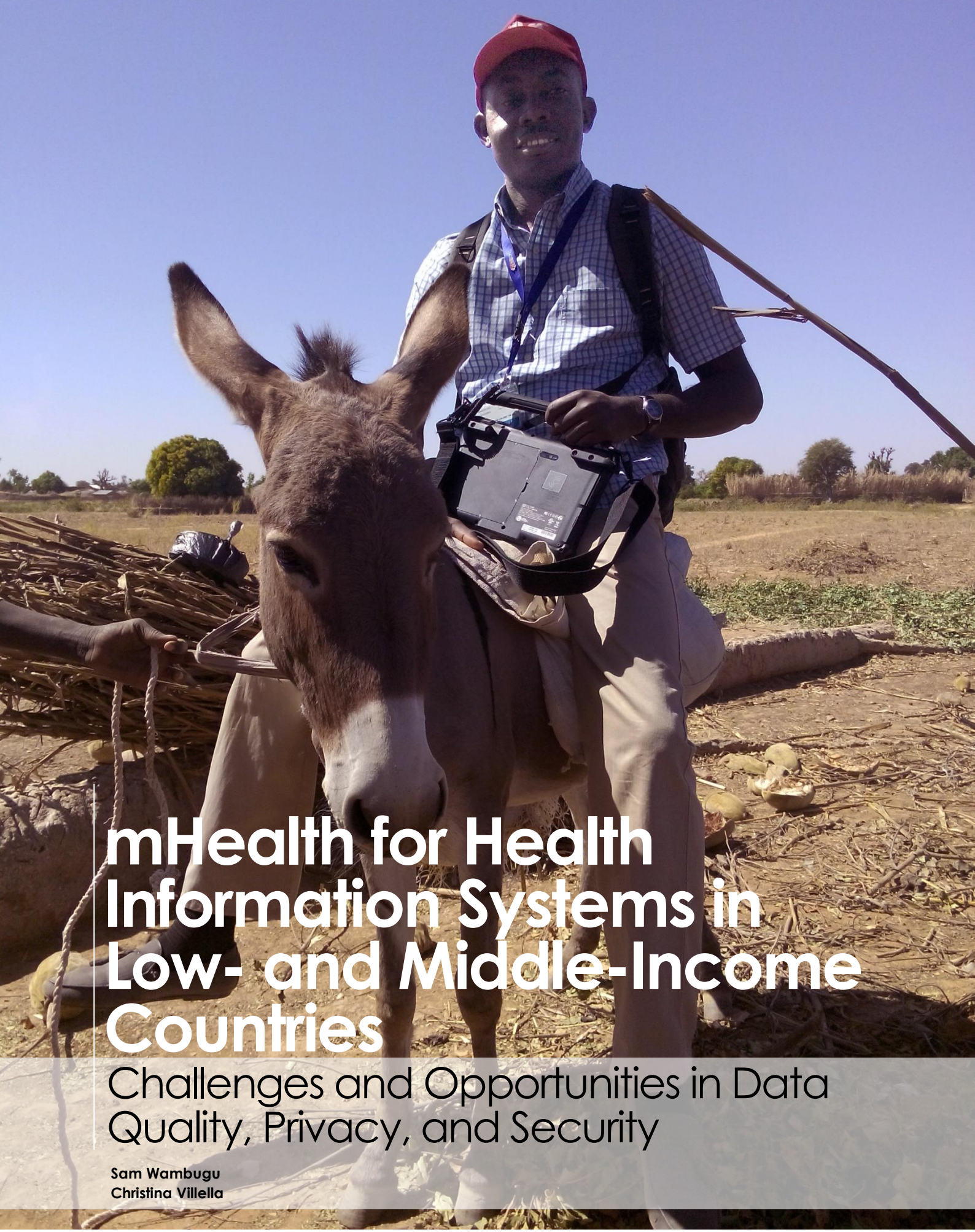

mHealth for Health Information Systems in Low- and Middle-Income Countries

Challenges and Opportunities in Data Quality, Privacy, and Security

Sam Wambugu
Christina Villella

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MEASURE Evaluation

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Cover: GIS analyst travels by donkey with his mobile tablet to record household level data at isolated Fulani settlements in Sokoto, Nigeria.

CONTENTS

ABBREVIATIONS

GPRS	general packet radio service
GSM	global system for mobile communications
HIS	health information system(s)
HMIS	health management information system(s)
ICT	information and communication technology
IVR	interactive voice response
LMIC	low- and middle-income country
MNCH	maternal, neonatal, and child health
NGO	nongovernmental organization
PHI	personal health information
SMS	short message service
WHO	World Health Organization

1. INTRODUCTION

Governments, nongovernmental organizations (NGOs), and international development organizations are working to improve health outcomes through better national health systems. One of the six building blocks for strong national health systems is the use of health information systems (HIS), according to the World Health Organization. A well-functioning HIS provides timely and relevant information about health outcomes and performance of the components of the health system (WHO, 2007). Governments and organizations working in low- and middle-income countries (LMICs) are seeking ways to improve health-related information and communication technologies (ICTs) to improve data availability and accessibility (Sanner, Roland, & Braa, 2012). Moreover, tools and systems that can help healthcare workers become more efficient and effective are especially crucial in LMICs facing health personnel shortages (Agarwal, Perry, Long, & Labrique, 2015).

> "Strong health information systems (HIS) are the backbone of strong health systems. A properly functioning HIS gets the right information into the right hands at the right time, enabling policymakers, managers, and individual service providers to make informed choices about everything from patient care to national budgets."
>
> MEASURE Evaluation (2016)

LMICs are experiencing an unprecedented increase in the number of users of cell phones and Internet technologies, while the prices of devices and services decline. This provides new opportunities to support healthcare delivery using mobile technology (known as mHealth). About 8 in 10 people in developing economies own a mobile phone, and the number is steadily rising. The use of mobile devices in healthcare can make it easier to access care, improve care delivery, empower patients through targeted messaging, and collect real-time data to optimize resources and decision making (World Bank, 2016). As a result, health programs are exploring ways to harness mobile technology to increase health coverage, improve the quality of care, and reduce healthcare costs.

For mHealth to assume a fully integrated role in healthcare, it must be provided in a way that gives patients and providers confidence that patient privacy will be protected and the confidentiality and security of patient information will be assured. Data need to be credible and consistent, and collected and stored securely in a trusted electronic health record with managed access for patients, caregivers, and healthcare professionals (Kumar & Wambugu, 2015).

Cell phones, tablets, and other mobile devices are already being used to collect and transmit individual and aggregate data from points of collection to centralized health information systems in LMICs. Indeed, mHealth is becoming an important strategy for delivery of health services and for collection, reporting, analysis, and use of data in near-real time. However, mobile devices used effectively in healthcare also may be used for personal activities such as calling, texting, playing games, taking photos, web browsing, e-mailing, and accessing social media. Such activities may take place through personal telephone services and Internet transmission systems that are vulnerable to viral attacks and other security risks that could lead to data breaches. While some smart phones and tablets have as much power as computers, they may not be as well maintained and secure. Without proper security safeguards, the personal use of mobile devices and sharing of devices with other people (such as family and friends) could jeopardize the quality, security, and confidentiality of health data.

MEASURE Evaluation undertook this assessment to study how mobile phone user behavior among health workers in LMICs may affect data quality, including data privacy, security, and confidentiality.

Through this assessment, the research team also learned that technical issues associated with mobile technology can affect data quality and security. We documented emerging best practices and challenges, studied reports in available peer-reviewed journals and gray literature, and gathered insights through interviews and consultations in two countries: Kenya and Tanzania. Our findings and recommendations are enclosed.

2. METHOD

This assessment consisted of two steps. First, the research team conducted a literature review to learn how mHealth is being used to strengthen health information systems in LMICs, and how data quality might be affected by the use of mobile devices in these programs. At first, we focused on user behavior with mobile devices. We soon learned that technical challenges also might be affecting data quality in mHealth programs. For this assessment, we searched both peer-review and gray literature, using terms such as "data quality," "data security," "official mobile devices," "mobile," "LMIC," "cellular phone," "mobile phone," "mobile device," "health," "cell phone," and "personal use of mobile phones by health workers." Section 3 summarizes the results of this literature review.

Using those results, we drafted a guide for consulting and interviewing program informants. We spoke with key informants from six mHealth programs in Kenya and Tanzania. The key informants were community health workers, program managers, health coordinators at district offices who monitor data quality, national eHealth managers in the capital cities of both countries, and one software developer in Kenya. Respondents represented both urban and rural areas and were based in clinics, offices for community-based interventions, and district health offices. Section 4 summarizes the findings from these consultations and interviews.

Section 5 integrates the evidence from both the literature review and key informant interviews to provide a foundation for the recommendations presented in Section 6.

3. LITERATURE REVIEW

3.1. mHealth for Health Information System Strengthening

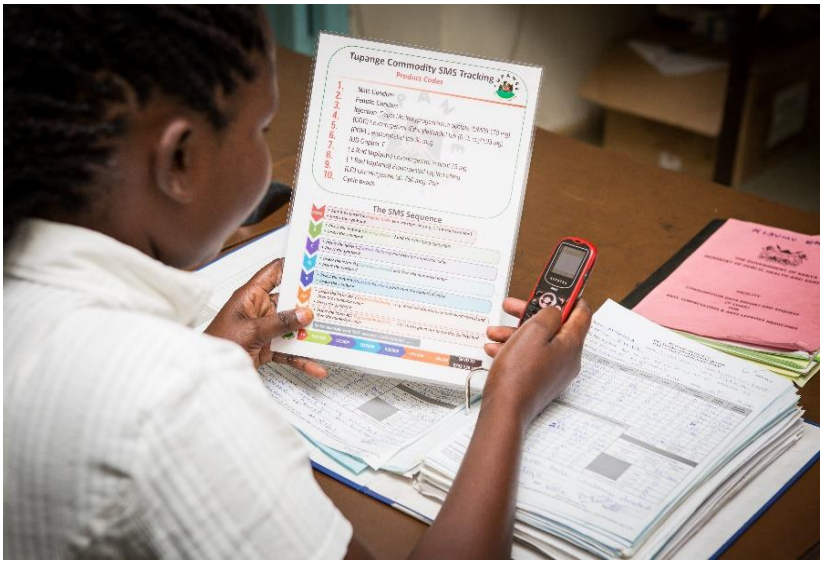
The use of mHealth is on the rise, particularly in LMICs, where access to the Internet and computers is often sparse (Lewis, Synowiec, Lagomarsino, & Schweitzer, 2012; Sanner, Roland, & Braa, 2012). As of 2012, the World Bank figures show an estimated 6 billion cellular subscriptions worldwide, with about 5 billion in developing countries. In 2000, there were fewer than 1 billion subscriptions, demonstrating the rapid adoption of this technology (World Bank, 2012). World Health Organization officials proclaimed in 2011 that mobile technology for health has the "potential to transform the face of service delivery across the globe" (Kay, Santos, & Takane, 2011).

As of 2014, the real-time tracker operated by GSM Association (a mobile technology trade association) put the number of mobile connections at 7.22 billion. The United States Census Bureau says the number of people is somewhere between 7.19 and 7.2 billion. These statistics mean that there are more mobile devices in the world than there are people.

The functions of mHealth span many components of a health system (see Table 1). Data generated from these functions could contribute to a country's national HIS. Four types of mobile phone solutions are already in use for HIS strengthening: interactive voice response (IVR), plain text SMS (short message

service), locally installed applications on handsets and SIM cards (data storage cards), and browser-based applications (Sanner, Roland, & Braa, 2012).

Many countries and organizations are testing ways that mHealth can extend the reach of Internet-based health information systems to mobile devices. Health systems are transitioning from paper-based systems to more real-time reporting of routine health data by health workers (Labrique, Vasudevan, Kochi, Fabriquant, & Mehl, 2013). This involves the use of mobile devices such as phones or personal digital assistants (PDAs) to collect data transmitted to a server that aggregates data across many sites and levels. Such aggregated data can be accessible on a computer program or web-based application that enhances data analysis across many variables (Labrique, et al., 2013). For example, DHIS 2, an open source health management information system used in more than 40 countries, mainly LMICs, has options for countries to adopt mobile extensions so that local health workers can report data into the system (DHIS 2, n.d.; DHIS 2 Mobile, n.d.).



In Nairobi, Kenya, a facility in-charge uses her phone and a system job aid to submit a monthly CDRR (consumption data report and request form) to the Tupange SMS commodity tracking system (TSCTS).

Two JAVA ME applications are available for data entry and patient tracking in DHIS 2 using general packet radio service (GPRS) or text messaging on mobile devices. Additionally, a browser-based client allows for data entry (DHIS 2 Mobile, n.d.). For example, in the state of Punjab, in India, auxiliary nurse midwives use the DHIS Mobile Java application to report routine health data in DHIS 2 (Sanner, Roland, & Braa, 2012). Data collected from mobile DHIS systems can be managed at the local or the national level (Labrique, et al., 2013). Mobile devices also are used to collect and track other routine health information, such as diseases and drug supplies (Hall, Fottrell, Wilkinson, & Byass, 2014; Barrington, Wereko-Brobby, Ward, Mwafongo, & Kungulwe, 2010; Mtema, et al., 2016; Tumusiime, et al., 2014).

Other platforms, such as Open Data Kit (ODK) and Frontline SMS, allow users to customize mobile data collection systems for nonroutine information, such as data from surveys and research (Labrique, et al., 2013; Rotherman-Borus, et al., 2011).

Table 1. Twelve common mHealth functions

mHealth Functions
Client education and behavior change communication
Sensors and point-of-care diagnostics
Registries/vital events tracking
Data collection and reporting
Electronic health records
Electronic decision support
Provider-to-provider communication
Provider work planning and scheduling
Provider training and education
Human resource management
Supply chain management
Financial transactions and incentives

Source: Labrique, et al., 2013

Table 1 shows many other functions for mHealth beyond data collection and reporting that have the potential to increase access to healthcare and coverage of healthcare services. Governments and global health development organizations are exploring the feasibility and effectiveness of using mobile devices to arrange for patient referrals to hospitals and for transportation to a hospital in an emergency (Agarwal, et al., 2015). Other solutions being tested to improve continuity of care involve the use of automated reminders and alerts for follow-up visits and treatment (Agarwal et al., 2015).

3.2. Data Quality

Data quality (which includes data security, privacy, and confidentiality) is critical to ensure the credibility and effectiveness of the HIS and the privacy of patients who share confidential information. We reviewed literature on how the use of mobile devices to collect health data can affect data quality. Studies have raised concerns about whether mobile systems can protect data from being altered, lost, or disclosed to unauthorized users (Akter, D'Ambra, & Ray, 2013). User behavior can determine how well mobile systems protect data. Another layer of complication is added when the mobile device used for health information also is used for personal use by the health worker or data collector. One study of mHealth projects for frontline health workers found that 74 percent of phones were provided by the project and 26 percent were personal phones (Agarwal, et al., 2016). Another report (Hampshire, et al., 2016) suggests that health workers in LMICs are using their personal mobile devices for "informal mHealth" activities, such as calls or messages related to their jobs. Additionally, sharing mobile devices among family members and friends is common, with reported sharing rates of 30 percent to 50 percent (Earth Institute, 2010).

> According to the World Health Organization (WHO, 2003), data quality is determined by several traits: "accuracy and validity of the original source data; reliability, when data are consistent and information generated is understandable; completeness, if all required data are present; legibility, when data are readable; currency and timeliness, if data are recorded at the time of observation; accessibility, if data are available to authorized persons when and where needed; meaning or usefulness, if information is pertinent and useful; and confidentiality and security, both of which are particularly important to the patient and in legal matters. Data quality is proportionate to the attainment of achievable improvements in healthcare."

The risks related to data quality and security also have an impact on an information system's overall performance, which can be broken down into system quality and information quality. System quality depends on factors such as reliability, ease of use, response time, accuracy, and perceived usefulness (Delone & McLean, 1992). A complicated mobile user interface can affect system quality, by decreasing ease of use. Similarly, data lost in transmission to a server from a mobile device would affect the system's reliability and perceived quality. Information quality relies on the quality of the information generated by the system, such as its reports. Measures of information quality include accuracy, completeness, timeliness, reliability, and relevance (Delone & McLean, 1992). In an HIS where mobile devices collect data for aggregation on a web-based platform, information quality would relate to the reports generated through this system. If a health worker does not submit data on time, or does not report on all required data elements, the report generated will be incomplete, affecting the system's information quality.

Many mHealth projects in LMICs have been studied only during their pilot stages. Hence, the evidence provided here may not reflect all the data quality risks posed by scaled-up mHealth interventions (Sanner, Roland, & Braa, 2012).

Our review of the literature determined two categories of challenges that can influence data quality: technical challenges and user-behavior challenges.

3.2.1. Technical Challenges

Security safeguards are important to ensure accurate information and to protect patients' confidentiality. The quality and security of data handled via mobile phone technology can be compromised by technical challenges. The literature shows that breaches can occur while information is stored on a mobile device with weak security safeguards and when data are sent to a centralized server through unsecure networks (Woodard, Weinstock, & Lesher, 2014; Siau & Shen, 2006; "DHIS 2 Mobile," n.d.). The theft of personal health information (PHI) can lead to medical identity theft, inaccurate health records, and the misuse of patients' credentials to obtain treatment under false pretenses (Agaku, Adisa, Ayo-Yusuf, & Connolly, 2014). Disclosure of PHI to unauthorized persons also can lead to stigmatization, discrimination, financial damages, and embarrassment for patients (Nass, Levit, & Gostin, 2009). In many countries, data security regulations do not address using mobile technology to transmit sensitive health information (Woodard, Wenstock & Lesher, 2014).

DHIS 2 Mobile is an application that stores data locally on a mobile device before it is transmitted to a server. Therefore, data has the potential to be lost or viewed by others who access the phone ("DHIS 2 Mobile," n.d.). Data quality also can be threatened if the physical security of the mobile devices used to report or collect health information is compromised (Chang, et al., 2011; Tumusiime, et al., 2014). One study of an mHealth initiative in Uganda reported that the light produced by the solar charging system resulted in phones being stolen while recharging (Tumusiime et al., 2014).

Some programs configure passwords and data encryption to increase security for their mobile devices and applications (Earth Institute, 2010). Another study (Arora, Yttri, & Nilsen, 2014) recommended that health organizations put passwords on phones prior to distribution and make it possible to erase the data from the device remotely. A peer health worker intervention in Uganda tried to create an incentive for workers to protect their phones against theft, by holding them responsible for replacing the stolen device (Chang, et al., 2011).

Furthermore, studies show that data also can be lost or compromised, owing to inadequate network coverage, weak or spotty transmission, poor access to charging devices, memory shortages, and problems synchronizing with a central server (Earth Institute, 2010; Sanner, Roland, & Braa, 2012). One study reported only 52 percent of 7,965 text messages were successfully transmitted (Perosky, et al., 2015). When DHIS 2 Mobile was first rolled out in Punjab, many SMS messages were lost because the modem could not send messages to DHIS 2 fast enough (Sanner, Roland, & Braa, 2012).

3.2.2. User Behavior Challenges

User behavior can also affect data quality when information is entered using a mobile device. Some challenges relate to how the user interacts with the device itself and others are more related to how the data is entered. One study of health workers using smartphones to complete electronic forms found that users sometimes accidentally deleted the application, inactivated the GPRS network, or lost the phone (Medhanyiie, et al., 2015). Another report found DHIS 2 Mobile users sometimes accidentally deleted the mHealth application from the mobile device (Sanner, Roland, & Braa, 2012). Other studies have reported that users entered data into test accounts by mistake or made spelling errors (Sacks, et al., 2015).

Projects have also had trouble with users losing mobile devices or not keeping them in good condition. Some organizations have adopted personnel policies about responsible use of the phone (Leon, Schneider, & Daviaud, 2012). Another study recommended downloading the mHealth application to the user's personal phone to create more accountability for not losing the phone (Mtema et al., 2016). Digital providers recommend using the simplest technology available (Leon, Schneider, & Daviaud, 2012).

3.2.3. Data Quality Improvement

Studies also show that the use of mobile devices can enhance data quality. One research project found that real-time data quality checks were easier to perform and another reported faster data collection (Leon, Schneider & Daviaud, 2012; Ginsburg, et al., 2014). In a system designed to identify child malnutrition in Malawi, health workers sent signs and symptoms to a central server that sent back instant advice on how to manage the child's health. Reports indicate that data quality was better than it had been with the paper tools used previously (Hall, Fottrell, Wilkinson, & Byass, 2014). In a mobile rabies surveillance system in Tanzania, more electronic forms were completed than paper forms (Mtema, et al., 2016).

4. FINDINGS FROM KEY INFORMANT INTERVIEWS

4.1. Summary Observations

This section summarizes findings from the key informant interviews we conducted in Kenya and Tanzania. Like the rest of the continent, these two countries have experienced a rapid increase in the number of health programs that use mobile devices to collect and transmit data, share health messages, and report data. Health workers use mobile devices to remind patients when it is time to take their medicine or come to a clinic appointment. We learned that mHealth empowers health workers, by giving them easy access to information on mobile devices that in turn helps them make decisions and improve the quality of service. For example, a health program in Tanzania has equipped health workers with low-end mobile phones loaded with important job aids and standard-of-care references that help them deliver high-quality care.

> "To send data is sometimes so hard. The [phone] signal is sometimes not strong enough to send the data at the end of the month. If data are urgent and the deadline is near, we have to take a "dala dala" [a public transport van] to the district office and deliver data physically. It takes our time away from work."
>
> —A key informant in Tanzania

Some programs have multilayer protection and built-in antivirus software, while others have no mechanism to assure data security. The types and capacity of phones vary by program. In three of the mHealth programs in this assessment, health workers use the same mobile device for work and personal use. Health workers in one program use tablet computers.

Many health programs use paper registers and forms for part of the information process, and mHealth applications and mobile devices for other parts of the system. For example, one maternal, neonatal, and child health program employs mHealth in more than 800 health facilities in Tanzania for recording and reporting data. Health staff in this program use phones for work and for personal use (including voice, data, photography, and videos). Program staff aggregate data from paper registers and report them to the district health management information system using a mobile phone-based reporting program. Below are some of the common themes that emerged from discussions with key informants in Kenya and Tanzania.

4.1.1 Data Transmission

mHealth programs in both countries commonly transmit data from mobile devices to the receiving database through GSM services offered by mobile service providers. Zones with poor mobile service

connections reported that it can take days before a strong signal is available to transmit the data. The only alternative is to travel long distances on unreliable roads to areas with better phone coverage.

4.1.2 Client Confidentiality

Health workers in an HIV program said that some clients they visited at home were concerned that personal information recorded on mobile phones could be misused. They feared that the phones could be used to film them or take their photographs. They also worried that their private health information could be shared with other people, either deliberately or inadvertently, if the phone got into the wrong hands. However, there was no evidence to show that discrete filming or taking photograms of patients was taking place.

A community health worker uses D-tree International's mobile application to provide comprehensive family planning services to a client in Shinyanga, Tanzania. © 2015 Ueli Litscher, Courtesy of Photoshare

4.1.3 Data Quality Checks

A program officer in Kenya implementing mHealth applications in HIV health services highlighted some data quality issues. Community health workers use mobile devices to capture and transmit sensitive data from clients in remote villages. These workers have limited formal education and prefer to use voice or phone calls, rather than typing text, to enter data using their phones. This sometimes results in mistakes in capturing and transmitting information using figures or characters that looked alike (such as "zero" and the letter "o").

> "The hype about technology sometimes drowns the voices of users, thereby ignoring a most important element in technology solutions; that is, human-centered design."
>
> —Key informant in Kenya

In another program, health workers collect and send data using tablet computers. However, the platform they use does not allow them to review the data to correct mistakes before transmitting, which makes them uneasy about data quality. This leaves health workers feeling that their only role is to record and submit data. Although the tablets were password protected, the health workers were not sure if the data in the tablet were secure from online access by unauthorized persons.

4.1.4 Device Charging

Several interviewees mentioned poor access to electricity as a barrier to optimal use of mHealth. Many residents of rural communities do not have electric power in their homes, making it difficult for health workers in these areas to keep their mobile devices fully charged. This can compromise the quality of data, especially when the phone runs out of battery power during data capture. In these communities, workers share phones among friends and family: One whose phone has a full charge will share with another whose phone battery charge is about to run out. Users charge phones at the nearest shopping centers, which are often the places with power points. At the phone-charging shops, it is common for phones to get lost, as they are not always closely monitored.

> "As a community, it is not uncommon to lend a friend your phone to call or text when theirs is down."
>
> —Key informant in Tanzania

4.1.5 Language Barrier

Nearly all key informants mentioned that the language of mHealth programs is a barrier. Most applications are in English, yet, most community health workers are more comfortable speaking their local languages.

4.1.6 Accidental App Deletion

A staff member of one program reported that it is common for workers inadvertently to delete the mobile application used to collect health data. This can result in lost or incomplete data. This risk is higher where health workers collect and store data on their mobile devices before transmitting the information, because the data can be deleted with the application.

4.1.7 Device Maintenance

Many of the phones used in mHealth programs in this assessment lack routine maintenance programs to ensure that they are in good working condition. Device failure from poor maintenance can result in lost data.

4.1.8 National mHealth Policies

Kenya and Tanzania are making progress in laying foundations for the effective use of ICT in the health sector. Each country has a national eHealth strategy. In addition, Kenya has completed an mHealth strategy. Kenya has completed a health enterprise architecture for guiding the implementation of a strong HIS, and Tanzania is in the process of developing one. Both countries will use the enterprise architecture framework to guide the development of an integrated national HIS.

> "… we want to reduce fragmentation of information systems and duplication of effort and promote greater interoperability in our health management information systems."
>
> – eHealth director, Tanzania

4.1.9 mHealth and HMIS integration

In both countries, DHIS 2 is the national health management information system (HMIS). However, their mHealth systems are not interoperable with DHIS 2 as yet, and none of their mHealth programs transmit data electronically into DHIS 2. Instead, the data are printed and manually entered in DHIS 2, which increases the likelihood of transcription-related errors. The eHealth framework and the health-enterprise architecture framework in Kenya have outlined steps for achieving interoperability of information systems.

5. DISCUSSION

As shown in the literature review and key informant interviews, it is clear that data quality and security in mHealth can be compromised by technical challenges, user behavior, and organizational limitations. This section explores these issues and considers ways to overcome them.

5.1. Technical Challenges

The physical integrity of mobile devices and their capacity to transmit data securely and reliably are issues that should be addressed in the design stage for developing mHealth solutions. Strong health information systems need measures to protect data from being lost or mishandled when phones are misplaced, shared, or stolen. Measures also are needed to prevent data from being intercepted or altered through faulty transmission. These measures are especially important when the data are stored on the phone prior to transmission.

The protection of personal health information should be at the heart of any attempt to develop health ICT systems. Architects of mHealth apps need to assess security of the applications and allied systems before deployment. Privacy and security safeguards should be embedded in all phases of health ICT systems development. Designing a system framework that provides mobile devices with a secure connection to electronic health record systems would minimize data breaches. Strong end-to-end encryption would protect health data during transmission. To ensure patient confidentiality and privacy, mHealth systems should have effective authentication technologies, such as smart health cards, tokens, one-time passwords, or biometrics.

Program policies should clarify who is responsible for lost, stolen, or damaged devices; how devices are maintained; and who is accountable for the physical security and maintenance of the device. Additionally, policies are needed to determine acceptable use of devices, such as whether or how they may be used for personal activities (MEASURE Evaluation SIFSA, 2015).

A training session on Maternal and Perinatal Deaths Review (MPDR) in Kenya. Photo: Akaco Ekirapa, DDU Specialist

When designing an mHealth program, developers should consider mobile phone signal coverage in the targeted program area. If the signal is strong, then the use of cloud solutions to store data should be explored. Many technology-based health solutions in developed countries use cloud solutions to store data as a measure to increase data security. Cloud-based mHealth involves data being transmitted directly to cloud-based storage once it is collected, leaving little patient data stored on mobile devices that could become compromised. Still, sufficient end-to-end data encryption is necessary to protect health information during the transmission between the mobile device and the server.

While the use of cloud-based storage can enhance data security, some countries are hesitant to use it, and may mandate that data must be stored locally. In areas with poor signal coverage, other options need to be considered, such as encrypting data while they wait on the device to be transmitted, and protecting the device and application with antivirus software, encryption, or other technologies previously mentioned.

By providing the necessary technical measures to safeguard data quality and security, organizations could help to alleviate the concerns that clients may have about their data being collected or transmitted with mobile devices.

5.2. User Behavior Challenges

Other issues that can affect data quality relate to user interaction with the application. Our program interviewees acknowledged that users can accidentally delete an application. This can lead to data loss if the data have not been transmitted yet, or if the application cannot be reinstalled in time for the next data collection attempt. Evidence shows that many data quality issues in mHealth stem from user-introduced errors during data entry into the application. Several factors are associated with user errors, such as a language barrier, unfamiliarity with the application and data entry format, or an inability to review and edit the data.

Designing mHealth applications with the user in mind increases the likelihood that users will be more effectively engaged, and the program will be more relevant, appropriate, and sustainable. When users feel included in the development process, they may be less likely to misunderstand the application and more likely to use the system properly (Principles for Digital Development, n.d.). Users should be trained on how to use the application once it is on their device, and they should be made aware of technical support contacts for the application (MEASURE Evaluation SIFSA, 2015).

5.3. Organizational Issues

Data quality also depends on the organizational and policy environment of each mHealth program. Determining how an mHealth application will fit into the architecture of existing national HIS can improve data quality. If an application does not transfer its data into an HIS, or it collects the same data as another system, errors can occur due to data loss or duplication of efforts.

In the mHealth programs in Kenya and Tanzania, data are not yet being transferred electronically into their health management information systems. The programs still rely on manual data entry, which increases the risk for human error.

When designing an application that collects routine health information, efforts should be made to determine how to make the application interoperable with the existing HIS from the beginning, to prevent duplicative data collection efforts. Moreover, the quality of data collected via mobile devices should be subjected to systematic data quality assessments before the data are used. The process of data assessment and timely feedback to data collectors can gradually improve the quality of data and promote their use. A best practice is for countries to have an eHealth and/or mHealth framework to guide the effective use of ICTs in the health sector.

Additionally, organizations and countries implementing an mHealth program should include activities to help the community understand the importance of shifting from paper-based data collection to mobile device-based data collection. Once program beneficiaries understand that mobile technology can enhance data collection and improve healthcare services and health outcomes, they may begin to trust the use of the devices.

6. RECOMMENDATIONS

Based on our assessment, we present the following recommendations for improving data quality, security, and privacy in mHealth programs. We have categorized them as technical, behavioral, or organizational.

6.1 Technical

- mHealth app developers should assess the feasibility of using cloud-based data storage to eliminate data storage on mobile devices. They should research local laws regarding cloud storage and where health data can be stored, and explain the benefits of cloud storage to host governments. Data transmitted to the cloud should be encrypted end-to-end to reduce security threats.

- Before mHealth programs are deployed for use, project implementers should install data protection technology such as anti-virus software, firewalls, and data encryption. They should provide a plan for regular maintenance in order to ascertain data integrity. Applications should have effective user authentication technologies.
- mHealth app developers and programs need to assess and mitigate the risks to data privacy and security, as outlined in Principle 8 of the Principles for Digital Development (Principles for Digital Development, n.d.). The mHealth Assessment and Planning for Scale (MAPS) toolkit can help organizations assess readiness for scaling up their mHealth program (WHO, 2015). Organizations and software developers should also create policies and procedures for mitigating risks before mHealth solutions are deployed. They should schedule regular reviews of such policies and modify them when new risks or security concerns are discovered.
- Governments, organizations, and donors interested in using mHealth solutions should conduct feasibility studies before starting to design technology. Studies should focus on the added benefits from the perspective of clients (patients). They should show how the use of mHealth helps programs fulfill their health goals efficiently. This will help sensitize the community to the use of mobile devices to collect their health information.

6.2. Behavioral

- Governments, organizations, and donors seeking to use mHealth solutions should design their applications with the end users in mind, as outlined in Principle 1 of the Principles for Digital Development (Principles for Digital Development, n.d.). This will ensure that end users can easily learn, or figure out, how to use the application, making it more likely that it will be used correctly. Developers should focus on enhancing existing processes, norms, and phone-user behavior to encourage integration into the local context.
- Organizations, implementing partners, and donors investing in mHealth solutions should continue to study how personal use of mobile devices can compromise data quality, security, privacy, and confidentiality. As this is a rapidly advancing field, there is not yet enough evidence to understand the implications of personal use. As mHealth becomes more integrated in health information systems, it will be important to consider whether health workers should carry two devices: one for personal use and one for mHealth. Assessments should be conducted to understand whether the risks introduced by personal use can be mitigated effectively so that health workers can carry just one device, or whether the risks associated with carrying two devices could lead to mHealth devices being forgotten or uncharged. In the meantime, implementing organizations should provide guidelines on acceptable use of the mHealth device both for work and personal use, to mitigate security risks.

6.3 Organizational

- A national framework on the use of mHealth would ensure proper use of technology, including standards-based interoperability. This would encourage existing mHealth initiatives to meet minimum standards, and new initiatives to be developed within an architecture that protects data and assures client confidentiality.
- All mHealth programs should have policies delineating which parties are responsible for damage to the device, maintenance and replacement of devices, and lost or stolen devices, whether or not the device is provided by the project. These policies should also include steps for mitigating security risks, such as remotely wiping the phone or changing user access privileges when the phone is lost or stolen.
- Implementing partners and governments should develop metrics to regularly monitor and evaluate mHealth data quality and security, making corrections as needed.

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