# Mobile health use in low- and high-income countries: an overview of the peer-reviewed literature

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DECLARATIONS

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## Summary

The evolution of mobile phone technology has introduced new possibilities to the field of medicine. Combining technological advances with medical expertise has led to the use of mobile phones in all healthcare areas including diagnostics, telemedicine, research, reference libraries and interventions. This article provides an overview of the peer-reviewed literature, published between 1 August 2006 and 1 August 2011, for the application of mobile/cell phones (from basic text-messaging systems to smartphones) in healthcare in both resource-poor and high-income countries. Smartphone use is paving the way in high-income countries, while basic text-messaging systems of standard mobile phones are proving to be of value in low- and middle-income countries. Ranging from infection outbreak reporting, anti-HIV therapy adherence to gait analysis, resuscitation training and radiological imaging, the current uses and future possibilities of mobile phone technology in healthcare are endless. Multiple mobile phone based applications are available for healthcare workers and healthcare consumers; however, the absolute majority lack an evidence base. Therefore, more rigorous research is required to ensure that healthcare is not flooded with non-evidence based applications and is maximized for patient benefit.

## Introduction

Mobile phone technology has evolved so greatly in recent years that phones can no longer be considered as simple mobile communication devices. Smartphones are mobile devices with advanced computing capabilities and high-resolution cameras with global positioning systems (GPS) built in as standard. Experts estimate that by 2013, 280 million (20%) of the 1.4 billion mobile phones sold will be smartphones.[1] Over the last decade the medical community has embraced this technology and is realizing its potential in healthcare information delivery, realtime patient monitoring, research data collection and mobile telemedicine for the provision of expertise to remote locations.

While high-income countries remain at the forefront of developing the latest mobile technologies used in healthcare, the rate of penetration of such technologies in low- and middle-income countries has recently exceeded that of their wealthier neighbours. Low- and middle-income countries have major restrictions on their healthcare due to a lack of infrastructure, human and physical resources, as well as being burdened by poverty and disease. Mobile phones have allowed those in the poorest countries to bypass

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fixed-line technology and jump straight to mobile technology in a term coined 'leapfrogging',[2] thereby having access to many modern means of health provision without the previously required infrastructure.

## Methods

The literature sources searched included PubMed, MEDLINE and Embase. Journal articles published between 1 August 2006 and 1 August 2011 were included. Search exclusion criteria included citations not in the English language, lack of abstract availability and not defined as a journal article. Search terms used included: 'mobile health' OR 'mHealth' OR 'mobile phone' OR 'iPhone' OR 'smartphone' OR 'cell phone' OR 'text message' OR 'short message service'. This yielded 1421 citations, from which two independent authors (AB, MJA) reviewed the abstract text. Articles were then excluded based on a lack of relevance to healthcare, those describing mobile phone health risks (i.e. cancer risk, car accidents while using a phone), conference/work shop summaries and when the full manuscript was not available online (or on request). In total, 725 abstracts were then reviewed for specific areas of interest, including chronic disease, infectious disease, acute medical/emergency/primary healthcare, patient/professional education and health psychiatry/psychology. In total, 260 articles were identified and the full manuscript was reviewed in full (AB, MJA). Reference lists of selected articles were also reviewed. The articles referenced in the current review were selected when both independent reviewers (AB, MJA) judged the manuscript to be of high methodological quality, study design, relevant to the field, high clinical impact (inclusive of Web links from within the text) and when multiple manuscripts focusing on a similar subject were identified, the highest quality (based primarily on study design) were selected for inclusion. All randomized controlled trials were included.

## Aims

The primary aim of the current article is to provide the reader with an informative overview of the peer-reviewed publications describing the use or evaluation of mobile technology in healthcare. Due to the breadth of the mHealth literature, as highlighted by the number of citations identified, a detailed systematic review was not deemed appropriate. Illustrative examples have been selected based on the range and breadth of how mobile phone use is being used by healthcare providers and consumers. Future medical applications and the potential impact of these mobile devices will also be discussed.

### Related work

Despite being a relatively new field in medicine, mobile health (mHealth) is a very broad subject, with pre-existing systematic reviews specifically focusing on single diseases, interventions or specific uses of mobile phone devices within mHealth (e.g. diabetes[3] or smoking cessation).[4] Supplementary Table S1 (please see http://jrs.rsmjournals.com/lookup/suppl/doi: 10.1177/0141076812472620/-/DC1) provides a selected list of existing reviews (in particular systematic reviews) and valuable web-based resources for further reading, which cover details that are beyond the scope of the current review.

### High-income countries

Over the last decade the mobile phone industry has developed progressively intelligent telecommunications devices in high-income countries. These devices showcase higher resolution images/video, offer near-ubiquitous coverage and greater processing power, with mobile infrastructures capable of ever-increasing data exchange and interfacing with an array of technical sensors. Smartphones, in particular, provide users with a pocket-sized personal computer that is invariably switched on, connected, locatable and equipped with increasingly intuitive and sophisticated applications, otherwise known as 'apps.'

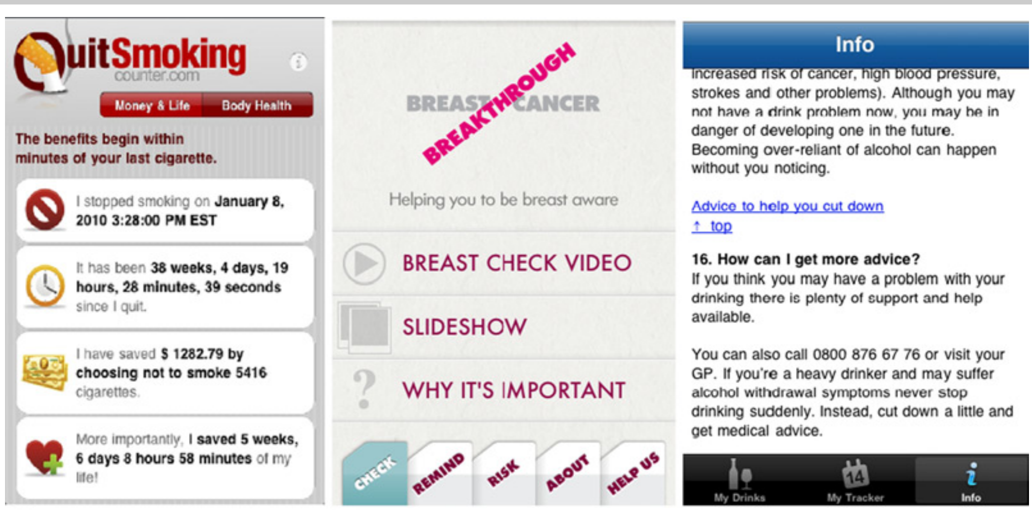
The popularity of smartphones is set to increase as more apps are developed. In 2009, two-thirds of American doctors reported that they were using a smartphone professionally and by the end of 2012 that proportion is estimated to reach 90%.[5] New medical apps for smartphones are becoming available on an almost daily basis. Most of these are directed at healthcare consumers, while some are specifically directed at physicians and other healthcare providers. It is important to note that not all mobile phone apps will work on all phone types. Several different operating systems are used in present day smartphones including Android, Symbian, Apple iOS, RIM BlackBerry, MeeGo, Windows Phone and Bada. Apple's iPhone operating system (iOS) having the most apps currently available having recently reached 25 billion downloads (www.moneycontrol.com). Android is a Linux-based operating system for mobile devices such as smartphones and tablet computers. It is developed by the Open Handset Alliance led by Google,[6] and is favoured by many software engineers due to its open-source nature, and therefore availability to consumers. Android currently holds the highest worldwide smartphone Mobile OS Market share at 53% (http://en.wikipedia.org/wiki/MHealth).

## Health promotion and behaviour

Mobile phones have shown some promise in modifying health behaviour, such as smoking cessation and alcohol intake, to such an extent that their use is being increasingly considered in healthcare interventions.[7,8] Most of these mobile phone interventions rely solely on short messaging service (SMS), also known as the text-messaging feature.[4,9] However, with the recent proliferation of smartphones, numerous apps have emerged with novel ways of promoting healthier lifestyles.[7,8,10] Of importance is the degree to which these apps adhere to evidence-based principles.

In the case of smoking cessation, a recent American-based quality assessment study of 47 iPhone applications available by mid-2009 (i.e. hypnosis and calculator apps [Figure 1a]) highlighted that the general level of adherence to proven strategies for smoking cessation was low.[7] Most concerning was the fact that the apps with the lowest levels of adherence to peer-reviewed guidelines were found to be the most frequently downloaded.[7] Currently available apps may serve as powerful tools in smoking cessation, but require careful revision around evidence-based guidelines and reference to other available health strategies. A good example of this type of app is the UK's National Health Service (NHS)

**Figure 1**
**Smartphone applications (screenshots from www.apple.com/iphone/from-the-app-store) used for lifestyle modifications and disease awareness. (a) iQuit – Stop Smoking Counter that provides the user with personalized readouts on health and money savings.[7] (b) iBreastCheck – provides user with breast check video and information on how to reduce cancer risk. (c) NHS Drinks Tracker – provides users with a alcohol drinks counter, track and information for local NHS support service[7]**




[a] [b] [c]

Choice's 'Drinks Tracker' app (Figure 1c), which was designed as part of a range of public NHS initiatives to reduce the harmful effects of excessive alcohol intake in the UK.[8] It allows the user to calculate the number of alcohol units they have consumed, with personalized feedback on their drinking and most importantly, contact information for the local NHS support services available.[8]

Several apps exist for raising cancer awareness and drug compliance.[5,11] One example, 'iBreastCheck,' includes videos that show women how and when (i.e. monthly reminders) to check their own breasts, and provides information on lifestyle modifications to reduce cancer risk (Figure 1b).[5] The majority of these apps still require external, expert accredited peer-review, but under certain circumstances the US Food and Drug Administration (FDA) has begun to approve selected smartphone apps as medical devices in the USA (www.fda.gov/medicaldevise). One of the first, of what is likely to be many, apps to receive FDA endorsement was the 'Pill Phone' app for its use in medicines management.[5] The interface of this app looks like an electronic dossette box, and it allows patients to input the names, dosages and frequency at which their prescription drugs must be taken; this initiates interactive reminders being sent to the patient and/or carer for each scheduled dose, including a photograph of the pill they need to take.[5]

Some apps are intended to be of use by both the patients and their healthcare professionals. One example includes the 'Radiation Passport' iPhone app[12] that is designed to aid both professionals (radiographers, referring clinicians, etc.) and patients in view of the rapid increase in the use of radiological examinations. The app provides radiation dose estimates and associated cancer risks, as well as serving as a method by which to track an individual's cumulative exposure with time.

## Sensors and peripherals

Peripheral devices, often described as wearable medical systems, can collect information on a patient such as respiratory rate and be synchronized to a mobile device to transmit the information to a healthcare professional. Wearable systems enable patients to take clinical measurements over long periods of time, thus avoiding the stress associated with frequent hospital visits.[13] They also aim to personalize healthcare by initiating preventative health measures against illness and earlier detection of diseases.[14]

**Figure 2**
**Medical uses of the wireless iPhone′s accelerometer capabilities. (a) Gait analysis.[15] (b) iCPR application is used wearing the device with an armband, with the display clearly visible for the user. The built-in metronome produces a clear audible sound sample indicating the right chest compression rate to the user[23]**


Proof of concept has been demonstrated in the applicability of smartphones to biomedical engineering by utilizing their wireless three-dimensional accelerometer for quantifying and evaluating gait characteristics (Figure 2a).[15] After mounting the iPhone to the ankle of a subject in Pittsburgh (USA), gait cycle data were recorded and then wirelessly transmitted via email for expert analysis 2000 miles away in Los Angeles (USA).[15] This allowed the authors to create a 'Virtual Proprioception' inspired iPhone app with the capacity to modify gait status in realtime using biofeedback to aid the rehabilitation process of individuals with hemiparetic gaits.[15]

Everyday commercial peripherals (i.e. headsets) for smartphone have also been recently modified for use in the medical field. After adapting an auricular Bluetooth headset to continuously measure and record the central body temperature at the tympanic membrane, data were stored and processed by a smartphone and sent by email or SMS to a clinician or medical facility.[16] The Portuguese authors state that the prototype can identify abnormal circadian rhythms (based on temperature changes) and thus may aid in the diagnosis of sleep disorders. A team of biomedical engineering experts from Canada has gone one step further by developing a non-contact sensor that reliably detects respiratory rate and transfers the results directly to an iPhone.[17] Despite the importance of measuring respiratory rate in the clinical setting (i.e. intensive care/neonatal units, home monitoring), it has the poorest measurement compliance among the vital signs.[17] Using Respiratory Inductance Plethysmography as a 'gold-standard' comparator, the authors showed that when placed under the bed sheets the sensor pad reliably captured respiratory movements between 5 and 55 breaths per minute.[17] Even though the device has only been tested on healthy volunteers to date, it offers future potential for practical application in both the home (apnoea detection for infants and adults) and hospital settings (automatic patient respiration monitoring).

## Medical education and training

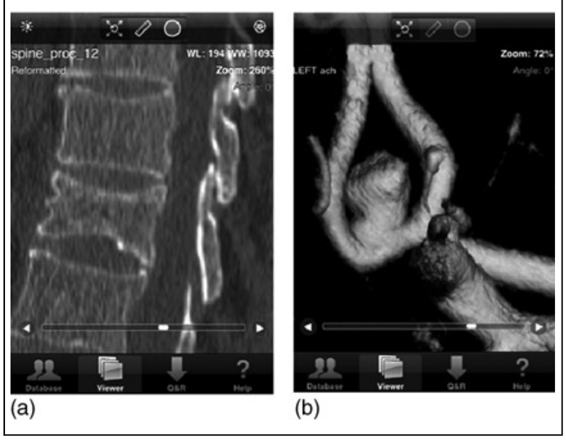
In September 2010, iPhones were issued to medical students at Leeds University (UK) to enable them to access drug prescription information and medical textbooks in the palm of their hand, but at a cost of £380 per student (www.bbc.co.uk/news/education-11427317). The Welsh Deanery has also recently invested £500,000 in supplying their junior doctors with smartphones, each with up to 17 medical textbooks predownloaded (including the British National Formulary) (www.cardiff.ac.uk/pgmde). This project, known as the All-Wales Foundation Programme iDoc Project, is prospectively accessing user satisfaction with six-monthly surveys. Based on the hypothesis that the phone will not only reduce NHS spending (i.e. updating print copies of textbooks) but will also promote the best possible care for patients, this study is due to conclude in 2012. Four years previously, a cohort study based in an American community hospital reported that physicians found smartphones easy to use and perceived the information retrieved immediately from the Web to be beneficial for patient care.[18] Toronto's Mount Sinai Hospital has chosen to fully integrate the iPhone into the hospitals daily operations.[19] Their in-house iPhone app, called VitalHub, provides doctors with secure remote access to patient information such as patient records, laboratory/radiology results and medication charts. In addition, as with iDoc, it includes extensive pre-downloaded medical literature. This enables clinicians to review and monitor a patient's status from within and external to the hospital setting, enabling much quicker informed decisions.[20]

There is now a rich array of smartphone apps for optimizing practical skills within a wide variety of healthcare specialties, including neurology (e.g. visual acuity testing[21]), plastic surgery (e.g. canthal ligament alignment[22]) and the emergency services (e.g. cardiopulmonary resuscitation [CPR]).[23] In the field of cardiology, for example, many studies have focused on optimizing cardiopulmonary resuscitation (CPR),[23–25] as even though the survival benefit of high-quality CPR is well documented, concerns still remain about the ability of both lay people and healthcare professionals to perform good chest compressions even shortly after training.[23] Two randomized controlled trials to date have demonstrated the correct use of cardiopulmonary ventilation breaths by untrained individuals (e.g. bystanders)[25] and chest compressions[24] with video communication via mobile phones. In 2011, Italian anaesthetists[23] reported the first randomized study of the free CPR feedback iPhone app, iCPR, which is based on American Heart Association and European Resuscitation Council guidelines. Using a prospective, randomized crossover design with 50 participants (52% health professionals, 48% lay people) they reported that the phone's accelerometer significantly improved chest compression rates and depth in a simulated cardiac arrest scenario (Figure 2b).[23] Both iCPR and Pocket CPR (a similar iPhone app) are only intended for CPR training at present (www.pocketcpr.com/iphone).

## Emerging trends in remote diagnosis

Radiology-related mobile applications, including OsiriX and Mobile MiM, represent important steps in the advancement of medical imaging and preliminary diagnosis (Figures 3a and b).[26]

**Figure 3**
**Radiological screen captures using OsiriX software.[26] (a) Thoraco-lumbar junction on saggital computed tomography imaging. (b) Cerebral angiogram demonstrating an aneurysm of the anterior communicating artery**




The aim of these applications is to provide physicians with the ability to view images and make diagnoses without having to wait for a radiology film or return to a work-based computer system (i.e. picture archiving and communication systems). The US FDA's recent approval of the Mobile MiM application for viewing radiological images highlights that rapid consultation via dissemination of digital imaging to smartphones is a future possibility; especially in emergency or remote situations in which there is no access to computer-based workstations (www.fda.gov).

## Low-Income countries

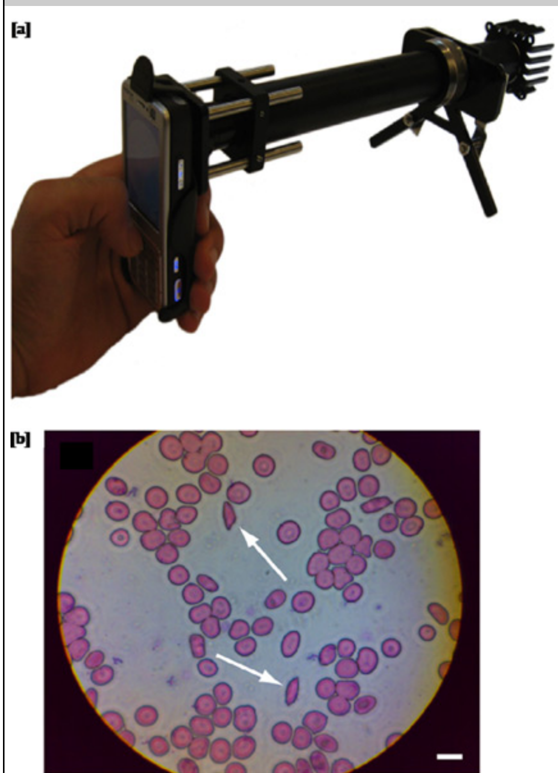
Mobile phone access in low-income countries is greater than 60% as a result of personal or shared ownership (www.itu.int/ITU-D/ict/statistics). Smartphones, on the other hand, are yet to be widely used in these areas due to cost and availability. Their affordability, however, is likely to change in the coming decade as a result of more competitors entering the market. The majority of studies from low-income countries have therefore used second-generation mobile technology with SMS and multimedia messaging (MMS) in addition to voice calling. Only a small number of descriptive articles describe the potential use of smartphones (e.g. mobile microscopes[27] and epidemiological data tools[28]) in resource poor environments.

## Diagnostics and monitoring

Poor access to laboratories and personnel trained in the skills to interpret human samples has resulted in a gross under diagnosis of potentially treatable and curable conditions. Ironically, this is most pertinent in areas in which infectious and haematological diseases are most prevalent (e.g. Sub-Saharan Africa).

A Peruvian study[29] has recently harnessed the potential of mobile phones in the diagnosis of tuberculosis by electronically transmitting microscopic culture images (i.e. *M. tuberculosis*) for expert analysis in previously inaccessible remote sites. Images taken initially by a camera (attached to a microscope) were transferred to a mobile phone for transmission to a blinded, trained reader at a separate location. The concordance of readings between the direct observation on the local microscope and the mobile phone-transmitted image was 98.7%.[29] This high level of agreement, however, is most likely as a result of directly comparing like with like images taken from the same source, with the only difference being that the remote location received the image via mobile phone transmission. Although promising, this type of diagnostic evaluation would require a laboratory with high-quality photographic and imaging tools, both of which are unlikely to be plausible in present-day settings with limited resources. One solution may be in the form of a recently developed high-resolution microscope attachment for camera-enabled mobile phones (Figure 4a), which is capable of both bright field and fluorescence imaging.[27] This telemedicine system has already been shown to be of high enough image resolution to detect malaria parasites (*Plasmodium falciparum*), sickle red bloods cells (Figure 4b) and *Mycoplasma tuberculosis* in blood smears and infected sputum cultures, respectively.[27] It also has over the required resolution quality and ability to conduct automated *M. tuberculosis* bacteria counts in conjunction with image analysis software.[27] Similarly, by attaching a light (28 g), cost-effective (approximately 14 US dollars) wide-field fluorescent

**Figure 4**
**(a) The high-resolution microscope attachment for the camera-enabled smartphone.[29] (b) Example of an image taken with the high-resolution microscope, highlighting sickle-shaped red blood cells (with white arrows) on a blood smear[27]**




imaging platform to a smartphone researchers have been able to identify pathogenic water-borne parasites (e.g. *Giardia lamblia* cysts).[30] Such platforms may be adapted to use various lab-on-a-chip assays for global health applications, including the monitoring of CD4 counts and viral loads in HIV positive individuals.[30]

## Health reporting and surveillance

Epidemiological research is vital for informing policy and planning of health services. Data collection can be problematic when poor infrastructure exists, making access to remote locations difficult and expensive. Equipment (e.g. diagnostics, computers) required is frequently cumbersome and difficult to transport. Surveillance of active disease and spread requires near to realtime detection if preventative measures are to be taken. Both health reporting and surveillance have been made substantially more plausible with the development of mobile technology.

Systems, such as Ushahidi, that provide open-source platforms for collecting and visualizing user-driven crisis data collected via SMS, Web and email have been successfully implemented in Kenya, Afghanistan, Uganda, Malawi and Zambia.[31] Ushahidi also provides tools to aid with translating, classifying and geographically referencing these reports.[31] The findings of a recent Chinese study[32] indicate that mobile phone reporting systems can help restore the reporting capacity of healthcare agencies in earthquake-affected areas. For the true potential of these systems (Table 1) to be realized, however, they must be incorporated into regular emergency preparation programmes prior to an actual natural disaster or disease outbreak.[32]

In low-income countries, surveys are often the only way of collecting reliable health and socio-economic research data. Paper-based collection methods have been standard practice for many years; however there is scope for input error and high costs associated with double entry and data cleaning.[33] To overcome these limitations, community health workers from a periurban settlement in South Africa, with no prior experience in data collection, successfully performed a large-scale (approximately 40,000 households) health survey using second-generation, non-smartphone mobile phones (known as 'Mobile Researcher' system).[34] Enforced validation meant users could not skip questions or input inappropriate data, the contents of which were automatically encrypted and firewall protected to ensure respondent confidentiality. Project management was made possible by realtime quality controls, automatic uploading of completed surveys and data collection supervision (which enabled area managers to monitor individual health workers efficiency in data collection).[34] Even though these results are promising at a cost 0.30 US dollars per completed survey, the current study lacks a control group (e.g. those performing the same tasks but via paper format) and potentially places researchers at risk as mobile phones are valued items in resource-limited settings, especially high crime areas.[35] Some of these

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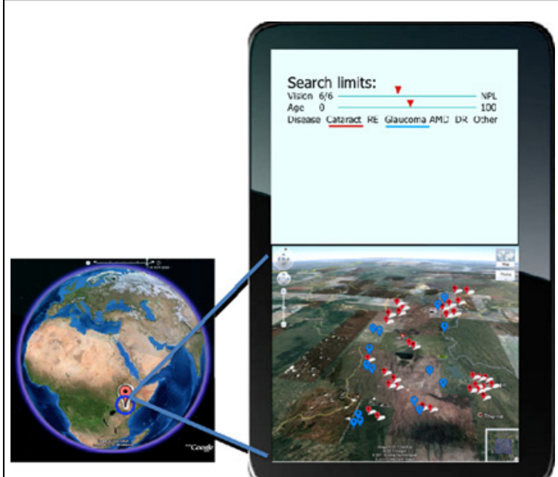
**Table 1**
**Overview of mobile phone applications for health and natural disaster reporting in low- and middle-income countries (adapted from Yang *et al.*[32])**

| *Organization/ system (year)* | *Location* | *Example use* | *Key description* | *Web link* |
|---|---|---|---|---|
| FrontlineSMS; FrontlineSMSMedic (2005) | Malawi, Honduras and other low-income countries | • Health and emergency alerts | • Two-way communication platform via SMS | http://frontlinesms.com |
| | | • Pest/disease control | • Mobile phone connection required only (no Internet required)<br>• No cost to users (open-access) | http://medic.frontlinesms.com |
| Ushahidi (2007) | Kenya, Uganda, Malawi, Zambia and Haiti | • Tracking medical supplies | • Mobile phone platforms collect and visualize data | http://www.ushahidi.com |
| | | • Disaster response (Haiti 2010) | • Internet-connected computer required to view data<br>• Software is open source | |
| GeoChat (2008) | Thailand, Cambodia and others | • Natural disasters (communication amongcrisis response team) | • Platform hosted on the Internet and uses Web, email, SMS and Twitter | http://instedd.org/technologies/geochat |
| | | | • Software is open source and free to download<br>• Communication between crisis response team via SMS gateway (i.e. SMS without mobile connection) | |
| Outbreaks Near Me (HealthMap community) (2009) | Worldwide (especially low-income countries) | • Realtime infectious diseases outbreak reporting (i.e. H1N1) | • Data from personal experience or official sources | http://healthmap.org/outbreaksnearme |
| | | | • Applications and access free to all users<br>• Data viewed via smartphones or the Web | |

*Key*: SMS, short message service; H1N1, influenza A virus limitations, especially the latter, may not be overcome until larger social issues are addressed; especially ones that will shrink the technological divide across incomes.

A more robust and interactive, open-source system, known as EpiCollect,[28] has been developed by Imperial College London (UK) to allow field researchers to utilize GPS, Google Maps and the phone's own operating system to directly communicate epidemiological data from remote field areas to central web databases. Information such as text, numerical data or images can be recorded and viewed on an interactive land map (Figure 5), allowing field workers similar displays and analysis tools on their smartphone that they would have if viewing information in the central laboratory. EpiCollect has yet to be trialed for healthcare data collection in low-income countries, which may be a reflection of the current status of network availability in remote areas of Africa. This, however, should be overcome by the phone's storage capacity and its ability to synchronize with the central database upon returning to an area with network coverage.[28]

**Figure 5**
**Interactive land map created by the EpiCollect Software.[28] (a) EpiCollect screenshots of 'demo mode' and (b) potential for collecting and mapping epidemiological data, example shows information on visual impairment in Africa by visual acuity, age and condition**




## HIV/AIDS and malaria

Sub-Saharan Africa is in the midst of a growing HIV epidemic, with over 3.9 million adults and children in the region now receiving antiretroviral treatment (ART).[36] Consequently, improving support systems for HIV management is now high on the international public health agenda in such resource-limited regions.[37] Over the last five years the effectiveness of telecommunication has been well demonstrated in multiple HIV-endemic areas, with particular focus on the ability of mobile phones to improve adherence to ART.[38] A cross-sectional study undertaken in an ART clinic in South Africa recently highlighted that 81% of HIV/AIDS patients attending the clinic owned a mobile phone, of whom, the vast majority would be willing to be contacted by the clinic either verbally (99%) or via SMS (96%).[39] This promotes the possibility of improving drug compliance and clinic attendance through sending health promotion text reminders to remote locations in Africa,[39] something which has already been demonstrated to be successful in clinical trials of chronic disease management in high-income countries (e.g., hypertension,[40] obesity,[41] Cystic Fibrosis[42] and asthma).[43] Improved ART clinic attendance in Uganda was demonstrated when participants were sent SMS or voice reminders.[44] Two large (>400 participants) randomized controlled trials (RCTs) undertaken in Kenya demonstrated that regular SMS reminders significantly improved ART adherence[45,46] and, in the case of the multicentre WelTel Kenya1 trial, significantly suppressed viral loads compared with the control arm.[46] It is not clear, however, if the weekly text reminders were sufficient to remind patients of their daily need to self-medicate or whether other social factors (e.g. regular attention from a healthcare provider) led them to take greater self-ownership and responsibility for their disease management.[46] Even though the true cost-effectiveness of such mobile interventions in Kenya still requires formal analysis, the estimated intervention expense of less than 8 US Dollars per patient per year[47] versus the cost and practicalities of second-line ART, makes it an attractive option.

Despite high levels of interest and participation and the fact that the system of delivery of patient information is vital for achieving healthcare

**Table 2**
**Overview of randomized controlled trials that assessed the use of mobile phone interventions in healthcare from 2006 to 2011**

| *Country (reference)* | *Indication/disease* | *Sample size* | *Mobile use* | *Results* |
|---|---|---|---|---|
| New Zealand (10) | Smoking cessation in adolescents | 226 | Video | No significant improvement in continued smoking abstinence at 6 months (Intervention 26.4% vs. Control 27.6%) |
| USA (24) | Cardiopulmonary resuscitation (CPR) | 160 | Audio | Delayed initiation of CPR but better hand position, compression rates and depth and fewer pauses than control |
| USA (41) | Weight loss | 65 | SMS and MMS | Outcome measure – weight change. Significantly greater weight loss in intervention arm |
| Austria (53) | Acute decompensation in heart failure | 120 | Tele-medicine | Reduced hospital admission in intervention arm and reduced hospital stay in those admitted |
| Canada (54) | Vitamin C tablet adherence | 102 | SMS | No significant difference in self-reported adherence |
| Japan (55) | Speed to reach Automated External Defibrillator (AED) | 43 | Interactive maps | No significant difference in time to reach AED. Shorter distance travelled to reach AED in intervention arm |
| USA (56) | Smoking cessation in HIV/AIDS patients | 77 | Phone call counseling | Intervention arm significantly more likely to abstain from smoking |
| UK (57) | Recruitment to clinical trials | 811 | SMS | SMS containing quotes from existing participants increased randomizations into the Txt2stop trial [64] |
| UK (58) | Smoking cessation | 5800 | SMS | The txt2stop smoking cessation programme significantly improved smoking cessation rates at 6 months vs. controls that received SMS's unrelated to smoking (10.7% vs. 4.9%, $P < 0.0001$) |
| Malaysia (59) | Attendance to a primary care clinic | 993 | SMS and voice call | SMS and phone calls significantly improved adherence to a primary care clinic compared with control. No significant difference between SMS and phone call reminders |
| Kenya (51) | Health workers' adherence to malaria treatment guidelines | 2269 | SMS | Intention-to-treat analysis showed that correct management improved by 23.7% (95% CI 7.6–40.0; $P = 0.004$) immediately after intervention and by 24.5% (8.1–41.0; $P = 0{\cdot}003$) 6 months later |
| Kenya (Rural clinic) (45) | ART adherence in HIV/AIDS patients | 431 | SMS | Significant increase in adherence in those receiving text reminders |
| Kenya (Multisite) (47) | ART adherence in HIV/AIDS patients | 538 | SMS | Significant increase in adherence in recipients of text reminders and reduced viral load |

*Key (unless stated)*: SMS, short message service; MMS, multimedia messaging service goals, two-way communication is not without its challenges.[48] Over 66% of Ugandan HIV patients studied were unable to use their mobile phone personal identification numbers to feed back information to the healthcare provider, resulting in effectively only one-way communication from the caregiver to the patient proving successful.[48]

Healthcare worker adherence to malaria case management guidelines is an essential part of the World Health Organization's (WHO) goal of eliminating the disease. Lack of conformity to these guidelines has, however, proved to be a major barrier to achieving this goal in low-income countries.[49] In Thailand, integrating mobile phone technology into paper-based malaria prevention and control programmes used by healthcare workers has been shown to be successful in increasing patient follow-up rates and compliance with antimalarial therapy.[50] In the *Lancet*, Zurovac *et al*.[51] have recently reported promising results of using twice-daily mobile phone text messaging to remind healthcare workers in Kenya to adhere to national treatment guidelines for paediatric malaria. This, the largest RCT of its kind (107 health facilities), showed improvements in drug-specific management practices by almost 25%, both immediately and six months after the text messaging intervention was introduced.[51] Although only 51% of children were being managed according to national treatment guidelines after the mobile phone intervention, preliminary analysis suggests that such interventions would be cost-effective and easy to scale up nationally.[52] Details of the RCTs that assessed the use of mobile phone delivery in both low- and high-income healthcare systems between 2006 and 2011 are summarized in Table 2.

## Discussion

The increasing use of mobile platforms in low-income countries is providing new methods of accessing healthcare services without traditional fixed infrastructures. Despite a vast number of available smartphone-based applications and proposed uses of mobile phones, very few comply with regulated/expert body guidelines. There is also a clear paucity of data from well-designed prospective studies that would enable the validation of these promising advances in mobile phone technology. Existing studies in low-income countries lack the type of evidence that usually convinces funders of utility (e.g. control arms and cost-effectiveness analyses). It is important to recognize the limitations of the peer-review process in a rapidly evolving field of mHealth, which is innovating at a rate that is appreciably quicker than the process of designing, completing and publishing scientific evidence for the effectiveness of mHealth.

Low-income countries can now leapfrog existing systems using mobile technology, the gap between high- and low-income countries can be bridged using such advances. With more people on the planet currently having access to a mobile phone than clean water and sanitation it is the responsibility of the healthcare profession to ensure that mobile technology is not only engaging, accessible and user-friendly, but most importantly evidenced based in order to increase their likely impacts. There is a need to embrace this rapidly growing technology to ensure medicine not only keeps pace with the current innovations, but also maximizes their use for patient benefit.

### References


1 Hempel J. How blackberry does it. *Strateg Dir* 2010;**160**:92–100 2009

2 Goldemberg J. Leapfrogging energy technologies. *Energy Policy* 1998;**2**:729–41

3 Chomutare T, Fernandez-Luque L, Arsand E, Hartvigsen G. Features of mobile diabetes applications: review of the literature and analysis of current applications compared against evidence-based guidelines. *J Med Internet Res* 2011;**13**:e65

4 Whittaker R, Borland R, Bullen C, Lin RB, McRobbie H, Rodgers A. Mobile phone-based interventions for smoking cessation. *Cochrane Database Syst Rev* 2009:CD006611

5 Senior K. Smart phones: new clinical tools in oncology? *Lancet Oncol* 2011;**12**:429–30

6 Shih G, Lakhani P, Nagy P. Is android or iPhone the platform for innovation in imaging informatics. *J Digit Imaging* 2010;**23**:2–7

7 Abroms LC, Padmanabhan N, Thaweethai L, Phillips T. iPhone apps for smoking cessation: a content analysis. *Am J Prev Med* 2011;**40**:279–85

8 Pulman A. Mobile Technology as a mechanism for delivering improved quality of life. *J Res Center EducTechnol* 2010;**6**:111–21

9 Brendryen H, Kraft P. Happy ending: a randomized controlled trial of a digital multi-media smoking cessation intervention. *Addiction* 2008;**103**:478–84; discussion 85–6

10 Whiitaker R, Maddison R, McRobbie H, Bullen C. A multimedia mobile phone-based youth smoking cessation intervention: findings from content development and piloting studies. *J Med Internet Res* 2008;**10**:e49

11 Capozzi D, Lanzola G. A configurable home care platform for monitoring patients with reminder messaging and compliance tracking services. *Stud Health Technol Inform* 2010;**160**(Part 1):63–7
12 Baerlocher MO, Talanow R, Baerlocher AF. Radiation passport: an iPhone and iPod touch application to track radiation dose and estimate associated cancer risks. *J Am Coll Radiol* 2010;**7**:277–80
13 Rigoberto MM, Toshiyo T, Masaki S. Smart phone as a tool for measuring anticipatory postural adjustments in healthy subjects, a step toward more personalized healthcare. *Conf Proc IEEE Eng Med Biol Soc* 2010;**2010**:82–5
14 Teng X, Zhang Y, Poon C, Bonato P. Wearable medical systems for p-Health. *IEEE Rev Biomed Eng* 2008;**1**:62–74
15 Lemoyne R, Mastroianni T, Cozza M, Coroian C, Grundfest W. Implementation of an iPhone as a wireless accelerometer for quantifying gait characteristics. *Conf Proc IEEE Eng Med Biol Soc* 2010;**2010**:3847–51
16 Sanches JM, Pereira B, Paiva T. Headset Bluetooth and cell phone based continuous central body temperature measurement system. *Conf Proc IEEE Eng Med Biol Soc* 2010;**2010**:2975–8
17 Hart A, Tallevi K, Wickland D, Kearney RE, Cafazzo JA. A contact-free respiration monitor for smart bed and ambulatory monitoring applications. *Conf Proc IEEE Eng Med Biol Soc* 2010;**2010**:927–30
18 León SA, Fontelo P, Green L, Ackerman M, Liu F. Evidence-based medicine among internal medicine residents in a community hospital program using smart phones. *BMC Med Inform Decis Mak* 2007;**7**:5
19 Dala-Ali BM, Lloyd MA, Al-Abed Y. The uses of the iPhone for surgeons. *The Surgeon* 2011;**9**:44–8
20 Apple. Inc® [Internet]. *iPhone in business. c2010*. See www.apple.com/iphone/business/profiles/mt-sinai/ (last accessed 30 September 2011)
21 Busis N. Mobile phones to improve the practice of neurology. *Neurol Clin* 2010;**28**:395–410
22 Mezzana P, Scarinci F, Marabottini N. Augmented reality in oculoplastic surgery: first iPhone application. *Plast Reconstr Surg* 2011;**127**:57e–8e
23 Semeraro F, Taggi F, Tammaro G, Imbriaco G, Marchetti L, Cerchiari EL. iCPR: a new application of high-quality cardiopulmonary resuscitation training. *Resuscitation* 2011;**82**:436–41
24 Merchant RM, Abella BS, Abotsi EJ, *et al.* Cell phone cardiopulmonary resuscitation: audio instructions when needed by lay rescuers: a randomized, controlled trial. *Ann Emerg Med* 2010;**55**:538–43.e1
25 Yang C-W, Wang H-C, Chiang W-C, *et al.* Impact of adding video communication to dispatch instructions on the quality of rescue breathing in simulated cardiac arrests – a randomized controlled study. *Resuscitation* 2008;**78**:327–32
26 Choudhri AF, Radvany MG. Initial experience with a handheld device digital imaging and communications in medicine viewer: OsiriX mobile on the iPhone. *J Digit Imaging* 2011;**24**:184–9
27 Breslauer DN, Maamari RN, Switz NA, Lam WA, Fletcher DA. Mobile phone based clinical microscopy for global health applications. *PLoS ONE* 2009;**4**:e6320
28 Aanensen DM, Huntley DM, Feil EJ, al-Own Fa, Spratt BG. EpiCollect: linking smartphones to web applications for epidemiology, ecology and community data collection. *PLoS ONE* 2009;**4**:e6968
29 Zimic M, Coronel J, Gilman RH, Luna CG, Curioso WH, Moore DAJ. Can the power of mobile phones be used to improve tuberculosis diagnosis in developing countries? *Trans R Soc Trop Med Hyg* 2009;**103**:638–40
30 Zhu H, Yaglidere O, Su T-W, Tseng D, Ozcan A. Cost-effective and compact wide-field fluorescent imaging on a cell-phone. *Lab Chip* 2011;**11**:315–22
31 Freifeld CC, Chunara R, Mekaru SR, *et al.* Participatory epidemiology: use of mobile phones for community-based health reporting. *PLoS Med* 2010;**7**:e1000376
32 Yang C, Yang J, Luo X, Gong P. Use of mobile phones in an emergency reporting system for infectious disease surveillance after the Sichuan earthquake in China. *Bull World Health Organ* 2009;**87**:619–23
33 Lane SJ, Heddle NM, Arnold E, Walker I. A review of randomized controlled trials comparing the effectiveness of hand held computers with paper methods for data collection. *BMC Med Inform Decis Mak* 2006;**6**:23
34 Tomlinson M, Solomon W, Singh Y, *et al.* The use of mobile phones as a data collection tool: a report from a household survey in South Africa. *BMC Med Inform Decis Mak* 2009;**9**:51
35 Kaplan WA. Can the ubiquitous power of mobile phones be used to improve health outcomes in developing countries? *Global Health* 2006;**2**:9
36 Chan M, Sidibe M, Lake A (on behalf of the WHO). *Towards Universal Access: Scaling up Priority HIV/AIDS Interventions in the Health Sector: Progress Report Summary.* 2010. See www.who.int/hiv/pub/2010progressreport/summary_en.pdf (last checked 10 October 2011)
37 UNAIDS. *Resource Needs for an Expanded Response to AIDS in Low- and Middle-Income Countries*. Geneva: World Health Organisation, 2005
38 Rueda S, Park-Wyllie LY, Bayoumi AM, *et al.* Patient support and education for promoting adherence to highly active antiretroviral therapy for HIV/AIDS. *Cochrane Database Syst Rev* 2006;**3**:CD001442
39 Crankshaw T, Corless IB, Giddy J, Nicholas PK, Eichbaum Q, Butler LM. Exploring the patterns of use and the feasibility of using cellular phones for clinic appointment reminders and adherence messages in an antiretroviral treatment clinic, Durban, South Africa. *AIDS Patient Care STDS* 2010;**24**:729–34
40 Friedman RH, Kazis LE, Jette A, *et al.* A telecommunications system for monitoring and counseling patients with hypertension. Impact on medication adherence and blood pressure control. *Am J Hypertens* 1996;**9**(Part 1):285–92
41 Patrick K, Raab F, Adams MA, *et al.* A text message-based intervention for weight loss: randomized controlled trial. *J Med Internet Res* 2009;**11**:e1
42 Marciel KK, Saiman L, Quittell LM, Dawkins K, Quittner AL. Cell phone intervention to improve adherence: cystic fibrosis care team, patient, and parent perspectives. *Pediatr Pulmonol* 2010;**45**:157–64
43 Neville R, Greene A, McLeod J, Tracey A, Tracy A, Surie J. Mobile phone text messaging can help young people manage asthma. *BMJ* 2002;**325**:600
44 Kunutsor S, Walley J, Katabira E, *et al.* Using mobile phones to improve clinic attendance amongst an antiretroviral treatment cohort in rural Uganda: a cross-sectional and prospective study. *AIDS Behav* 2010;**14**:1347–52
45 Pop-Eleches C, Thirumurthy H, Habyarimana JP, *et al.* Mobile phone technologies improve adherence to

antiretroviral treatment in a resource-limited setting: a randomized controlled trial of text message reminders. *AIDS* 2011;**25**:825–34
46 Lester RT, Ritvo P, Mills EJ, *et al.* Effects of a mobile phone short message service on antiretroviral treatment adherence in Kenya (WelTel Kenya1): a randomised trial. *Lancet* 2010;**376**:1838–45
47 Chi BH, Stringer JSA. Mobile phones to improve HIV treatment adherence. *Lancet* 2010;**376**:1807–8
48 Haberer JE, Kiwanuka J, Nansera D, Wilson IB, Bangsberg DR. Challenges in using mobile phones for collection of antiretroviral therapy adherence data in a resource-limited setting. *AIDS Behav* 2010;**14**:1294–301
49 Rowe AK, de Savigny D, Lanata CF, Victora CG. How can we achieve and maintain high-quality performance of health workers in low-resource settings? *Lancet* 2005;**366**:1026–35
50 Meankaew P, Kaewkungwal J, Khamsiriwatchara A, Khunthong P, Singhasivanon P, Satimai W. Application of mobile-technology for disease and treatment monitoring of malaria in the 'Better Border Healthcare Programme'. *Malar J* 2010;**9**:237
51 Zurovac D, Sudoi RK, Akhwale WS, *et al.* The effect of mobile phone text-message reminders on Kenyan health workers' adherence to malaria treatment guidelines: a cluster randomised trial. *Lancet* 2011;**378**:795–803
52 Moonen B, Cohen JM. Text messaging to improve adherence to malaria guidelines. *Lancet* 2011;**378**:750–2
53 Scherr D, Kastner P, Kollmann A, *et al.* Effect of home-based telemonitoring using mobile phone technology on the outcome of heart failure patients after an episode of acute decompensation: randomized controlled trial. *J Med Internet Res* 2009;**11**:e34
54 Cocosila M, Archer N, Haynes RB, Yuan Y. Can wireless text messaging improve adherence to preventive activities? Results of a randomised controlled trial. *Int J Med Inform* 2009;**78**:230–8
55 Sakai T, Iwami T, Kitamura T, *et al.* Effectiveness of the new 'Mobile AED Map' to find and retrieve an AED: a randomised controlled trial. *Resuscitation* 2011;**82**:69–73
56 Vidrine DJ, Arduino RC, Lazev AB, Gritz ER. A randomized trial of a proactive cellular telephone intervention for smokers living with HIV/AIDS. *AIDS* 2006;**20**:253–60
57 Free C, Hoile E, Robertson S, Knight R. Three controlled trials of interventions to increase recruitment to a randomized controlled trial of mobile phone based smoking cessation support. *Clin Trials* 2010;**7**:265–73
58 Free C, Knight R, Robertson S, *et al.* Smoking cessation support delivered via mobile phone text messaging (txt2stop): a single-blind, randomised trial. *Lancet* 2011;**378**:49–55
59 Leong KC, Chen WS, Leong KW, *et al.* The use of text messaging to improve attendance in primary care: a randomized controlled trial. *Fam Pract* 2006;**23**:699–705