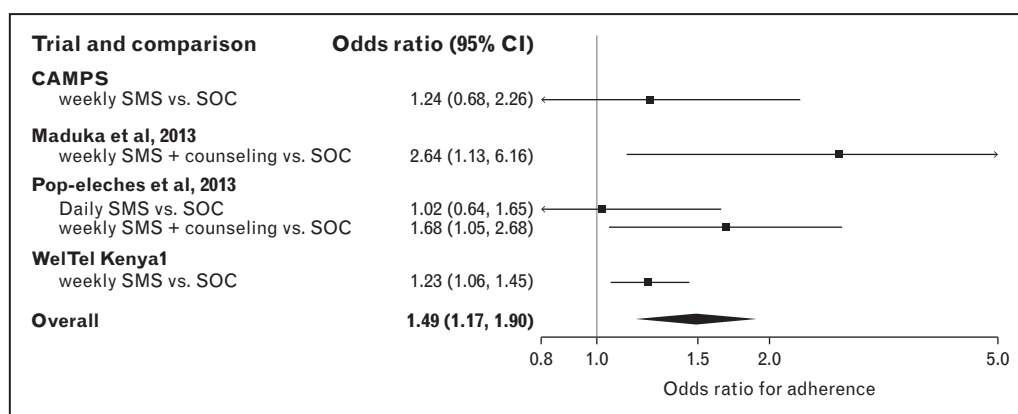
FIGURE 2. Forest plot of the relative efficacy of m-health interventions aimed at improving adherence to antiretroviral therapy in Africa. There are four trials included in this plot [6–9] and the dots represent the point estimates for the odds of adherence in patients receiving the intervention as reported by the four trials. Whiskers represent the 95% confidence intervals around these point estimates.

not only much earlier, but were more satisfied with their care [18▪]. Furthermore, this intervention was also associated with cost-savings. In Uganda, clinic attendees with an abnormal test result were randomized to receive one of three message formats designed to evaluate trade-offs between clarity and privacy [19▪]. The researchers found that literacy is an important predictor in understanding and interpreting SMS-delivered laboratory results. These results suggest that more work is required to determine optimal methods of results notifications, which is also likely to differ substantially according to regional patterns of education and literacy. Furthermore, a greater dialogue on the ethical and privacy concerns related to laboratory test notification via a third-party telecommunications company is warranted.

HEALTH SYSTEM-FOCUSED M-HEALTH

Labrique *et al.* [5] identified 12 distinctive areas where m-health applications could be used for health system strengthening. In the case of m-health for HIV care and prevention, we focus on four unique subdomains where m-health is currently being evaluated (Table 2). The first of these domains is routine monitoring and data collection. Routine monitoring of persons living with HIV is a significant and growing barrier in HIV care in resource constrained settings. As treatment thresholds increase and as people with HIV live longer health systems are beginning to reach critical levels of capacity to monitor and evaluate their growing treatment programs. M-health applications to address this barrier are therefore both timely and necessary.

In Rwanda, the national HIV care program has implemented a system called TRACnet that allows administrators at the health-facility level to SMS monthly indicators to the national program office in Kigali [20]. By addressing the administrative burden of reporting indicators, Rwanda has been able to identify areas of the ART delivery program that are successful and where it may need to be strengthened [21]. In South Africa, a cluster randomized controlled trial evaluating an m-health peer-facilitated support group for PMTCT was able to utilize m-health to successfully collect routine information, complete questionnaires, and remain in contact with participants over time [22]. In another example, a study evaluating safety and adherence to pre-exposure prophylaxis among men who have sex with men and female sex workers in Kenya sent daily SMS to participants to collect data on sexual activity [23].

A second subdomain of health system focused m-health is for professional networking and clinical support. The rapid scaling of community-level health workers in many African countries and their expanding role within their health systems has led to significant improvements in access and care. However, many barriers have been identified in the provision of community-level care and the role of m-health in addressing these barriers is important. In Uganda, a cluster randomized controlled trial evaluated a support intervention used by community-based peer health workers. Although no significant differences in patient virologic outcomes were found, but qualitative analyses reported broad support for intervention and improvements in the logistics of delivering patient care [24]. In Malawi, the K4Health Project is a knowledge management project designed to increase the dissemination and use of the latest research and best practices to improve processes among HIV community health

workers in Malawi [25]. A recent systematic review of mobile health applications for community health workers found that these interventions can improve both the range and the quality of health provision at this level, which addresses a critical public heath gap [26].

A third subdomain is supply-chain management. The prevention of stock-outs has been identified as a major priority in the scale up of ART. This was one of the many objectives of the Cell-life program in South Africa, where the integration of mobile technologies was used to support the provision and distribution of medication, the continuous monitoring of patients and the communication of relevant data to administrators [27]. Further evaluation of this strategy is needed to assess its applicability in other African settings.

A final subdomain is in HIV surveillance. This includes incidence monitoring, disease surveillance, and potentially point-of-care diagnostics. An m-health intervention by community health workers in western Kenya used mobile phones to administer a structured survey to two million people for the purpose of both HIV testing and disease surveillance [28]. There is also promise for the development of technologies that will enable point-of-care HIV testing with a smart phone. These technologies are currently in development, although rates of smart phone use and improvements in data transmission are needed before these can be applied to many African settings.

POPULATION HEALTH-FOCUSED M-HEALTH

Population health-focused m-health interventions are organizationally outside of the patient and the health system because interventions employing the use of mass communication via mobile phones can transcend individual health systems. Examples formally evaluated to date are interventions that aim to communicate messages of health information and health promotion. In northwest Uganda, a pilot intervention explored the efficacy of an m-health SMS campaign to disseminate and measure HIV/AIDS knowledge and promote testing at rural clinics [29]. The campaign had limited success in increasing knowledge levels on a mass scale. Although the researchers recognized the potential for m-health interventions extended to millions of mobile phone users, measuring an effect of any such intervention would be limited. In another example of population health-focused m-health application, researchers in South Africa successfully recruited more than 2500 participants via SMS after messages were sent to more than 24 000 mobile

numbers randomly sampled from a preexisting data frame [30].

There is promise for an expansion of public–private partnerships between health providers and telecommunication companies. Many industry-sponsored education, awareness, and testing campaigns are being implemented in several African countries. In a partnership with Vodacom South Africa, an Internet and mobile-enabled platform (WAP) allows providers to deliver HIV and STI prevention information by engaging young people on the topics of sex, love, and relationships. The platform has an estimated 1.3 million users and has now expanded to Kenya and Tanzania [31].

CHALLENGES AHEAD

The acceleration of computing power, as characterized by Moore's Law [32], has facilitated more and more opportunities for the integration of technology in healthcare. However, this rapid acceleration has also posed serious challenges for researchers and implementers. Often new technologies become obsolete before they are pilot tested, evaluation and brought to scale. For example, SMS has been extensively evaluated as a tool to improve many patient care and health service challenges, but other innovations such as the smart phone app, *WhatsApp*, is quickly being adopted by users across the continent. What role will messaging apps play in the future and how translatable are findings of SMS interventions to this newer technology?

Evaluating m-health interventions comes with many challenges. The further the innovation is from direct clinical care, the more challenging it is to detect an effect at the individual level. Conventionally, interventions are evaluated by randomized trials; however, conducting such methodologically rigorous methods of evaluation tends to be a lengthy process. Given the rapid acceleration of mobile technology, is this the best strategy for evaluating all potential interventions? Bridging the disconnect between the rate at which technologies are being developed and adopted, and the rate at which their use as a health intervention can be evaluated will require innovative thinking. The role of case studies should be given more consideration when looking at evidence to support the efficacy and scalability of m-health interventions. A website called Mobile for Development Impact, is building a thriving community of innovators in the developing world mobile technology ecosystem to highlight innovations that serve underserved consumer segments and drive positive social change.

As more users across the continent switch to smart phone technology, the opportunities for

m-health interventions become even more numerous. Two important additions with smart phone technology are applications, including apps for social media. Applications allow for a passive two-way communication in which the interaction between the app and the patient can be known without the patient actively providing the information to healthcare providers. Social media is an example of this new frontier for health service delivery in Africa. Facebook announced in 2014 that 100 million users were from African countries; representing half of the continent's Internet-connected population [33]. Improving the integration of health services into existing social media innovations and demonstrating its success will be an important next step for implementation scientists working in the field of m-health in Africa. The challenge will be in evaluating the use of social media and adopting it in a health system before the technology changes again.

Finally, it is important not to forget that the risk factors for poor health outcomes among people at-risk and living with HIV are also the same risk factors that prevent technology uptake. Poverty, mental illness, and social isolation are all risk factors for HIV and are also factors that may inhibitor a user from adopting new mobile technologies. Key populations, such as sex workers, men who have sex with men and transgender people in criminalized environments, will be less likely to engage in services such as social media that may increase their vulnerability to harm. As new, exciting innovations are presented to the field of m-health, careful consideration of their applicability, relevance and potential harms is crucial to mitigate the potential for m-health interventions to further marginalize individuals and communities.

CONCLUSION

M-health for HIV prevention and care in Africa extends beyond interventions that focus directly on patients and include higher-level applications to both health systems and populations. Assessing the role of m-health interventions within the domain of patient care has robust mechanisms for evaluating impact and shows some very promising results. However, the broader application of m-health within larger domains of social organization may have even equal or grander potential for societal benefit, but pose a greater evaluative challenge and methods need to be deployed to assess their impact at scale. Technology is rapidly expanding and interventions that were once applicable just five years ago may not be relevant today. The balance between methods that can rapidly evaluate

technologies in a timely way, and the long-term usefulness of technologies in dynamic settings requires consideration. In African settings, where rates of the uptake of mobile phone use are among the highest in world, basic phones with SMS and voice technology remain the norm, but alternate technologies are emerging. A renewed vision for the evaluation of m-health strategies in Africa is needed to keep pace with acceleration of uptake.

Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:
- ▪ of special interest
- ▪▪ of outstanding interest

1. International Telecommunication Union: measuring the information society. 2012. http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-ICTOI-2012-SUM-PDF-E.pdf. Accessed 11 July 2015.
2. Pew Research Center: Cell phones in Africa: communication lifeline. 2015. http://www.pewglobal.org/2015/04/15/cell-phones-in-africa-communication-lifeline/. Accessed 11 July 2015.
3. Qiang CZ, Yamamichi M, Hausman V, *et al.* Mobile applications for the health sector. Washington: World Bank; 2011.
4. Kahn JG, Yang JS, Kahn JS. 'Mobile' health needs and opportunities in developing countries. Health Aff (Millwood) 2010; 29:252–258.
5. Labrique AB, Vasudevan L, Kochi E, *et al.* mHealth innovations as health system strengthening tools: 12 common applications and a visual framework. Glob Health Sci Pract 2013; 1:160–171.
6. Lester RT, Ritvo P, Mills EJ, *et al.* Effects of a mobile phone short message service on antiretroviral treatment adherence in Kenya (WelTel Kenya1): a randomised trial. Lancet 2010; 376:1838–1845.
7. Pop-Eleches C, Thirumurthy H, Habyarimana JP, *et al.* Mobile phone technologies improve adherence to antiretroviral treatment in a resource-limited setting: a randomized controlled trial of text message reminders. AIDS 2011; 25:825–834.
8. Mbuagbaw L, Thabane L, Ongolo-Zogo P, *et al.* The Cameroon Mobile Phone SMS (CAMPS) trial: a randomized trial of text messaging versus usual care for adherence to antiretroviral therapy. PLoS One 2012; 7:e46909.
9. Maduka O, Tobin-West CI. Adherence counseling and reminder text messages improve uptake of antiretroviral therapy in a tertiary hospital in Nigeria. Niger J Clin Pract 2013; 16:302–308.
10. Finitsis DJ, Pellowski JA, *et al.* Text message intervention designs to promote
▪▪ adherence to antiretroviral therapy (ART): a meta-analysis of randomized controlled trials. PLoS One 2014; 9:e88166.
This is a systematic review and meta-analysis of SMS interventions to improve adherence to ART in any setting. The study found that SMS reminders yielded significantly higher odds of adherence compared with control conditions.
11. van der Kop ML, Ojakaa DI, Patel A, *et al.* The effect of weekly short message service communication on patient retention in care in the first year after HIV diagnosis: study protocol for a randomised controlled trial (WelTel Retain). BMJ Open 2013; 3:e003155.
12. Smillie K, Van Borek N, van der Kop ML, *et al.* Mobile health for early retention in HIV care: a qualitative study in Kenya (WelTel Retain). Afr J AIDS Res 2014; 13:331–338.

13. Bigna JJ, Noubiap JJ, Kouanfack C, et al. Effect of mobile phone reminders on
   ■ follow-up medical care of children exposed to or infected with HIV in
   Cameroon (MORE CARE): a multicentre, single-blind, factorial, randomised
   controlled trial. Lancet Infect Dis 2014; 14:600–608.
This study is a factorial design randomized controlled trial in Cameroon to assess
the efficacy and cost-effectiveness of SMS and phone call reminders on retention
in care among children infected with or exposed to HIV. The study demonstrated
that SMS + phone call was most effective, but SMS alone was most cost-effective.
14. Odeny TA, Bukusi EA, Cohen CR, et al. Texting improves testing: a randomized
   trial of two-way SMS to increase postpartum prevention of mother-to-child
   transmission retention and infant HIV testing. AIDS 2014; 28:2307–2312.
15. Mwapasa V, Pro G, Chinkhumba J, et al. Mother-infant pair clinic and SMS
   ■ messaging as innovative strategies for improving access to and retention in
   eMTCT care and Option B+ in Malawi: a cluster randomized control trial (the
   PRIME study). J Acquir Immune Defic Syndr 2014; 67 (Suppl 2):S120–124.
This study tested the effect of an SMS intervention to engage and retain mother–
child pairs in PMTCT services in Malawi. The cluster randomized trial design is an
interesting approach to evaluating SMS interventions that improve retention in
care.
16. Dean AL, Makin JD, Kydd AS, et al. A pilot study using interactive SMS
   support groups to prevent mother-to-child HIV transmission in South Africa. J
   Telemed Telecare 2012; 18:399–403.
17. Tomlinson M, Rotheram-Borus MJ, Swartz L, et al. Scaling up mHealth: where
   is the evidence? PLoS Med 2013; 10:e1001382.
18. Dryden-Peterson S, Bennett K, Hughes MD, et al. An augmented SMS
   ■ intervention to improve access to antenatal CD4 testing and ART initiation
   in HIV-infected pregnant women: a cluster randomized trial. PLoS One 2015;
   10:e0117181.
This study evaluated the effectiveness of an SMS-based intervention to improve
access to timely antenatal care by delivering CD4 results by an automated platform
with active patient tracking. The intervention was effective at delivery results and
notifications and could be useful in a variety of settings, but it did not appear to
improve access to timely care.
19. Siedner MJ, Santorino D, Haberer JE, et al. Know your audience: predictors of
   ■ success for a patient-centered texting app to augment linkage to HIV care in
   rural Uganda. J Med Internet Res 2015; 17:e78.
There are privacy and confidentiality concerns regarding interventions that delivery
patient results via SMS. This study sought to describe those with high uptake of
this intervention and evaluate its efficacy. The researchers found that literacy is the
most important predictor of message receipt and coded messages were as
effective as direct messages and may support privacy. This study highlights the
need for close ethical consideration of m-health for the delivery of confidential or
sensitive information.

20. Nsanzimana S, Ruton H, Lowrance DW, et al. Cell phone-based and internet-
   based monitoring and evaluation of the National Antiretroviral Treatment
   Program during rapid scale-up in Rwanda: TRACnet. J Acquir Immune Defic
   Syndr 2012; 59:e17–e23.
21. Nsanzimana S, Remera E, Kanters S, et al. Life expectancy among HIV-
   positive patients in Rwanda: a retrospective observational cohort study.
   Lancet Glob Health 2015; 3:e169–e177.
22. Rotheram-Borus MJ, Richter L, Van Rooyen H, et al. Project Masihambisane: a
   cluster randomised controlled trial with peer mentors to improve outcomes for
   pregnant mothers living with HIV. Trials 2011; 12:2.
23. Mutua G, Sanders E, Mugo P, et al. Safety and adherence to intermittent
   preexposure prophylaxis (PrEP) for HIV-1 in African men who have sex with
   men and female sex workers. PLoS One 2012; 7:e33103.
24. Chang LW, Kagaayi J, Arem H, et al. Impact of a mHealth intervention for peer
   health workers on AIDS care in rural Uganda: a mixed methods evaluation of a
   cluster-randomized trial. AIDS Behav 2011; 15:1776–1784.
25. Lemay NV, Sullivan T, Jumbe B, et al. Reaching remote health workers in
   Malawi: baseline assessment of a pilot mHealth intervention. J Health Com-
   mun 2012; 17 (Suppl 1):105–117.
26. Braun R, Catalani C, Wimbush J, et al. Community health workers and
   mobile technology: a systematic review of the literature. PLoS One 2013;
   8:e65772.
27. Rivett U, Tapson J. The Cell-Life Project: converging technologies in the
   context of HIV/AIDS. Gateways 2009; 2:82–97.
28. Rajput ZA, Mbugua S, Amadi D, et al. Evaluation of an android-based m-health
   system for population surveillance in developing countries. J Am Med Inform
   Assoc 2012; 19:655–659.
29. Chib A, Wilkin H, Ling LX, et al. You have an important message! Evaluating
   the effectiveness of a text message HIV/AIDS campaign in Northwest
   Uganda. J Health Commun 2012; 17 (Suppl 1):146–157.
30. de Tolly K, Skinner D, Nembaware V, et al. Investigation into the use of short
   message services to expand uptake of human immunodeficiency virus testing,
   and whether content and dosage have impact. Telemed J E Health 2012;
   18:18–23.
31. Willis A. Mobile for development impact: young Africa live. 2015; http://
   www.m4dimpact.com/analysis/case-studies/young-africa-live. Accessed 11
   July 2015.
32. Vosburgh KG, Newbower RS. Moore's Law, disruptive technologies, and the
   clinician. Stud Health Technol Inform 2002; 85:8–13.
33. The Independent: Facebook hits 100 million users in Africa (that's half the
   continent's online community). 2014. http://www.independent.co.uk/life-
   style/gadgets-and-tech/news/facebook-has-100-million-users-in-africa-
   9719100.html Accessed 11 July 2015.