ABSTRACT  Developing countries face steady growth in the prevalence of chronic diseases, along with a continued burden from communicable diseases. “Mobile” health, or m-health—the use of mobile technologies such as cellular phones to support public health and clinical care—offers promise in responding to both types of disease burdens. Mobile technologies are widely available and can play an important role in health care at the regional, community, and individual levels. We examine various m-health applications and define the risks and benefits of each. We find positive examples but little solid evaluation of clinical or economic performance, which highlights the need for such evaluation.

Economic development improves health. It increases life expectancy and well-being and decreases child mortality and birth rates.\cite{1, 2, 3} This relationship reflects the effect of rising incomes on access to health-enhancing goods and services,\cite{4} such as improved diet, sanitation, and health care. Further, economic development drives an “epidemiological transition,” from a predominance of infectious diseases to chronic, noncommunicable ones.\cite{5, 6} At the same time, improved health spurs economic growth. Better physical and mental health increases labor productivity; reduces days lost to illness; decreases medical spending; and fosters investment in education and capital as a result of longer expected life spans.\cite{6, 7, 8} Thus, a “virtuous cycle” exists, with mutual reinforcement of economic and health progress.

Mobile health, or m-health—the use of wireless communication devices to support public health and clinical practice—has great potential to enhance this virtuous cycle. More than any other modern technology, mobile phones are used throughout the developing world.\cite{9} Innovative applications of mobile technology to existing health care delivery and monitoring systems offer great promise for improving the quality of life. They make communication among researchers, clinicians, and patients easier, and as chronic disease becomes more prevalent, mobile technologies offer care strategies that are particularly suited to combating these conditions.

In this paper we propose a conceptual model to consider the potential contributions of m-health to help address the huge health care challenges in developing countries. We examine the relationship between wealth and health, and we document the growing burden of chronic disease in developing countries. We describe ways in which mobile health technologies can contribute to a nation’s health care response, at the regional, community, and individual levels.

Health And Health Systems In The Developing World
Developing countries face an increasing incidence of noncommunicable chronic disease, even as communicable disease remains a persistent threat. Diseases formerly concentrated in developed countries, such as hypertension, obesity, heart disease, and diabetes, are on the rise (see Online Appendix).\cite{10} The combined effect of communicable disease and chronic or noncommunicable disease is described as a “dual burden” for developing countries.\cite{11} Successful efforts to reduce the dual burden of disease will...
improve quality of life for millions. M-health offers some hope on both fronts.

The leading preventable causes of noncommunicable diseases globally are tobacco, poor diet, and low physical activity. They contribute to heart disease, diabetes, lung disease, and cancer—conditions that account for half of all deaths worldwide. All are projected to increase in the developing world as incomes rise. Chronic, noncommunicable diseases require unique care strategies that may be difficult to deliver in developing countries and that may benefit from mobile technology. This is the case for several reasons.

(1) The long latency period for chronic diseases often requires early, broad-based community health interventions. (2) Reducing chronic disease often requires rejecting behaviors associated with greater wealth (for example, tobacco, diets high in fat and sugar, and low physical activity) and thus relinquishing perceived status value. (3) Treatment of chronic diseases typically uses complex interventions involving ongoing interactions with multiple components of the health system. This requires skilled health professionals and coordinated and continuous care. (4) Chronic diseases often require chronic medication, introducing issues of access, cost, and quality of pharmaceuticals and adherence to treatment regimens. Self-care is often required by people with chronic diseases. Health systems must equip patients to deliver self-care.

Many factors constrain health system performance in developing countries. Infrastructure is limited, and hospital resources are concentrated in urban areas (see Online Appendix). Disease burden—that is, incidence of disease and its impact on people’s livelihoods and economic productivity—is great. There are not enough health care workers (shortages are estimated at 800,000 for Africa), and such workers are difficult to recruit and retain, especially in rural areas. Supervisory and management systems are often lacking or weak. One review of these constraints identified several areas where mobile health might help by removing physical barriers to care and service delivery and by improving weak health system management, unreliable supply systems, and poor communication.

The Promise And Pitfalls Of M-Health In Developing Countries

We define m-health as the use of portable electronic devices for mobile voice or data communication over a cellular or other wireless network of base stations to provide health information. Mobile phones are the most ubiquitous type of equipment in the world: 3.3 billion people—one of every two of earth’s inhabitants—has at least one. The growth of this technology has been transformative worldwide. The penetration is more than 90 percent in the developed world and more than 33 percent in the developing world, including close to 90 percent among some high-risk urban populations.

Exhibit 1 lists some of the ways in which the growing presence of mobile technology may be advantageous and how these technical applications may greatly influence developing countries’ health systems. Mobile communication can foster solutions at different organizational levels: large geographic areas, local communities, and individual patients and providers.

As we review this range of m-health opportunities, we include a few illustrative examples. We identified these examples through professional networks (m-health meetings and colleagues involved in innovative health service delivery), online searches in the journal database PubMed (using terms such as “mobile” and “cell phones”) and Google (for example, “mobile health”); and scrutiny of bibliographies. A useful resource, including capsule summaries of fifty projects, is a report titled The Opportunity of Mobile Technology for Healthcare in the Developing World.

Using the strategies noted above, we found minimal formal evaluation of m-health. Two systematic reviews indicated little formal outcome evaluation of m-health in developing countries. Santosh Krishna examined use of mobile calls and short message service (SMS), or text messaging, in twelve clinical areas and found “significant improvements in compliance with medicine taking, asthma symptoms, HbA1C, stress levels, smoking quit rates, and self-efficacy. Process improvements were reported in lower failed appointments, quicker diagnosis and treatment, and improved teaching and training.” However, this research was conducted in wealthier countries, except for one study in China. A 2006 review reported that “there is almost no literature on using mobile telephones as a healthcare intervention for HIV, tuberculosis, malaria, and chronic conditions in developing countries. Clinical outcomes are rarely measured.”

**LARGE GEOGRAPHIC AREAS** The integrated nature of mobile communication systems provides unique opportunities for m-health in large geographic areas. We discuss some specific applications of m-health below.

▸ **SOCIAL NETWORKING**: Social networking models (that is, techniques to electronically link large numbers of individuals) include various tools, of which mobile text messaging is the most ubiquitous. At the large geographic level, this mass communication capacity can be used to
<table>
<thead>
<tr>
<th>Level of application</th>
<th>M-health tools</th>
<th>Health system functions</th>
<th>Benefits</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large geographic areas</td>
<td>Social networking: users connected via short message service (SMS), instant messaging, or third-party application</td>
<td>Health promotion</td>
<td>Rapidly lower exposure to ecological or epidemic threats; obtain field reports; provide advice; coordinate response; efficiently direct scarce resources</td>
<td>Incorrect information (through error or malfeasance) may create alarm or havoc</td>
</tr>
<tr>
<td></td>
<td>Web surfing: users browse Web sites</td>
<td>Information on health condition diagnosis and care</td>
<td>Patient self-education can speed diagnosis; providers in remote areas can obtain latest information</td>
<td>Poorly designed campaigns could have unintended effects</td>
</tr>
<tr>
<td></td>
<td>E-mail lists for communication</td>
<td>Commodity pricing and purchasing</td>
<td>Health care providers and individuals pay less for supplies and equipment, via price shopping and buyer power</td>
<td>Inaccurate/confusing information can lead to delay or error in care</td>
</tr>
<tr>
<td></td>
<td>Web-based data entry</td>
<td>Disease surveillance case reporting</td>
<td>Improved disease surveillance; increased community awareness and participation</td>
<td>Loss of coordinated supply chain</td>
</tr>
<tr>
<td></td>
<td>Web-based learning</td>
<td>Online courses that allow novel and independent learning</td>
<td>Health care workers maintain and improve knowledge and skills</td>
<td>Misinformation; misunderstanding or not appropriate literacy</td>
</tr>
<tr>
<td>Community</td>
<td>Social networking</td>
<td>Share experiences regarding local health care system</td>
<td>Efficiently navigate health care system to best/most appropriate provider</td>
<td>Incorrect or partial information; loss of confidentiality (disclosure of personal health information)</td>
</tr>
<tr>
<td></td>
<td>Peer-to-peer education: providers and patients</td>
<td>Provide information on health topics of special interest</td>
<td>Shared resources, information exchange</td>
<td>Loss of confidentiality</td>
</tr>
<tr>
<td></td>
<td>Web surfing</td>
<td>Supply pricing and purchasing (local)</td>
<td>Health care providers and individuals pay less for supplies</td>
<td>Loss of coordinated supply chain</td>
</tr>
<tr>
<td>Individual</td>
<td>Data transmission: Send and receive data</td>
<td>Medical imaging: raw data sent to processing center, image returned</td>
<td>Medical imaging services provided in remote areas, improved diagnosis</td>
<td>Loss of confidentiality</td>
</tr>
<tr>
<td></td>
<td>E-mail/text messaging</td>
<td>Provider-to-provider communication</td>
<td>Share information about care for specific patients; exchange best practices; raise quality</td>
<td>Loss of confidentiality; incorrect or misunderstood information</td>
</tr>
<tr>
<td></td>
<td>Provider-to-patient communication</td>
<td>Provider-to-patient communication</td>
<td>Answer questions, provide data and guidance, encourage medication and visit adherence</td>
<td>Burden providers with new channel of patient interaction; loss of human interaction, for empathy/support</td>
</tr>
</tbody>
</table>

**Source:** Authors’ analysis.
mitigate disasters. For example, a message that alerts millions of people about an impending storm or tsunami, or a simple instruction to move 100 yards inland or seek cover, may save hundreds of thousands of lives and reduce an extraordinary unplanned health burden. (To be sure, false alarms—due to erroneous or ill-timed alerts—are a risk of this tool.) After a natural or other disaster, the same tool could be used to conduct damage assessments; coordinate relief efforts; and direct individuals and direct them to safe havens, clean water, health care, and other essential items. Social networking tools can share information about how to treat injuries and prevent the emergence of communicable diseases. Personal digital assistants (PDAs) can be used to tabulate and report survey and surveillance data.

Social networking can also be effective in health promotion, such as in encouraging healthy behaviors through carefully crafted messages disseminated via text messaging. Health-oriented media campaigns that traditionally use billboards, television, and radio can be expanded to include cellular networks. In rural areas, such networks may be the only efficient channel available for public information campaigns. Project Masiluleke in South Africa, for example, sends a million text messages per day to encourage people to be tested and treated for HIV/AIDS. Messages are sent in local languages, directing recipients to the National AIDS Helpline, which provides information about testing services and locations. Messages can target tobacco use prevention, smoking cessation, improved dietary choices, avoidance of risky sex behavior, and violence and injury prevention. A potential downside, though, is that poorly designed or implemented messaging risks antagonizing, de-sensitizing, or confusing the public.

▸ **WEB SURFING:** The Internet has made once-specialized information, including medical information, widely available. Accessing information through Web surfing allows patients to learn more about medical conditions. This can ease the burden on health providers (by providing an alternative path for patients to obtain information), speed diagnosis, and improve interactions between patients and providers. Similarly, providers can use the Internet to obtain information about advances in medical practice, clinical best-practice guidelines, and information on rare diseases, even in physically remote areas.

However, expanded access to information without controls over the quality of information can result in the consumption and spread of inaccurate information. Without proper training, some people might not fully understand information or interpret it accurately. This can lead to misdiagnosis and delayed care seeking, incorrect self-treatment, conflict over appropriate care, or nonadherence to essential treatment plans and medications.

The Internet is also a source of information on health commodities, such as medicines and devices, cost, quality, and suppliers. This m-health approach may interfere with a coordinated supply chain, replacing a single supplier and single delivery system with multiple suppliers and diverse logistical needs for delivery.

▸ **ELECTRONIC MAILING LISTS:** Electronic mailing lists among a community of subscribers (often managed using Listserv software) can be used to help spread information gleaned from the Internet or developed in clinical settings among providers or patients. Such mailing lists operate as channels for the diffusion of information, innovations, and resources to improve care. However, they are also susceptible to misinformation and misunderstanding, which can lead to confusion, incorrect application of information, or divisiveness through disagreement regarding information exchanged.

▸ **WEB-BASED LEARNING:** Web-based learning is a tool to provide core and continuing training to increase the number and skills of health care workers. Less constrained by limitations on the number of instructors and facilities, this learning method allows for decentralized training at a pace matched to students’ circumstances, needs, and skill levels. It may also help reduce the financial barriers to training and expand opportunities for professional continuing education and satisfaction. Potential downsides are the absence of face-to-face interaction and limited options for advanced training that requires direct patient interaction. These make Web-based learning a valuable adjunct to but not a replacement for traditional training methods.

▸ **WEB-BASED DATA ENTRY:** Web-based data entry and storage allow for large databases to be available online. This can enhance the completeness and timeliness of disease surveillance. Immediate access to disease reports by key health officials can lead to timely identification and control of disease outbreaks, as well as more efficient long-term surveillance of endemic conditions. In this context, m-health is a tool that allows providers to send data to a central repository; data can be sent from a central location to the periphery as well. One study suggests that this approach to monitoring for malaria outbreaks in East Africa could be economically attractive. However, once again there is a potential downside. This form of m-health risks the importation of incorrect or misleading data that may lead to false action on disease outbreaks or the mismanagement of individual patients.
although these risks may be no higher than with current systems. Patient privacy must also be addressed in Web-based data entry systems.

**COMMUNITY** At the community level, social networking can be used to exchange information about the local health system. People in the community can share experiences about how to obtain health system resources they need, identify scarce resources, and exchange information (for example, on price, the experience of care, and quality) for specific providers. The “Smile for You” campaign to provide cleft palate surgery for children in South Africa used “Please Call Me” text messages, which mobile phone users send at no cost, to identify potential candidates for this free care. (Vodacom, the local telecommunications company, donated spare space in a million “Please Call Me” messages to ask recipients if they knew of children needing this specialized surgery.) Phone and text message inquiries rose tenfold, and forty-two children were identified for surgery—more than three times the number identified during a traditional media campaign lasting six weeks.²⁷

Effective messaging can connect people to needed and available services. Sharing service information can also encourage providers to improve services or lower prices. The risks involved include the exchange of incorrect or partial information that may misdirect patients seeking care. There is also the potential for a loss of confidentiality as users share their own experiences and those of others.

Social networks can also foster peer-to-peer interactions among both providers and patients. Discussions can extend beyond a local area to include clinician specialists and can provide support for improved health care practices. Similarly, patients (or community members) can support each other on specific behaviors—whether preventive (such as smoking cessation) or management of a common disease (such as diabetes). This model of interaction is, of course, open to miscommunication as well as to contentious differences of opinion.

Social networks created among health care organizations and individuals can be used to share information. They potentially create economies of scale at the local level to purchase supplies and equipment. The risks involved in this approach, however, are miscommunication among local organizations, leading to overexpenditures, and, as noted above, an uncoordinated supply chain that can lead to system inefficiency.

**INDIVIDUALS** For individuals, m-health offers improved communication, access to diagnostic tools, and ability to store and access personal medical data in central repositories. Advances in cellular technology allow for transmission of large data files, including medical imaging data, from remote areas to processing centers or higher-level medical centers. This can lead to more rapid and potentially better diagnosis and care.³¹ For example, Aravind Eye Systems (Madurai, India) established a regional wireless network to support nonphysician providers in thirty-one dispersed eye care centers. Each patient is examined by a nurse on site, followed by a one-to-two-minute consultation with an ophthalmologist at the main hospital, including transmission of a slit-lamp photograph if needed.³² Use of m-health in this way must ensure that patient confidentiality is not compromised in the transmission of images.

E-mail can strengthen communication between individuals in the health care system. Better provider-to-provider communication can improve patient care coordination, including team management of chronic disease. It can also allow exchange of best practices and can raise quality standards through professional consultation. PDAs may also serve this purpose.³³ Good provider-patient communication is essential for chronic disease management. M-health offers the chance to ask and respond to questions, send key data and guidance, and act as an avenue of case management once patients leave the clinical setting.

The complex care required for people living with HIV/AIDS has fostered use of m-health tools. Several groups have reported increased mobile access among such people, with some evidence of resulting improvements in medication adherence and health.³⁶,³⁷ Other applications include automated medication adherence reminders,³⁵ in-the-field consultations for providers,³⁶ and encouraging healthy behaviors.³⁷,³⁸

Perhaps the most common documented use of m-health is text-message and phone reminders to encourage follow-up appointments and healthy behaviors. In the United Kingdom, use of text-message reminders in a sexually transmitted infection clinic had two important benefits: decreasing time to treatment for chlamydia, and decreasing appointment no-show rates (with increased revenue of rebooking far exceeding implementation cost).³⁹,⁴⁰ In Hangzhou, China, text message and telephone reminders improved appointment attendance by 7 percent, and messaging cost less than telephone reminders.⁴¹ A recent randomized controlled trial of patients with chronic diseases in Malaysia found that nonattendance rates were about 40 percent lower in the text-messaging and phone groups than in controls.⁴²

In Zambia, Population Services International uses m-health for several aspects of male circumcision services. The circumcision service sends
fifteen text messages as postoperative reminders to patients to encourage appropriate behavior to protect wound healing, and it conducts service satisfaction surveys. New messaging services include a referral system, appointment scheduling, and addressing patients’ clinical questions. The risk for these types of interventions is that they may complicate clinical practice with more communication options/burdens, and decrease the important element of direct human interaction.

Discussion
The positive potential for m-health is huge, although not without risks to be monitored and minimized. Several broader points bear emphasis. First, rigorous evaluation is essential. Evidence for the value of m-health remains scarce, especially for the developing world. Ongoing evaluation of specific initiatives should guide m-health growth. A mixture of randomized controlled trials, natural experiments, and other designs will be needed.

We believe that the field would benefit greatly by the establishment of an m-health evaluation registration, similar to registration of clinical trials at http://ClinicalTrials.gov, a service of the U.S. National Institutes of Health, which lists federally and privately supported clinical trials around the world. Global health coordinating bodies such as the World Health Organization (WHO) could contribute importantly by fostering research using comparable outcome measures and disseminating findings.

Finally, economic outcomes are important. For example, lowered costs, even absent improved health outcomes, could justify m-health strategies. If m-health is to compete with other health interventions, it will need to be measurable in terms of cost per disability-adjusted life-year (DALY) averted, which is increasingly the accepted measure of health intervention performance (see Appendix Figure 2). An economic evaluation framework for m-health would characterize the interventions, their costs, and their intended clinical outcomes and potential adverse effects.

Assessment of m-health should also include awareness of practical issues, such as sustainability. Real-world challenges greatly influence the ability of programs to survive and grow. Issues include participating organizations, technical capacity, and financing. The WHO and other organizations should develop guidance on best m-health practices and support countries’ implementation efforts.

Vigorous expansion of m-health may also have a nonhealth benefit: fostering local economic development beyond health care. Although technological advances in hardware often occur in developed countries, advances in software are more widespread. Thus, m-health innovation and implementation are unlikely to be limited to external consultants. M-health software applications will be designed and employed in strategic partnerships with governments, health systems, individual businesses, professionals, and communities in developing countries. M-health platforms will be tailored, refined, and expanded by and in consultation with local experts.

To implement m-health, local technical capacity and training will be necessary. Thus, m-health should foster local microenterprise, creating upgraded platforms and new functionalities that will generate ongoing economic opportunities. Ultimately, increased economic opportunities in turn would contribute to improved health. The “virtuous cycle” would continue, with m-health at the very center of it.

NOTES
7 Bloom DE. The effect of health on economic growth: a production
10 To access the Online Appendix, click on the Online Appendix link in the box to the right of the article online.
25 Vital Wave Consulting. The opportunity of mobile technology for healthcare in the developing world. Washingh (DC) and Berkshire (UK): UN Foundation–Vodafone Foundation Partnership; 2009.
27 Kaplan WA. Can the ubiquitous power of mobile phones be used to improve health outcomes in developing countries? Global Health. 2006:2:9.
30 Thulasiraj RD, Avarind Eye Care. Personal communication (e-mail and phone); 12 November 2009.
36 Curioso WH, Kurth AE. Access, use, and perceptions regarding Internet, cell phones, and PDAs as a means for health promotion for people living with HIV in Peru. BMC Med Inform Decis Mak. 2007;7:24.
41 Gesualde S. Population Services International. Personal communication. 7 November 2009.