Barriers and Gaps Affecting mHealth in Low and Middle Income Countries: Policy White Paper

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It is our sincere hope that by identifying the key mHealth barriers and gaps more proactive efforts can be undertaken to create an enabling environment to promote mHealth scale, sustainability, evidence-based research, and business models.

EXECUTIVE SUMMARY

There is growing momentum and enthusiasm to capitalize on the rapid spread of telecommunications infrastructure and uptake of mobile phones and mobile broadband services in low and middle income countries to support the achievement of global, national, district, community, and individual level health priorities. Still in its infancy, mHealth, the use of mobile technologies for health, runs the risk of not realizing its full potential due to small-scale implementations and pilot projects with limited reach. To help shed light on these issues, the mHealth Alliance commissioned an in-depth exploration of the policy barriers and research gaps facing mHealth. This White Paper, written by a team of researchers at the Center for Global Health and Economic Development at the Earth Institute, Columbia University, examines and synthesizes the existing mHealth literature to assess the current state of mHealth knowledge and identify barriers and gaps.

The body of literature documenting studies and initiatives exploring the scope of mHealth in high-income and low- and middle-income countries is considerable and an indication of a burgeoning field. The review identified significant gaps in mHealth knowledge stemming from the limited scale and scope of mHealth implementation and evaluation, a policy environment that does not link health objectives and related metrics to available mHealth tools and systems, and little investment in cost-benefit studies to assess mHealth value and health outcomes research to assess success factors and weed out poor investments. The current mHealth evidence base, mostly in the field of computer science and not health, is not sufficient to inform and influence governments and industry partners to invest resources in nationally scaled mHealth initiatives. However, it does provide indications of the barriers to be overcome to create the policy environment needed to develop strategies for community, district, regional, and national programs to implement and evaluate programs that link mobile technologies to national health objectives and health information systems in a way that benefits citizens and health workers alike. Coordination and the identification of incentive structures and the rules of engagement for meaningful collaboration between the public and private sector is needed to better inform public and private investments and the deployment of socially beneficial and commercially viable solutions.

As illustrated throughout the literature, the current single-solution focus of mHealth needs to be replaced by using mHealth as an extension and integrator of underlying health information systems along the continuum of care. End-to-end patient care systems and point-of-care support for health workers are needed whereby mHealth applications are interoperable and integrated with provider systems linking the most remote community health worker with the most appropriate sources of information when and where it is needed. Such systems have the ability to generate individual level data at the household and facility level that when aggregated can serve as the basis for health information and disease surveillance systems as well as link into financial systems for claims and reimbursements. Creating a strong collaborative foundation will be instrumental in driving and positioning public and private investment in mHealth in a way that contributes to achieving improved access to health information and services, health outcomes, and efficiencies. Within such structured paradigms, planning for infrastructure investment and human resources capacity strengthening and identifying public and private stakeholders within the ecosystem to take leadership for the development, testing, implementation, and evaluation of mHealth activities can be appropriately mapped and planned and mHealth services more effectively extended to support the health of citizens and the work of health professionals and administrators.

BACKGROUND

Mobile health or mHealth broadly encompasses health-related uses of mobile telecommunication and multimedia technologies within health service delivery and public health systems (F1). While this definition of mHealth was established in 2003, it has since been expanded to include public health and well-being and gained significant momentum through the unanticipated spread of mobile telecommunications infrastructure and uptake of handsets and services throughout low- and middle-income countries (LMICs). Further, the term "mobile phone" has evolved as the technological capabilities have advanced over the years. In the literature, the term mobile phone, and sometimes cellular phone, is used to denote standard voice, short message service (SMS), and multimedia messaging service (MMS) functionality, and in some cases web browsing and email. The term PDA stands for *personal digital assistant* and refers to the earliest version of a mobile phone with personal organization functionalities such as web browsing, email, and the ability to write easily using pen or stylus. Despite being almost discontinued, many studies in the literature focus on the use of PDAs, especially for data collection and health information support. Smart phones are the most recent technology and combine the functions of a mobile phone and PDA, in addition to enabling Internet access and imaging and video functionality. Although these phones are gaining popularity in high-income countries, for most individuals in LMICs, the cost is prohibitive. Nevertheless, the lines between smart phones and mobile phones are increasingly blurring, and the distinction between the two is decreasing rapidly.

Throughout the world, there has been a mounting interest within the health sector to take advantage of the overall improvements in telecommunications and the rapid uptake of mobile communication technologies. Despite the interest in this emerging field particularly as it pertains to LMICs, in-depth examination and synthesis of what works and does not work or the evidence base for mHealth has yet to be rigorously assessed and established. Absence of such information hampers efforts to capitalize on expanding telecommunications networks and successful mHealth pilot projects.

Though the mHealth field is still in its early stages, there are indications that it is starting to transform health systems—demonstrating its potential for extending the reach of health information and services to remote populations and promoting a shift toward citizen-centered health care and well-being. mHealth projects throughout the world are generating benefits (F2), including:

- Increased access to healthcare and health-related information, particularly for hard-to-reach populations
- Increased efficiency and lower cost of service delivery
- Improved ability to diagnose, treat, and track diseases
- Timely, more actionable public health information
- Expanded access to ongoing medical education and training for health workers

While mHealth has great *potential*, current research, as identified in this white paper, does not provide much evidence for *actual* and wide-scale health impacts, nor answers to critical research questions such as access to health-related information; improved ability to diagnose, treat, and track diseases; and ongoing medical education and training for health workers.

The momentum surrounding mHealth is rapidly increasing; however organizations, development agencies, telecommunications companies, and governments require more intensive evaluation and research for better informed investments. Evidence from early mHealth deployments should be informing and guiding subsequent projects to ensure that ineffective approaches are not duplicated and early successes can be replicated and scaled. **The aim of this White Paper is to synthesize what is known in the mHealth evidence base, identify gaps in knowledge, and profile risks and barriers that are hampering mHealth scale and sustainability.**

mHealth Review Process

With support from the mHealth Alliance, the Center for Global Health and Economic Development (CGHED) at the Earth Institute, Columbia University has completed its annual update of the Review of mHealth literature to promote the expansion of the evidence base and create an enabling environment for mHealth projects to thrive. The first review of mHealth projects was sponsored by the World Health Organization (WHO) Global Observatory for eHealth in 2007. This was then updated by the Earth Institute in 2008. While the focus of the first two reviews was a mix of project descriptions and research, the review for 2009-2010 has been structured to serve as a searchable and updatable database of mHealth studies and research that will be housed in the mHealth Alliance Public Square (now being developed) and released later this year. The 2009-2010 review has been used to inform this mHealth white paper, which aims to identify barriers and gaps to mHealth growth. The database of studies will serve as a public resource to be used to inform future activity and research in mHealth as in the case of this policy white paper. References have been included in this report by thematic area.

mHealth White Paper on Barriers and Gaps

This mHealth White Paper on Barriers and Gaps aims to first examine and synthesize research done to evaluate the impact of mHealth implementations in LMICs, and second, to examine the programming, policy, and research-related barriers to and gaps in mHealth scale and sustainability. This paper is divided into two main sections. The first section reviews and summarizes the peer-reviewed literature on mHealth initiatives with a focus on LMICs to highlight mHealth trends and challenges as identified in the literature. The second section examines the existing mHealth policy environment, barriers and gaps, and key drivers needed for an enabling policy environment to help accelerate mHealth.

This white paper aims to inform the work of current and future mHealth project implementers, Ministries of Health (MoH) and Information and Communication Technology (ICT) as well as the Ministries of Finance (MoF), policy makers (including WHO, International Telecommunications Union (ITU), World Bank, bi-lateral funding agencies, and private donor institutions), academic and research institutions, private sector companies (including telecommunications, software development, medical devices, pharmaceutical, among others), health professionals and administrators, and individual citizens. Unlike previous reviews that map mHealth projects and trends, this update focuses on peer-reviewed publications. It compiles and examines large and small studies that investigate the use of mobile technologies for health in both high-income countries and LMICs.

To begin, a team of researchers conducted a targeted review that segmented mHealth into major thematic areas. A thorough literature review was conducted using pre-determined keywords with prominent databases for each thematic area. These databases included JSTOR, Medline OVID, PubMed, Scholars Portal Science, Scopus, and Web of Science. Selection and analysis of key papers was conducted by identifying literature that met specific inclusion criteria. These included:

- Evidence-based studies on mHealth technologies with a sound study design, including descriptive studies, qualitative studies, and randomized trials
- Drawing on evidence, where possible, from LMICs, and evidence from high-income countries in the absence of studies from LMICs
- Using a broad definition of mobile technologies, which includes examining its core function (i.e., voice), and its applicability to health, in addition to supplementary features and functions such as SMS, video, imaging, Global Positioning System (GPS), General Packet Radio Service (GPRS), Unstructured Supplementary Service Data (USSD), Bluetooth, web browsing and cell broadcasting, and health-related software applications

This body of peer-reviewed evidence was complemented by an analysis of secondary literature including white papers, articles, theses, and reports. Through the analysis of these two sources of evidence, themes and patterns that existed across the literature were derived to gain a thorough understanding of the barriers and gaps in each mHealth thematic group.

OVERVIEW OF MHEALTH CHALLENGES, BARRIERS, AND GAPS

In each mHealth thematic area, the challenges, barriers, and gaps in mHealth manifest themselves in unique and inter-related ways both in LMICs as well as in high-income countries. For the purposes of this white paper, we have synthesized research findings to specifically examine **policy barriers to mHealth scale and sustainability** and **mHealth research gaps**.

From the literature review, six major themes in mHealth applications emerged. This white paper discusses research gaps and policy barriers specifically for five of these themes, as telemedicine was found to be a cross-cutting theme. We also note that there have been very few trials of integrated, comprehensive systems that include most or all of these themes in single deployments. The current single-solution focus may itself be a major barrier to deployment as it requires each "silo" to stand on its own, rather than leverage the benefits of other areas. Single solutions tend not to be integrated with other mHealth solutions or into broader eHealth systems. For example, software for mobile electronic health records used to support primary care could be modified to include searchable databases for the purposes of data collection and disease surveillance, eliminating the need for a parallel system. However, such integrated solutions have yet to be deployed.

The themes that have been identified from the literature review are as follows:

- Treatment Compliance
- Data Collection and Disease Surveillance
- Health Information Systems and Point-of-Care Support
- Health Promotion and Disease Prevention
- Emergency Medical Response

Table 1 provides a summary of the findings of the literature review for each thematic area of mHealth.

Table 1: Framework for mHealth applications

mHealth theme	# of relevant citations from literature	Trends	Research Gaps	Policy Barriers
Treatment compliance	43	• SMS applications used to remind patients to take drugs, attend appointments • Bluetooth and web-based interfaces used to track patient data in high-income countries • Studies from high-income countries focused more on chronic or non-communicable disease treatment compliance • Studies from LMICs focused more on infectious disease drug adherence • Chronic disease management applications will become more relevant as epidemiological shift accelerates in LMICs	• Published case studies abound, but few studies with adequate sample size and rigorous study design • Most mobile systems analyzed worked in tandem with an Internet-based management system—in many LMICs this is not an option as broadband penetration is still low	• The scope of mHealth for treatment compliance is limited in areas where access to health services and drug supplies is poor or inconsistent. Programs are most effective when patients are able to access treatment when needed. Health systems strengthening as a whole may be important to the success of mHealth for treatment compliance as reminders to attend clinics without reliable services and a steady drug supply is meaningless.
Data collection and disease surveillance	34	• Paper and pen method being replaced by data collection using PDAs—literature shows mixed results on reduction of errors and time as well as cost savings • Open source applications are being used • Data being collected from forms on PDAs (and now shifting to smart phones), SMS, Voice and Health Call Centers	• Most of the literature focuses on comparative studies between effectiveness of PDAs versus paper and pen methods • Little work detailing the use of the data to affect health outcomes and programs after collection • Updated studies required to investigate the outcomes using newer phone models in high-income countries and LMICs	• Rights to data and guidelines on usage • Data storage, i.e., where servers should exist • Coordination of data aggregation and sharing between local communities and regional and national health information systems to inform decisions
Health information systems and point-of-care support	30	• Shift from health information systems being designed solely for clinicians to including Community Health Workers. • Telemedicine can dramatically help overcome barriers to accessing expertise and relevant information. • Considerable differences and outcomes between the application of telemedicine in high-income countries and LMICs • Key to success weighs heavily on user friendly products and	• The literature on the use of mobile technologies for information support for health professionals and service delivery in developing countries is anecdotal and fragmented. • mLearning in the healthcare context has not been widely studied in LMICs.	• Clinician resistance to new technology is a significant barrier to implementation of mHealth systems. Broader discussion of incentives for adoption is required. • Cost and infrastructure implications for nationwide community- and facility-based data collection and universal access to support systems are unknown.

		systems (i.e., portability, task structure, spatial mobility, system reliability), understanding of local information and communication technology (ICT) usage habits, and integration within existing health systems		
Health promotion and disease prevention	25	• Use of SMS to disseminate health information and prevention messaging, or direct patients to services • Games and quizzes being used to communicate health prevention messaging	• Better understanding of context and culture to develop effective mobile health prevention programs • Strategies for overcoming language and literacy barriers	• Liability and accuracy of health information • Security challenges as result of shared mobile phones
Emergency medical response	37	• Challenge to study emergency medical response systems (EMRS) due to nature and sensitivity of emergencies • Citizen reporting becoming a more common and reliable source of timely information during an emergency • Use of mobile technologies to mobilize support for disaster management and recovery	• Emergent field—little work measuring impact of mHealth initiatives for EMRS in LMICs • Lacking EMRS infrastructure in LMICs—challenging to use mHealth as an enhancement tool • Beyond voice, text, and basic image transfer, funding in LMICs not adequate to support more complex telemedicine systems for use in EMRS	• Regulations such as network capacity bar the effectiveness of EMRS • Nationwide alert systems that are understood by citizens during an emergency • Infrastructure costs (transportation and roads) are prohibitive, especially for nationwide emergency call centers • Guidelines that outline acceptable use of mobile phones as imaging device

The use of SMS technology for **treatment compliance** interventions was a prevalent theme in the literature across LMICs and high-income countries. While studies from high-income countries primarily focused on tackling non-communicable and chronic diseases, such as asthma and diabetes, as epidemiological shifts occur in LMICs these interventions will become more relevant. Already, mHealth is being applied in LMIC settings for chronic infectious diseases such as tuberculosis and HIV/AIDS. Moving forward, translating these studies from a high-income country context to a LMIC context will be required to further understand effectiveness and usefulness.

In the area of **disease surveillance**, more and better research is needed to compare and contrast mHealth interventions, including having community health workers collect data, self-reporting data, and obtaining data from clinic and hospital records. Comparative studies that examine a range of reporting mechanisms are needed for more informed investments by governments and organizations like the WHO and the Centers for Disease Control in surveillance and response activities. In particular, systems that combine surveillance with point-of-care support tools need to be increasingly deployed and studied. mHealth presents an opportunity to break down the traditional information barriers between diagnosis and treatment and surveillance activities.

The widespread use of mobile technologies in LMICs for data collection and improving access to information as part of **health information systems (HIS) and point-of-care support tools** is well-documented in the gray literature, but studies in peer-reviewed journals are generally weak and the results focus on intermediary benefits such as cost savings and improved reliability of data, but do not go to the next level to show improved work flow, efficiency, quality of care, and/or health outcomes. Implementations remain modest in size and often sit outside of the broader government-led district HIS deployments. The term 'improving access to information' is very broad and needs to be defined more specifically. The types of health information that have been shown to be more accessible through mHealth are treatment protocols, drug information, and guidelines for facility-based health workers (nurses and physicians). While programs exist to provide similar tools for community health workers, limited research has been done to assess their effects. These point-of-care support tools also enable real-time data collection through structured question and response fields, which may—if implemented effectively to capture the data needed for national surveillance and health information systems reporting—displace traditional approaches to HIS, which focus on the implementation of data collection platforms for aggregated facility- and community-based health information within a service delivery context. There is a shift toward decision support tools aimed at improving quality of care that also enable data capture for more real-time reporting and use of information for management purposes. As in other areas, the trials have tended to be of single solutions, rather than integrating those with broader patient and provider information flows.

Mobile phones have also been used as vehicles for **health promotion and prevention messages**. Many studies described here have shown that text messaging is able to elicit healthier behaviors, such as smoking cessation and dietary and exercise regimes, that can prevent the development of costly diseases. Additionally, many projects were identified that either provided health information through platforms such as SMS or allowed mobile phone users to access health information, such as family planning or sexually transmitted diseases, through health hotlines. Although a lot of evidence suggested that the mobile phone has been an effective tool for improving behaviors, there were challenges in containing health messages within the 160-character limit of text messages. This was particularly the case when a project's catchment area contained more than one spoken language. This highlights the need for more sophisticated, patient-specific messaging systems.

In relation to **emergency medical response**, there has been very little work in LMICs on the role of mobile phones in emergency medical response systems (EMRS). In high-income countries, the focus of research tends to explore effects of mHealth applications on aging populations, introducing high-tech medical devices, wearable devices, and wireless network sensors with integrated alarm systems connected to emergency departments. In LMICs, qualitative studies have shown that mobile phones are used in the general population and the health sector to improve access to transportation and emergency coordination, although often in the absence of a formal EMRS.

Overview of Study Findings Across Thematic Areas

During the two-month intensive literature review period (November and December 2009), 2,449 unique articles that documented and evaluated the range of mHealth applications and systems were found through literature searches using targeted key words and secondary sources. Of these, 172 articles and reports were analyzed for this white paper, including a few that were published in early 2010 and identified during the virtual review process. These articles were primarily in the fields of computer science, health informatics, and public health. They were selected on the basis of the following criteria: peer-reviewed publication or secondary source report, focus on LMIC setting or direct applicability to LMICs, and diversity of mHealth implementation and study design to illustrate the range of applications and research approaches. The unanticipated volume of articles illustrates the growing body of programs and research in mHealth, and its staying power in the fields of computer science, health informatics, and public health. It serves as a call to the health research community to improve documentation and peer-reviewed publication in this area.

Each section below highlights the main findings in the literature for each of the core mHealth themes, including:

- Treatment Compliance
- Data Collection and Disease Surveillance
- Health Information Systems and Support Tools for Health Workers
- Health Promotion and Disease Prevention
- Emergency Medical Response Systems

This is followed by a discussion of the main research gaps and policy barriers highlighted within the ever-growing evidence base for mHealth as well as some of the programming challenges faced by those implementing programs.

Treatment Compliance

Key points

- Current literature on treatment compliance is focused primarily on the management of chronic diseases (i.e., diabetes, nutrition, smoking cessation, breast cancer) in high-income countries. As epidemiological shifts occur in LMICs, these studies and lessons will become more relevant.
- Additional studies investigated the use of mobile technology for drug adherence and appointment reminders. This highlights the natural overlap between treatment compliance, disease management, and prevention of primary and secondary illness.
- SMS is the main technology used for treatment compliance, with an increasing focus on voice, web browsers, and health hotlines that mimic traditional customer service call centers. Studies found mixed results regarding effectiveness and impact on health outcomes. Further studies that investigate which medium is the most effective for specific conditions are required to enable more thorough understanding of the role of mobile technology for behavior change related to treatment compliance.
- Some randomized control trials studying treatment compliance were found, but were often limited by sample size to produce statistically significant studies. A strong focus on feasibility and usability was found with little connection to health outcomes.

Treatment compliance, the extent to which a patient follows a prescribed regimen, is a natural application of mobile technology to health. In relation to mHealth, treatment compliance focuses on direct communication between healthcare providers or facilities and patients. For LMICs, treatment compliance is focused on monitoring infectious disease drug adherence, including antibiotics for tuberculosis and antiretroviral therapy for HIV/AIDS. In high-income settings, however, mobile technology is utilized for long-term management of chronic diseases, such as type 2 diabetes and smoking cessation. As LMICs increasingly bear the burden of chronic disease in addition to infectious disease, the body of knowledge surrounding mHealth treatment compliance for chronic disease management will become more universally applicable. The literature shows the extension of treatment compliance beyond these initial applications, changing from a primarily one-way monitoring system to a two-way flow of information. This is allowing patients to take ownership of their health, inevitably overlapping with the goals of the health information tools, prevention, and awareness fields. Adoption of this behavior in LMICs is being observed through the increased accessibility of health information via SMS and mobile web browsers, and the growth of "health hotline" services, which mimic traditional customer service call centers.

Research Findings Related to the Use of Mobile Technologies for Treatment Compliance

The analysis of study findings related to treatment compliance focused on 43 studies, honing in on those that were most relevant in the context of LMICs. Studies performed in higher income settings were included because of their potential for future applicability in LMICs. The area of treatment compliance is particularly rich and multifaceted, with applications ranging in focus from drug adherence to appointment reminders.

In 2006, a review explored studies, primarily in high-income countries, that looked at direct interventions in which mobile and fixed-line telephones were used to address health conditions such as diabetes (patient blood sugar level monitoring), breast cancer (telephone counseling), tuberculosis (adherence to medication), treatment compliance for a variety of conditions, attendance at health facility appointments, depression outcomes, immunization rates, asthma management, and smoking cessation (A1). The review specifically explored the use of mobile phones for the "express purpose of supporting or altering one or more health outcomes." Through an intensive web-based and library search, the author documented and compiled the results of evaluations of intervention studies of fixed-line and mobile telephone applications to address specific health care issues in LMICs. The limited number of studies that were identified mainly consisted of small pilot projects that offered mixed results in terms of demonstrating the effectiveness of fixed-line and mobile phones to serve as a support for delivery of healthcare services. In 2010, a similar systematic review was conducted, which consisted of 12 studies investigating the use of SMS for disease management and prevention. Again, all studies except one were from high-income countries. Of the studies reviewed, most sample sizes were small, ranging from 16 to 126 subjects, and short-term behavior change was found in eight studies, impacting subjects' weight loss, smoking addictions, and diabetes management. This review found the area of diabetes to be the most advanced in its use of text messaging for disease management and prevention, both areas that significantly overlap with treatment compliance (A2).

Functional and structural properties of mobile phones, namely low start-up cost, text messaging, and flexible payment plans, make them attractive to use for healthcare intervention. Utilized in tandem with standardized health-related software applications, mobile phones can provide the real-time feedback needed to monitor treatment compliance. Further, back-end systems connected to mobile phones have the capability to serve as a platform for enabling pre-programmed portable automated services to increasingly decentralized health systems. This is seen most frequently in health prevention and awareness programs.

Drug adherence

The use of mobile technologies for drug adherence is relatively well documented. Completed scientifically sound studies show mixed results in improving treatment compliance. Other illustrative studies focus on feasibility and/or user acceptance, and/or are just being implemented. For instance, SMS reminders were shown to *not* improve malaria chemoprophylaxis adherence in a large (n=424) randomized controlled trial in Cote d'Ivoire of French soldiers during deployment and after return home. Soldiers receiving the messages, however, were satisfied with them and did not find them annoying. The investigators recommend further research, because the study may have been confounded by the fact that the soldiers were in close proximity, so all were quite aware of the reminders (A3). Other studies have shown serious potential for mobile technology to improve drug adherence, or have demonstrated the acceptability or feasibility of such interventions.

In the context of feasibility and acceptability of mobile interventions for drug adherence, mHealth shows great promise. Curioso and Kurth, in a paper that explores the larger ramifications of information and communication technologies (ICTs) for management of HIV in Peru, point out the potential use of such technologies for antiretroviral drug adherence. After acknowledging the potential of these applications, the authors performed a qualitative study of the acceptability of ICT-based interventions for HIV treatment. Within their 31-person study population, general attitudes were positive regarding the use of ICTs for the treatment of HIV, including for antiretroviral adherence (A4). A follow-on study by Curioso et al. used focus groups, which found that 26 HIV-positive Peruvian individuals expressed positive perceptions about receiving reminders to antiretroviral therapy via SMS, but specified certain characteristics, such as being simple and concise. It was also important that the messages maintained confidentiality and privacy by using coded words or phrases ("Remember, it is the time of your life") instead of "sensitive" words (HIV or antiretroviral). The study suggested that patients want health-related SMSs that appropriately notify them, deliver a carefully crafted message, and are sensitive to the context in which they are received (A5).

Also in Peru, Curioso et al. conducted focus groups with 19 adult diabetic patients and 6 caregivers from a national hospital in Lima. Most of the patients were interested in participating in a program that used cell phones and the Internet to support their diabetes care. Caregivers mentioned that although a system using cell phones and the Internet seemed novel, they were skeptical that the idea could support patients for the long term. Most of the patients reported a willingness to use cell phones to receive reminder messages for medication and appointments. The majority of patients expressed their interest in receiving messages about diabetes care, including information about nutrition, physical activity, complications from diabetes, control of cholesterol and blood pressure, emotional support, and oral health, among others (A6). Likewise, Sahm et al. evaluated the acceptability of SMS reminders to improve medication adherence for patients. Of the study population prior to the imlementation of the intervention, 54% of 59 participants reported that they were unintentionally non-adherent. Of these patients, 60% reported that text message reminders were acceptable to them. The investigators stress that the rationale for refusing SMS reminders should be investigated further (A7).

Puccio et al., in a different vein, explored the potential of phone calls, rather than text messages, as a way to remind young, HIV-infected adults to adhere to highly active antiretroviral therapy (HAART) in a pilot study. The use of these reminder calls was found practical and acceptable to the pilot's participants. Like other investigators, however, the researchers conclude that larger prospective studies are necessary before large-scale rollout (A8).

Beyond feasibility and acceptability to patients, however, several studies have demonstrated an actual success of mobile technology as an intervention for drug adherence. Stranbygaard, Thomsen, and Backer, for instance, examined the impact of receiving a daily cell phone reminder on compliance with asthma medication. Twenty-six asthma patients were randomized to receive SMS reminders to take anti-asthma medication. After three months, differences in mean adherence rate were 17% greater among those receiving reminders (A9). Encouraging results were also reported in another study that used GPS-enabled PDAs to trace tuberculosis patients who interrupted treatment (A10). A trained worker with one of the GPS-enabled devices worked twice as quickly as a research assistant without.

Additionally, several studies were ongoing or just beginning at the time of writing this white paper. While the outcomes of these studies are not known, their rigorous study design demonstrates the felt need within mHealth to develop an evidence base for interventions. Lester et al. describe a protocol for evaluating effectiveness of the WelTelKenya randomized controlled trial for SMS-supported HIV management in a population receiving antiretroviral therapy in Nairobi, Kenya. This paper does not describe results so much as a study design, as the trial had not yet taken place at time of publishing, but appears promising as one of the more rigorous study designs proposed (A11). In addition, Curioso et al. are currently evaluating Cell-POS (http://www.cellpos.org), a computer-based intervention using cell phones to enhance adherence to antiretroviral treatment (ART) and support of HIV transmission risk-reduction among adult HIV- positive patients in Peru. Curioso is currently conducting a randomized controlled trial of a 12-month intervention, comparing [1] standard-of-care with [2] standard-of-care plus cell phone-based system among patients receiving ART at Via Libre, a nongovernmental organization established to support people with HIV (A12). Similarly, Cell-Life in South Africa is about to begin a randomized control trial of its HIV treatment compliance initiatives (A13).

Chronic disease management

There are a variety of mHealth applications within the management of chronic diseases. While generally seen as a problem faced by high-income countries, epidemiologic transitions are accelerating in such a way that LMICs are now beginning to bear a burden of chronic diseases along with the burden of endemic infectious diseases. In light of this, many studies are included in this section that were conducted in high-income settings, but may be relevant in LMICs. mHealth appears to be well suited to address chronic disease management because of its ability to submit and process data, automate messaging, and provide consultations as needed in a discreet, timely, and personalized manner.

Mobile technology can play an empowering role for both type 1 and type 2 diabetes mellitus patients, traditionally one of the least well-managed groups of patients. While not a study in and of itself, one analysis suggests the multitude of ways in which wireless technology, particularly mobile phones, can enhance patient self-management of a disease that can seriously detract from quality of life. Additionally, the authors point out that a cost-benefit analysis suggests time and resource savings for patients and healthcare providers (A14). Diabetes management via mHealth can focus on blood glucose management as well as facilitate dietary management for diabetic patients.

Literature is accumulating in the area of blood glucose management. Researchers conducted a randomized trial in Korea (n=69) centered around a device informally known as the “Diabetes Phone,” which was launched in 2003, with a glucometer integrated into its battery pack, facilitating mobile blood glucose monitoring as well as transmission of patient data. Participants were assigned to an Internet glucose management group or a phone glucose management group. After three months, HbA(1c) levels of both groups had decreased, from 7.6 to 6.9% for the Internet intervention group and from 8.3 to 7.1% in the phone intervention group (A15). The challenge with the Diabetes Phone was the requirement to purchase the hardware to access the solution, in addition to treading the increasingly fine line between mobile phone and medical device. In a market with infinite choices of mobile phones, this inflexibility is a challenging proposition for consumers—forcing many to carry multiple devices.

Gammon et al. employed mobile technology to transmit data from a diabetic child's glucometer to a parent's phone via text message. Over a study period of four months, 15 children with type 1 diabetes used the developed prototype three times per day. The investigators found that the system appealed to both parents and children (A16). Insulin-treated adolescents and young adults were randomized to receive electronic reminders to check blood glucose levels via CARDS (Computerized Automated Reminder Diabetes System) in a study performed by Hanauer et al. (A17). Some received email reminders, while others received SMS reminders. Young people who received SMS reminders were more likely to transmit blood glucose test results after reminders than those who received email reminders. Kim, Kim, and Ahn also looked at ICTs in the context of diabetes management. Patients with diabetes were asked to report blood glucose levels every day via the Internet or SMS. Recommendations based on this data were sent back to patients weekly. At the end of the 12-week study period, patients had experienced a 1.1% decrease in HbA(1c) levels and an increase in compliance with anti-diabetic medications (A18). The WellDoc randomized controlled trial aimed to assess the impact of a cell phone-based diabetes management system on HbA(1c) levels of 30 patients with type 2 diabetes in Baltimore, Maryland (A19). Patient data was captured and transmitted via mobile phones as well as a web-based application. Patients using the system had an average HbA(1c) decrease of 2.03%, compared to a decrease of 0.68% among controls.

For more holistic disease management, including dietary advice, there is also a growing evidence base. Arsand, Tufano, Ralston, and Hjortdahl designed both web- and mobile phone-based systems to facilitate dietary management for diabetic patients. Implementing the systems with a very small study population (n=6), the researchers conducted qualitative usability tests, finding that study participants highly valued many of the aspects of the systems implemented (A20). The text messaging support system “Sweet Talk” was evaluated by Franklin, Greene, Waller, Greene, and Pagliari for its effectiveness in encouraging good diabetes management in young people. Sixty-four young diabetes patients participated in a randomized controlled trial. The system was found to effectively engage young people in self-management of diabetes (A21). Stressing the necessity of type 1 diabetes patients to be active participants in their disease management, Kollmann et al. (A22) conducted a pilot to test the feasibility of using a mobile phone-based data service to monitor diabetes-related data. In the small study (n=10), significant improvements were reported in metabolic control (A22). Focusing on the multi-morbidity present in many diabetic patients, Mohan, Marin, Sultan, and Deen describe MediNet, a system that seeks to personalize self-management of patients with diabetes (and also cardiovascular disease) through mobile telephony. This paper was not a research endeavor so much as a description of a developed system (A23). In another ongoing randomized controlled trial, the effect of availability of minutes and different types of phone models is being assessed with regards to a mobile phone-based diabetes management system (A24).

In a feasibility study for management of asthma and asthma symptoms, Holtz and Whitten used a very small study sample (n=4) in the United States to encourage tracking of patient peak flow readings by a mobile phone application. If patients did not transmit data, they received a text message reminder. The investigators claim that the resulting data demonstrated the feasibility of such a system, and show results indicating that patients were satisfied in recording and reporting data in this manner (A25). Ostojic et al. further explored SMS for the purpose of monitoring peak flow measurements for asthma patients. In a randomized controlled trial on 16 asthma patients, the investigators provided self-management plans for all participants and then randomized them to intervention and control groups with text message monitoring of peak flow readings. The researchers observed no significant difference in compliance, but note that a study size of at least 40 is needed to achieve 80% power with a 95% confidence interval to be quantitatively rigorous (A26). Pinnock, Slack, Pagliari, Price, and Sheikh conducted a qualitative study with 48 key stakeholders in asthma care (patients, nurses, and doctors) and concluded that mobile phone monitoring systems have great potential for guiding self-management of asthma and facilitating patient monitoring (A27). Ryan et al. conducted an observational study assessing acceptability and other attitudes of asthma patients to using a mobile phone-based asthma management system. Of 46 participants who used the system, 69% were 'satisfied' or 'very satisfied' with the system, and 74% indicated that the system facilitated better management of asthma symptoms (A28).

While the body of literature is not as large for the topic as for other chronic diseases, mHealth appears to offer promise for monitoring of dermatologic conditions. Hayn et al. describe a system currently in pilot with 20 psoriasis patients that intends to increase patient-physician communication for psoriasis management. Physicians provide feedback to patients if photos of lesions are submitted. The investigators report that preliminary results of the pilot demonstrate feasibility and usability of such systems (A29).

Appointment attendance

mHealth applications for appointment reminders abound. Results are mixed, however. Several studies selected for analysis found that SMS reminders improved appointment attendance in a variety of settings, such as in China (A30), Brazil (A31), and the United Kingdom (A32, A33, A34). Other investigations found inconclusive or discouraging results. Fairhurst and Sheikh (A35) conducted a randomized controlled trial in Scotland to evaluate the impact of text message reminders on improving non-attendance rates in primary care, failing to demonstrate significant reduction in non-attendance rates for repeat non-attendees (A35).

Expanding on the idea of SMS reminders, Mao, Zhang, and Zai demonstrate a mobile phone pharmacy service system to remind clients of prescription information (after discharge from a medical facility and ongoing) as well as providing practical information about medicines such as methods of administration or indications of adverse reaction. Qualitative surveys demonstrated patient satisfaction with this system and overall positive attitudes for pharmaceutical care via mobile phones (A36). Many major pharmacy retail chains in high-income countries have implemented similar programs, using opt-in SMS programs to remind patients about medication pick-ups, refills, and dosage information.

Prevention and healthy behavior promotion

Beyond management of existing disease, applications of mHealth are being extended to preventive and healthy behavior promotion. Whether it is daily vitamin C supplement adherence (A37) or daily sunscreen application (A38), SMS reminders have shown to improve adherence to preventive activities in randomized controlled trials, and were found to be acceptable. While more broad-based outreach programs and research will be presented in the section on prevention and health promotion, we include in this section prevention and well-being services that include a targeted compliance approach to a particular health behavior.

Managing weight and other healthy behaviors are critical in preventing chronic disease, yet many do not engage in healthy behavior despite widespread knowledge of its benefits. mHealth has been found feasible or used successfully for managing weight both in the United States among African American women (A39) and in Korea for a community-based weight control program (A40). Morak et al. conducted a pilot study to test feasibility of an Internet-based therapy program (with mobile access) to support treatment programs for obese patients. Out of the relatively small sample (n=25), there were significant mean reductions in abdomen girth, body weight, and body mass index after the 70-day study period. Participants expressed positive attitudes toward the system (A41). Free et al. report the results of an ongoing randomized controlled trial that utilizes SMS reminders for smoking cessation support. Thus far, results have been encouraging, and may represent a previously untapped method of smoking cessation support (A42).

The growth of health hotlines in LMICs offers a new method to access medical professionals for advice on treatment compliance. A study conducted by Ivatury, Moore, and Bloch investigated four health hotlines in Bangladesh, Pakistan, India, and Mexico. Collectively, the hotlines have provided health information and medical care to over 10 million individuals, most of whom were women and from rural areas. The health hotline model helps overcome common barriers in LMICs such as limited available health professionals, reliance on untrained and/or informal providers, cost of service and transportation, and lack of correct information. In this way, a health hotline serves as a reliable and supportive source of help for chronically ill patients, increasing the likelihood of treatment compliance (A43).

Barriers to and Gaps in the Use of Mobile Technologies for Treatment Compliance

Many studies focusing on the use of mobile technologies for treatment compliance had very small sample sizes, and in these cases, the size was scarcely enough to show statistically significant differentials. Weak study design may also contribute to a paucity of quality data. The literature has many quasi-experimental designs, but very few randomized controlled trials. Many trials and case studies from high-income settings were highlighted in this section, under the assumption that many treatment compliance issues in more high-income countries will be faced soon by LMICs. Yet many of the mobile solutions here worked in tandem with Internet management systems; infrastructure that does not exist in many poor countries, especially in sub-Saharan Africa. The infrastructure gap in LMICs is two-fold, as there are many parts of the world that do not have universal or reliable basic telecommunications coverage and the networks being deployed in LMICs often do not provide GPRS or other mobile broadband services.

While there were some applications of smart phones or other advanced phone functionality within the context of treatment compliance, on the whole, the evidence indicates that SMS is the most effective way of utilizing mobiles for disease management, drug adherence, and appointment reminders. Even though examples cited here were from high-income settings, SMS can be easily translated to LMICs. It has been found to be efficient and cost-effective, and the infrastructure for SMS is available throughout most of the world. However, to truly understand the health impact of SMS, longer-term studies that isolate the technology will have to be conducted more rigorously. Cole-Lewis and Kershaw caution that SMS should not be viewed as a stand-alone model for behavior change, but rather as a tool by which behavior change methods can be administered (A2). The overlap between treatment compliance and disease prevention and control is obvious, and alludes to the need to move toward comprehensive mHealth solutions instead of silos. The next challenge for many treatment compliance mHealth applications will be to translate the relative success of such interventions from high-income settings to LMICs, and from small study samples to larger groups with a particular disease or condition.

DATA COLLECTION AND DISEASE SURVEILLANCE

Key Points

- Majority of the literature studying data collection focuses on comparing data quality, accuracy, time, training required, and cost between traditional paper and pen methods and mobile technology. Results were found to be inconclusive with effectiveness varying depending on the type and complexity of data being collected.

- Many data collection software programs have been developed using an open source platform, resulting in widespread adoption among small pilot projects (i.e., EpiSurveyor, PDACT, RapidSMS), many of which have not been documented or evaluated.

- Studies were found to primarily use PDAs, an older model of mobile phones and not as applicable in the current marketplace. Further studies are required to investigate data collection using low-end mobile phones found in LMICs and smart phones found in high-income countries and increasingly in LMICs.

- Data collection using mobile technology was found to be implemented using SMS, voice, and electronic forms. Increasingly, as mobile technology advances, GPS information is being used to tag data to specific locations. Further studies are required that investigate the effectiveness of different data collection methods using mobile phones.

- The primary gap in data collection is the focus on implementation as an independent system in comparison to partnering in the development of initiatives such as electronic health records that can act as a repository from which data can be extracted. Additionally, further integration between local, regional, and national data collection and access is required so that data being collected is benefiting the communities from which the data is taken.

- Barriers related to security, confidentiality, and ownership of data is central to this mHealth thematic area.

The ability to collect disease and syndromic data in real time can have a dramatic effect on reducing mortality and morbidity. The evaluation and analysis of data can and should directly impact the speed at which health prevention and treatment reaches communities in LMICs. Traditionally, this data was difficult to obtain, taking three to six months or more using traditional, paper-based methods. However, with the advent of applications that allow for survey and electronic form development on PDAs, mobile phones, and handheld computers, data can be collected and processed in a fraction of the time.

Research Findings Related to the Use of Mobile Technologies in Data Collection and Disease Surveillance

The literature on data collection and disease surveillance has a strong focus on investigating the effectiveness of mobile technology in comparison to traditional methods. Few studies have demonstrated the impact of the mHealth data collection on health outcomes and system strengthening. Our analysis of 34 studies demonstrated that findings primarily report lower or reduced error rates and time saved in the data collection process. Further, most studies adopted the use of PDAs to conduct trials. However, in LMICs today, low-end mobile phones are more prevalent, particularly in rural areas, and in high-income countries more and more people use either Java-enabled or other smart phones. As a result, updated studies are needed to investigate if the change in technology affects data collection and surveillance outcomes.

Mobile Technology versus Traditional Methods of Data Collection

The bulk of literature on the use of mobile technologies compares the effectiveness of using a PDA, handheld computer, or mobile phone with traditional paper and pen methods (P&P). Benefits found include improved accuracy (B1, B2, B3, B4); reduction in time (B5, B2, B6, B1, B7, B8), human resources (B1), and cost (B2, B9); improved data quality (B1, B4); potential for real time authentication and receipt of data; less interviewer bias; and the ability to test and modify questions easily (B10). Training has been seen as integral to executing programs effectively, with training time ranging from five hours to five days (B11, B2, B6, B12). In addition, some studies have adopted the use of open source software, which contributes to cost effectiveness in addition to having the option of manipulating the platform to fit within the study setting (B1, B11).

The following studies provide evidence for these benefits, but also show the variability in accuracy and error rates throughout the literature. This is perhaps linked to the type and complexity of data being collected. Forster et al. studied the use of PDA data collection for malaria morbidity as early as 1991, finding error rates between 0.1 and 0.6% and improved accuracy and efficiency over paper forms (B3). Mobile phone-based surveys were just as accurate as paper-based surveys, but provided the added benefit of time and cost savings and could be adapted easily for a broad range of research needs.

Since then, an abundance of studies have investigated similar situations. Bernabe-Ortiz et al. found a 14% error rate reduction between PDA and paper formats in self-administered surveys on sexual behavior in Lima, Peru. Overall, higher error rates were found among subjects who did not finish secondary school in comparison to those who did, despite receiving two to three minutes of training prior (B11). Similarly, a study in Fiji showed that none of the errors found in 20.8% of the paper questionnaires were found in the PDA data set. In addition, 62% perceived the method to be faster, and there was a 93.26% reduction in the time required for data entry, validation, and cleaning (B9).

The study by Galliher et al. at the American Academy of Family Physicians National Research Network found significantly lower errors of omission and missing data items when comparing the use of handheld computers in data collection versus traditional paper and pen methods. Their results showed 3 versus 35% errors of omission in handheld computer compared to paper-and-pen, and 0.04 versus 3.5% missing data items for handheld computer compared to paper-and-pen (B4). Heiberg et al. found both methods to perform similarly, but 82.9% preferred using a PDA (B13). Tegang et al. in a study in Western Kenya found reduced time preparing data for analysis, from six weeks to seven days (B10). Buck, Rochon, and Turley (B6), Escandon et al. (B7), and Safaei et al. (B8) anecdotally reported faster data collection with PDAs and mobile phones in addition to positive feedback from interviewers. A preliminary study and randomized control trial collecting tuberculosis bacteriology data in Peru for Partners in Health found a decrease in errors of 57.1%, in addition to work hours reduced by 70% (B2). These results are relatively high in comparison to other studies, and may be linked to the nature of laboratory data.

A tool called the Personal Data Collection Toolset (PDACT) for the PalmTM Pilot is described by Seebregts et al. (B14), and has been used in seven studies with over 90,000 interviews. Five of the studies were in rural settings with poor communication infrastructure. The number of questions ranged from 20 to 580, and questionnaires were available in up to 11 languages. This capability is an important consideration in some LMICs that have several languages and dialects. The authors' findings were primarily anecdotal and reported a reduction in data validation and cleaning time, fewer errors, a preference among interviewers and respondents compared to paper and pen, and faster processing time. Although the hardware increased the cost of the first study, it was thought to reduce overall costs through ongoing use for other studies in comparison to the cumulative cost of paper-based studies.

Other programs that have used PDAs and mobile phones for data collection in LMICs are Datadyne's EpiSurveyor, which has been widely deployed across Africa (B15) and is argued to be more effective than the paper form, and EpiHandy, which provides tools for developing electronic forms on PDAs and is being used to collect health data in South Africa and Uganda (B16). Neither has conducted a rigorous analysis of accuracy outcomes to our knowledge. Although the literature has been consistent in describing the benefits of PDA data collection, Dale and Hagen's systematic review of randomized and quasi-randomized control trials that compared the methods in clinical research outcomes found inconsistencies in methodologies and noted that more stringent measures were needed in the design of studies. The authors were also concerned about a publication bias, as all the studies evaluated were in favor of the PDA method (B17).

All the studies have been limited to mHealth software that is solely intended for disease-specific data collection, i.e., a direct replacement for the paper survey method. This entirely misses much broader potential benefits when the new technologies are used to approach health service delivery in a different way than simply digitizing current business processes. As yet there have been no studies in LMICs of the costs and benefits of an integrated system where disease surveillance and reporting is one of many uses or a byproduct of an electronic medical record-based point-of-care support system, ideally also linked to laboratory and supply chain systems. This type of integration would eliminate the duplication of effort in data entry purely for reporting and then entering the same kinds of data into patient care records (paper or electronic). This has the potential to promote additional efficiencies as well as overall improved outcomes through early detection and control of epidemics beyond merely replicating the current paper process. Several platforms well positioned to serve in this manner for real-time surveillance are now being implemented and evaluated in the field, including the Millennium Villages Project ChildCount+ system and D-tree's eIMCI and CommCare systems. One of the perceived advantages of such approaches is that they give the initial recorders of the information a stake in its accuracy, as they and their colleagues will be using the information for patient care. This motivation does not exist for one-way data collection systems.

Alternative Methods of Data Collection using Mobile Technology

The effectiveness of other data collection methods that leverage functions of the mobile phone, such as voice, camera, and SMS, has also been studied. For example, Voxiva's Cell-PREVEN product uses interactive voice response and voice recording to monitor adverse events among female sex workers (FSW) in Peru. During a three-month pilot test, 797 reports were collected—30 severe enough to trigger an SMS alert to a team leader. All interviewers said they were satisfied or very satisfied with the system. The main reported advantage of using cell phones was adequate organization of the data collected. FSWs were asked about their satisfaction with cell phone data collection after having reported an adverse event; following 710 out of the 797 (89.1%) adverse event reports, FSWs reported being very satisfied (B18).

To compare the effectiveness of different data collection methods, a study investigated error rates using voice, SMS, and electronic form methods on low-end mobile phones in Gujarat, India. Surprisingly, it found the voice method to have the lowest error rate, followed by electronic forms and SMS. The results caused the authors to reevaluate their data collection study design and move from electronic forms to voice. The researchers concluded that voice should be further explored as a high-accuracy, low-cost means for data collection (B19). Modern voice to text technology and the limited and structured taxonomies of public health should make this an efficient and low-cost option apart from the minutes of use on commercial wireless systems that would be required.

Trapl et al. conducted a study using an audio-based PDA for self-administered surveys in a middle school in Ohio, United States. This method was used to circumvent reading, comprehension, behavioral, and language barriers often faced with paper and pen and traditional PDA methods. Six hundred and forty-five children with a mean age of 12.6 years participated in the study and reported 94% satisfaction rates with the audio PDA survey, especially appreciating that questions were read out loud to them (B20). In LMICs, this method could overcome literacy challenges faced in many rural areas, in addition to overcoming interview bias by allowing for self-administration of surveys.

As a supplemental disease surveillance method, a study investigated if a correlation existed between respiratory illness data from TeleHealth Ontario, a health hotline, and diagnosis discharge data from emergency departments in Ontario, Canada. Using time series models, diagnosis discharge data from 819,832 patients were compared to diagnosis data from 216,105 calls to TeleHealth Ontario, and found a positive correlation between the peaks and valleys of respiratory illness diagnoses in the region. The authors asserted that using multiple sources for disease data can significantly improve the detection accuracy of syndromic surveillance (B12).

For cases where paper forms are integrated into an organization's workflow, the CAM (or camera-based) framework presents a method that integrates both the use of paper for organization and phones for data entry. Each field on the paper form is annotated with a barcode, which is recognized by a camera on the phone prior to data entry. Users in rural India that lacked prior camera or computer experience were trained to a level of comfort within 5 to 15 minutes (B21). A separate study measures error rates of 1% or below using the CAM system (B22).

Krishnamurthy et al. leveraged the GPS capability of a mobile phone in rural Mozambique to overcome the challenge of having no detailed maps, location of houses, and valid addresses while collecting data. This study successfully mapped the location of 4,855 houses dispersed in 32 villages in eight districts of Manica and Sofala in 10 days by 18 field interviewers, to more effectively conduct surveys and follow-ups. Results were analyzed, aggregated and presented in less than one day, and found that the GPS location enabled collection of a statistically accurate random sample with geospatial data (B23).

A tool called RapidSMS was used to study surveillance of child nutrition in Malawi, submitting data to the central server using the SMS platform. In January to June 2009, its pilot project produced improved data quality and reporting rates and reduced human resource requirements. A qualitative study was conducted with Health Surveillance Assistants (HSAs) after the data collection period. It found that HSAs experienced technical challenges with the system, including sending multiple SMS messages with the same data, a challenge resulting from poor mobile phone reception and inconsistent servers powering RapidSMS. The cost of sending text messages was also noted as a concern (B24). This illustrates the need to continue testing and costing systems to improve interventions prior to integrating them into broader eHealth systems and architectures.

Disease Surveillance

While the use of PDAs and mobile phones can have dramatic effects on monitoring disease prevalence and onset, few studies have shown its effectiveness in informing action and impacting health outcomes. This demonstrates that disease surveillance using mobile phones is still in its infancy, with little integration into local, regional, and national health systems.

Studies have used mobile phones for different types of disease surveillance, for example: gathering infant mortality data from 21,000 households in rural southern Tanzania (B25); assessing acute respiratory illness at a health center in Kenya (B26); monitoring maternal and child health as part of the Ca:sh project in India (B27); and collection of child nutrition data in Malawi with the RapidSMS tool (B24). Further, Cell-Life employs electronic forms on mobile phones to improve tuberculosis and HIV treatment in South Africa (B28, B29); Jiva TeleDoc uses them for improving rural healthcare in India (B30); and Pesinet uses them for monitoring infant health in Mali (B31).

SATELLIFE has customized data collection tools for diverse purposes. In its implementation of the Uganda Health Information Network (UHIN), SATELLIFE is working with the Ministry of Health and Marie Stopes International to send and receive Health Management Information Systems (HMIS) data and obtain medical information. However, health outcomes and effectiveness have yet to be reported (B32).

Barriers to and Gaps in the Use of Mobile Technologies in Data Collection and Disease Surveillance

PDAs and mobile phones have been shown to reduce error rates and reduce reporting costs throughout the literature. Few studies, however, document the total time taken from program development (i.e., software and survey on PDA) to processing and analysis of data in comparison to paper methods. During program development, many studies noted the critical need to improve the lines of communication between health professionals, research assistants, and software developers to conduct an iterative development process (B33). Like other studies, the focus was on the users, but not on those responding to the survey questions.

A major barrier to the use of mobile technologies for data collection and disease surveillance is the implementation of multiple health-related data collection systems, flows, and platforms within the health system that track information directly within health service delivery that can also be used for disease surveillance, but currently is not standard practice. Much of this stems from a lack of coherence within health information systems and the lack of a policy to guide the data that is collected at the community level, within public and private health facilities, within national and district health reporting information systems, and within systems that are specifically designated for surveillance. In addition, donor data collection requirements for monitoring and evaluation of health initiatives compound the numbers of disparate sources of health-related information.

In a resource-constrained environment, one way of overcoming such systems challenges is to move toward a system with defined data standards for mobile and computer-based platforms that are interoperable and open. This shift will allow real-time data collection at the community level and reporting within health delivery facilities (including electronic medical recorders) to be linked directly to district health information systems for aggregation and access at the regional and national levels. Accessing this data, at all levels, should be made available through mobile phone and web-based viewing and reporting systems with password and access controls assigned according to the position of the individual within the health system. The speed of reaction and cost savings possibilities would be substantially greater than even those exhibited by studies examining paper versus electronic data collection systems. While the approach raises a new set of policy barriers and issues (e.g., access control, identity management), it would provide a mechanism through which healthcare and public health could be technologically linked and the linkages between the two more easily monitored.

With respect to mobile data collection platforms, a number of technical challenges were reported that may hinder national scaling up—especially in environments with patchy connectivity in rural areas. This includes the loss of data as a result of PDA malfunction, hardware loss, and challenges syncing data with a personal computer or sending over a wireless network to a central server (B11). One study lost all the data on the PDAs when they were turned off (B7). Further, the challenges of battery life and memory shortages were found to reduce efficiency. While upfront costs of PDAs and mobile phones were shown to be high in some cases, many studies acknowledged that this would be amortized over time (B14). Many of the technical challenges have been overcome through better hardware and software design. Indeed, since most of the studies were done, PDAs have been replaced by smart phones, and the prices of mobile phones are declining rapidly. At the same time, wireless networks have been vastly extended, so the areas lacking coverage have been substantially reduced. It is clear, however, that any data-gathering device must have store and forward capabilities. Asynchronous communications, or store and forward and off-line means that enable sending information through less reliable networks when connections are stronger, must be assumed. This is becoming increasingly feasible through enhanced functionality of platforms migrated from PDAs to smart phones that rely on GPRS and 3G networks. In this regard there is a need for national mobile coverage maps as essential planning tools for those interested in district, regional, and national level implementation. Few studies explored the use of alternative mobile functions such as voice, SMS, and camera for data collection, and the literature would benefit from being able to compare the strengths and weaknesses of these methods in collecting different types of data. In one study that used SMS to send survey data to a central server, the cost of each SMS was seen as prohibitive (B24).

The need for security and privacy of data was noted in many studies, and measures such as encryption of data and hardware passwords were used to overcome this barrier. However, given the scope of data collection using mobile phones, guidelines outlining confidentiality protocols need to be developed and the adoption of encryption systems used in mBanking should be considered for mHealth.

A significant gap in the literature is the lack of studies measuring health outcomes and prevention programs implemented as a result of the data collected using mobile technology. While a clear understanding of improved accuracy, quality, and time efficiency has been shown, the evidence of its effectiveness remains inconclusive. This next step requires significant integration between health professionals, surveillance assistants in the field, and government bodies to ensure a steady flow of data and analysis, in order to make decisions based on evidence. While we acknowledge this step is far more challenging than feasibility and pilot studies, it is the natural next step to advance this field.

Data serve a powerful role in facilitating health behavior change, yet the field of mHealth has yet to embrace the behavior theory to underpin its projects. We know that mHealth for data collection ‘works,’ in the sense that data can be successfully collected, but only by understanding the behavioral and psychosocial processes that underlie the health behavior change aspects of a program will we have a complete grasp of the system (B34). Theories of social and behavioral change such as Bandura’s social cognitive theory and the transtheoretical model may be well-suited to address this gap in mHealth implementation. Fostering this understanding of behavior change will strengthen the ability to expand and scale mHealth applications (B34).

Health Information Systems and Point-of-Care Support Tools for Health Workers

Key Points

- Few studies investigating health information systems and point-of-care support tools for health workers in LMICs were found, indicating a need for further research in this mHealth thematic area.
- Mobile technologies in LMICs have been found to increase communication between health professionals and community health workers for advice and consultations, resulting in a collaborative support system and better patient care.
- Electronic Medical Records are a key aspect of health information systems; however, no literature was found that supported the use and development of Electronic Medical Records on mobile phones. This foundation is a key cornerstone to mHealth development, which has the potential to inform health professionals not only as a point-of-care support tool but also as a method for collecting data and developing treatment compliance and disease management programs.
- The primary barrier found to implementing health information systems and point-of-care support tools is clinician resistance. Mobile phones may enable access to information easier, but not necessarily faster, depending on the level of integration of systems, which stands to significantly hinder adoption.
- Studies investigating the benefits of telemedicine found that rural health professionals had more learning opportunities in addition to consulting physicians for uncertain diagnoses.

LMICs have few resources to put toward investigating ways to improve quality of health services and health outcomes and managing their resources. Health information systems and tools that utilize mobile phones can be used to help provide data for decision making within the health sector. With the increasing adoption of health information systems and point-of-care decision support tools in both high-income countries and LMICs, and the shift from computer to mobile phone-based data entry and access platforms, traditional health information systems (HIS) and related policies may need to be updated. Furthermore, there has been a shift from designing HIS solely as clinician support tools to also including systems and deployments for Community Health Workers (CHWs).

Research Findings Related to the Use of Mobile Technologies in Health Information Systems

As discussed in the previous section, systems and applications related to HIS include the use of PDAs, basic mobile handsets, and smart phones to enable access to health information for health workers and the general population, and also for routine data collection and reporting and as point-of-care support tools. In this section, the focus is on the use of such systems at the service delivery level and for direct engagement between citizens and the health sector.

Point-of-Care Health Information Tools

Using PDAs and mobile phones at the point of care can provide health professionals and CHWs with access to pertinent information to increase the accuracy of diagnosis and treatment in an effort to improve quality of care and in turn health outcomes. One form of this links current patient information with historical patient information from the Electronic Medical Records (EMR) and uses sophisticated decision support software to guide health professionals. At the same time, increasing numbers of support tools and mobile phone-based systems are being used to enable access to static and algorithm-driven health information for health professionals. A survey of 463 health professionals, 60% of whom were physicians, in Medellín, Colombia, showed that the majority not only owned a mobile phone but were most interested in health education tools on the mobile phone, but did not address how they were currently using mobile phones as a support tool (C1). Similarly, a needs assessment of medical residents from Yaounde University in Cameroon found that all the residents had access to a mobile phone and used it to call mentors for guidance while completing their training in a rural setting. The use of mobile phones as a tool for communication by health workers to get advice from a senior colleague and/or peers through voice calling or SMS is one obvious benefit of mobile phones that few people research. An ethnographic doctoral thesis on health-related uses of mobile phones in Egypt conducted in 2002-2003 highlighted the benefits of mobile phones for coordination and consultation among health workers and the ability for patients to contact their healthcare provider directly (C2). A qualitative study of maternal and newborn health conducted in Dangme West, Ghana supports the above with its findings that nurse midwives consult with their peers, supervisors, and other medical colleagues on complex cases via mobile phones. Respondents also mentioned using mobile phones to facilitate communication between patients and healthcare providers on an individual basis or en masse in communities, avoiding travel and yielding more timely and efficient health service delivery (C3). Communication between health workers using such tools as mobile phones falls within the realm of informal telemedicine, point-of-care support, and access to health information. Many would say it is the single most important mHealth application—yet it seems to be relatively ignored by researchers and policy makers alike. The residents in the Yaounde study believed they would benefit from being able to access medical and healthcare information, in addition to being able to exchange images for point-of-care consultation advice (C4). This finding implies that research into mobile phones and access to this kind of health information is at the stage of 'belief that mobile phones could be useful,' which is an indication of lack of progress in the area of mobile learning or mLearning for health professionals.

Prgomet et al. identified 13 studies that provided evidence of the positive impact PDAs have on work practices and patient care in a hospital. The authors noted that the technology was especially useful where time is a critical factor, and rapid response is crucial (C5). However, Patrick et al. warn that although mobile phones have the potential to become an increasingly indispensable health device, there are core issues that may influence how well and how quickly mobile phones are integrated into health care systems. These include unresolved technical issues such as network connections and policy-related issues such as health data security and confidentiality (C6). Similarly, Martins and Jones assert that mobile information and communication technologies (MICTs) make access to information easier but not necessarily faster because they depend on integration with other hospital systems (C7). Claim Mobile is a project in Uganda that uses the mBanking/mPayment initiative as part of healthcare financing. The system allows for live updates and enables ongoing communication between management and providers. It has reduced claims paperwork and has the ability to cross-check claims information and catch errors (C8).

Tele-education & Tele-consultation

The use of telemedicine can dramatically help overcome the barriers to accessing expertise and relevant information. While there are applications of telemedicine in the literature, there are considerable differences in how it is applied in LMICs, with different contexts and potential, and as a result, outcomes. Tele-consultation is defined as the electronic transmission of medical information (voice, data, video, documents, digital images, ECG, heart sounds) from one site to another using telecommunication technologies (C9). This idea is further supported by a review of telemedicine in LMICs, which found that it allowed health care professionals to use connected medical devices in the evaluation, diagnosis, and treatment of patients over distances with the help of networking technologies, database management, and application software (C10-26). Clearly, the definition is wide, and the review encompasses many diverse uses for the advancement of patient care.

The lack of access to information and services not only results in feelings of isolation for health providers, but also creates obstacles to diagnosing specialized conditions. The Ministry of Health in Malaysia implemented The Teleconsultation Network, which facilitated 1,034 consultations via video or “store and forward” between March 2001 and September 2002. Analysis found that the diagnosis between primary care physicians and specialists differed by 42%. The implementation of the tele-consultation system in Malaysia, which allows healthcare providers to communicate with one another, has led to more appropriate patient care, and thus, better health outcomes. The authors found that frequent contact with rural and urban peers through tele-consultation has beneficial effects that continue well past the single tele-consultation, with the provider retaining skills learned in the tele-consultation that benefit future clients experiencing similar symptoms (C9).

In 2004, African Medical and Research Foundation (AMREF) began a telemedicine program in Kenya and Tanzania to facilitate tele-consultation, ease requests for supplies and surgical lists, facilitate the return of laboratory reports from the AMREF Central Laboratory in Nairobi, and share training materials, written guidelines, and scientific papers with health workers in remote hospitals in rural, arid regions of Tanzania and northern Kenya. AMREF is now piloting the use of the mobile phones to support distance learning for its existing Nurse Upgrading Program and Continuous Professional Development (CPD). AMREF mLearning enables mid-level health workers to access study and reference materials, tests, and health news messages. The mobile application is designed for use on phones that support low-level mobile entertainment and is downloadable similar to a mobile game or ringtone. An area of study in high-income countries is the use of "instant messaging," such as Google Chat, on mobile phones to communicate with colleagues and providers for instantaneous collaborative medical advice. Research on this topic was not found in LMICs.

Barriers to and Gaps in the Use of Mobile Technologies in Information and Support Tools for Health Professionals

The literature on the use of mobile technologies for information support for health professionals and service delivery in developing countries is anecdotal and fragmented. Much more research is needed in this area. While "case studies" and "pilots" are many, little research in the way of replicable study design with adequate sample sizes was found. Numerous studies described system implementations, but few showed improved patient outcomes and workflow efficiencies. Thus, further research that examines the impact of mobile devices on work practices and outcomes, rather than assessing feasibility, is needed (C5). Kaplan also notes the paucity of controlled studies concerning mHealth (C11).

A primary aspect of health information systems is the development of patient electronic medical records (EMR) as a means to record health activity and create continuity between the patient and healthcare provider for better care. Studies investigating EHRs on mobile phones were not found as the literature focused mainly on internet-based solutions. In LMICs where broadband coverage is sparse and inconsistent, the need for this capability on mobile phones is critical. In many ways, EHRs have the potential to create a foundation for which the scope of mHealth can be realized. For instance, a single patient's EHR can be used to inform data collection, treatment compliance, and disease management programs. This shift toward integrated mHealth solutions will be increasingly crucial to drive adoption among healthcare providers, who already struggle with time constraints.

Txt2MEDLINE is a text messaging system that processes incoming texts, retrieves the appropriate journal citation from MEDLINE/PubMed, and sends that information to the person who requested it. The system was designed to provide a mobile reference resource to physicians to support evidence-based medicine and translational medicine. It is comprised of a server with a Global System for Mobile Communication (GSM) modem, a subscriber identity module (SIM) card for wireless connectivity to the mobile network, and UltraSMS to interface between the modem and database and a mobile device. The Txt2MEDLINE team developed a medical abbreviations and acronyms database that contains 3,000 medical terms (and counting). Queries for journal citations can be sent via SMS or email using the system's search commands. The system relies heavily on abbreviations due to SMS character limits, which poses an obstacle to user adoption of the system in addition to being a challenge for the team—they are currently testing several versions of the word abbreviation algorithms. Another limiting structure of the system is its dependence on wireless networks. Overall, the early user feedback has been positive.

Primary challenges facing implementing and scaling health information systems were found to include clinician resistance (C12), cost (C13, C14, C15), inadequate infrastructure (C16, C15), staff workload, understaffing, power shortages, and network breakdowns. The Lu study (C12) focused on physicians in a general sense and did not delve into specialties. Some reasons for clinician resistance included dissatisfaction with the physical characteristics of digital technologies, uneasiness with its use, and ineffectiveness of the technology. Furthermore, staff workload may be too complicated such that multiple technologies need to be used and/or the technologies are unable to be easily integrated into the workflow. For understaffing, the introduction of a HIS may create more work, thus overextending the staff further. In addition, data and technology standards will be needed in order to benefit from the increasing volumes of data being generated through these systems. Since most HIS (including open source software) have been designed and implemented in high-resource settings (with the assumption of reliable broadband access), the adaptation of studies, technologies, and systems from such settings may pose a problem for LMICs.

In order to successfully incorporate mobile technology into their overall point-of-care support strategy, healthcare organizations need to consider issues like portability, task structure, ease of use, and system reliability. Such issues influence the use of mobile technology by healthcare professionals, their degree of satisfaction with the technology, and the realization of overall benefits (C17).

The developed world model of personal ownership of a phone may not be appropriate as the sole model in the developing world where shared mobile telephone use could be common, particularly when dealing with sensitive patient-related information. Sharing may be a serious drawback to use of mobile telephones as a healthcare intervention in terms of stigma and privacy, but its magnitude is unknown (C11). In 2008, Nokia released survey findings on consumers in emerging markets. The surveys were conducted in India, China, Brazil, Pakistan, Vietnam, Russia, and Egypt in October and November 2007. According to the survey, a new trend was on the rise—phone sharing. More than 50% of those surveyed in India and Pakistan and nearly 30% in Vietnam noted that they currently share or would share their mobile phone with family or friends. Phone renting is a method of phone sharing. For example, in the mid-1990s “cholulares,” a nickname for "cholos con celulares" or people who rent cell phones on the streets, were popular in many cities in Peru (C19). But now, more and more people are acquiring personal mobile phones since they have become more affordable (C19). The ITU noted that by the end of 2007, the number of mobile phone subscriptions surpassed the 100% mark in Europe with inidviduals have more than one subscription and/or phone and at the end of the year, almost one out of every two people in the world owned a mobile phone. The rate of penetration is expected to rise with the continued high level of competition in the telecommunications sector and decreases in prices for mobile devices. Such trends are evident throughout the developing world in countries such as Zambia, Kenya, and several other African countries where mobile phones are used to make cashless payments (C20). Sensitivities to shared mobile phones would presumably apply only to some types of health information, especially personal medical records and targeted SMS messaging for conditions that may be stigmatized such as HIV/AIDS; it would apply less, if at all, to other kinds of generic health information such as preloaded generic first aid information.

One key area that appears not to have been studied is related to the types of incentives that ought to be provided to health professionals to encourage adoption and proper use of mHealth-related health information systems. Key research questions in this area might include: How do EMRs and associated software and hardware make the professional's job easier and more rewarding? How can mobile technology be part of an empowering two-way conversation, rather than single directional data entry? How can such tools be used as part of an effective human resource management system that rewards excellence and identifies errors and weaknesses in order to improve quality of care? Salary payments through cell phones would provide immediate reward for effective usage of mHealth applications. Similarly, payment in cash or minutes/message units could enhance public health compliance in the general public (see next section). These all need to be studied.

DISEASE PREVENTION AND HEALTH PROMOTION

Key Points

- Studies investigating the use of mobile technology for disease prevention and health promotion have found positive results when used to affect the health outcomes of patients managing smoking cessation and nutrition.
- Mobile technology has been a critical medium to promote and disseminate information regarding confidential and stigmatized issues such as sex, family planning, sexually transmitted infections, and HIV/AIDS.
- The literature found studies illustrating the use of mobile phones to strengthen the relationship between patients and providers, for example midwives and pregnant women. This increase in communication allows health providers to monitor patients more closely, leading to earlier detection and treatment of health issues.
- Disease prevention and health promotion programs tailored specifically to a patient's needs and health profile are being created using intelligent back-end systems through the increasing integration of rules-based engines and algorithms. Integrating solutions with platforms such as electronic health records can accelerate this development, which can be used to inform people-centric programming.
- Barriers to disease prevention and health promotion programming are commonly found in the limitations of SMS (i.e., 160 characters), language, and privacy. It has been found that mobile phones are often shared among family members in LMICs, leading to potential challenges with protecting confidential information.

It has recently become understood that preventing a disease from occurring is more cost-effective than treating a disease. As a result, more emphasis is now being placed on disease prevention, such as mitigating the transmission of infectious diseases or improving unhealthy lifestyles in order to decrease the risk of contracting or developing deadly, costly diseases. These diseases—HIV/AIDS, diarrhea, pneumonia, and heart diseases—impose great economic burdens on society, making prevention efforts a worthwhile investment across the world. This is particularly the case in LMICs where traditional infectious diseases and, increasingly, chronic conditions are putting a strain on existing health systems. To effectively manage and prevent these diseases, the WHO has identified four essential elements for action in health promotion and prevention (D2):

1. Support a paradigm shift towards integrated, preventive health care
2. Promote health financing systems and policies that support prevention in health care
3. Equip patients with needed information, motivation, and skills in prevention and self-management
4. Make prevention an element of every health care interaction

Although there is presumably a large market for prevention efforts, systems for health care delivery are often not adequately structured to focus on prevention activities and health care providers do not take advantage of opportunities to enforce healthy behaviors when with patients (D2). Challenges are increased by the fact that persuading individuals to adopt healthier lifestyles is difficult. Moreover, in LMICs, very large segments of the population do not come into contact with the formal health care system frequently, if at all. However, the rapid uptake of mobile phones by individuals offers several opportunities for enhanced prevention activities. Since mobile phones are portable (making them easy to carry everywhere) and personal, they have become a creative vehicle for positive health behavior changes and disease prevention activities. This section details studies that demonstrate the ways mobile phones are being utilized for promoting health and preventing disease. Drawing together current trends, the analysis of these research findings will be followed by a description of barriers, gaps, and suggestions for next steps.

Research Findings Related to the Use of Mobile Technologies for Disease Prevention and Health Promotion

A total of 25 studies have been selected to illustrate the current state of mHealth prevention strategies. Mainly focusing on the use of mobile phones for preventing heart disease, diabetes, HIV/AIDS, and other sexually transmitted diseases, the studies were performed on interventions in countries such as Canada, the Democratic Republic of Congo, India, Philippines, South Africa, Tanzania, Thailand, Uganda, and the United States. Generally, prevention efforts are classified according to the disease they are trying to prevent; however, mHealth prevention initiatives must be understood in the context in which they are deployed. This required employing a modified version of the WHO framework for integrating prevention activities into health services. Articles were categorized by this framework, rather than by the disease each intervention intends to prevent.

Mobile phone uses to support a paradigm shift towards integrated, preventive health care

There have been many documented uses of mobile phones for prevention activities in health care. Among the mHealth-related prevention articles, one study explored the feasibility of using mobile phones for telephone counseling as a smoking cessation intervention in a low-income, HIV-positive population (D3). Through personal interviews, participants expressed that although transportation and telephone availability were barriers to receiving the intervention, they were interested. These findings led to a subsequent study in which participants were provided with free mobile phones and received counseling sessions over the phone. Ninety-five percent of the participants attempted to quit, and 75% were abstinent one to two weeks post-quitting date (D3). Interestingly, Labonne and Chase, thinking that individuals may pay for communication with the same money they would normally spend on tobacco, explored the impacts of mobile phone ownership on tobacco consumption (D4). Using panel data from 2,100 households in 135 communities of the Philippines collected in 2003 and 2006, the analysis found that mobile phone ownership led to a 20% decline in monthly tobacco consumption, and among households in which at least one member smoked in 2003, purchasing a mobile phone led to a 32.6% decrease in tobacco consumption per adult over the age of 15.

The increasing interest in how mobile phones can play a role in prevention activities is reflected in the systematic review performed by Krishna et al. (D5). This review covered literature addressing the use of mobile phones and text messaging in health care provision and disease management support. A total of 25 studies covering 13 different countries (mostly high-income) were identified based on inclusion criteria. Twenty of these studies were randomized controlled trials and 5 were controlled studies; 19 assessed outcomes, and the remaining assessed processes. Most of these studies used what the review termed “push” technology where messages delivered to phones were tailored to personal needs. These messages were sent at a frequency between once per week to once per day. For those studies that included outcomes, significant findings involved improvements in treatment compliance, symptoms, stress levels, smoking cessation, and self-efficacy because of either voice- or text-based communication over cellular phones. Those studies focused on examining processes saw improvements in clients making scheduled appointments, and in providers diagnosing and treating faster (D5). One process study found improvements in performance and satisfaction after teaching communication via text messages to individuals with disabilities (D5).

Mobile phones equipping patients with needed information, motivation, and skills in prevention and self-management

“When patients are systematically provided with information and skills to reduce health risks (or adopt healthy behaviors), they are more likely to reduce substance use, to stop using tobacco products, to practice safe sex, to eat healthy foods, and to engage in physical activity…[which] can dramatically reduce the long-term burden and health care demands of chronic conditions” (D2). Information and communications technologies are providing new communication channels for disease prevention messages.

ALIVE! is a program that sends email reminders or text messages to patients to encourage healthy eating and regular exercise (D6). Study findings describe how mobile phones are equipping populations with a convenient tool to become better informed, motivated, and self-managed to integrate more healthful daily activities (D6).

In 2009, Roura et al. demonstrated that equipping patients with appropriate preventive information alongside treatment has transformed HIV into a manageable condition in a rural ward of Tanzania (D7). In prevention, strategies to mitigate contracting an infectious disease or developing a chronic condition are to provide health information on how to protect oneself, and how to exercise and eat better. Mobile phones have become a medium for relaying these types of information, as well as providing contact information for hotlines, counseling, and educators. For example, an intervention called mDhil offers text messages, in 40 characters or less, with information on various health topics not commonly discussed in India, such as diabetes, H1N1, maternal health, and human reproduction, on a for-profit business model (D8). The team at mDhil is working toward one million users by the end of 2010 and hopes to hit three million by the end of 2011 (D8).

Prevention information delivered via text messages has been effective with targeted populations including those of young people aged 10 to 24. In response to rising gonorrhea rates among African American youth in San Francisco, Internet Sexuality Information Services, in partnership with the San Francisco Department of Public Health, developed SEXINFO, an effective sexual health text messaging service (D9). After the pilot, usage of the service was greater than expected, and an initial evaluation to assess the impact of SEXINFO on increasing access to sexual health services among at-risk adolescents showed promising results. Additionally, La Ligne Verte ("hotline" in French) exemplifies the use of mobile technologies for health education information in the Democratic Republic of Congo, where access to health services has been seriously compromised by violence of the past decade (D10). Callers to the hotline are able to speak confidentially to educators trained to offer high-quality information on family planning and contraceptives and also able to make referrals to clinics located near the callers. The hotline is available virtually countrywide, between Mondays and Fridays from 8:00 am to 4:40 pm. In 2007, between 600 and 2,000 calls per month were made to la Ligne Verte. The system operates through a contract with mobile phone provider VODACOM, where VODACOM is paid 36 cents for each call limited at two minutes. It has been found that three minutes may be a more appropriate length of time for responses, so the project is exploring options in its next stages. Knowledge about the hotline is spread through mass and individual information sessions, radio broadcasts, and billboards. Monitoring data is collected and analyzed two times a month for internal project use, and a report is sent to the project's provincial offices every month. Originally targeting the family planning information to women, the project to date has surprisingly experienced more than 80% of callers to be men of reproductive ages—possibly a reflection of the unmet need for family planning information (D10).

The provision of health-related information has also been shown to improve satisfaction levels. One randomized control trial in a hospital setting in Bangkok, Thailand demonstrated that healthy, pregnant women who received text messages for prenatal support had significantly higher satisfaction levels than those who did not receive any text message support (D11). A total of 68 women were randomized into either a treatment group, which received two SMS messages per week from 28 weeks of gestation until giving birth, or a control group, which did not receive messages. Information provided to the treatment group included abnormal symptoms that may come about during pregnancy that would require the consultation of a health care worker, and tailored messages were sent based on each woman's specific gestational age (e.g., "after giving birth, breast milk is the best food for your baby and can improve immunity" was sent prior to expected date of delivery) (D10). However, this study did not find a difference in pregnancy outcomes, such as gestational age at birth, infant birth weight, preterm delivery, and route of delivery. Though Jareethum et al. aimed to assess satisfaction levels and measured the aforementioned pregnancy outcomes, the study did not address whether or not there were differences between treatment and control groups for the specific messages sent (D10).

Another avenue in which mobile phones can be utilized for disease prevention is providing individualized targeted interventions. Several of the articles describe mHealth-related prevention efforts specifically for increasing physical activity, which is encouraged as motorized transport and sedentary leisure time (e.g., television watching) rises globally (D2). Intel Research has developed UbiFit Garden, which is an application aimed to encourage regular physical activity (D6). When an individual is physically active, the application will reflect the activity by displaying “a blooming garden” on the individual’s mobile phone screen. Additional activity, detected by on-body sensors, turns into additional flowers in the garden. Overall, UbiFit Garden has effectively assisted individuals into a more active lifestyle (D6, D12). In addition to visual stimulation motivating individuals to become more active, a short-term study demonstrated that sharing activity information among a group of friends encourages reflection and provides increased motivation for daily activity (D13).

Better disease prevention is also related to self-management as indicated in the treatment compliance section. The universal Mobile Diabetes Management and Internetworking System (MDMIS), which aims to improve diabetes control by providing a portable, secure, and ubiquitous diabetes management service for both diabetics and medical providers, is one example (D14). The relevant experimental and test results of this system have shown a successful implementation of a GPRS wireless diabetes management system. The presented architecture can be adopted for other mobile chronic disease management such as asthma, cardiac disease, and COPD (chronic obstructive pulmonary disease). Similarly, Anderson et al. explored how mobile phones could help people track their daily exercises. To estimate the movement of a mobile phone user, an Artificial Neural Network was designed to analyze the mobile network’s signal strength in relation to the user’s mobile phone based on distance from the network (D13).

Mobile phones are also allowing individuals to receive information for self-management for themselves in addition to family members or friends that may have an illness or injury. The hotlines, such as SEXINFO mentioned previously, are prime examples where information can be readily accessed to improve self-management of more healthful behaviors. One study found that receiving text messages on mobile phones does not share the disadvantages that are present when using web services for monitoring and self-management of health outcomes (D15). Four messages were received daily by asthma patients regarding medication reminders, requests for peak flow information, data on sleep loss, and medication dosages. Responses were recorded as diary data and approximately half the patients reported 69% of the requested data (D15). A focus group was held with nine of the users, and they expressed that SMS had become an “integrated part of their everyday life,” though a request for a more simple process was expressed (D15).

In a similar project, during a six month period, approximately 950 text messages were sent to a treatment group while standard methods for information provision were used with a control group of patients who had been diagnosed with *Chlamydia trachomatis* infection,. Results demonstrated that patients with *Chlamydia trachomatis* were diagnosed quicker and received treatment faster after a text messaging results service was incorporated into clinic care. The provision of results saved time for the treatment group; however, there was no difference between treatment and control groups when it came to the time taken for patients to attend the clinic once contacted with the results (D16). Menon-Johansson et al. additionally found that during the last month of their analysis, when 33.9% of results were provided via text messages, the clinic had saved 46 hours of staff time and 40.4% in costs per month (D16).

One way of improving information to elicit improvements in self-management for prevention and health promotion has been published by Traver et al. (D17). For patients with chronic cardiac conditions, a home tele-care platform was developed that can be used on PDAs, personal computers (PCs), mobile phones, and tablet PCs (D17). The platform contains tele-monitoring (e.g., online and offline monitoring of vital signs), alarms (e.g., warning alarms for when threshold levels have been reached for some measurements), scheduling (e.g., scheduling appointments and pill reminders), electronic health records, electronic prescriptions (e.g., recommendations and pill information available to the patient via database), customized patient information (e.g., available and customized information complementing patient profiles), and videoconferencing (e.g., visual and virtual examinations) features (D17). Some features are available for the patient to use and some are for health care staff. Findings from a two-year evaluation of 18 patients found that 71% of the patients reported that the tele-care services had increased their independence, 85% said that they wished to keep the service after the trial, and both patients and health professionals remarked that the platform was complementary to traditional health care services, and not replaceable (D17).

Some mHealth interventions tie together strategies for improving information, motivation, and self-management. For example, in the United States, Delaware Physicians Care, Inc. (DPCHI) has enrolled patients to receive pre- and post-natal appointment reminders as well as health information through text messaging (D6). In another study, a randomized control trial demonstrated that individuals who received “tailored solutions for perceived barriers, a schedule to plan weekly exercise sessions with mobile phone and email reminders, a message board to share their experiences with others, and feedback on their level of physical activity,” as well as real-time feedback through the Internet, reported a significantly greater increase in both the perception of control and the intention or expectation to exercise compared to the control group (D18). However, the study lacked qualitative data, which could have helped understand participants’ perceptions of the program.

Make prevention an element of every health care interaction

As mentioned previously, health care has traditionally consisted of curative care; however, stakeholders in health systems are beginning to realize that factors that increase the risks of developing or contracting diseases can be largely prevented. For this to happen on a large scale, prevention must be an element of every health care intervention (D2). In the articles that fall in this category, some mHealth projects sought out opportunities to build upon existing prevention campaigns, such as Text to Change’s HIV/AIDS efforts in Uganda, and others developed strategies to improve patient-provider or provider-provider relationships.

The non-profit nongovernmental organization (NGO) Text to Change uses mobile telephony as a medium to synergize the communication of HIV/AIDS issues, existing prevention campaigns, and other HIV/AIDS health services in Uganda (D19). The main objectives of the pilot intervention were to scale up VCT (Voluntary Counseling and Testing) uptake, bring about a behavioral change, increase the knowledge of HIV/AIDS, and facilitate monitoring and evaluation of current prevention programs. Text to Change developed an interactive SMS-based, multiple-choice quiz to improve knowledge of HIV/AIDS. Quizzes were sent by SMS to the 15,000 Celtel mobile phone users in the Greater Mbarara region who were targeted over the course of eight weeks. Between February and April of 2008, 2,610 of the 15,000 Celtel mobile phone users responded to one or more questions sent via text. Some questions received responses more often than others (e.g., the question "HIV is not present in a) semen, b) sweat, or c) blood" had the smallest number of responses with between 1,000 and 1,500 respondents, whereas "Is the HIV test accurate" had around 2,500 respondents). The trial indicated that it is essential to have an extensive marketing campaign, using radio, billboards, and newspapers, an introductory message containing an explanation of the program and explaining the ways in which anonymity is guaranteed, a shorter program duration so that people will not lose interest, and various technical improvements (D19). Similarly, another NGO, Cell-Life, reported their results on how mobile technology can be used in the prevention, treatment, and care of HIV/AIDS, as well as supporting the HIV sector in general in South Africa (D20). Cell-Life sent text messages containing treatment reminders as well as information on treatment side effects to 120 people twice a day. When the report was published by de Tolly and Alexander in 2009, the pilot had only been running for three months, which was not a sufficient amount of time to measure an impact; however, coordinators were receiving positive feedback, and those who were not allowed to participate in the program expressed displeasure (D20). Because services were available in both English and Xhosa and because Xhosa generally contains 20% more characters than English, Cell-Life experienced challenges in translating messages and fitting proper messages within the 160-character limit.

Another mHealth approach is to strengthen the patient-provider relationship by using mobile phones. Ray et al. describe a simple concept—if a health provider is able to have a higher "awareness level" of the actions and location of his/her patients, the provider may be able to provide better and more appropriate health services (D21). In their study, mobile health becomes a platform for a health professional to receive "awareness" information, such as the vitals of a chronically ill patient who is connected to a sensor linked to a monitoring device. The authors suggest that with mobile eHealth strategies, many of the latency issues in care can be resolved with automated processes and wireless networks. This also applies to activities that generally require face-to-face appointments between patients and physicians (D21). With routine checkups and closer monitoring with strengthened communication links provided by mobile phones, a provider can anticipate risk factors for diseases that are more likely to develop in individuals and enhance early detection. For patients, the ability to participate more closely with health providers has the potential to promote a more health conscious attitude.

Mobile phones have also been demonstrated to fill communication gaps among health care workers. An example of this is the Aceh Besar Mobile Phones Project, which has received recommendations to extend mobile phone call credit subsidies for midwives to improve communication with midwife coordinators and doctors in the area (D22). These subsidies would complement potential networking sessions between healthcare workers and medical experts held on a regular basis. Another study sought to investigate whether text messages could be an affordable option to improve outreach communication and information dissemination between community practitioners (D23). A field study of 50 participants was conducted to collect communication protocol responses through a text-messaging simulation. Findings suggested that the use of text messages was a viable communication medium for information exchange between field practitioners (D23). This study has important implications for LMICs, particularly where rapid growth of mobile phones and networks is offering health worker to health worker communication support to perform preventive outreach services. This is another example of communication between health workers that raises an important and controversial question for policy makers: *Should governments do more to equip health workers with mobile phones for their work and/or take steps to encourage mobile phone ownership among the general population?*

Additionally, Varshney presents a framework for using wireless technologies for prevention, healthcare maintenance and checkups, short- and long-term monitoring, incidence detection and management, and emergency transportation, treatment, and intervention (D24). He argues that medical errors, stress on health professionals, and limited access to health services could be improved with the integration of mobile and other wireless technologies (D20). Mobile phones could also reduce the overall cost of health services in the long term; however, wireless networking solutions (i.e., wireless local area networks (LANs), ad hoc wireless networks, cellular/GSM/3G networks, and satellite-based systems) have to address security and privacy issues, as well as potentially spotty coverage, which could hinder attempts at continuous information flow across networks.

Barriers to and Gaps in the Use of Mobile Technologies for Disease Prevention and Health Promotion

The review of articles related to mHealth strategies for disease prevention demonstrates that mobile phone and network integration into prevention activities is new and developing rapidly; however, this integration is not without barriers to development or gaps in knowledge. Common barriers experienced across several of the aforementioned projects included limiting health-related content to 160 characters for text messages or to a certain amount of time for voice calls; translating messages from one language to another (D20); having sufficient technical and mobile phone provider support in remote areas (D10); encountering language barriers (D20); lacking sufficient qualitative data to explain certain findings (D18); and addressing security and privacy issues (D8). Though most of the mHealth interventions for disease prevention described the use of text messages for providing health information, motivating individuals, and encouraging self management, illiteracy is clearly an issue for future text-based prevention interventions. When investigating the interplay among ART scale-up, different types of stigma, and Voluntary Counceling and Testing (VCT) uptake two years after the introduction of free ART in a rural ward of Tanzania, Roura et al. demonstrated the importance of culture-specific approaches to equipping patients with proper preventive information (D7). The authors found from in-depth interviews with a purposive sample of 91 community leaders, 77 antiretroviral clients, and 16 heath providers that availability of effective treatment had transformed HIV into a manageable condition that was contributing to a reduction in self-stigma and stimulating VCT uptake (D7). These contributions are being counterbalanced by the persistence of blaming attitudes and emergence of new sources of stigma associated with anti-retroviral provision.

Other challenges mentioned in the mHealth-related prevention interventions included technical problems, costs, and financial sustainability. La Ligne Verte in the Democratic Republic of Congo described technical problems they had early on, such as setting up and running their hotline; however, these issues were resolved through collaboration with mobile phone provider VODACOM (D10). Cost issues were reported to be barriers for some of the projects during pilot stages as well as in plans for scale-up or sustainability. The founder of mDhil had described frustrations of working with foundations that are not as willing to work with for-profit startups, which was the case for mDhil (D8).

Increasing numbers of individuals with chronic diseases will become more and more expensive if not mitigated now, resulting in a strong demand for more prevention efforts. The communication channels that can be created across mobile phone networks have great potential to support the type of individual and community involvement in healthier behavior and lifestyles. As these projects move beyond pilot stages, they may face barriers that other mHealth prevention projects have experienced. Many decades of advancements in the field of health prevention occurred before mobile phones became the first technology to begin to reverse the digital divide (D5). “Successful [preventive] programs have emphasized the need for individual and community involvement and have been characterized by responsible government policies for equitable implementation of efficacious and cost-effective health interventions” (D1). This work should not be ignored amidst the excitement about the potential role mobile phones can play in preserving health and preventing disease. Indeed, mHealth should generally be seen as an effective new tool in a broader campaign, rather than a “silver bullet.”

The **digital divide** refers to the gap between people with effective access to digital and information technology and those with very limited or no access at all. It includes the imbalances in physical access to technology as well as the imbalances in resources and skills needed to effectively participate as a digital citizen.

EMERGENCY MEDICAL RESPONSE

Key Points

- The most natural linkage between emergency medical response systems and mobile phones is access to transportation using a centralized dispatch phone number. However, no studies were found that discussed this type of deployment in LMICs.
- Significant literature investigating the use of mobile technology for monitoring elderly patients in high-income countries with integrated feedback mechanisms during an emergency was found. It is evident that high-income countries are preparing for the predicted demographic shift in the next 5 to 10 years. Such systems are appropriate for urban areas and increasingly for rural areas in LMICs.
- Reports were found that described the use of mobile technology during natural disasters such as the Indian Ocean tsunami, Hurricane Katrina, and the devastating earthquake in Haiti. Mobile phones were primarily used for citizen reporting of food, health, and shelter needs and to coordinate search and rescue missions.
- SMS provides a significant opportunity to alert citizens before, during, and after an emergency, given the fact that it is not only an audio signal, like a siren, but is also a method to communicate calls to action.
- Studies investigating the use of mobile phones for telemedicine during an emergency found them to be an effective means to treat patients faster and more accurately by consulting physicians via phone while in transit, sending images for faster diagnosis and using video capabilities when available.

In LMICs, comprehensive emergency medical response systems (EMRS) are a rarity, often given low priority on the totem pole of public health priorities (E1). Kobusingye et al. argue that the reason for this is a skewed perception of the prohibitive costs of transportation and technologically advanced clinical care, as seen in high-income countries, in comparison to a focus on simple and effective strategies (E1). The use of mobile phones presents the opportunity to circumvent some of the challenges of implementing an EMRS—during both pre-hospital and within-hospital care.

VanRooyen et al. describe the 15 essential components to consider when developing an EMRS in a LMIC (E2). Most of the studies reviewed show that many of these components can be enhanced—if not fully addressed—with the use of mobile phones. These include manpower, training, communications, transportation, consumer participation, access to care, patient transfer, coordinated patient record-keeping, public information and education, disaster planning, and mutual aid.

Research Findings Related to the Use of Mobile Technologies in Emergencies

Our analysis of 35 studies showed little research on mobile phones in EMRS in LMICs; however, studies from high-income countries present transferable lessons and ideas. The literature can be segmented into five primary areas of study: access to emergency medical response, remote patient monitoring and emergency alert systems, point of emergency care, telemedicine, and natural disaster management and recovery. The studies ranged from proposing complex systems using advanced technology such as wireless sensor networks (E3, E4, E5, E6, E7), to leveraging basic functions of a mobile phone, such as voice, video, wireless application protocol (WAP) browser, imaging, and GPS (E8, E9, E10, E11, E12, E13, E14, E15). The second group shows potential for application in LMICs. Given the time-sensitive nature of emergency medical response, most studies looked at improved response time and accuracy of diagnosis and treatment support as measures of success.

Access to Emergency Transportation and Services

In a qualitative study of health-related uses of mobile phones in Egypt in 2002, Mechael showed the critical role of mobile phones in accessing emergency transportation, health personnel, police, and family members during an accident, injury, or medical emergency. Of the 66 people interviewed, almost all recounted using a mobile phone to increase access to emergency care, either directly or through an intermediary. Although a national emergency phone number, “123,” existed, respondents preferred to use mobile phones to access local private transportation, as a result of emergency calls being routed to a call center in Cairo, slowing the response time (E16).

In India, a privatized company, *Dial 1298 for Ambulance*, launched a national emergency number and ambulance system to overcome the lack of an organized EMRS. Its cross-subsidization business model charges individuals according to the requested hospital with public being cheaper then private. During the Mumbai attacks in 2008, 1298 was a first responder, subsequently resulting in contracts from state governments to provide emergency medical services and transportation to poor individuals who cannot afford to pay for such services (E17).

Point of Emergency Care Support

Mobile phones are often highlighted for their potential in improving response times to emergencies and coordination of emergency support. Studies investigating the use of mobile images and multimedia message service (MMS) for tele-consultation purposes during emergencies showed mixed results when testing for accurate diagnoses, but confirmed the ease of use, low cost, and high portability (E12, E15, E18, E19). Hsieh et al. studied the feasibility of tele-consultation with a mobile camera phone for diagnosis of soft-tissue injuries in Taiwan from January to May 2003 in 45 patients. It found 15% discordance between the tele-consultation triage and actual treatment by a surgeon due to the inability to show instances of tiny exposed digital bone or tendon in the low-resolution image. Authors noted that the system would be feasible if accompanied with online or telephone communication, in addition to more advanced mobile technology (E18).

Tsai et al. also conducted a feasibility study in Taiwan for tele-consultation using a mobile camera phone for remote management of an extremity wound in 60 patients between January and August 2003. Three surgeons conducted evaluation of the images and found agreement in descriptions of gangrene, necrosis, erythema and cellulitis in 80, 76, 66, and 74% of cases respectively. Gangrene had the highest agreement, sensitivity, and specificity, likely the result of its distinct color, while erythema had the lowest. The authors concluded that the mobile camera phone was a feasible option in comparison to expensive telemedicine systems, although advanced mobile technology would be more beneficial. Accurate diagnoses are limited by the inability to touch, smell, and measure the temperature of the wound (E19).

Using the mobile camera phone for tele-consultation in LMICs, between rural and urban physicians or between high-income country and LMIC physicians, is a feasible option in comparison to costly telemedicine systems. However, guidelines on its applicable use should be further defined as results between medical disciplines vary. The use of mobile phone video functionality has the potential to increase access to accurate emergency care in LMICs, overcoming the barriers of distance to health care facilities and the lack of specialists in rural areas. While some of the studies reviewed utilized mobile phones with cameras and/or video capabilities, there was concern over the quality and size of the images and screen shot size (E18). There is also the barrier of affordability of such mobile devices in LMICs. However, with advances in mobile technologies and companies creating more affordable phones, mobile phones with camera and video may produce clinic-quality visual content and be supported by 3G networks.

Telemedicine

Rural areas and community hospitals and clinics throughout the world have limited or no availability of medical specialists. As a result, the use of telemedicine in early diagnosis of remote patients has been widely studied by researchers, mostly in the United States—particularly in relation to stroke patients (E9, E20, E21, E22, E23). Studies assessed the agreement between traditional and telemedicine-enabled consultations for the delivery of stroke care, and the difference between telephone and video use.

A review of the evidence for use of telemedicine in stroke care was conducted by the American Heart Association and found the highest level of evidence (Class 1, Evidence Level A) to support the use of this technology in cases where a stroke specialist was not available for a bedside consultation. The evidence found varying results in the effectiveness of telephone versus bedside consultations (Class 2b, Evidence Level C) (E23).

Duchesne et al. studied patient outcomes and the management of patient transfer between seven rural hospitals and an urban-based trauma center using a telemedicine system in Mississippi. In five years, 814 traumatically injured patients were presented at the rural hospitals. Of this sample, 351 patients were directly transferred to the trauma center with out a consultation, and 463 patients were assessed through a telemedicine consultation. Of these, 51 were transferred to the trauma center after consultation. The remaining 412 patients were treated at the rural hospital, saving the time and expense of being transferred to the trauma center. When patient files were reviewed afterwards, it was found that patients directly transferred without a consultation (n=351) were more severely injured then those for whom a consultation was undertaken (n=463), validating the need for immediate transfer to the trauma center. The implementation of the system significantly reduced hospital costs ($1,126,683 versus $7,632,624), and was overall found to increase trauma capacity at rural hospitals, and conserved resources at trauma centers by avoiding unnecessary transfers (E24).

In LMICs, the implementation of hub and spoke telemedicine networks could be used to support more prevalent time-sensitive health conditions—such as HIV/AIDS and tuberculosis—to overcome the shortage in human resources and specialists. The evidence from tele-consultation for stroke and trauma networks demonstrates the effectiveness of using video to diagnose patients in an emergency, in the event that a face-to-face option is not available.

Remote Patient Monitoring and Emergency Alert Systems

In Taiwan, a remote patient monitoring (RPM) system for elderly patients suffering from dementia uses wearable sensors and in-home wireless sensor networks and radio-frequency identification (RFID), GPS, GSM, and geographic information system (GIS) technology. Access to a patient's location is constantly available and messages to health providers and family members are triggered in case of an emergency. The study found high accuracy in location data after conducting 320 tests in three locations at four different time periods. However, during bad weather, GPS technology was found to not be as effective (E4). Similarly Chien-Chih Lai et al. developed a system in Taiwan that constantly monitors a patient's echo-cardiogram (ECG) through wearable sensors and in-home wireless sensor networks (E6). Also in Singapore, a study of remote patient tracking leveraged telecommunications infrastructure to capture location data from hybrid GPS/GSM wearable sensors with pre-programmed alert mechanisms (E3). Wearable sensors have benefits in comparison to mobile phones; they are not bulky, easy to wear, require no technological know-how, and can be pre-programmed to send out emergency alerts.

By contrast, in Taiwan a more basic RPM system uses a blue tooth-enabled mobile phone and wireless-enabled hema-dynamometer to process signals such as blood pressure and pulse rate. Mobile phones are programmed with a physiological signal recognition algorithm that alerts health care providers and family members with an SMS signal in case of an emergency. Since the mobile phone is simply a processing centre, battery life is conserved (E7). This decentralized model would also be effective in low- and middle-income areas where there are significant human resource shortages, particularly in remote settings.

Natural Disaster Management and Recovery

The use of mobile phones in natural disaster management and recovery has been understood to be critical after experiences during the Indian Ocean tsunami in 2004, Hurricane Katrina in 2005, and more recently in the earthquakes in Haiti and Chile demonstrated its value (E25). It has applications as a complementary (and often sole) communication tool, fundraising tool, and data collection tool and should be considered in a country's disaster management plan. An effectiveness study of using mobile phones for disease surveillance was conducted following the Sichuan earthquake in China in 2008. Mobile phones were distributed to 495 local health agencies. Patients manually filled out paper forms, which were subsequently collected by epidemiologists, and sent to the national database via SMS. Overall, 38 infectious diseases were identified as a result of high reporting by the agencies. There was a natural time delay as a result of responding to the disaster and guidelines for phone usage were not outlined, leading to agencies running out of phone credit. It was suggested that reporting should start directly with the physician to increase efficiency, in addition to integrating GPS functionality to spatially map reported diseases (E26).

In 2005, the GSM Association released a report, *The Role of Mobiles in Disasters and Emergencies*, that assessed the impact of mobile phones in recent large-scale disasters. Its findings indicated that mobile phones play a critical role in decentralized communication during the four phases of a disaster: early warnings, disaster impact, immediate aftermath, and recovery and fundraising. his is especially true in LMICs where there are few communication resources. However, there are limitations of mobile phones during a disaster that include overloaded networks and mostly one-way text message-based communication. That being said, the evidence also showed that mobile networks can be easily recovered or supplemented with emergency base units following a disaster. The rule of thumb should always be “text don’t talk” after a disaster, as transmitting an SMS or an email is faster and takes far less bandwidth. Mobilization of financial resources through SMS has shown to be an effective strategy for raising funds during the recovery phase, and was used to raise 27 million Euros for the United Nations Children’s Fund (UNICEF) in Italy after the tsunami in December 2004 (E25) and more recently in the case of the earthquakes in Haiti.

Further, the UN Foundation and Vodafone Foundation recently released a report, *New Technologies in Emergencies and Conflicts*, that describes, through a series of case studies, the application of technology to increase the effectiveness of alerts, preparedness, response, and rebuilding after major disasters or emergency situations. The use of mobile phones in the deployment of alert systems has been pursued more aggressively since the Indian Ocean tsunami in 2004. This has resulted in the revision of regulations previously hindering infrastructure development, the creation of early warning systems, and the increased freedom of citizen-driven information exchange. However, the latter has often been found to be prone to misinformation and propaganda.

The report highlights three alert and preparedness systems deployed: Global Impact and Vulnerability Alert System (GIVAS), European Media Monitor (EMM), and the Emergency Preparedness Information Centre (EPIC). The United Nations established GIVAS to provide decision makers with real-time information during a global crisis. The EMM monitors non-static web content, with the ability to search over 4,000 websites, collect thousands of new articles daily in multiple languages, and subsequently categorize all of the information. Users can then customize their alert preferences, and receive current updates through email or SMS. EPIC will focus on aggregating regional and country-specific data on activities pertinent to humanitarian workers, so information can be easily queried and accessed on computers, mobile devices, and satellite phones. The report also discusses the potential of geospatial technologies in providing data to identify crisis patterns and show evidence of military preparations. For example, in Sri Lanka, satellite imagery supported and provided evidence for a field report on escalating conflicts and disasters in the region (E27).

Another project, which has recently drawn significant attention as a result of its use to map crisis information after the earthquake that hit Haiti and Jamaica in 2010, is Ushahidi (E28). The open-source platform maps information collected from citizens through SMS, reporting on supply needs, human rights abuses, conflicts, etc. The challenge with this platform and other platforms like Twitter that rely on crowd-sourced information is developing a systematic method for rapid verification of the incoming information.

Organizations playing a coordinating role during a natural disaster that leverage mobile technology tools include Télécoms Sans Frontières (TSF), Global Disaster Alert and Coordination System (GDACS), and Innovative Support to Emergencies, Diseases and Disasters (InSTEDD). TSF, an organization founded in 1988, is usually one of the first responders during an emergency or natural disaster. Their team is able to set up a telecommunication center in one to two days that includes a satellite receiver and mobile phones equipped with SIM cards. This is a vital need for on-site relief agencies.

Mobile technologies, such as the mobile payments system M-PESA and mass text messaging platform Frontline SMS, have been used during post-emergency rebuilding efforts. Other examples from the report include Souktel, which is a mobile service in Gaza that connects people with job opportunities and connects aid agencies with those who need assistance through SMS. LabourNet in Bangladesh registers users with a mobile phone for easy contact if a job opportunity becomes available. Registrations have doubled each year since its inception in 2004. The report's key recommendation includes the reevaluation of regulations, which currently act as a barrier to developing comprehensive emergency response systems, in addition to increasing investment into the development of these systems (E27).

An alternative study conducted by Jagtman investigates a different approach to alerting citizens during an emergency. By using a cell broadcast on mobile phones as a supplementary strategy to sirens, there is an opportunity to deliver a sound alert alongside textual information. SMS messages require the GSM network for transmission, which can be blocked during an emergency, whereas cell broadcasts use frequencies that are not affected. Three mock trials were conducted from 2005 to 2007 for four to six weeks involving 400 to 6,500 subjects, specifically testing citizens receiving and responding to messages with a keyword to confirm action would be taken. Results were analyzed by the Delft University of Technology, and the study found that in 2005 and 2006 only 46% of messages were correctly dispatched, in comparison to very few errors in 2007. In 2006 and 2007, between one-third and one-half of the study sample responded to the text message within seven minutes. Given that the study was not conducted during a real emergency, the lack of panic could have affected this outcome. The challenge for mass implementation would be to engage telecom operators (who incidentally fear a widening definition of "emergency" justifying mandatory use of their networks by various levels of government), in addition to programming mobile phones to track data after the emergency (E29). Similarly another study of the use of SMS and cell broadcasting during an emergency suggests that SMS should be used to reach first responders, such as journalists, government officials, and key informants, and that broadcasting information to mobile phones through the operators should be used for mass communication. The challenge with cell broadcasts is that individuals must have the feature turned on, despite little knowledge that the feature exists. The authors assert that multiple communication mechanisms are required during an emergency, and that SMS should be seen as one part of a larger strategy, involving the Internet, radio, and television (E30).

Barriers to and Gaps in the Use of Mobile Technologies in Emergencies

The review of the use of mobile technologies in emergencies demonstrates that the study of mobile phones and EMRS is a relatively emergent field, beyond their well understood value in reporting emergencies and speeding the initial response through universal "N11" emergency numbers. No studies looking at the direct impact of mHealth in EMRS in a LMIC was found, outside of their use in mitigating the effects of natural disasters. The challenge of studying EMRS is the nature of emergencies and the sensitivity of trying new technology when human lives are at stake. Some studies conducted mock scenarios, which seemingly eliminate the panic and chaotic nature that defines an emergency, and likely skew outcomes. Most studies investigating the use of mobile phone and wireless technologies for remote patient monitoring and point of care emergency response were either proposed systems (E3), pilot projects, or feasibility studies with small sample sizes (E10, E11). Almost no studies had conclusive clinical evidence (E19), making the advancement of implementation challenging.

The challenge of developing a comprehensive EMRS in LMICs is that it involves a significant capital investment, namely emergency medical vehicles and information technology systems to connect moving parts (E16, E31). In high-income countries, these systems are mostly in place,[1] and as a result, mobile phones are able to enhance these systems. In LMICs, these systems usually informal or privatized, making organized coordination efforts challenging. Further, studies suggest similar challenges for countries and projects that want to engage in telemedicine activities, given the large equipment requirements to facilitate videoconferencing between multiple locations and entities (E20). Even hospitals in the United States face the challenge of funding these expansions, relying heavily on temporary government grants and subsidies without a sustainable business model. Moreover, while mobile phones can play a critical role in communicating information during an emergency, the inevitable congestion of the network makes it an unreliable tool (E25, E29, E30).

In order for EMRS to be effective, citizens must have knowledge of protocols to be observed during an emergency (E9), in addition to the meaning of an alert (E25, E29). In countries where systems are fragmented by informal and privatized systems, general knowledge of who to contact in the case of an emergency may be a challenge (E16). As parts of these systems come into place, it will be important to accompany them with social marketing campaigns.

The technology proposed in some EMRS studies is advanced and complex, even for user adoption in high-income countries. Remote patient monitoring systems require a set-up of wireless sensor networks in the individual's

[1] While the emergency systems in the United States have significant human and physical resources, they are generally unable to share information between segments of the response chain, reducing the effectiveness of information gained at a particular stage, e.g., 9-1-1 emergency calls, emergency medical (ambulance) services, and emergency departments or trauma centers.

home. Traditional systems require significant equipment and capital (E3, E4, E5, E6, E7). Further, studies leveraging basic mobile phone functionalities such as GPS, video, and camera were found to still require improvement, challenged by accuracy and transmission (E10, E12, E13, E14, E15, E18, E19). Since mobile phones have been advancing rapidly, the field would benefit from repeating these studies with updated technology.

The cost of implementing studies to evaluate impacts in this area can often be prohibitive, requiring the distribution of mobile phones to all study participants (E26). The lack of data interoperability between response elements makes end-to-end data collection and assembly costs significant, and usually prohibitive. Some programs that rely on grants are at risk of ending operations once the study is completed (E21). Further, the implementation of technologically advanced systems such as wireless sensor networks and telemedicine systems can be cost prohibitive for users and institutions (E20, E21). Uptake of these technologies will rest heavily on the industry's ability to drive costs down and leverage existing infrastructure, as well as changes in reimbursement policies.

In relation to policy development, the use of mobile phones for sending photo images has yielded inconclusive evidence. It appears the functionality works better in some fields of medicine in comparison to others, depending on the photographic detail required to make a diagnosis. Health care providers would benefit from guidelines that outline the acceptable use of mobile phones as an imaging device.

mHealth Barriers and Gaps

There are many opportunities within mHealth as highlighted throughout the literature. Many of the barriers to and gaps in mHealth scale and sustainability result from the lack of policies, strategies, and guidelines to better align international and national health priorities with the opportunities generated by the expansion of telecommunications infrastructure and the evolution of lower cost, more powerful handsets and more advanced mHealth applications and systems. Much of this is due to the limited knowledge of what works, how it works, and how much it costs. There are a number of challenges that ought to be acknowledged within the discussion of the barriers to and gaps in mHealth in LMICs.

Cost-Benefit

The first challenge is examining benefit in relation to cost, both at the macro systems level as well as at the level of the individual citizen and healthcare provider. The research presented in this report has focused primarily on the health benefits generated through mobile technology and makes clear that there is little evidence of the health value of mHealth (and eHealth for that matter). On the cost side, there is a need to move from corporate social responsibility (CSR), in-kind support, and funding for pilot projects at district and regional levels, to national programming with defined targets. This will only be possible through well-negotiated and informed public-private partnerships that marry political will and national health infrastructure with telecommunications core business expertise and national telecommunications infrastructure in an effort to mesh the public interest in efficient and effective public health and health service delivery with private sector interests. To support this, appropriate economic evaluation studies are needed to develop the health and economic value chains throughout the continuum of care. Understanding the overall values created by applying modern ICT, especially mHealth, will allow the parties to then have a better understanding of the individual roles of the private sector, public sector, and governments, in addition to partnerships and hybrid models that exist between them. Examples of south-south collaborations have been shown to support the development of mHealth solutions that are more sustainable and culturally appropriate (F3). Project Masiluleke, based in South Africa, brought together mobile phone operator MTN, public sector organizations National AIDS Helpline and National Geographic Society, and handset manufacturer Nokia, to launch a mass awareness campaign on HIV/AIDS.

Access to and delivery of health services in many LMICs is complex, and the introduction of ICT solutions may not be seen as a critical priority. This particular challenge highlights the need to show the contribution that technology can make toward addressing key health priorities and the efficiencies and cost-benefits they generate. mHealth project impact must be assessed not only by touting uptake, usage, and the potential of a particular technology, but also by specifically addressing how the technology is affecting people’s behaviors and health outcomes and lives in both positive and negative ways so that appropriate investments can be made.

Architecture, Standardization, and Platforms

As illustrated throughout the white paper, there are many mHealth applications systems and platforms in development and use throughout the world: both open source and proprietary. At present, there is no common architecture for mHealth. Indeed, there is no common architecture for eHealth. A key challenge is that there is almost never a single "owner" of all of the elements within a health system who can require an overall, interoperable approach. Movements toward a single "owner" are occurring in several LMICs through the development of eHealth strategies, councils, and enterprise architectures; however, the multiplicity of countries would guarantee an inability to gain the benefits of information interoperability between countries unless some basic standards for interoperability and information are developed and used to drive national e- and mHealth implementations. What is needed is a common technical architecture that enables interoperability and scale, while enhancing country ownership and control of policy, business rules, information flow, and the like. There is a clear need for an agreed-on mHealth and eHealth technical architecture, including data exchange standards, to overcome the barriers to integration and interoperability in the overall health system that are epitomized by the inability of these related systems to contribute to and derive information from one another. A fundamental aspect of this problem is the growth of mHealth-supported initiatives and eHealth-supported initiatives that are not integrated with relevant national health systems or priorities for multiple points of access. In many cases, due to vertical funding programs, they have been developed only for a specific disease (e.g., HIV/AIDs) and cannot be used to support other health conditions or primary health care in general.

In this respect, LIMCs are at a critical impasse. ICT generally and mobile solutions specifically are just beginning to be used in these countries, albeit almost invariably in uncoordinated, non-interoperable ways. The present path leads to the current state of health information technology (IT) in the United States and other developed countries: large IT implementations with interoperability problems and major difficulties in deriving the full benefits from a new, highly disruptive technology like mHealth. In the developed world we are now paying an enormous price to create interoperability and standards, and impose them on resistant legacy infrastructures and political and service delivery environments.

High-income countries and LMICs alike are facing similar challenges, including integration of complex software and networks, human resource coordination and training, and confidentiality enforcement while allowing interoperability. Billions of dollars are now being spent in the United States to try to overcome this legacy of individual proprietary health IT development and implementation. LMICs have an opportunity to learn from the case of the United States and Western Europe. As part of their health systems strengthening efforts, LMICs can develop policies and enterprise architectures to guide and inform the deployment of small- and large-scale health IT systems in a way to ensure contributions to health-related Millennium Development Goals and national health priorities, while optimizing conditions for scale and sustainability. What is lacking is a guide for countries on how to integrate mHealth into existing eHealth and overarching health and ICT policies and then how to practically put such policies into operation. Also lacking is a global program to develop such a guide. There have been halting steps toward this, but many of them have been country and/or disease specific.

We need to start by thinking of health as an overall project or "enterprise" or "eco-system" with many stakeholders. A system that is tailored to facilitate the achievement of an agreed set of health objectives is needed to identify the requirements for this "virtual enterprise." From those requirements a common architectural design that can scale can be developed and implemented that shares as much technological hardware and software as possible between countries, while enhancing individual countries' control of policies, information distribution, and content.

An architecture of this kind would identify where and what standards for information exchange are needed. There are valuable current standards efforts underway by groups and communities such as the Continua Alliance, OpenROSA, OpenMRS, and the Open Mobile Consortium (OMC). An accepted architecture would provide a context for their standards work. We note that these groups are not internationally recognized standards development organizations (SDOs). Efforts to establish interoperability standards by groups such as International Organization for Standardization (ISO), Health Level Seven International (HL7) and the supporting U.S. Health Information Technology Standards Panel (HITSP), are excruciatingly slow, and focused entirely on high-resource settings in high-income countries. While it is in the wireless industry's interest to help solve this problem, because of the significant growth in wireless demand that mHealth interoperability solutions would create, they are not equipped to define the standards themselves—particularly those related to health.

Policy Barriers

Beyond the effective use of mobile technologies by the health sector is a broader discussion of the mHealth policy environment that encourages deployment, supports it financially, governs utilization, recognizes it as a legitimate medical service, and advances the interests of both health workers and citizens. Policy makers and other stakeholders are moving and need to continue to move from technology-driven approaches (solutions in search of problems) to health sector-driven demand. To date, there are few national eGovernment, eHealth, and health information systems (HIS) policies that take into account the increasing access to telecommunications infrastructure and availability of mHealth solutions. Practitioners feel that the pace and demand of mHealth on the ground is not being met by enabling policy, funding, and regulations at national and institutional levels. The more typical approach by governments in the developing world is to believe that they must wait for the delivery of broadband before major health benefits can follow. This creates an enormous investment barrier to the deployment of eHealth, a barrier that is simply unnecessary given the widespread and rapid deployment of commercial wireless networks almost invariably using solely private funds built on market penetration.

To help support the transition to scale, policies are needed to coordinate the objectives of mHealth initiatives with nationally defined goals and objectives. These should be based on the growing evidence as exhibited in this analysis of peer-reviewed literature on mHealth as well as frameworks that help link national priorities to proven mHealth solutions with the potential to scale, while fostering an environment for informed innovation to continue to generate novel mHealth approaches to addressing health issues. As will be discussed in more detail in the section to follow, more rigorous research to evaluate costs and benefits, quality of care, and impact on health outcomes is needed to fully enable governments to make well-informed investments in mHealth. Similarly, there needs to be more evidence of the business value of mHealth to drive private investments. The absence of such policies and related studies hampers mHealth scale and sustainability.

The global health objectives and policies that are most affected by and that can help drive mHealth scale and sustainability are outlined below, in addition to suggestions and considerations on how they should be shaped.

Table 2: Summary of mHealth-related policy barriers

Major policy barriers	**Lead actor (other stakeholders)**	**Potential benefits from policy reform**
Network coverage	▪ Telecom Operators ▪ Network Manufacturers ▪ Government	▪ Encourage private sector to deploy transport capacity allowing Increased scope of mHealth initiatives in rural and low-income communities
ICT rights and regulation	▪ eGoverment (usually based within the Ministry of Communication or ICT)	▪ Social priorities for use of ICTs ▪ Broader guidelines defining identification, security, confidentiality
National health priorities	▪ National Ministry of Health ▪ eGovernment	▪ Alignment of mHealth initiatives with broader health system goals
Global eHealth and mHealth architecture, interoperability enabling services, and standards	▪ United Nations and agencies ▪ Donors ▪ Governments ▪ Wireless and IT industries ▪ SDOs	▪ Cooperative environment needed to find and address common requirements, design, shared systems and services, standards, and the like ▪ Show how common ICT architecture enables greater national control over health care delivery, outcomes, and costs
Acquiring systems that comply with architecture and interoperability standards	▪ Government ▪ Ministries of Health ▪ Donors	▪ Foundation for a cohesive national health information system, including eHealth and mHealth ▪ Stop funding lack of interoperability; insist vendors comply with architecture and standards
Personal ID	▪ Government ▪ Health Information Systems	▪ Crucial for Electronic Health Records (and mBanking) ▪ Systems integration ▪ Better care and treatment from being able to access patient health profiles from multiple touch points
Developing policies for use of systems and data that are effective, efficient, secure, and responsive to local needs	▪ National Governments ▪ Provincial Governments	▪ Provides country ownership of what counts—use—while gaining benefits of global technical market

Management of core services: identity, access control, registries of parties	▪ Government ▪ Non-profit stakeholder collectives	▪ Increased trust from community ▪ Increased adoption of mHealth and eHealth
Data rights and governance	▪ Government ▪ National Ministry of Health ▪ Health Information Systems	▪ Maintaining integrity of data collected using mHealth initiatives ▪ Ensuring data is used to benefit the communities it is collected from
Medical advice liability	▪ National Ministry of Health and Legislatures	▪ Patient and professional protection ▪ Liability protection when protocols are followed ▪ Increased trust ▪ Governance of using mobile technology and ICTs to deploy medical advice
Telemedicine	▪ National Ministry of Health ▪ Health Information Systems ▪ eHealth	▪ Capitalize on the opportunity to use telemedicine to overcome human resource challenges in developing countries and rural areas ▪ Increased patient care from increased access to medical advice using mobiles
Access to health information	▪ eGovernment ▪ Health Information Systems ▪ National Ministry of Health	▪ Increased commitment to developing in-country ICT infrastructure as a pathway to accessing health information
Public-Private Partnerships Codes of Practice or Rules for Engagement	▪ Government ▪ Telecom Operators, IT operators ▪ Device Manufacturers ▪ NGOs; Donors; Foundations	▪ Developing success models where public and business interests are both served ▪ Seek ways to increase entrepreneurial and commercial investment and solutions for mHealth, while maintaining openness to ensure equitable access to services in a cost-beneficial manner
National mHealth initiative guidelines	▪ National Ministry of Health ▪ NGOs; Donors; Foundations ▪ ICT leaders	▪ Requirement for mHealth pre-implementation analysis to ensure initiatives align with national health goals and include strategy for monitoring and evaluation
Standardized metrics	▪ Academic experts ▪ Business experts	▪ Consensus on common metrics ▪ Opportunity to compare effectiveness of mHealth initiatives across geographies and health verticals

Millennium Development Goals (MDGs)

In 2005, the United Nations Millennium Project identified practical ways to achieve the MDGs, however, questions arose regarding sub-Saharan Africa's ability to achieve the targets given its low food productivity, heavy burden of infectious disease, and insufficient core infrastructure—including water, roads, power, and telecommunications. The key MDGs for health focus on reducing maternal and child mortality and improving the health of women and children alongside reducing the burden of what are known as the diseases of poverty, namely HIV and AIDS, malaria, and tuberculosis. Many of the mHealth interventions described throughout this white paper address the MDGs. However, there has been limited concerted effort devoted to setting targets for how many people can be reached or what intermediate health outcomes can be attained. As part of our work at the Earth Institute with the Millennium Villages Project, we have developed a framework for exploration of the critical pathways between mHealth interventions and inputs and the MDGs at the patient level as well as in relation to health professionals. Within the international health community, mHealth has the potential to increase reach and improve quality of services and prevention efforts aimed at the accelerated achievement of the MDGs. Institutions such as WHO, ITU, GSM Association, and World Bank along with the mHealth Alliance and Digital Health Initiative should work together to develop a framework to guide national level mHealth efforts that aim to leverage mobile and other electronic systems to accelerate the achievement of clearly articulated sub-targets within the MDGs.

National Policies

At the national level, many governments have a broad range of policies that can be leveraged to drive and guide mHealth implementations, beginning with eGovernment, Health Strategic Plans, eHealth, and Health Information Systems, among others. mHealth should be considered as part of the overall eGovernment and eHealth/HIS policy frameworks, which often define broad parameters including identification, security, and network reach and highlight social priorities for the use of ICTs including education and health. Commercial wireless signal coverage is being rapidly extended to more and more rural areas, whereby over 90% of the world's population is now covered and the percentage is rising rapidly. However, the continuing lack of universal coverage in some rural areas weakens the ability to implement mHealth initiatives at a national scale. While pure market forces have driven, and continue to drive, the global wireless explosion almost entirely, it is likely that some government incentives to extend network coverage may be required to ensure coverage for remote populations where such services stand to have the greatest impact.

It is highly desirable to begin conversations with operators, manufacturers, governments, and users to determine how market-based approaches to usage and fixed pricing for voice and data services can be leveraged to meet the needs of all relevant stakeholders. For example, wireless carriers in the United States and other countries had great success giving away handsets and making emergency calls (to 9-1-1 in the US) free. It is conceptually straightforward to see how providing smart phones to community health workers for free or at reduced rates could help create broader demand for them. Similarly, carriers could encourage acquisition of phones by the public by providing free or reduced rate calls to or for medical personnel (or governments could contribute to the reduced rate through fixed payments to carriers). Social marketing of mHealth services and building fixed pricing structures to eliminate surprises for governments need to be explored and tested to ensure sustainability and a win-win for industry and the public sector.

Enabling policies that minimize entrepreneurial risk and maximize reward for telecom operators will help spur market-driven solutions for mHealth, similar to the development and success of mobile banking systems such as m-PESA. Commercial solutions that are affordable and accessible will reach scale and sustainability by providing customer-defined value. Currently, governments are relying on NGOs to test how mHealth works and fits into national systems. The risk with this approach is that if mHealth is seen as being largely driven by external forces, then it may begin to be perceived as a technology searching for problems, and foisted on governments as another expensive, hyped, "silver bullet" that does not fulfill expectations. Instead mHealth should be driven by a country's health priorities and targets so that donors and mHealth implementers are collectively contributing to them in a systematic and structured fashion. Similarly, it may be driven by the private sector. Much of health care in the developing world is private (even in rural areas, such as those in India, where out of pocket expenses are the largest single source of health payments). Governments should consider encouraging private employers, private providers, and operators to work with NGOs, health experts, and others to develop, trial, and evaluate solutions with an emphasis on costs and benefits to assess mHealth value.

Global policies are needed to establish data and interoperability standards for mHealth and eHealth implementations. Standards and other IT elements of scale simply cannot be done country by country. Policy, rules, finance, and content generally must be developed at the country level. Where countries are developing eHealth plans, mHealth ought to be included. It does not make sense to develop mHealth and eHealth into different silos. Using the mHealth Alliance and other collaborations, such as the Digital Health Initiative, as a platform for collaboration between international bodies, national governments, practitioners, and the private sector to draft the international policies needed to better inform architecture, standardization, information security, and telecommunications legislation is critical to accelerate progress. It is also important to consider the end-user during policy development, engaging community members for more human-centered policy development.

Within such policies, issues such as data security, access control, and thus confidentiality must be addressed (as they have been for mFinance). The development of personal identity systems for the public in LMICs is crucial for developing integrated systems across local, regional, and national health boundaries, in addition to making electronic health records securely accessible through multiple platforms (i.e., mobile, computer). However, this shift will have to be accompanied with an agreement on how to address systems for identity management and security. Mobile phones in LMICs are often shared among household members, meaning the device itself cannot be counted on as the identifier. Discussions regarding the intersection of mFinance and mHealth should be given high priority because they may yield common policy and technological solutions to address such concerns—and provide a stronger business and sustainability case for mHealth.

As the deployment of more formalized mobile technology-enabled telemedicine expands, policies and legislation are needed to define liability when delivering health information and medical advice using voice and text as well as other mobile phone functionality such as SMS, video, camera, remote patient monitoring devices, and payments. Telemedicine technology and capacity has advanced in countries such as Malaysia and India, and while some countries have developed policies and legislation to govern its use, the need for liability and malpractice guidelines are crucial for scale and sustainability. This was shown in the case of Thailand, where the lack of telemedicine policies inhibited the scale-up of mHealth applications related to emergencies. A central way to address such issues is to develop global (or at least regional or national) templates and protocols.

An area that needs further exploration is the obligation of governments and the international community to promote access to health information by citizens as a key determinant of the right to health. Work in this area is now being undertaken by the Healthcare Information For All by 2015 initiatives in partnership with the New York University Law School. The updated review illustrated that data being collected through mobile initiatives is only going one way and generally through one operator at a time, with few examples of how it is being used to benefit individuals or their communities. Questions surrounding the rights to health information should be addressed under this policy framework, in addition to issues regarding information usage. This is essential to building trust within communities, as there are cultural distinctions about how personal health information is viewed, along with fears as to how it might be used by authoritarian governments. Taking this into account during the deployment of initiatives and research studies is imperative to honor the integrity of individuals and communities. Efforts should be made to streamline access to information through a common set of short-codes for voice and text-based mHealth services to advance universal access and to increase bandwidth for mobile broadband services to minimize the burden of multiple SIM cards to access each mHealth platform through a separate network operator.

Further, as the field continues to accelerate, increased investment in the development of a workforce to support mHealth initiatives will be critical for sustainability. This includes engaging institutions and academics to support the development of training programs for project managers, health informatics specialists, and application developers to name a few.

When making budgetary decisions regarding mHealth, governments, donors, and industry partners will need to become acquainted with their respective roles and strengths in driving scale and sustainability. There is significant untapped expertise within the telecommunications and IT industries in how best to leverage networks and deploy applications at scales that governments could benefit from. However, governments and health experts must be clear about their needs and desired outcomes to negotiate partnerships and drive and hold industry accountable to its commitments. Public-private partnerships must strike a balance between the promotion of entrepreneurship locally and regulation of healthcare to maintain the integrity of its patients' security and health. Increasingly, discussions on rules of engagement for telecommunications companies in health activities are emerging, indicating a need for guidelines that can facilitate relations and negotiations between public and private partners. Some basic recommendations for overcoming the absence of a policy framework and guidelines for mHealth include:

- Map a country's public and private health system alongside telecommunications and ICT infrastructure and services in its entirety, including all the stakeholders and participants, not just the formal providers of acute care and public health, and how they can be leveraged to address targeted health priorities. This can be called a virtual enterprise because it has no single owner.

- Ensure that new and existing mHealth initiatives contribute to health priorities and conform to existing policies. In other words: *What are the requirements of this virtual enterprise and how should each stakeholder position itself to make a meaningful contribution?*

- Develop the basic skeleton of an enterprise architecture and data integration standards based on internationally recognized platforms and standards in response to identified priorities and requirements.

- Focus national attention on content, use rules, and policy, i.e., the use of underlying ICT infrastructure.

- Identify policy gaps and initiate efforts to address them.

- Develop solutions that leverage existing infrastructure and knowledge and comply with international standards.

- Conduct pre-implementation analysis and adapt software solutions based on priorities, context, and available infrastructure and resources.

- Develop consensus on a "priority package" of mHealth services for a national government to adopt at the outset and how to phase in additional services over time.

- Develop and commission research studies and metrics to explore the health impact and value of mHealth, using metrics identified in the international community for comparisons across countries and types of mHealth applications.

Specifically, governments, donors, and implementing partners in the private sector and within NGOs can work collaboratively to help foster coherence within mHealth and contribute to the growing evidence base by aligning on implementation guidelines such as:

- Requiring that organizations developing software solutions comply with global and countries' enterprise architectures to ensure that systems can be integrated and are interoperable, and that they align with a country's national health priorities, context, available infrastructure, and resources.

- Being open to agile research design, but ensuring the study is replicable and includes qualitative and quantitative analysis and adequate sample sizes.

- Promoting standardized metrics so that project champions and governments can compare mHealth projects within a country and between countries on specific health domains to better understand the value and impact of each.

- Creating a collaborative environment where plans, projects, successes, and failures can be shared globally.

mHealth is dynamically shifting from pilots to integration and mainstreaming into existing health systems strengthening and other health-related initiatives, including the accelerated achievement of the MDGs. Since measuring impact is challenging for short periods of time or with small, point-solution projects, the movement to scale poses an opportunity to quantify impact. The excitement about mHealth is based on its potential to improve health and reach people who have been beyond the reach of traditional, facilities-based approaches. It will become more and more important to identify policy gaps and develop guidelines that will govern the use of mobile technology-based solutions for health that link them to national and international targets such as the MDGs.

RESEARCH GAPS

The emphasis on eliciting research gaps as highlighted in peer-reviewed publications was a significant departure from other mHealth reports, which focused on program and applications descriptions with very little documentation of what does and does not work. While many claim that the evidence base for mHealth is weak due to the lack of published material on the subject, this review found that there is a rapidly growing body of literature on the subject. However, the geographic location, scope of the implementation, sample sizes, and methods used do not provide statistically significant results that would inspire governments, industry, and donors to make the investments needed to truly capitalize on the reach of telecommunications infrastructure and the widespread uptake of services in LMICs. Further, a large portion of the research is concentrated on initiatives pertaining to HIV/AIDS, tuberculosis, and malaria, as a result of available funding. While important, the combination of epidemiological shifts in developing countries with the vast potential of mHealth calls for a more inclusive research agenda with funding that supports varied initiatives. This section highlights some of the research gaps in mHealth that need to be overcome to solidify the evidence base for more informed decision making by potential stakeholders in the mHealth value chain.

A key challenge is that there is very little accountability among donors to show what works among mHealth implementations, as illustrated by the historic lack of funding for monitoring and evaluation. Those that need the evidence to invest more broadly are governments and companies, while those investing in pilots tend to be bilateral and private donors. With governments not involved in the project planning process, key decision makers are often unaware of the complete picture of mHealth activity across the country, making it difficult to draw upon evidence to inform planning and policy development. On the other hand, practitioners struggle with supporting the cost and resources required for monitoring and evaluation. Even further, the nature of the technology is such that by the time projects are completed and evaluations are conducted, the technology has changed, often resulting in outdated conclusions. As such both the evidence base and the business model for mHealth remain weak.

In general, most projects implemented were pilots addressing a specific, single problem using a small population and a fixed duration, often limited to one to two years. For the projects that integrated a research component, mostly in high-income countries, the sample sizes ranged from 5 to 200 individuals and/or were implemented retrospectively after the project was implemented. Longer duration studies—those that were implemented for over one year—showed a substantial difference in health, standard of living, communication, and systemic change. Many of the published studies employed qualitative study design parameters, including ethnographic methods, interviews, and observations. Those using quantitative methods varied significantly in the variables under study depending on the mHealth program objectives (i.e., treatment compliance versus data surveillance), making it difficult to make comparisons across implementations. Overall, the evidence base presented fails to adequately reflect how mHealth addresses current health system shortcomings to help governments achieve overarching national health goals. In fact, the ease of use of mobile technology, and thus the ease of implementing studies, may prove to be dangerous from a research perspective, resulting in the development of a series of islands versus coordinated efforts and systems.

Furthermore, many of the studies are conducted by the implementers themselves and focus on users and user perceptions, including tracking the number of days it takes for a user to utilize all the functions of a particular technology or how long it takes for them to figure out how to use a new application or system. In this vein, one must differentiate between whether the results of a study are statistically significant or practically significant. It appears that researcher and practitioner activity are becoming increasingly separate, with practitioners focused on implementation and innovation, without any time or tradition of analysis, evaluation, and publication. Since many practitioners come from a technology background, in comparison to academia or health, the skills to conduct rigorous impact evaluation and project costing may be a barrier, and thus an opportunity for health researchers and practitioners to collaborate for increased guidance.

An evidence base is a crucial foundation upon which to build a public health intervention. However, more agile research methods may be needed than the gold standard of randomized control trials that may sacrifice precious time in implementation and widespread rollout of an intervention with proven results from other types of study or a cross-section of studies. Perhaps, there is a need for a systematic review of the literature that highlights where evaluation has been rigorous, and the types of evaluation methods employed in mHealth and ICT in general.

In relation to targeted mHealth research, there is need for more:

- **Comparison studies** (applications/technologies) to study effectiveness of technology for health intervention (e.g., SMS, voice, mobile for data collection)
- **Cross-country studies** (how one technology works in a couple of countries—what is similar, what is different)
- Studies that show the **role of integrated technologies** (decision support tools, data collection platforms, telemedicine, electronic medical records, community engagement platforms, and other new and legacy systems connected to share information about a patient during the continuum of care, or among providers about their work)
- **Replicable study design**, which includes quantitative and qualitative analysis, and **adequate sample sizes**
- **Rapid staged evaluations** to assess the early effects of new applications
- Long-term studies that report tangible **health and patient outcomes, and business outcomes**
- **Cost-benefit studies of all kinds**, including for countries with national insurance schemes, to help make the case for provider reimbursement, in addition to providing evidence to governments that mHealth is an economic development strategy that can lead to job creation and entrepreneurship. Donors also need to

see that there are more efficient ways to spend their billions of dollars worth of contributions to health initiatives in LMICs.

- **Standardized indicators** (process and outcome) for monitoring and evaluating mHealth effectiveness and impact at different levels of the health system and among clients

While the increase in the past year of studies in peer-reviewed journals is a promising trend toward better knowledge of what works and why, the speculation in existing reports in the gray literature points to economic benefits and improving health outcomes with little documentation of which projects and what characteristics result in such benefits.

Ultimately, fulfilling these research needs will require significant funding from governments, donors, and the private sector. To more strategically contribute to the growth of the industry, it has been suggested that funding partners for mHealth should each take on separate but coordinated roles. Government should focus on initiatives that align with health systems strengthening and have potential for integration within existing health information systems. Donor funding should complement government initiatives, focusing on front end research and development to produce successes that governments in collaboration with others can scale. Lastly, telecommunication operators and device manufacturers should support funding and in-kind leveraging of their infrastructure and core business expertise for innovations in mHealth that have potential to be commercially viable with adherence to some basic principles of corporate engagement and advance scale and sustainability. Additionally, creative ways to sustain funding for mHealth should be further explored. Some suggestions include allocating funds generated from mobile spectrum auctions, allocating a portion of the taxes generated through mobile services such as voice and other value-added services, or allocating funds from the general budget of the national health insurer, if applicable.

To maximize the impact of this proposed funding for mHealth, the following recommendations should be considered. Firstly, health research experts from across the globe need to develop a consensus on research priorities in mHealth, in addition to advising on the methodologies, research designs, and metrics that should be employed for future studies. Secondly, partners need to create an environment that rewards open communication and sharing of successes and failures, without the fear of losing future funding opportunities. Sharing platforms will ensure interoperability and advance scale more rapidly, while openness about failures and lessons will allow the area to expand in depth and quality of services provided. Lastly, this review found significant duplication of efforts among mHealth projects, indicating the need for a clearinghouse of what works and what does not. Developing an “open source” approach will enable individuals to learn and build on the successes and failures of previous mHealth efforts.

Recommendations and Considerations

The following recommendations are based on findings from the review and suggestions from our panel of roundtable members and virtual reviewers.

1. **Collaboration**

   a. If mHealth project ideas are developed in tandem with a support body from the Ministry of Health there will be a greater likelihood that the project will address already identified needs. Further, it will start the conversation to begin mobilizing greater support for mHealth at an institutional level, driving policy changes that need to take place for national scale.

   b. There is significant duplication of efforts among mHealth projects, indicating the need for a clearinghouse of what works and what does not. This "open source" approach will enable individuals to learn and build on the successes and failures of previous mHealth efforts.

   c. There are clear synergies between mobile payment systems (mBanking) and mHealth, and each is likely to be an integral component of the other, especially since micropayments will be a significant method of payment in LMICs without a pervasive health insurance system. Research and policy development should begin viewing mobile initiatives holistically, versus in silos.

   d. Using the mHealth Alliance and other collaborations, such as the Digital Health Initiative, as a platform for collaboration between international bodies, national governments, practitioners, and the private sector will be critical to draft international policies pertaining to architecture, standardization, information security, and telecommunications legislation.

   e. Health research experts from across the globe need to develop a consensus on research priorities in mHealth, in addition to advising on the methodologies, research designs, and metrics that should be employed for future studies.

2. **Financing for mHealth**

   a. Funding partners for mHealth should each take on separate but coordinated roles to more strategically contribute to the growth of the industry. Government should focus on initiatives that align with health systems strengthening and have potential for integration within existing systems. Donor funding should complement government initiatives, focusing on front-end research and development to produce successes that others can scale. Lastly, telecommunication operators and device manufacturers should support funding and in-kind leveraging of their infrastructure and core business expertise for innovations in mHealth that have potential to be commercially viable and advance scale and sustainability.

b. Creative ways to sustain funding for mHealth need to be further explored. Some suggestions include allocating funds generated from mobile spectrum auctions, allocating a portion of the taxes generated through mobile services such as voice and other value-added services, or allocating funds from the general budget of the national health insurer, if applicable.

c. A strong evidence base that includes cost-benefit studies is crucial to identifying “mission critical” mHealth scenarios and applications essential for LMICs, and subsequently mobilizing funds to support these targeted initiatives.

d. Funding partners need to create an environment that rewards open communication and sharing of successes and failures, without the fear of losing future funding opportunities. Sharing platforms will ensure interoperability and advance scale more rapidly, while openness about failures and lessons will allow the area to expand in depth and quality of services provided.

e. Unless sustainable business models are developed, the current approach of donors subsidizing provider costs will ultimately prevent projects from ever being financially capable of reaching scale, or remaining viable following the end of project funding. The need to engage business professionals to construct innovative business models that take into account the constraints of a country’s health system and a community’s purchasing power is crucial for sustainability.

3. Infrastructure

a. Increased coverage in rural areas, including faster networks, is critical to realizing the potential and scope of mHealth.

b. High-performance devices at affordable prices for Community Health Workers, including larger screens, faster processors, and increased memory, are needed to support the capabilities of applications. Further, the devices should account for security, imaging, and ruggedness to support the conditions of rural areas in developing countries.

c. Consideration of investment into alternative power sources, such as solar panels and micro-wind turbines, will help overcome the barrier of having charged mobile phones that are reliable in a healthcare setting.

4. Community Engagement

a. Initiatives are being developed without the end-user at the table. Taking more of a human-centered approach to developing mHealth initiatives will be crucial for sustained demand, and can be achieved by finding a balance of working with Ministries of Health in addition to local communities.

b. Developing trust among consumers and communities will be important when trying to engage a large sample of research participants, in addition to creating sustained demand for scale. This will require conveying the benefits of mHealth initiatives, in addition to ensuring information is secure and confidential. In LMICs, where some health conditions are stigmatized, communicating this to communities will be crucial for support.

c. Literacy, language barriers, and perceptions about western medicine are factors unique to each community, and should be addressed during the deployment of mHealth projects.

5. Human Resources

a. Additional efforts in educating health professionals about the potential role of ICT in healthcare delivery will be critical for mass adoption. These must be focused on the benefits to the professionals themselves.

b. The sustainability of mHealth will weigh heavily on a workforce that is able to support it and use the tools being created. Training within institutions should be happening concurrently as the field advances, preempting the requirements when scale is achieved. This includes the need for project managers, health informatics specialists, and application developers, to name a few.

6. Monitoring and Evaluation

a. Evaluation is important, but can be expensive until integrated information systems are deployed (making creation of data to study a byproduct of care delivery). Funding mechanisms need to be better structured to include high-impact monitoring and evaluation requirements and support for mHealth initiatives to ensure lessons can be extracted for the field as a whole.

b. Guidance on how to conduct rigorous evaluation and research on mHealth projects in a consolidated and accessible manner, that emphasizes “agile” research approaches, may be needed for the technical professionals in the mHealth community.

CONCLUSION

There is a growing body of evidence for what works within mHealth and where the underlying barriers to and gaps in scale and sustainability are at present. Mobile technologies when applied to addressing health issues such as treatment compliance, disease prevention and health promotion, point-of-care support for health professionals and outreach workers, telemedicine, and emergency medical services are beginning to gain traction and show positive, albeit mixed results. Many of the systems have been implemented and evaluated as stand-alone initiatives at too small a scale to ascertain health impacts and value for investment. For mHealth programs to succeed, an enabling well-informed policy and business environment that engages all relevant public and private health and IT stakeholders to drive scale and sustainability is needed. The potential of this technology will only be realized if a systematic approach is taken to integrate all its moving parts and direct them toward concrete measurable health objectives and desired outcomes. Governments need to develop a strategic eHealth framework in which mHealth is an integral component in order to provide mHealth implementers in the NGO and private for-profit sectors more guidance when implementing projects to ensure alignment with their eGovernment, health information systems, and other relevant policies and aims to leverage technology for public good. This should include national health priorities, enterprise architecture for interoperability and data standards, and commonly used metrics evaluation techniques for assessing the impact of mHealth. A proactive cycle of strategy, implementation, and evaluation to in turn inform strategy at the global, national, regional, district, and community levels will generate the platform needed for implementation of more and better mHealth systems that generate health benefits for citizens and health workers in LMICs.

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