Chapter 2
Innovative Healthcare Applications of ICT for Developing Countries

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Abstract Globally, there is a rising demand for an effective, efficient, and trustworthy healthcare delivery system, particularly in developing countries with large populations and significant remote or inaccessible areas. The use of ICT to deliver healthcare services, in particular eHealth and its sub-category m-health, offers an enormous potential to reduce costs, advance health information exchange, and improve healthcare access, as well as public and personalized medicine. However, developing countries also face unique challenges to optimally develop and apply ICT in healthcare sector, including financial feasibility, infrastructure, access, equity, and quality; knowledge and research evidence; leadership and governance; security and interoperability; and social and technological environments. We review innovative ICT healthcare applications and different types of implementation challenges in developing countries and provide specific application examples in both developed and developing countries. Finally, we propose a comprehensive design model for ICT applications in developing countries as an aid for: (1) disease management and surveillance, (2) treatment planning and monitoring, and (3) quality control of healthcare. The integrated system consisted of eight key elements: patients, healthcare providers, data and data analytics, regulators, researchers, healthcare payers, telecommunication providers, and hardware and software vendors. It is our hope
that this proposed model will serve as a basis for the implementation of ICT in healthcare sector in developing countries.

Keywords Chronic diseases • Developing countries • e-Health • Healthcare • Information and communication technology • m-Health • Quality of life • Wellness management

1 Introduction

Globally, there is a rising demand for an effective, efficient, and trustworthy healthcare delivery system (Wanless 2002). Developing nations with large rural areas and populations particularly have more crucial healthcare issues to deal with, such as the prevalence of chronic infectious diseases, the lack of adequately trained healthcare personnel and healthcare facilities, and the limited number of healthcare programs (World Health Organization 2006).

Information and communication technology (ICT) plays a critical part in unifying communications, allowing people to access, process, store, and transmit data through fully integrated audiovisual, data communications, and electronic systems (Henriquez-Camacho et al. 2014). ICT has profound impacts across different sectors in society, including the healthcare sector (Henriquez-Camacho et al. 2014). eHealth—also known as “e-health” and defined here as the use of ICT to deliver healthcare services—has existed since 1999 (Della Mea 2001; Eysenbach 2001). eHealth technologies offer an enormous potential to reduce costs and advance health information exchange and improve healthcare access and public and personalized medicine (Bashshur and Shannon 2009; Wentzer and Bygholm 2013).

Ownership and usage of cell phones is widespread in low- and middle-income countries (LMICs) (Agarwal and Labrique 2014; Qiang et al. 2011; Sanou 2014). In 2014, 90% of people in developing nations were active cell phone subscribers (pre-paid and postpaid), followed by the Asia-Pacific region with 89% of the population as subscribers and Africa with 69% (Sanou 2014). Together these three regions accounted for 75% of worldwide cell phone users in 2014.

The widespread distribution of cell phones and tablets—collectively known as portable devices—and their ease of use have resulted in the rise of mobile health (“m-health”), in which medical and public health practices are carried out via portable devices (Qiang et al. 2011; Labrique et al. 2013; Tomlinson et al. 2013; Kay et al. 2011; Lozano et al. 2011; Vital Wave Consulting 2009). Besides the exponential growth in portable device ownership (Piette et al. 2012), other factors also contribute to the popularity of m-health, including rapid technical development of mobile applications (“apps”), continual drop in the cost of cell phones, and improved network coverage levels (Brinkel et al. 2014). Cell phone-based text messaging has been utilized in both developed and developing countries for reminder systems,

However, LMICs often have inadequate health services and medical care infrastructure (Kahn et al. 2010). The average gross domestic product (GDP) per capita for developing and developed countries from 1995 to 1999 was $1100 and $27,000, respectively (Gaziano 2005). Furthermore, LMICs assign 6% of their gross national income (GNI) in healthcare costs compared with 10% for developed countries—resulting in a huge budget allocation gap ($74 vs. $2733) between the two (Gaziano 2005). One of the proposed solutions to these limited resources and budget for health and medical care is to use e- and m-health interventions for chronic disease management, to allocate medical resources more efficiently and allow patients to maintain their quality of life at lower cost.

1.1 Definitions of e-Health, m-Health, e-Learning, and m-Learning

In recent years, m-health has become one of the most important subfields of e-health (World Health Organization 2012b). In the absence of international standard definitions of those terms (Kay et al. 2011), here we list some of the more common current definitions.

- **Electronic health** or **e-health** (Eysenbach 2001) can be defined as “an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies” (e20|p.1, Eysenbach 2001). Similarly, the World Health Organization (WHO) and the International Telecommunication Union (ITU) defined the term “e-health” as “concerned with improving the flow of information, through electronic means, to support the delivery of health services and the management of health systems” (p.1, World Health Organization 2012c). Globally, the term e-health is not only related to a technical development but also a commitment to enhance healthcare services locally, regionally, and globally by utilizing ICT (Eysenbach 2001).

- **Mobile health** or **m-health** can be defined as the use of portable devices to deliver medical and public health services and is a subset of e-health (Betjeman et al. 2013; Wittet 2012). Most studies in this field have focused on mobile application development like short messaging service (SMS or text), voice calling, and wireless data transmission to gather or distribute health data or to directly deliver healthcare services (Labrique et al. 2013; Kay et al. 2011; Vital Wave Consulting 2009; Betjeman et al. 2013).

- **e-Learning and m-learning** are terms used in education and training fields. Again, these terms are a subset of e-health, with intended services accessible via computers and portable devices (Wittet 2012).
The aim of this book chapter was to propose a comprehensive design model for ICT applications in developing countries as an aid for: (1) disease management and surveillance, (2) treatment planning and monitoring, and (3) quality control of healthcare.

2 Challenges

For successful developments and applications of ICT in healthcare, especially in developing countries, we have to consider existing and potential challenges. This section discusses various factors, based on existing examples of applications already developed in a number of countries. These challenges include: funding needs, infrastructure and related factors, knowledge and research evidence, leadership and governance, security and interoperability, and sociocultural and technological environments. These factors need to be considered before developing e- or m-health systems in developing countries.

2.1 Financial Feasibility

One of the common challenges of e- and m-health systems is funding sustainability for long-term care, for example, ongoing sexual and reproductive e-health initiatives (World Bank 2012). In addition to initial equipment procurement and software development costs, there are often ongoing and hidden costs (routine system troubleshooting, part replacement) incurred during implementation of e- and m-health systems (Wittet 2012). To resolve high implementation costs, financial supports from government and philanthropic as well as private agencies are often required to ensure programs can continue beyond the pilot stage (Wittet 2012).

It is difficult to get policymakers to understand the importance of prioritizing scaling up m-health activities over other public health intervention projects when there is little evidence on the financial feasibility of m-health interventions, such as cost-effectiveness and operating costs (Chib et al. 2015; Leon et al. 2012). Low-level user engagement with m-health services may have occurred in the past due to prohibitive operational costs of mobile communication, particularly cell phone subscription fees (Tamrat and Kachnowski 2012). To confirm this, researchers need to assess incentives of different stakeholders, including end users, investors, platform providers, and policymakers (Ivatury et al. 2009). The Mangone et al. (2016) review found that the costs of the Mobile for Reproductive Health (m4RH) program in Tanzania could only be covered if all SMS costs were paid by the patients and the discounted SMS prices were provided by telecom partners. On the other hand, the maintenance cost to implement one-way SMS-based activities was far more viable, irrespective of the size of a program, since there was only a minimal initial investment with a relatively low and stable operational cost.
required for that type of project (Vital Wave Consulting 2009; Tamrat and Kachnowski 2012).

Donor funding also plays an important role in achieving long-term sustainability in m-health interventions (Kay et al. 2011). Most projects are heavily (or fully) dependent on donor funding for their survival (Kay et al. 2011). Government succession can be viewed as one effective solution to eliminate program dependence on donor funding in the future (Ogunmefun et al. 2010). Some examples of a donor exit strategy include: Thailand’s Better Border Healthcare Program (Tamrat and Kachnowski 2012; Seebregts et al. 2009) and an m-health program expansion and integration in Rwanda (Tamrat and Kachnowski 2012; Mechael 2008). In the case of the Better Border Healthcare Program, the Thai government took over operational costs of sending text messages to obstetric patients to lessen the financial burden of end users (Tamrat and Kachnowski 2012; Seebregts et al. 2009). Another possible solution is that the toll-free mobile communication networks for healthcare purposes should be adopted gradually, particularly for countries in the lower–middle-income category (Kay et al. 2011; Tamrat and Kachnowski 2012; Mechael 2008).

2.2 Infrastructure, Access, Equity, and Quality

Poor infrastructure is one of the main hurdles to be overcome when implementing m-health programs (Tamrat and Kachnowski 2012), particularly unavailability of advanced infrastructure to support m-health programs in LMICs compared with high-income countries (Vesel et al. 2015). For example, poor telecommunication infrastructure may prohibit optimal use of (broadband) Internet services and applications from handheld portable devices to access and update electronic medical records (Betjeman et al. 2013). Larsen-Cooper et al. (2015) showed a lower level of mobile phone ownership, a limited access to mobile phone, and a lack of understanding of mobile phone usage patterns among vulnerable populations hindered their access to m-health interventions (Larsen-Cooper et al. 2015).

Due to economic circumstances and other barriers, cell phone ownership and cellular subscription levels remain particularly low among the vulnerable populations in LMICs, such as women and communities living in rural areas (Rashid and Elder 2009; Wesolowski et al. 2012; Zurovac et al. 2013). A persistent gender gap exists in cell phone subscription in LMICs, with 300 million fewer female than male subscribers (GSM Association 2013). African women are 23% less likely to be the sole owner of a cell phone than men, due to costs (of the phone itself and services), a perceived absence of need, and fear of new technology (GSM Association 2013).

There are many ways to share cell phones, including informal sharing between family and friends (which results in generally free usage) and via public “pay-for-use” services (James and Versteeg 2007). Around two-fifths of Kenyan study participants were not the sole owner of a cell phone due to age, education, gender, literacy, poverty, and urbanization (Zurovac et al. 2013). In another example, about 30% of
people in South Africa and Kenya share portable devices with others (Aker and Mbiti 2010; Crankshaw et al. 2010), with sharing being more common among women than men in South Africa (Crankshaw et al. 2010). However, the practice of sharing may pose challenges when accessing m-health services, such as convenience, feasibility of receiving personalized text messages, phone availability, privacy, and retention of information (Jennings et al. 2013; Mechael et al. 2010).

To resolve a persistent gender gap in cell phone ownership in India, women have been involved in direct selling and distribution of cell phones and products with health-related applications, with the aim of social and economic empowerment of women (Misraghosh et al. 2011). In that study, some husbands had positive attitudes toward the rise of the female breadwinner and ultimately decided to join their wives in mobile retail businesses.

In some countries, these problems of unequal access and coverage of m-health services are likely to be countered by increased cell phone penetration and rapidly expanding cell phone infrastructure (Zurovac et al. 2013). As the telecommunication infrastructure becomes more evenly distributed due to market forces in LMICs, there is undoubtedly a huge expectation that operational costs will lower and expanding telecommunication services will reach rural areas of low-income countries (Betjeman et al. 2013). The availability of m-health has greatly improved the delivery of healthcare services to unreached rural communities (Vesel et al. 2015). m-Health has a great potential to speed up democratization and decentralization of healthcare systems and processes as well as resolving some barriers faced by rural communities when seeking healthcare such as limited transportation, travel time, and costs—thereby improving productivity and performance of health workers to provide quality healthcare interventions (Braun et al. 2013; Mahmud et al. 2010).

Challenges to m-health systems to improve the quality of healthcare are a lack of investment in infrastructure, an absence of long-term financial viability, and inadequate training in technological advances (Braun et al. 2013; Chib et al. 2008). The m-health programs available to date have not provided concrete evidence of program impact on quality and efficiency in terms of improving healthcare delivery service processes, strengthening health systems, and/or attaining better health outcomes (Leon et al. 2012).

### 2.3 Knowledge, Research, and Evidence

Two of the largest obstacles to improving m-health coverage are the lack of knowledge and evidence of the impact of m-health system on key health outcomes and the lack of standardization when designing m-health programs (Vesel et al. 2015). To facilitate standardization and reproducibility of randomized controlled trials (RCTs), the WHO recommended scientists shift their research focus around m-health interventions from usability to health outcome assessment (Kay et al. 2011; Betjeman et al. 2013). However, to date there is little research on m-health effectiveness in LMICs, particularly around cost-effectiveness and
behavioral change (Betjeman et al. 2013; Chib et al. 2015). Furthermore, there have been few studies exploring failure factors of implementing m-health interventions or examining the driving factors and processes around adoption of technology (Vesel et al. 2015).

Collaboration is essential between ICT innovators, public health practitioners, and social scientists to establish universal standards for conceptual frameworks and guidelines to measure and evaluate m-health systems (Chib et al. 2015). Although the m-health systems offer profound opportunities, there are some issues that must be addressed, including the excessive volume of choices and the lack of evaluation and assessment frameworks (Kahn et al. 2010; Betjeman et al. 2013). This particular problem was noted in Bangladesh, where the private sector conducted the majority of m-health activities (Kay et al. 2011). “Stumbling blocks” that affect the development of governmental regulatory policy (Kay et al. 2011) include the exponential evolution of ICT and the lack of review of m-health initiatives internationally. To put more simply, m-health technology has progressed faster than governments’ agility to adapt and update policies (Vesel et al. 2015). To achieve wider distribution of m-health systems, governments must engage in an iterative process of monitoring and evaluating their strategies; further governments’ decisions must be made in accordance with a proper contextualization of the evidence (Vesel et al. 2015).

2.4 Leadership and Governance

2.4.1 Policy and Oversight

Comprehensive monitoring, evaluation, and regulation must be performed in a way to adequately address barriers to accelerating uptake and scale-up of m-health interventions (Vesel et al. 2015). It requires key stakeholders’ influence and commitment to drive and deliver an effective, sustainable, and impactful use of m-health (Mechael et al. 2010). The majority of m-health applications, initiatives, and strategies have suffered from the absence of support by relevant government legislation, policies, and procedures (Vesel et al. 2015). These factors may influence uptake, including introduction rate, scalability from pilot studies to integrated national health initiatives, utility, and cost–benefit balance (Betjeman et al. 2013). In addition, diversity of m-health intervention tools and systems and limited guidelines to compare alternatives on their relative potential to strengthen health systems and improve health outcomes at a country level may leave decision-makers in LMICs in a state of confusion (Mitzner et al. 2010). Because it is difficult to evaluate the relative potential of m-health solutions, there is a need for evidence-based guidance to inform decision-makers—such as ministries of health, technical agencies, donors, and implementing partners—on how to select the best solution (Mookherji et al. 2015).

Another example of the broader issues faced by developing countries is the regulation and evaluation of m-health initiatives, such as its standard practice in the
biotechnology sector (Barton 2012). This issue is much more complicated in LMICs with weak governance (Vesel et al. 2015). In general, although most of the engagement with m-health systems is managed by private sectors, it still requires the government to take a leadership role in developing related policies and guidelines (Vesel et al. 2015). While the main purposes of an innovation policy are more related to macroeconomics—in particular financial or productivity growth, expanding employment opportunities, and increasing competitiveness—m-health innovation is primarily aimed at improving direct impacts to individuals (Vesel et al. 2015). Additionally, the fact that associated innovations in technology are mostly funded by commercial rather than public sector organizations has raised deep concern around a possible imbalance between incentives and boundaries for related development and research (Chaminade and Edquist 2010).

2.4.2 Regulatory Frameworks

When expanding a project beyond the pilot phase, conflicts between health systems policies at the governmental level and legal issues need to be resolved (Gleason 2015). Technology and policy in m-health is an international concern when implementing cross-border healthcare systems, as they must be delivered in accordance with policies in all regional and transnational areas (Vesel et al. 2015). The regulatory frameworks for e-health must be applied consistently across regulated countries and qualities defined by international agencies (The Rockefeller Foundation 2010). Although these regulatory frameworks on e-health have been widely adopted by developed countries, not many LMICs have adapted or created their own regulatory frameworks (World Health Organization 2012c). For example, in the study by Holeni (2014) regardless of the fact that South Africa has a supportive policy environment, the absence of a comprehensive legal framework for m-health implementation was risky for both health facilities and CHWs (Holeni 2014).

Application developers believe innovative mobile health applications can reduce the growing incidence of chronic diseases, such as diabetes, allowing chronic disease patients to self-manage their condition using portable devices for remote monitoring and assessment of daily life, health, and well-being (Olla and Shimskey 2015). However, there are specific regulatory requirements for mobile applications, such as those targeted at diabetes mellitus (Brooke and Thompson 2013). Any clinical application in healthcare settings, either used by patients or medical professionals, requires approval from regulatory bodies (Olla and Shimskey 2015). This requires collaboration between application developers and regulatory bodies to achieve the full potential of health applications (Olla and Shimskey 2015). For example, the US Food and Drug Administration (FDA) issued regulatory standards for mobile m-health applications (Olla and Shimskey 2015) and the equivalent “EC” standard in the European Union. Notwithstanding that guidelines are predominantly aimed at protecting the safety of patients, industries are concerned about consequences posed by excessive regulation to the process and nature of health service delivery in terms of innovation and discovery (Blumenfeld and Garvin 2013).
Blumenfeld et al. (2013) recommend that the FDA issues the regulation of m-health applications with an open mind and applies a risk-based approach to regulation. As technology evolves, there is a need to be aware that a nonregulated m-health approach could harm patients (Blumenfeld and Garvin 2013).

2.5 Privacy, Security, and Interoperability

There are several steps to achieving significant impact with global m-health interventions, with the first—and perhaps most essential—to resolve privacy and security issues (Collins 2012). Privacy standards vary internationally, with some countries even having few or no standards (Gleason 2015). Definitions of the term “protected health information” also vary (Gleason 2015). Considerably more research and standardizing health data privacy and security in m-health interventions are required to protect the confidentiality of patients and research trial participant data while also ensuring continuity of studies and quality of care (Gleason 2015). It must be noted that transmitting data throughout wireless networks increases the risk of privacy violations and exposing sensitive patient information (Gleason 2015). The next important questions that need to be addressed are: who will define privacy protection rules and who will address repercussions if confidential and sensitive information is leaked (Collins 2012)?

The growing popularity of “bring your own device” (BYOD) among healthcare staff may risk non-compliance with new rules under the Health Insurance Portability and Accountability Act (HIPAA), in particular, when patient health information (PHI) or personal/electronic health records (PHR or EHR, also known as electronic medical records (EMR)) are inserted or retrieved from a database through m-health applications via portable devices (Marek 2015). To ensure the security of PHI and to minimize the risk of unauthorized access, many institutions require clinicians to complete procedural training before viewing records online or via email on portable devices using password-protected, secure networks and user authentication (Olla and Shimskey 2015). In some instances, however, healthcare personnel are unable to send email from portable devices due to security features, despite complying with required security procedures (Olla and Shimskey 2015). In some respects, the advantages of examining secure PHI on a portable device such as a cell phone versus a computer at a large hospital are that a cell phone is easier to carry and has a smaller screen, which can actually lead to greater productivity (Olla and Shimskey 2015). The healthcare worker retrieves PHI (for instance, a patient chart or an x-ray image) from the hospital server through a secure network that complies with HIPAA regulation (Marek 2015). This can be accomplished through using advanced encryption standard (AES) or a virtual private network (VPN) that requires a username and password so staff can access required information from their own portable device or any computer in the hospital, without the need to access a specific computer (Alder et al. 2015). Once security measures have been defined by institutions and healthcare facilities, then a device can be connected to the facility server and any specific
hospital programs that retain PHI (Alder et al. 2015). The healthcare staff must comply with privacy and confidentiality policies, including HIPAA; they must not leave PHI accessible in a public area and must ensure that their portable devices are also password protected (Alder et al. 2015).

Despite the understanding of the importance of data privacy, many LMICs do not have clear legal and policy frameworks to protect data privacy against unauthorized access (Fraser and Blaya 2010). Still, multiple levels of security and firewalls have been used by some small-scale m-health activities in LMICs to ensure that community health workers (CHWs) cannot access data beyond that to which they are authorized (Betjeman et al. 2013; Leon et al. 2012). Overall, however, standardizing information security and policy implementation remains a challenge and can only succeed with full support from large-scale industry (Betjeman et al. 2013).

Another technological obstacle in m-health is the complex process of making the information systems fully interoperable and integrated (Leon et al. 2012). Software overhead incurred by security mechanisms is one of the reasons why phones may slow down over time, and this situation may lead to unusable portable devices, particularly in rural areas with low infrastructure (Gleason 2015). The lack of interoperability between cellular devices and software is seen as a major obstacle in some areas (Gleason 2015).

Interoperability can be defined as the capability of different ICT systems to interchange data, which enables effective and highly efficient communication across and between platforms, in addition to integrating with selected work practices (Leon et al. 2012). Examples include transmitting data from CHWs to centralized health systems and synchronizing patient records between remote and central health centers to facilitate monitoring of bidirectional referrals, follow-up care, and medical prescriptions (Leon et al. 2012). An example of interoperability failure is that some m-health applications are limited to particular operating systems (OS) (Qiang et al. 2011; Zurovac et al. 2013) and may actually be incompatible with certain portable devices (Betjeman et al. 2013). One real-world case of interoperability failure was the implementation of m-health initiatives in Uganda, which was conducted and financially supported by different agencies (Betjeman et al. 2013). In that instance, the healthcare staff entered reproductive health data on one device, malaria data on another device, and the rest of recorded data on paper. This interoperability failure is a complicated issue that many have tried to resolve throughout the years (World Bank 2012; Al-Shorbaji and Geissbuhler 2012).

Standardization policies for data security—in particular, data encryption or open architecture—will not only resolve security and privacy issues related to interoperability of information systems but also will encourage more innovation in this sector (Luxton et al. 2012; Estrin and Sim 2010). Open architecture m-health applications can be modified based on any attributes, such as diseases, targeted populations, and treatment protocols (Estrin and Sim 2010). However, interoperability of information systems may not be in the best interests of some stakeholders, notably commercial entities, since it has the potential to reduce competitive advantages (Tate et al. 2013).
The next major challenge when scaling up m-health projects is related to sociocultural issues (Czaja et al. 2006; Charness and Boot 2009). The driving forces behind users’ decisions to adopt new technology include age, attitudes toward technology, education, local perception, and socioeconomic status (Czaja et al. 2006; Charness and Boot 2009). While perceptions of technology may vary by age, technology adoption among the elderly is much lower than younger generations due to age-related cognitive impairments, low awareness of the benefits of emerging technologies, technology anxiety, and perceived competence with technology (Czaja et al. 2006; Charness and Boot 2009). Delivering m-health programs that are commensurate with local contexts is the first recommended step for resolving sociocultural issues; local contexts may include language, cultural nuances, and interpretations (Tamrat and Kachnowski 2012).

Collaborations with local partners can help ensure the successful development of culturally appropriate and language-friendly messages (Vital Wave Consulting 2009; Chib et al. 2008). Examples are the mobile midwives project in Aceh Besar, Indonesia (Chib 2010) and the Wired Mothers study in Zanzibar, Tanzania (Lund et al. 2010). The use of Indonesian language for the mobile midwives project made the program more accessible and effective than other digital media that only used English in the area (Chib 2010). For the Tanzanian example, one of the strategies for engaging pregnant women in behavioral change practices was to adapt SMS services to the local context (Lund et al. 2010).

The availability of e- or m-health interventions may place an additional burden on healthcare staff. Take, for example, an instance where an EMR system replaced a paper-based data entry in a reproductive health department (Shaw 2012). In the pilot stage of that program, there was no guarantee that the new system would provide better outcomes to satisfy decision-makers any more than the old system. Therefore, a parallel adoption method—which involved running both old and new systems—was preferable for decision-makers and staff who were not quite ready to commit to the new system. As a consequence, the contraceptive uptake reports needed to be entered twice: by filling out the paper forms and by using portable devices. Although better outcomes were seen in the end of that project, a full system migration to e- or m-health systems took years to accomplish. The process was complicated since many staff felt uncomfortable and showed reluctance to switch systems due to their negative perceptions about the consistency of the new electronic system over the longer term.

An example of contextualizing m-health is the integration of ICT with the Confucian tradition of guanxi in China’s rural healthcare system (Chib et al. 2013). This integration facilitated the use of advanced technologies to exchange health information, providing end users with a sense of trust and security (Chib et al. 2013). Possible cultural barriers and disparities in the m-health system were overcome by improving self-efficacy, providing stress management training for such groups, and explaining the benefits of technology use for elderly and minority groups (Mitzner et al. 2010; Czaja et al. 2006).
2.7 Technological Challenges

The study by Zapata et al. (2015) revealed that 12 out of 22 selected papers on m-health focused on evaluating Android OS applications and only seven papers concentrated on iOS applications. In 2015, Android and iOS were the two top portable device platforms worldwide, with approximately 82.8% and 13.9% of the smartphone market share, respectively (International Data Corporation 2015). The benefits of Android OS when compared with iOS and Windows include:

1. Open source, which enables the Android developers to port systems to various devices and to connect it to various hardware peripherals (Kalkov et al. 2012).
2. Distributing, installing, and testing/commissioning Android applications can be done on any device, which accelerates prototype development and further facilitates the delivery process to a small group of users (Zapata et al. 2015).
3. A high degree of customizability, which allows developers to build their applications in accordance with customer needs and preferences (Zapata et al. 2015).

Some customization examples for older people are keyboard applications with bigger buttons (Chicago Logic Inc) and simple and easy-to-use launchers with basic functions, big buttons, and large font (Big Launcher; UIU LTD; Necta).

The Zapata et al. (2015) review also found that tablets have been used to access applications, with eight papers focusing on the use of the Apple iPad. iPad and Samsung tablets are the two dominant tablet platforms in the world, with approximately 25.8% and 15.6% market share, respectively (Statista Inc 2016). Tablets have become an effective medium for communication and educational purposes for a number of reasons related to both service providers and related patients (Sclafani et al. 2013) and have been adopted widely by physicians due to features such as large displays or wireless network connectivity (Robinson and Burk 2013), and some patients find tablets easier to interact with than smartphones due to larger screens (Cheung et al. 2013).

There is a need to improve existing technologies and applications, so that they can capture data from associated medical devices like cardiac monitors, physical activity monitors, stethoscopes, sleep analyzers, and other health trackers, while also having the ability to analyze and interpret recorded data and provide insightful and actionable information to physicians (Gleason 2015). The key to effective use of m-health applications is to establish technology and software that will address and resolve overloading data and oversampling biomedical signals (Clifford and Clifton 2012).

Other areas that require more attention are imperfect wireless technologies and standard data storage (Gleason 2015). Large delays in data transmission can create unwanted problems like unsynchronized data (Clifford and Clifton 2012). In the case of data storage standardization, there is an urgent need to establish ontology standards for medical data comparison and analysis (Gleason 2015). Unfortunately, these are not easy to create due to vendor-specific proprietary database formats (Gleason 2015). A recommended solution for resolving this challenge is the use of open source, proprietary software (Gleason 2015).
3 Recent Mobile Applications

There has recently been an increase in e-health applications in many developed and some developing countries. This section reviews various recent developments and applications of different types of e- and m-health systems. Examples include applications for specific diseases and conditions (such as asthma and chronic obstructive pulmonary disease (COPD), cardiovascular disease (CVD), diabetes mellitus, human immunodeficiency virus (HIV), malaria, tuberculosis, and obesity), as well as for specific target groups (mother and child). Each of these cases is briefly discussed.

3.1 Asthma and Chronic Obstructive Pulmonary Disease

Two common chronic obstructive lung disorders are asthma and COPD (Himes and Weitzman 2016). Asthma is a heterogeneous chronic inflammatory disorder involving airway hyper-responsiveness and variable airflow limitation, affecting more than 25 million Americans (Akinbami et al. 2012) and 300 million people worldwide (Masoli et al. 2004). Approximately 1 in every 250 deaths is caused by asthma, and the majority of these deaths could be preventable through long-term follow-up and assessment of disease progression (Masoli et al. 2004). COPD is a progressive lung disease involving alveolar destruction, shortness of breath, cough, and sputum production, affecting more than 24 million Americans (Mannino et al. 2002).

Exacerbations of asthma and COPD—in which flare-up or worsening of symptoms requires systemic corticosteroids or other treatments to reduce the risks of serious adverse effects—are associated with substantial morbidity and healthcare costs and even deaths in severe cases (Moorman et al. 2007; Barnett and Nurmagambetov 2011; Ford et al. 2015; Aaron 2014). Asthma and COPD cannot be cured but can be managed by taking steps to improve lung function, to prevent exacerbations, and to control symptoms as outlined by clinical guidelines (National Asthma Education and Prevention Program 2007; Pauwels et al. 2012). Hence, the primary aims of clinical therapy for patients with asthma or COPD are to avoid more damage to the lungs and to help keep symptoms under control and maintain everyday life activities (Himes and Weitzman 2016).

The process of decision-making based on a patient’s disease symptoms, environmental exposures, and medical history is an essential component of COPD management (Himes and Weitzman 2016). Several procedures play a key role in driving better health behavior and fulfilling health-related goals, that include providing more information about factors that lead to symptoms of worsening lung disorders, encouraging patients to take medication properly and seek care, and, finally, empowering patients with required skills and knowledge to manage their...
condition independently (Foster et al. 2007; Apter et al. 2013, 2015). Instead of directly giving feedback to patients, some applications use validated symptom diaries for children (Santanello et al. 1999) or adults (Santanello et al. 1997) as part of self-monitoring. Use of symptom diaries and instructions on medication usage in controlling disease symptoms can improve quality of life and reduce hospital visits for patients with these lung disorders (Gibson et al. 2002; Bourbeau et al. 2004). The availability of health information technologies (HITs), and particularly m-health applications, does help in self-managing chronic conditions (Estrin and Sim 2010).

Initially, asthma and COPD applications were largely built as either tools to provide information about disease symptoms, how to use inhaled medication, and other educational materials; or to provide electronic-based diaries to access symptoms and triggers of these lung disorders, as well as to detect changes in pulmonary function (e.g., peak flow meter rate). Examples include CareTRx (Gecko Health Innovations, Inc., Cambridge, MA), Propeller Health (Propeller Health, Madison, WI), and Wizdy Pets (LifeGuard Games, Inc., Brighton, MA). Bluetooth-enabled sensors that attach to inhaler medication with CareTRx and Propeller Health applications have been used to retrieve the time and location of inhaled medication usage (Himes and Weitzman 2016). These mobile applications provide a chronological record of inhaler use to guide asthma management, list of potential asthma triggers, and intuitive graphs to users (Himes and Weitzman 2016). A 4-month pilot study evaluated the use of Propeller Health sensors in 30 individuals and reported better asthma control as measured by a derived Asthma Control Test™ (ACT) score by the end of the third month of the study (Van Sickle et al. 2013). A subsequent RCT accessed the use of Propeller Health sensors in 495 patients (245 people in routine care and 250 with the intervention) and reported decreased use of a short-acting beta agonist (SABA) among those who received sensor-based feedback during the 12-month study: 0.19 vs. 0.14, respectively (Merchant et al. 2016). The improvement was notable among participants who began the trial with uncontrolled asthma: the average daily use of SABA for each individual was 0.25 in the routine group vs. 0.19 in the intervention group (Merchant et al. 2016). That study also found that the significance of the outcomes was more important than the size of the effect alone; participants who had a history of asthma and were allocated to the intervention group were more likely to show higher ACT scores than participants in the routine care group (Merchant et al. 2016).

The developers of the Wizdy Pets application aimed to teach, guide, and support children with knowledge about asthma triggers and the importance of taking medication through a game that involved children as the caretaker of an animal, a fire-breathing dragon with asthma (Himes and Weitzman 2016). Although there is much promise with the use of these applications for improving the self-management of these lung disorders, more large-scale studies are required to determine the clinical effectiveness of these applications (Wu et al. 2015).
3.2  Cardiovascular Disease

According to an Organization for Economic Cooperation and Development (OECD) report published in 2008, ischemic heart disease (IHD) and cardiovascular disease (CVD) were responsible for 75% of all heart disease-related deaths in 20 countries in Asia (OECD/World Health Organization 2012). The CVD mortality rate was over 1000 per 100,000 population for people aged 60 years and above in Southeast Asia (OECD/World Health Organization 2012).

The biggest contributors to heart disease are elevation in blood pressure (BP), cholesterol, tobacco, obesity, and lack of physical activity (Gaziano et al. 2010). The use of tobacco or smoking products is more common in China (around 60% of males), Indonesia (>60%), and Russia (>60%) (Eriksen et al. 2013). In these three countries, the combined total of smokers is nearly 50% of total smokers worldwide (Eriksen et al. 2013). Figure 2.1 shows the mortality rates and the causes of CVD deaths for different countries reported in 2008 (WHO Global Burden of Disease 2011).

One of the recommended cost-effective solutions for CVD management is cardiac rehabilitation (Bethell et al. 2009; Eshah and Bond 2009). The core components of cardiac rehabilitation include education to reduce cardiac risk factors, medical evaluation, and prescribed exercise (Jolliffe et al. 2001). Prescribed exercise has been proven not only effective in reducing CVD morbidity and mortality (Jolliffe et al. 2001) but also to improve exercise capacity and physical fitness in patients with CVD (Bethell et al. 2009). Despite the advantages of cardiac rehabilitation, its
provision still remains inadequate in many countries (Bethell et al. 2007). For example, the majority of British patients were excluded from a cardiac rehabilitation program or decided not to be a part of the program (Bethell et al. 2007). Uptake rates for cardiac rehabilitation have been reported to be lower in America (Suaya et al. 2007), Australia (Walters et al. 2008), Canada (Banerjee et al. 2007), and New Zealand (Doolan-Noble et al. 2004; Parks et al. 2000). Factors that affect patients’ uptake of cardiac rehabilitation schemes include domestic responsibilities, health problems, limited access to transport infrastructure, and parking space issues (Jones et al. 2007), as well as age, with younger people more likely to miss or reschedule appointments due to working commitments (Doolan-Noble et al. 2004).

Current approaches to the delivery of cardiac rehabilitation have not fully addressed the needs of the patient (Scott et al. 2003; Thomas 2007). Innovative approaches are required to increase utilization of cardiac rehabilitation. To accommodate varied patient needs and preferences, it is important to provide diverse options when delivering rehabilitation services (Jolly et al. 2007). While telephone-based interventions have proven effective in sustaining behavior changes (Castro and King 2002; Elley et al. 2003), the most effective and efficient way to deliver m-health interventions to a greater number of people is through the use of mobile and Internet-based technologies (Krishna et al. 2009).

Reducing modifiable risk factors, such as dietary intake, physical inactivity, and smoking, showed significant potential to reduce CVD mortality and morbidity rates (Smith et al. 2015; Deaton et al. 2011). A qualitative study was conducted in multiple primary healthcare centers in the Ernakulam district, Kerala, India, evaluating perceptions of three stakeholder groups toward the potential use of m-health in CVD management (Deaton et al. 2011). Ariani and Soegijoko (2014) proposed the use of a lifestyle application and physiological signal monitoring application to analyze and classify the health condition of patients with CVD. As shown in Fig. 2.2, a general practitioner, a health coach, and a hospital specialist were responsible in accessing collected data from each individual and providing required treatments to reduce the severity of CVD (Ariani and Soegijoko 2014). The challenges of delivering CVD management were poor knowledge and practice of healthy lifestyles among recruited patients, as well as difficulties in implementing primary prevention. Physician barriers to m-health interventions were fears of cell phone radiation exposure, fears of being replaced by technology, uncertainties around the usability of cell phones, and the view that online consultation cannot replace face-to-face consultation (Smith et al. 2015). The researchers concluded that the major potential uses of m-health in CVD management were as follows: (1) as an educational tool to improve of health education and lifestyle behaviors, (2) to optimize use of scarce resources by breaking down geographical barriers and financial constraints, (3) to improve utilization of healthcare services, and (4) to improve prevention and management of CVD by using appointment and treatment reminders. Acknowledging barriers to m-health design can help maximize the effective use of limited resources and complement current practice.
3.3 Diabetes Mellitus

Diabetes mellitus has reached epidemic proportions worldwide and could be one of the most serious threats to public health in the twenty-first century (World Health Organization 2014), as most people with type 2 diabetes have the disease for a period of time before diagnosis (Istepanian and Lacal 2003) and do not seek medical help until they experience serious complications. The top three regions with a high prevalence of diabetes mellitus are the United States, with approximately 26 million diabetic patients and 79 million prediabetic patients (Centers for Disease Control and Prevention 2011); Europe, with 60 million diabetic patients (World Health Organizations Regional Office for Europe 2016); and the Middle East, with nearly 34 million people suffering from diabetes and/or diabetes-related complications (World Health Organizations Regional Office for Europe 2016; Albright and Gregg 2013). Overall, the number of people living with diabetes worldwide is predicted by the International Diabetes Federation (IDF) to reach 552 million people by 2030 (International Diabetes Federation 2011). In other words, one out of every ten people in the world will suffer from diabetes mellitus and/or diabetes-related complications or associated comorbid conditions (International Diabetes Federation 2011). Costs of diabetic medical care are expensive and may lead to financial burden in the healthcare sector (Ajay and Prabhakaran 2011). Global expenditures on
diabetes are expected to increase from 316 billion in 2010 to around 490 billion in 2030 (Whiting et al. 2011). There is currently no cure for the disease with treatment focusing on optimal glycemic control to minimize complications (Diabetes Control and Complications Trial Research Group 1993). However, a less than 70% of diabetic patients achieve target values of an HbA1C level <7% (Bouma et al. 1999). For some people living in rural areas, the lack of access to healthcare facilities may contribute to not achieving optimal glycemic control (Ajay and Prabhakaran 2011).

Rami et al. (2006) accessed the feasibility of an m-health program for diabetes care and its effect on glycemic control in teenagers with type 1 diabetes mellitus. Participants stored relevant information (date, time, blood glucose, insulin dosage) on their cell phone and transferred the data daily to a central server. Healthcare staff would then respond to individuals on a weekly basis. Compared with traditional methods such as paper diaries, glycemic control improved significantly after the m-health intervention. Logan et al. (2007) evaluated the feasibility of remote monitoring of uncontrolled ambulatory hypertension and its effect in 233 diabetic patients. The system consisted of three modules: a Bluetooth-enabled home BP monitor, a cell phone to collect and transmit data, and a central server to process data. The intervention significantly reduced the 24-h ambulatory BP and a significant improvement in BP control. The majority of participants agreed that the proposed system was acceptable and effective for diabetes care.

The Diabetes Interactive Diary is a novel mobile application developed to enable effective communication with a dietitian via SMS and track carbohydrate intake in patients with type 1 diabetes (ClinicalTrials.gov 2016). The dietitian used the mobile application to monitor glycemic control and suggest insulin doses based on carbohydrate consumption.

A cross-sectional study conducted by Graffigna et al. (2016) examined an m-health intervention for type 2 diabetes patients in Italy. Participants were Italian, aged over 18 years, and had type 2 diabetes. The study aimed to investigate the association between the use of m-health technologies and patient activation and the association between the staff support, autonomy preference, and patient activation. The emotional support and encouragement from healthcare professionals was significantly associated with the willingness of type 2 diabetes patients to use m-health technologies. However, the study showed no connection between patient adherence or self-management and the frequency of m-health use.

### 3.4 Human Immunodeficiency Virus

In many countries, efforts to prevent HIV transmission are constrained by a large number of undiagnosed and late-diagnosed individuals (cluster of differentiation 4 (CD4) counts below 350 cells/mm³ within 3 months of diagnosis and significantly associated with increased risk of HIV/AIDS-related morbidity and mortality) (Joint United Nations Programme on HIV/AIDS (UNAIDS) 2015; Antinori et al. 2011).
The WHO and the Joint United Nations Programme on HIV and AIDS (UNAIDS) established global goals for HIV/AIDS prevention, with the aim of diagnosing 90% of people with HIV/AIDS, providing antiretroviral treatment to 90% of those diagnosed, and achieving viral suppression among 90% of those on antiretroviral treatment (ART) by 2020 (World Health Organization 2015a). To achieve these goals by 2020, the WHO and UNAIDS recommended developing and evaluating new approaches, specifically community-based approaches, as well as enhancing existing HIV testing strategies (World Health Organization 2015a). Keystones of HIV/AIDS programming worldwide are promoting HIV testing (Evans et al. 2016) and promoting public awareness of HIV infection and prevention (Rodrigues et al. 2015).

One HIV/AIDS prevention program is using m-health systems to prevent HIV transmission from mother to child (Jennings et al. 2013). Regardless of the sensitivity surrounding HIV/AIDS-related issues, the availability of m-health has been useful in discussing laboratory results with people living with HIV/AIDS (Siedner et al. 2012). m-Health systems have also been studied for HIV/AIDS counseling and treatment retention (Kalichman et al. 2011; Smillie et al. 2014) and ART adherence (Lester et al. 2010; Horvath et al. 2012; Miller and Himelhoch 2013; Puccio et al. 2006; Mbuagbaw et al. 2012; Pop-Eleches et al. 2011).

Without considering disease types, increasing adherence to treatment may lead to positive health outcomes (Sabate and World Health Organization 2003). Optimal adherence to treatment may decrease the risk of treatment failure and death as well as increase the survival rate of HIV-infected patients (Rodrigues et al. 2015). However, compliance with treatment is often hindered by forgetfulness (Rodrigues et al. 2015). The recommended solutions for resolving medication nonadherence are using pillboxes, electronic reminders (Vervloet et al. 2012; Munro et al. 2007), and cell phone reminders. Using a behavioral learning theory (BLT) framework, these interventions are regarded as external cues to support medication adherence (Munro et al. 2007).

An RCT reviewed effects of an m-health system for adherence intervention in ART programs across three clinics in Southern India with 16 participants (De Costa et al. 2010). Interventions were conducted over 84 weeks and weekly reminders sent to participants in the form of an automated interactive voice response (IVR) calls and a pictorial SMS. The majority of participants strongly agreed the m-health intervention was useful, perceiving the intervention as a sign of “care” from the clinic. They also preferred to receive IVR calls rather than SMS reminders but were concerned about the risk of unintentional disclosure to a third party.

Pop-Eleches et al. (2011) examined the role of automated text message reminders in improving HIV/AIDS medication adherence in Kenya for 431 patients who had received ART in the previous 3 months. Text message reminders were sent daily or weekly to participants in the intervention group. To measure adherence, participants were asked to take a prescribed drug dispensed in bottles with a medication event monitoring system (MEMS). The researchers made assumptions that adherence to at least one drug was associated with adherence to all types of drugs and compliance
with treatment regimes. In intention-to-treat analysis, 53% of participants in the intervention group adhered (\( \leq 90\% \) of medication taken) at 48 weeks compared with 40% in the control group (\( P < 0.03 \)). During the 48-week follow-up period, participants in the intervention group had fewer treatment interruptions of more than 48 h than those in the control group (81% versus 90%, \( P < 0.03 \)). Overall, short automated text messages proved to be convenient, affordable, and more effective at increasing medical adherence for HIV/AIDS patients on ARV therapy. Also, participants in the intervention group preferred to receive shorter, rather than longer, text reminders.

The effectiveness of community-based HIV testing programs was enhanced through use of cell phones (Fjeldsoe et al. 2009). Although research evidence in this field remains limited, the implementation of m-health intervention for HIV/AIDS prevention has already started yielding exciting results (Dégglise et al. 2012a, b; Cornelius et al. 2013; Odeny et al. 2014; de Tolly et al. 2012). Studies focused on HIV-related health promotion have used text messages to provide more information about HIV/AIDS, thus maximizing the uptake of HIV testing and increasing linkage to HIV care (Juzang et al. 2011; Chib et al. 2012; Uhrig et al. 2012). Outcomes relating to knowledge, changes in risk assessment, and testing behavior have usually been measured through proxy indicators—such as calls to help lines or changes in uptake of HIV testing in local clinics (Donner and Mechal 2012). Nevertheless, small-scale RCTs in Kenya (Odeny et al. 2014) and South Africa (de Tolly et al. 2012) indicate a direct impact of SMS interventions to encourage individuals to take the HIV test.

So far, the majority of studies on SMS-based interventions for HIV/AIDS prevention have been in LMICs (Dégglise et al. 2012a, b; Cornelius et al. 2013; Odeny et al. 2014); only a few have been conducted in developed countries, predominantly in the United States (Uhrig et al. 2012; Sidney et al. 2012; Peterson et al. 2015). Findings revealed that a social marketing approach is effective in accomplishing positive outcomes and enhancing recruitment and community engagement (Stead et al. 2007; Gordon et al. 2006). Before launching community-based programs, developers need to ensure the developed systems meet the users’ expectations and needs, as well as verify that procedures currently in place for both the intervention delivery and research are sufficient and being followed as required (Keller et al. 2012; Mckenzie-Mohr 2000). In Uganda, interactive quizzes and rewards have been used as strategies to introduce an SMS-based HIV/AIDS information dissemination program (Chib et al. 2012). These strategies proved effective in gaining public attention, with response rates nearly twofold higher among men than women participants (Chib et al. 2012).

Overall, SMS messaging systems for HIV/AIDS interventions have been shown to be effective (Horvath et al. 2012), despite the fact that research findings are somewhat mixed, with some studies showing high adherence (Lester et al. 2010; Pop-Eleches et al. 2011; Maduka and Tobin-West 2013) and others showing no proof of benefit (Leon et al. 2012; Tamrat and Kachnowski 2012; Ivatury et al. 2009). There are many other factors that need to be considered when measuring outcomes, for
example, the content, frequency, structure and tone of messages, and mechanisms through which those factors may affect final outcomes (Haberer et al. 2016; Ware et al. 2016; Lester 2013).

3.5 Malaria

Malaria is a life-threatening blood disease caused by *Plasmodium* parasites transmitted to definitive hosts through the bite of the *Anopheles* mosquito (Pirnstill and Coté 2015). After invasion of the hosts’ red blood and liver cells, the parasite progressively modifies the biochemistry and structural properties of host cells (Pirnstill and Coté 2015). The WHO reported that malaria caused an estimated 198 million new cases and 584,000 deaths worldwide in 2013 (World Health Organization 2013). Despite significant reductions in malaria mortality rates, malaria still remains the leading cause of death among African children (World Health Organization 2013).

Kamanga et al. (2010) assessed the feasibility of active case detection (ACD) of malaria in rural Zambia using mobile technology, testing the hypothesis that malaria control can be achieved through timely identification of new cases, their distribution and location, and by supplying affected populations with rapid diagnostic tests (RDT) and antimalarial medicines. Staff from 12 rural health centers in the Choma and Namwala districts sent weekly SMS reports of the number of positive malaria cases and rapid malaria tests at the Malaria Institute at Macha. After review by staff in a central office, the reports were mapped with global positioning system coordinates to identify the distribution pattern of malaria cases in surrounding villages and how the distribution was affected by local ecological condition. Using all this information, researchers were able to track the incidence of malaria in different areas of Zambia, showing that the incidence of malaria was high in the flood plain zones.

Meankaew et al. (2010) investigated the implementation of an e-health malaria control program in the Sai Yok District, western Kanchanaburi Province, along the Thai–Myanmar border of Cambodia. They deployed SMS software that included a case detection/registry, new case investigation, and case follow-up. The use of the case detection/registry feature allowed staff at health facilities to submit a standard e-health malaria form for each confirmed case of malaria, which detailed case characteristics, type of malaria, and treatment. The case follow-up feature allowed staff to track initial and follow-up visits of infected patients. The system generated weekly summary reports to assist malaria authorities to identify local or foreign malaria cases and tailor prevention and intervention programs. The weekly reports were sent in SMS and geographic formats. Challenges encountered in that program include expanding and maintaining the system to a national scale and adjusting systems to keep them running in a “user-friendly” mode that was easy to adopt, particularly in neighboring countries such as Thailand.
3.6 Maternal and Infant Healthcare

Globally, about 7.6 million children died in 2010 before reaching the age of five (You et al. 2011). The average mortality rates for children aged under five years were 63 per 1000 live births in developing regions and 7 per 1000 live births in developed regions (You et al. 2011). The four countries that had the lowest under-five mortality rate (with $\leq 5$ per 1000 live births) were Singapore, Japan, the Republic of Korea, and Australia (You et al. 2011). In contrast, the highest number of deaths occurred in Pakistan, Myanmar, India, Papua New Guinea, the Lao People’s Democratic Republic, and Cambodia, all with more than 50 deaths per 1000 live births (You et al. 2011). Mortality rates are also commonly higher for males than females (World Health Organization 2008). The top four leading causes of death for children under five are pneumonia, prematurity, birth asphyxia, and congenital anomalies (OECD/World Health Organization 2012). Preterm birth complications constitute around 20% of all deaths in either Asian or OECD countries, and nearly one-sixth of deaths from congenital anomalies occur in Asia (OECD/World Health Organization 2012).

Maternal mortality rates in 2015 were 239 per 100,000 births in developing countries vs. 12 per 100,000 births in developed countries (World Health Organization 2015c). Pregnancy- or childbirth-related complications (such as hemorrhage, obstructed labor, or infection), in combination with poor ante- or postnatal care, constitute the majority of maternal deaths (United Nations Children’s Fund 2008; Black et al. 2010). Long-term health consequences for mothers arising from these pregnancy or childbirth-related complications include chronic infections and infertility, depression, incontinence, obstetric fistula, or uterine prolapse, along with mental or physical disability in their offspring (Wulf et al. 2013; Mwaniki et al. 2012).

Even though a considerable amount of work has been undertaken to fulfill Millennium Development Goals 4 and 5, there is still a substantial gap between aspirations and actual, implemented reality with respect to maternal and infant mortality (World Health Organization 2012a). Death rates of newborn babies and mothers remain high in sub-Saharan Africa and Oceania (United Nations Children’s Fund 2014; World Health Organization 2015d). m-Health interventions have been considered highly effective in reducing maternal and newborn deaths, by providing support to pregnant women during the antenatal, birth, and postnatal periods (Qiang et al. 2011).

Ngabo et al. (2012) undertook a project in Rwanda that aimed to monitor pregnancy and alleviate bottlenecks in communication linked to maternal and infant deaths using a RapidSMS system. The system facilitated interactive communication between trained CHWs, a national centralized database, the local health facility, and the ambulance driver, specifically in the case of emergency. The system also allowed remote supervisors to monitor the activities of CHWs and had potential to deliver antenatal care for registered families preparing for children. As of 2012, approximately 15,000 cell phones have been distributed to more than 7000 CHWs.
in 18 districts across Rwanda. Two major contributors to the success of the project were financial support from the government and collaboration with both public and private sectors. The main obstacles were maintenance and replacement of cell phones in areas with no access to electricity or located far from the nearest healthcare center.

Other studies have assessed knowledge and attitudes of expectant mothers associated with antenatal care (Lau et al. 2014; Datta et al. 2014; Jareethum et al. 2008). Lau et al. (2014) examined effectiveness of educational messages sent via cell phones to expectant mothers. While the messages became the main source of information for the majority of the participants (98%), there was no significant difference in knowledge or attitude between expectant mothers who did vs. did not receive educational text messages. In contrast, Datta et al. (2014) revealed that respondents, who received text messages via cell phones, acquired useful and important knowledge about maternal and neonatal care after the completion of their pre–post intervention study.

An RCT assessed the emotional health of expectant mothers who received educational text messages for the duration of their pregnancy in Thailand (Jareethum et al. 2008). As expected, the respondents in intervention groups felt less distressed and more confident about the capacity of CHWs during normal labor and delivery ($P < 0.05$). There was also no significant difference in the outcomes of pregnancy (such as infant birth weight and preterm delivery) in women who did vs. did not receive educational messages.

Soegijoko et al. (2011) developed a simple e-prescription system for Puskesmas Babakan Sari (Bandung, Indonesia), a community health center (CHC) that has been functioning successfully for more than seven years. The functionalities of the e-prescription system (Fig. 2.3) were to support the patient and medicine data recording, conduct paperless prescribing (with additional benefits), prepare electronic medical record and drug inventory, as well as generate seven different reports for administrative purposes. With less than 300 standard drugs available at the CHC, the following additional benefits can be obtained: avoid confusion on specific drug names; prevent possible allergy, overdose, and drug interactions; warn possible adverse drug reactions; and improve efficiency. The e-health system can be implemented on just a single personal computer (PC) to a system with more than ten personal computers in a local area network. The system has been designed to provide future development and additional applications, namely different types of internet access, future use of mobile phones (and smart phones), online reporting to/from remote “stations,” tele-consultation, and tele-education.

A separate m-health system has also been developed by making use of an “SMS server” configuration. There were four different modes of operation in the m-health system:

- A predefined or spontaneous SMS to a particular patient or a healthcare provider.
- A predefined SMS to a particular client at the same time every day, e.g., 09:00 am.
An SMS for a particular client generated remotely by using a cell phone.

An SMS request from a patient to access information. Patients simply texted keywords to the system.

In addition, Irawan and Soegijoko (2015) also developed more complex m-health interventions to guide expectant mothers and their babies from pregnancy to delivery and beyond (as shown in Fig. 2.4). These interventions could be accessed via website (desktop computer or laptop) or mobile application (via portable device). The system had four modules, covering education, early detection, patient management, and data integration. At the end of 2015, the team had completed initial panel discussions with 54 midwives and other stakeholders to develop content and design.

Research in Zanzibar observed impacts of an m-health intervention on perinatal mortality rate (Lund et al. 2014). The free Wired Mothers intervention used a combination of unidirectional text messaging and direct two-way communication to deliver educational resources on pregnancy, appointment reminders for routine antenatal care, as well as an emergency medical response system. The perinatal
mortality rate dropped significantly by 50% (OR 0.50, 95% CI 0.27–0.90), the total stillbirth mortality rate was 27 per 1000 births, and the total neonatal mortality rate was 19 vs. 26 deaths per 1000 births in the intervention and control groups, respectively.

Few studies have been carried out to determine the impacts of m-health interventions on improving childhood vaccination uptake and strengthening immunization services (Kaewkungwal et al. 2010; Wakadha et al. 2013; Crawford et al. 2014; Mbabazi et al. 2014). Published data show that the percentage of children who received vaccines after the implementation of Mother and Child Care Module on the Expanded Programme on Immunization (MCCM-EPI) increased significantly (from 34.49% to 44.22%, \( P<0.001 \)) (Kaewkungwal et al. 2010). Two studies indicated that an m-health intervention also affected a mother’s likelihood of bringing children for vaccination, with mothers feeling more obligated to ensure that their children receive all their vaccinations on time after receiving SMS or voice reminders (Wakadha et al. 2013; Crawford et al. 2014). The mass vaccination campaign in Kenya introduced a mobile application to improve records and to send reminders, which improved the measles vaccine coverage rate (from 75% at pre-campaign to 92% at post-campaign) (Mbabazi et al. 2014).

### 3.7 Tuberculosis

Although the majority of tuberculosis (TB) patients are curable with affordable drugs, there are still approximately nine million new cases of active TB and 1.5 million TB-related deaths annually (World Health Organization 2015b). Barclay et al. (2009) performed a pilot study to assess patient adherence to tuberculosis treatment, recruiting 155 subjects from three clinics in Cape Town, South Africa, in
collaboration with the Western Cape Department of Health. Researchers used the SIMpill® medication adherence system to check if participants complied with their medication regimes. Each time the pill bottle was opened, a text message was sent to a central server. If a participant failed to take medication at a predetermined time, then the central server sent a reminder text. If there was still no response from the participant after a predetermined time, the central server notified the participant’s healthcare provider about missed doses. The study showed medication adherence remains stable at 86–92% with a 94% treatment success rate. Another investigation of TB medication adherence examined use of SIMmed®, where participants contacted a central server every time they took a dose. Although the success rates of treatment were not measured in that study, the compliance rate was still high (90%). These findings show the potential use of SIMpill® and SIMmed® to improve medication adherence of patients with TB and warrant further investigation or new evidence to help in decision-making by the South African government.

3.8 Obesity

“Globesity” is a global epidemic of overweight and obesity with complications and long-term effects of multiple chronic conditions (Castelnuovo et al. 2015), including chronic diseases such as cancer, CVD, dyslipidemia, hypercholesterolemia, hypertension, diabetes mellitus, and various psychosocial and psychopathological disorders (Wadden et al. 2002; Byrne et al. 2004; Flegal et al. 2005; Prospective Studies Collaboration 2009; Castelnuovo et al. 2014). Overweight and obesity occur mainly because of a complex interaction between behavioral, environmental, and genetic factors (Marcus and Wildes 2009). Compared with the other factors, behavioral factors—such as dysfunctional eating habits and low levels of physical activity—have the strongest effect on exacerbating obesity and obesity-related complications (Dombrowski et al. 2012).

Researchers should consider social and environmental factors to be more effective in promoting weight loss (Rosas et al. 2015). For instance, policy intervention may improve functional eating and physical activity behaviors in clinical and community settings (Barnidge et al. 2013). The socioeconomic context may also be a factor behind the spread of obesity, which is more prevalent in developed countries than in developing countries (Castelnuovo et al. 2015).

Long-term weight management of obesity must focus on psychosocial and psychopathological determinants since there are significant correlations between being overweight and having anxiety, eating, mood or personality disorders, family and systemic scenarios, life events, quality of life, self-esteem, and stress (Hudson et al. 2007; Pickering et al. 2007; Petry et al. 2008; Scott et al. 2008; Davin and Taylor 2009; Manzoni et al. 2010). Lifestyle changes must be maintained over time for the long-term maintenance of weight loss changes (Wing and Phelan 2005). Some m-health interventions may not be effective in maintaining significant weight loss in the long term, particularly if participants are fully dependent on a particular device.
to reduce their weight and keep it off (Tate et al. 2013). In such cases, once the device is removed (e.g., the study has completed or if a portable device with a mobile weight-related application breaks and is too expensive to repair), there is a risk that some participants may not able to maintain a healthy routine (Tate et al. 2013). For an m-health program to be successful in the long term, it needs to be either applicable to the participant’s own device, or alternatively researchers should offer several maintenance options to ensure devices are maintained for prolonged periods (Tate et al. 2013). Another possible alternative for longer-term m-health programs would be to use “stepped wedge designs” in which participants use a supplied device to slowly change their unhealthy habits into healthier new ones in the beginning of the trial and gradually create their own pathway to preserve the weight loss results for a lifetime (Tate et al. 2013).

4 A Universal Healthcare System for the Twenty-First Century

The previous sections introduced innovative ICT healthcare applications and different types of implementation challenges in developing countries and provided specific application examples in both developed and developing countries. There have been very large developments in ICT, especially in mobile devices and better-quality telecommunication infrastructures, which support further development of innovative e-health systems. There is also increased capability through more experienced users and system developers that allow the formulation of more accurate e-health systems specifications. Therefore, it is expected that more and more e-health systems will be continuously developed with improved performance.

Further developments of more and more m-health, e-health, and telehealth systems for specific healthcare applications and/or specific diseases are expected in the near future, based on the following reasoning:

• Relatively fast developments of ICT technologies in general and, more specifically, different types of new mobile devices and related accessories (memory, modems, Wi-Fi modules, etc.)
• Fast improvement in quality and the development of different types of telecommunication infrastructures
• Increasing user familiarity to implement various e-health systems, which leads to improved user experience in developing/formulating better systems specifications of new e-health systems
• Improving experience of the e-health system developers
• An expanding literature base as excellent sources to provide improved and current information for further developments of new e-health systems, including reports on relatively new e-health systems, which could offer appropriate stimuli for better and faster developments of new devices and systems
• Increasing variety of e-health systems for varied and specific applications with improved performance
Some examples of e-/telehealth and telemedicine systems are:

- Health support of specific community groups, such as children (from newborn babies, through under five years, to children under twelve years), women, and elderly people
- Specific diseases: CVD, dengue fever, distant diagnosis of cataract (with image processing), early detection of osteoporosis (with image processing), skin disease, tuberculosis, or typhoid
- Specific specialties: dietary services for obesity management, dentistry, ophthalmology, pathology, psychology, or psychiatry
- Midwifery practice
- Prescription systems with adverse drug alerts (especially for CHCs, relatively small- to medium-sized clinics, and small hospitals)
- Patient education
- Coordination of healthcare workers
- Mobile and/or movable healthcare clinics

An integrated healthcare system emerged as one recommended solution to ensure the secure and seamless flow of healthcare data among patients and their healthcare providers (hospitals, clinics, and third parties such as home care providers and informal care providers) (MacIntosh et al. 2014). The integrated system consisted of eight key elements: patients, healthcare providers, data and data analytics, regulators, researchers, healthcare payers, telecommunication providers, and hardware and software vendors (MacIntosh et al. 2014; International Telecommunication Union 2015).

As noted above, to harness the benefits of e-health, and acknowledge the challenges outlined here, any proposed system should use the existing telecommunication infrastructure, for instance, the Internet, global system for mobile communication (GSM), phone line, satellite, fiber-optic network, or specific radio wave networks, depending on the availability of technologies in the area. An implementation system diagram is presented in Fig. 2.5 (MacIntosh et al. 2014).

### 4.1 Patients

Within an e-health framework, patients would be able to use several technologies to maintain their health.

#### 4.1.1 Personal Health Records and Patient Portals

Two types of technologies that have improved patient self-management of chronic illness and enabled better communication between patients and their clinical teams are PHRs and patient portals (Weppner et al. 2010; Ricciardi et al. 2013). Several authors have defined the term “personal health record” in different ways (AHIMA
The American Health Information Management Association has defined the term as “an electronic, lifelong resource of health information needed to make health decisions (AHIMA e-HIM Personal Health Record Working Group 2005).” Individuals own and manage the information in the PHR, which comes from healthcare providers and the individual. The PHR is maintained in a secure and private environment, with the individual determining rights of access. The PHR does not replace the legal record of any provider (p.1, AHIMA e-HIM Personal Health Record Working Group 2005). Frost and Sullivan define a PHR as “a tool that is primarily used by patients for documentation of their medical records, mostly controlled by the patient themselves or a family member” (p.8, Frost and Sullivan 2015).

The advantages of using a PHR for individuals (Tran and Gonzales 2012) include: patient empowerment to manage their PHI (i.e., allergies, test results, immunization records, etc.) from their own PHR and the capability to share their record with healthcare providers (i.e., referring physician) or organization (i.e., hospitals, clinics, pharmacies, etc.). On the clinical side, a PHR enables healthcare providers to provide medical response and relief to patients in remote areas with
limited healthcare facilities (PricewaterhouseCoopers 2013a). Consequently, this may lead to improved decision-making, increased care coordination service effectiveness, and enhanced efficiency and effectiveness of healthcare resources utilization (PricewaterhouseCoopers 2013a).

After investigating some examples of commercial PHR products, Tran et al. (2012) proposed a consensus standard for PHRs consisting of 14 data components, divided into three subgroups: critical, desired, and recommended (as shown in Table 2.1).

Laxman et al. (2015) found that barriers to adopting PHR among healthcare consumers fall into eleven general categories: access to a PHR system, access to a computer or the Internet, cognitive disabilities, ensuring accurate data, familiarity and comfort, low health literacy, low literacy in computers or reading, physical disabilities, privacy, terminology, and usability. In terms of cognitive disabilities, people aged 65 years and over may find it difficult to use a PHR due to impaired cognitive function (Laxman et al. 2015). In terms of familiarity and comfort, the majority of consumers tended to use a PHR if they know how to operate it or they like the appearance of the interface (Wang et al. 2004). In this situation, the development team needs to customize the PHR based on the needs and preferences of the targeted consumers. In terms of low literacy in computers or reading, some patients require assistance to perform login into a PHR, use a mouse or keyboard, or even switch on a computer, and some patients were reluctant to perform those tasks, even though they had no recorded history of physical and cognitive impairments (Lober et al. 2006). Continuous training and encouragement to keep learning are needed to boost end user engagement and to reduce anxiety.

Frost and Sullivan (2015) defined a patient portal as “a web-based access point with secure log-in that allows doctors, payers (insurance companies), and patients to communicate and share health information remotely, supplementing the ongoing management of the patient’s care and billing information. This is mostly available as a module contained within the EHR system. It also allows the patients to download their health information, is available for use 24*7 and offers convenience for all stakeholders and an increased level of control for patients in particular” (p.8, Frost and Sullivan 2015).

A patient portal appears like a general website (as shown in Fig. 2.6); however, it functions as a secure and regulatory-compliant channel for data transmission and

<table>
<thead>
<tr>
<th>Table 2.1</th>
<th>A personal health record (PHR) with 14 health data categories (Tran and Gonzales 2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Critical</strong></td>
<td><strong>Desired</strong></td>
</tr>
<tr>
<td>Immunizations</td>
<td>Health providers</td>
</tr>
<tr>
<td>Medications/prescriptions</td>
<td>Insurance/payer information</td>
</tr>
<tr>
<td>Allergies/adverse reactions</td>
<td>Social history/lifestyle</td>
</tr>
<tr>
<td>Family history</td>
<td>Problem, diagnoses, conditions</td>
</tr>
<tr>
<td>Lab/test results</td>
<td>Clinical encounter</td>
</tr>
<tr>
<td>Procedures/surgeries</td>
<td></td>
</tr>
</tbody>
</table>

| | | |
| | | |

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reception between patients, providers (hospitals or medical practices), and payers (insurance companies) (Frost and Sullivan 2015). Patient portals can be designed with features and functions to increase the active engagement of patients in their clinical care and to help patients deal with complex administrative tasks (Frost and Sullivan 2015). The portal can enable patients to more easily manage administration tasks online, including completing forms, making payments for appointments, scheduling appointments, etc. (Frost and Sullivan 2015). It can also facilitate direct and active interactions between patients and their physicians and can provide patients with secure access to their clinical, laboratory, and medical results (Frost and Sullivan 2015), including blood tests, cultures (swab tests), urine tests, and other tests.

Patient portals fall into two general categories: “tethered” and “untethered.” For a tethered website, the patient portals are developed as modules in the existing EHR (Frost and Sullivan 2015). For untethered (or stand-alone) websites, the portals are stand-alone, but still may be integrated into the existing system in healthcare provider side (Frost and Sullivan 2015).

The HealthIT.gov (2015) initiative was based in the belief that availability of patient portals may help healthcare providers build quality interactions with their patients, to empower patients in their own health and support ongoing care for patients, which could then reduce recovery times and improve health outcomes. Several reports showed improved communication between patients and healthcare providers after the introduction of patient portals; however the direct effects of patient portals on health outcomes are quite difficult to measure accurately (Emont 2015; Ammenwerth et al. 2012).

Otte-Trojel et al. (2014) demonstrated that the four mechanisms of patient portals that impact on health outcomes are capability to collect, maintain, store,
and retrieve PHI; activating information; interpersonal continuity of care; and inconvenience of service utilization. To be more effective, these patient portals must be integrated with health service networks.

Another study found limited evidence around effectiveness of patient portals to manage chronic disease and mixed results regarding implementing patient portals and their impacts on health outcomes (Tenforde et al. 2011). Tenforde et al. (2012) showed positive results in quality measurements for diabetes care, but did not find any connection between dose response and patient portal use intensity, and they did not distinguish the effects specific to the features of patient portals. Some reported benefits after using that patient portal were enhanced patient satisfaction, better access to general practitioners outside regular visits, and improved quality and efficiency of face-to-face consultation services (Wade-Vuturo et al. 2013).

4.1.2 The Combination of an m-Health Application, Wearable Technologies, and Sensors

Health data can be recorded either manually (actively) or automatically (passively) (Aitken and Lyle 2015). The process of managing chronic diseases through m-health applications is quite complex and particularly challenging for older people; therefore, an automated passive data collection could be of tremendous value for that sector (Aitken and Lyle 2015). An example would be an m-health application connected via wireless network to an automated weight scale to help maintain a healthy weight and reduce acute episodes of congestive heart failure (Aitken and Lyle 2015). By having high-level functionality and seamless connectivity, healthcare providers could assess the current health status of patients using data that is automatically transmitted via a biofeedback device (Aitken and Lyle 2015).

According to a recent report, only one-tenth of m-health applications on 282 smartphones have a direct interconnection with other devices (Aitken and Lyle 2015). As shown in Table 2.2, most of these m-health applications focused on fitness and wellness, followed by applications to manage chronic diseases, aiming to better share information and assist effective communication between patients and their healthcare providers (Aitken and Lyle 2015). Of that 9% applications to manage chronic diseases, approximately 29% are intended for mental health applications, and the remaining is determined for the following diseases: diabetes (15%), heart and circulatory (10%), musculoskeletal (7%), and nervous system (6%) (Aitken and Lyle 2015).

The report also found that (out of a sample of 282 devices) only 15% of medical devices were cleared or approved by FDA (Aitken and Lyle 2015). Based on percentage level, the FDA eventually cleared just 5% of the fitness trackers, compared with 75% of ECG monitors and 100% of blood glucometers (Aitken and Lyle 2015). FDA clearance will be granted if a device meets the requirements for m-health applications (Aitken and Lyle 2015). Individuals can be at a greater risk of harm when using an unapproved medical device (e.g., an ECG monitor or a blood glucometer) than an unapproved fitness tracker, which connects wirelessly to smartphone (Aitken and Lyle 2015).
Ideally, fully automated data collection can be achieved by integrating wearable health monitors and medical devices into daily lives (Aitken and Lyle 2015). At the end of 2015, the majority of wearable devices were designed to be worn on the wrist (55%), around the chest (23%), and on the purse, pocket, or shoe (17%; Fig. 2.7) (Aitken and Lyle 2015). Most wearable devices (90%) were wirelessly synchronized with a mobile application, thus improving automatic data collection and analysis (Aitken and Lyle 2015). Another study also reported a new trend in developing wearable devices that can be unobtrusively attached to the human body (e.g., ear) and can record physiological signals in real time, such as blood pressure, heart rate, human movement, respiration rate, and oxygen saturation (Aitken and Lyle 2015).

### Table 2.2 m-Health applications on smartphones based on category in 2015 (Aitken and Lyle 2015)

<table>
<thead>
<tr>
<th>Wellness management (%)</th>
<th>Disease treatment and management (%)</th>
<th>Other (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fitness</td>
<td>Disease specific</td>
<td>Other functionalities</td>
</tr>
<tr>
<td>36%</td>
<td>Women’s health and pregnancy</td>
<td>11%</td>
</tr>
<tr>
<td>Lifestyle and stress</td>
<td>Medication reminders and information</td>
<td></td>
</tr>
<tr>
<td>17%</td>
<td>Healthcare providers/insurance</td>
<td></td>
</tr>
<tr>
<td>Diet and nutrition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disease specific</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women’s health and pregnancy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medication reminders and information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthcare providers/insurance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (%)</td>
<td>Other (%)</td>
<td>11%</td>
</tr>
</tbody>
</table>

### Fig. 2.7 Common placements of wearable devices on the body (Adapted from M. Aitken and J. Lyle, *IMS Institute for Healthcare Informatics*, 17. Copyright 2015 by Murray Aitken. With permission)
4.1.3 Communication Tools and Social Media

The widespread use and scalability of social media has further driven adoption of m-health solutions, allowing patients to get advice from someone online who may be suffering from the same illnesses, diseases, and medical conditions (Ernst and Young 2012).

A number of studies have found associations between the use of social media (such as Facebook and Twitter) and improvement of the health status of patients with breast cancer, chronic tobacco use, and HIV/AIDS (Abramson et al. 2015; Schnall et al. 2015; Haines-Saah et al. 2015). Some studies also found that many people shared their views and experiences of living with a disease to support others in similar situations and to enhance community understanding of the awareness and treatment of chronic diseases (Hale et al. 2014; Tsuya et al. 2014; Namkoong et al. 2013; Taubert et al. 2014). Ramirez et al. (2016) noted that the use of social media to share patient experiences in fighting disease can produce positive behavioral changes as well as strengthen social connections in the community.

4.2 Healthcare Providers

Healthcare, including m-health, is provided by a diverse ecosystem of actors that contribute to better health of people. Care is primarily provided by a cadre of trained professionals and semiprofessionals, including physicians, nurses, midwives, pharmacists, and technicians, among others (International Telecommunication Union 2015). These healthcare practitioners often belong to certain professional organizations and work together with health leaders, managers, and administrators under healthcare-providing organizations, such as hospitals, clinics, or private practices, to provide and manage healthcare services (International Telecommunication Union 2015).

The challenges faced by healthcare practitioners who do, or intend to, engage in m-health in LMICs are complex and multilayered. We contend that these challenges are primarily driven by the tension between two key realities on the market. On the one hand, the pace and scale of development and proliferation of m-health technology and applications creates a glut of options in terms of potential m-health applications (The Deloitte Centre for Health Solutions 2015). Further, the resource constraints and healthcare challenges in developing markets make m-health a potentially attractive and impactful solution. On the other hand, caution is needed, as there is still high uncertainty or dearth in terms of the supporting infrastructure and verifiable knowledge base needed to deploy m-health effectively and responsibly. The tension between these two forces creates several key issues.

Uncertainty in Demand, Efficacy, and Competency At a basic level, there is much uncertainty around prioritizing which applications or practices to adopt (The Deloitte Centre for Health Solutions 2015). There is a lack of clarity in terms of
demand: what patients want and need in terms of m-health (The Deloitte Centre for Health Solutions 2015). This lack of clarity is coupled by an insufficient knowledge base around best practices for impact, efficacy, safety, and security of m-health applications and no clear assessment criteria in choosing potential applications (The Deloitte Centre for Health Solutions 2015). Furthermore, practitioners may also lack technical knowledge, training, and support in how best to adopt m-health (Elsy and Rogan 2014).

**Operational and Sustainability Concerns** Practitioners may be reluctant to adopt m-health for operational reasons, such as support to deploy and integrate with existing practice (The Deloitte Centre for Health Solutions 2015; Cascella 2014). Practitioners in the private sectors may be especially concerned by the lack of clarity in verifiable business models and payment schemes (The Deloitte Centre for Health Solutions 2015; Cascella 2014). One example of operational concerns around implementing m-health is with online prescribing (Cascella 2014). One definition of online prescribing is a “provider’s ability to prescribe drugs to a patient who has been diagnosed and treated via telehealth” (p.1, Telehealth Policy Resource Center). The lack of physical interaction increases the risk for patient safety and liability concerns and has been a key source of telemedicine-related litigation in the United States (Cascella 2014; Natoli 2009). Major concerns include establishing an appropriate provider–patient relationship, the ability to make an adequate health assessment, the accuracy of health history information transmitted, specific m-health informed consent laws, and all relevant prescribing regulations (Cascella 2014). Even in the absence of regulations in relevant regions, providers should consider potential best practices that comply with regulations on potentially other relevant regions (Cascella 2014). For example, informed consent processes include providing necessary information, including comprehensive information regarding the telehealth service and all involved parties, potential risk related to electronic nature of the care delivery, the associated alternative in case of technological malfunction, alternative options for treatment and care, and a plan for ongoing care (Cascella 2014).

**Privacy and Security** The remote transmission of data inherent in m-health increases the risk of inappropriate data exposure (Cascella 2014). All m-health programs should include appropriate privacy and security measures that comply with regional standards and are present at all points of contact (originating and remote site, transmitting medium) (ECRI Institute 2015). Examples of security measures include passwords and user authentication, data encryption, and data tracking (Cascella 2014). It is important to recognize that the specific areas of exposure for a particular m-health application will depend on the type of services offered, the method of delivery and communication, and the types of technologies involved (Cascella 2014). For example, the use of social media and the security of different types of mobile devices and networks may present differing areas of risk (Cascella 2014).

**Regulation Uncertainty, Variability, and Risk Mitigation** As noted above, this high level of uncertainty in multiple facets of m-health is often exacerbated by an inadequate regulatory infrastructure in terms of license to operate, security, liabilities,
and accountabilities (Cascella 2014). Practitioners need to consider potential distinct requirements for licensing m-health programs and credentialing/privileging its practitioners (Cascella 2014; Natoli 2009; ECRI Institute 2015; Kepler and McGinty 2009; Health Resources and Services Administration 2001, revised 2006). The regulations for licensing and credentialing may differ—or even not yet exist—across different regions in which m-health is practiced, and practitioners involved in m-health should be aware of the relevant laws and standard of care for all areas they plan to practice in (Cascella 2014).

Legal concerns are particularly salient for m-healthcare providers, especially when services cross regions across with variable standards and regulations (Cascella 2014). Concerns may include, but are not limited to, issues of jurisdiction, procedure, choice of state law, malpractice, and standard of care (Cascella 2014; Natoli 2009; ECRI Institute 2015; Kepler and McGinty 2009; Health Resources and Services Administration 2001, revised 2006). To help mitigate liability risk in m-health, providers should carefully consider the relevant fraud, abuse, medical malpractice, licensure and standards of care laws across all locations in which they are providing services, and the professional liability coverage and contractual division of responsibilities for current, ongoing care, and follow-up across all parties involved in the m-health program (Cascella 2014).

We have highlighted the primary issues faced by healthcare providers in adopting and deploying m-health; it is important to recognize that each of these providers and organizations will have their own unique set of motivations, attitudes, knowledge, and skills, resulting in a plethora of unique challenges for engaging in m-health. For example, healthcare provider organizations from the private for-profit sector may face different challenges in terms of payment models when compared with those in the public sector. Similarly, healthcare providers operating across different regions with potentially different regulatory infrastructures will face differing challenges to those operating locally.

4.3 Data and Data Analytics

Digitized medical data may play an important role in fostering integration and connected care within a healthcare system and can be an enormous asset to both developed and developing countries (MacIntosh et al. 2014). The onslaught of new digital health devices and applications in the mainstream market creates unprecedented challenges in structured and unstructured data management and analysis (MacIntosh et al. 2014). Patient-generated health data (PGHD)—including biometric data, health history, lifestyle choices, signs and symptoms of chronic disease, treatment history, and other unstructured data—will be used by healthcare providers to ensure patients’ health concerns are addressed (Deering et al. 2013). Digitized medical data may also allow authorized stakeholders easier access to previously hard-to-access data, such as behavioral, environmental, genomic, molecular, and social/contextual data (MacIntosh et al. 2014). However, this data deluge poses a huge challenge in the healthcare industry, especially when considering the complexities
of extremely diverse data (Groves et al. 2013). Data analytics can greatly assist authorized stakeholders to make decisions around patient care and management (MacIntosh et al. 2014).

The aim of the proposed design for health data analytics is to provide an integration framework of information systems to improve health outcomes in LMICs. The system consists of the following software modules:

1. **Community and health worker training and educational modules.** This module has two parts, training and educational modules, and an official website. The training and educational modules provide continuous educational programs to relevant groups (e.g., government officials, health workers, or parents). The official website contains community education, a forum, and printable resources to socialize activities.

2. **Recording and reporting treatment surveillance data.** This module comprises the details of treatment at all relevant points of care, including public health centers and hospitals. It has a computer-based EHR, including a treatment and management plan, and functions for appointment and medication reminders. It is also equipped with teleconsultation facilities for patients who need to seek medical advice from doctors and specialists in other regions.

3. **Recording and reporting epidemiological trend data.** This module consists of two nodes: data collection and database. The data collection node is located at the point of care, where all gathered data are processed and standard reports are automatically generated. Subsequently, associated reports are periodically transmitted to the database node, located at a central health office, via the Internet or cellular phones. The summary of the reports will be used to distinguish short-term and long-term epidemics.

4. **Management of overall distribution and inventory for medication.** This module consists of an information system that manages the distribution of medical supplies. It plays a critical role in ensuring the availability of drugs and vaccines tailored to local community needs.

5. **Additional functions for special cases.** Additional modules can be added according to specific local needs. For example, in the case of TB (Koesoema et al. 2007), the software could be expanded to include a function to transmit sputum images via a telemedicine network to laboratory facilities, or error rate of clinical laboratory tests could be minimized by image processing software for diagnostic tools.

6. **User satisfaction measurement.** This module consists of questionnaires to assess end user satisfaction with the components of the e-health unit, covering ease of use, satisfaction with system interface, accuracy of alarms, feedback, technical problems, and global satisfaction.

### 4.4 Healthcare Policy and Regulation

The primary role of healthcare policymakers and regulators is to help formalize m-health ecosystems and facilitate growth (PricewaterhouseCoopers 2013a). On the highest level, new policies and regulations should help to integrate and align
m-health developments with relevant national healthcare strategies and priorities (PricewaterhouseCoopers 2013a). Integration can be achieved by harmonizing the gap between regulations around traditional and mobile health delivery (PricewaterhouseCoopers 2013a).

**Basic Viability: Accountability and Interoperability** To ensure accountability, regulators should ensure the basic regulatory infrastructure for m-health is well defined, including regulations related to medical device certification, security and privacy standards, as well as licensing and credentialing of m-health providers and services (PricewaterhouseCoopers 2013a). To ensure scalability and coordination across all aspects of an m-health ecosystem, regulations should cover technology and data standards that incentivize or mandate interoperability between solutions (PricewaterhouseCoopers 2013a).

**Commercial Viability: Compensation and Funding Mechanisms** A key part of establishing a sustainable m-health system is a robust compensation and funding mechanism (PricewaterhouseCoopers 2013a). Policymakers can support payers in establishing funding and compensation mechanisms that ensure a match between healthcare system needs and m-health investments - covering the relevant service costs while still ensuring equitable access for services - especially for low-income communities; develop incentives for providers and vendors that encourage adoption and healthy competition; as well as facilitate public–private partnerships to address the most important needs in healthcare (PricewaterhouseCoopers 2013a).

**Encouraging Growth: Incentives, Education, and Other Initiatives** Finally, policymakers and regulators can also facilitate growth and development of an m-health ecosystem (PricewaterhouseCoopers 2013a). For example, to accelerate solution-based m-health programs, regulators can develop policies to incentivize and facilitate developing a relevant evidence base and best practices for m-health and encourage clinical engagement in m-health program development (PricewaterhouseCoopers 2013a). Centralizing procurement may help incentivize developing standardized, interoperable, and scalable solutions (PricewaterhouseCoopers 2013a). To diffuse the knowledge on m-health and encourage a culture of adoption, regulators should facilitate establishing relevant m-health education and training systems for healthcare professionals, incentivize providers to adopt technology and promote m-health awareness in the community, and ensure m-health solutions are available in local languages (PricewaterhouseCoopers 2013a).

### 4.5 Researchers

Researchers play a key role in a swiftly developing field such as m-health, producing new knowledge to improve m-health technology, applications, organizations, and impact, specifically around achieving health goals (Mills 2004; Baris 1998).
As part of a broader research agenda covering health system research, m-health research can include how m-health is integrated to “the effort to plan, manage and finance activities to improve health, as well as the roles, perspectives and interests of different actors in this effort” (Baris 1998).

m-Health research is by nature cross-disciplinary and combines engineering, medicine, and social sciences across a breadth of research approaches and methods, including conceptual analyses, systems development, pilot and case studies, impact and economic evaluations, and operational research (Mills 2004). m-Health research may cover different stages, actors, and levels of analyses in m-health systems, from the individual, household, or community level to the organizational, national, and even supranational level (Mills 2004). m-Health research topics cover the spectrum of the WHO’s definition of a health system—stewardship, financing, resource development and distribution, and service delivery (World Health Organization 2000). The scope of m-health research encompasses public and private sectors, public policies and technological standards, design and production of m-health applications, as well as service delivery organization and impact (Mills 2004).

The breadth and depth of m-health research contributes to a growing knowledge base of existing m-health applications, lessons learned, potential impact, and hurdles in all aspects of healthcare systems that can be used for future improvements in applications, governance, and policies.

## 4.6 Healthcare Payers

Healthcare payers are third-party organizations that are responsible for financing the costs of medical services (International Telecommunication Union 2015). The paying party may differ across institutional contexts in LMICs and may be a combination of public payers (government health expenditure and aid) and private payers (private insurance and out-of-pocket patient expenditure) (International Telecommunication Union 2015). While a cost reduction as “value for money” may spur adoption of m-health applications among private payers, attaining better health outcomes for patients may be a higher priority for public payers (PricewaterhouseCoopers 2013b). The healthcare payers need to have a comprehensive funding strategy for m-health that matches investments with healthcare system needs, consider access equity for disadvantaged population, distribute benefits of m-health fairly across the stakeholders, and minimize economic consequences of unanticipated events or regulatory changes (PricewaterhouseCoopers 2013b; Protiviti 2014).

The healthcare payer efforts should be focused on creating compensation mechanisms to ensure fair distribution of the benefits of m-health across the stakeholders (Rashid and Elder 2009). Therefore, the establishment of funding mechanisms that provides direct m-health investments according to healthcare system needs would
lead to improved investment efficiency (Rashid and Elder 2009). To accomplish these goals, the healthcare payers could use the following strategies (Rashid and Elder 2009):

- Establish compensation mechanisms that not only cover the costs of m-health services for patients but also provide reimbursement for the healthcare providers.
- Customize product that offer favorable pricing models of m-health for low-income earners so that people have equal opportunity to gain access to m-health system.
- Create reward schemes for healthcare providers for accomplishing positive health outcomes and efficiency improvements by utilizing m-health solutions, advertising healthy competition, and persuading m-health adoption.
- Launch partnership with public, private, and community sector organizations to finance the m-health services that accommodate urgent medical conditions.

### 4.7 Telecommunication Operators

Generally, in m-health systems, telecommunication operators are responsible for providing seamless access to information and health data, facilitating intense communication between patients and their healthcare stakeholders, and ensuring privacy and confidentiality of data exchange (International Telecommunication Union 2015). In actuality, telecommunication providers are responsible for far more than this (International Telecommunication Union 2015); for sustainable m-health systems, providers must have strategies for managing billing and revenue mechanisms, customer care, device management, and distribution networks (International Telecommunication Union 2015).

### 4.8 Hardware and Software Vendors

Both hardware and software vendors have played a critical role in the development of m-health systems (International Telecommunication Union 2015). They are responsible for the design, functionality, cost, development, circulation, and sustainability of products that allow individuals to organize, store, and retrieve health data and information, such as mobile devices, applications, sensors, wearable devices, etc. (International Telecommunication Union 2015). Their active involvement in integrated healthcare systems would guarantee the development of products that satisfy the needs of both patients and healthcare stakeholders at a fair and reasonable cost (International Telecommunication Union 2015). To achieve economies of scale and low per-unit product costs, hardware and software vendors must ensure that products align with the Continua Health Alliance Design Guidelines.
(International Telecommunication Union 2013) and enable mass production (International Telecommunication Union 2015).

With such a wide selection of mobile devices to choose from in the commercial market, m-health providers could use specific parameters to select the best devices for specific programs: operating system, speed, memory, and access to data service; features, such as screen size and resolution, keyboard, camera, and Global Positioning System (GPS); durability, battery life, and longevity; security; and user needs and preferences, such as cost (Keisling 2014). For instance, in terms of an operating system, program developers would need to ensure that all mobile devices are compatible on-site devices; specifically, a cell phone must be unlocked and operated at a particular frequency band in each location (Keisling 2014). Program developers must also have a full understanding of the drivers and barriers toward users adopting specific devices; influencers include age, eyesight, literacy, and previous experience with devices (Keisling 2014).

A cross-functional development team is required to create software systems to support data collection and analysis processes throughout development through deployment to sustainability phases (Keisling 2014). A development team is composed of members with specialist skills and expertise that may change throughout the development life cycle, from analytical and financial modeling (such as a business analyst) to technical skills (such as a database administrator, enterprise architect, software engineer, systems analyst, and test specialist) (Keisling 2014). For instance, in the scale-up phase, the development team is responsible for tracing bugs and adding required modules to the software system (Keisling 2014).

5 Conclusion

Even though the capabilities of cell phones in high-income countries are more sophisticated than other LMICs, basic cell phone functions that allow users to send text messages and make calls offer huge advantages for research in the health sector (Mechael 2007). The implementation of mobile health (m-health) projects in developing countries not only enables more efficient and effective communication between healthcare service providers and patients, it also improves information delivery and retrieval processes over vast distances (Tamrat and Kachnowski 2012). These systems also enable healthcare workers to access educational resources, communicate and consult with other staff, as well as remotely perform ongoing surveillance and monitoring of patients’ health status (Chib et al. 2015). Consequently, these systems may help improve effectiveness and efficiency of under-resourced health infrastructures and may offer greater benefits to the patients (Bloch 2010; Ranck 2011).

General concerns that have been expressed regarding the use and development of m-health initiatives are cost, interoperability, lack of technical knowledge, and scalability, as well as data privacy, protection, and security (Kay et al. 2011; Olla and Shimskey 2015). Addressing the issues of data security before launching an m-health program is essential to overcome barriers to m-health adoption (Gleason 2015).
Establishing secure communication channels is crucial to serve the rights of the patients and to protect confidentiality of personal health data (Mechael and Todrys 2008). The Earth Institute has taken a special interest in the development of ethical guidelines, policies, and training curricula for maintaining confidentiality and security of public health data in rural villages across ten countries in sub-Saharan Africa, through its m-health activities within the Millennium Villages Project (The Earth Institute 2011). The strategy is aligned with the recommendations that “safeguarding the privacy, confidentiality, and security of any public health informatics or e-health project is an important undertaking” (p.378, Curioso 2006).

The feasibility of taking m-health projects to a larger scale remains low (Kay et al. 2011; Yu et al. 2006). Several factors have affected the scalability of small projects or controlled trials to wider state, national or international communities, including a prohibitive increase in costs, complications of policies and standards (Kay et al. 2011; Gleason 2015; Yu et al. 2006), and insufficient evidence to convince key policymakers and health practitioners to expand m-health systems (Mechael et al. 2010).

Moreover, there is a huge discussion around substituting physical contact with mobile technologies in the healthcare sector, in particular, the use of e-health systems to diagnose diseases and provide decision support around required treatment. Varied types of treatments can be chosen depending on case type, for example, whether the patient does or does not require x-ray, a physical examination, or laboratory tests (Mechael 2007). Remote consultations are not effective when a patient requires a series of diagnoses and treatments. Specialized protocols and training are required to recognize cases in which consultation services can be delivered through mobile technologies such as the Internet or cell phones. Assessing and circulating collected data must be preceded by careful evaluation to maximize the potential benefits (Mechael 2007).

Often family and community members in LMICs share cell phones (Mechael 2007). Researchers need to consider a better way to improve access to m-health projects to users with shared portable devices (Larsen-Cooper et al. 2015) without violating their privacy. In general, the availability of legal frameworks and liability boundaries are extremely important in guiding the implementation of m-health systems within and across countries (Istepanian and Lacal 2003).

m-Health technologies represent potentially powerful catalysts for strengthening health systems and improving communication between m-health innovators and health program implementers (Labrique et al. 2013). m-Health technologies have the potential to ensure access for all to life-saving health interventions by improving health system performance (including coverage, equity, efficiency, and quality), yet these must be explained in a way that will resonate with the health of decision-makers (World Health Organization 2000). Therefore, rather than acting as a stand-alone solution, m-health technologies must be used as a complimentary tool to an already-existing system, with the goals of accountability and governance, a functioning health information system, a well-performing health workforce, cost-effective use of medical products, vaccines and technologies, and health service provision (World Health Organization 2007).
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