# mHealth for the Control of TB/HIV in Developing Countries

Aishwarya Bakshi[#], Padmanesan Narasimhan[*], JunHua Li[#], Nick Chernih[#], Pradeep Kumar Ray[#], Raina MacIntyre[*]
[#]Asia-Pacific ubiquitous Healthcare research Centre (APuHC), The University of New South Wales, Australia
* School of Public Health and Community Medicine, The University of New South Wales, Australia

***Abstract*— mHealth (healthcare using mobile communication technologies) is being strengthened as a new tool to tackle the global crisis in inadequate workforce and patient monitoring, especially in resource-limited settings. High numbers of people living with TB/HIV fail treatment and develop resistance because they cannot maintain a high degree of adherence to their medication regimens. This paper illustrates how a simple and inexpensive SMS-based mHealth application can be used to facilitate the TB/HIV treatment.**

***Keywords*— mHealth; TB; HIV; Treatment; Medication Adherence**

## I. Introduction

Tuberculosis is a disease of poverty, affecting mostly young adults in their most productive years. The majority of the cases occur in the 22 high burden countries in Asia and Sub-Saharan Africa, which account for more than 70% of the cases worldwide. India ranks number one in the number of new cases per year, accounting for one fifth of the global incidence of the 9.1 million cases worldwide each year. WHO estimates that 1.9 million cases and 370,000 deaths (approximately 1000 every day) are from India [1]. Controlling TB in India is a challenge, particularly because of the crisis in human resources for health [2], and the disease is a major barrier to social and economic development incurring US$ 3 billion in indirect costs and US$ 300 million in directs costs [3]. The emergence and spread of drug-resistant tuberculosis further complicates the control of the disease.

eHealth is the delivery or facilitation of health services and information through the Internet, telecommunications and related technologies [4]. eHealth is concerned with the application of Information and Communication Technologies (ICT) in healthcare. Amongst types of ICT infrastructure (e.g. hardware, software and network), network has drawn the most attention in eHealth initiatives and implementations [5]. Limited web access and slow Internet speed are a major concern, particularly in developing countries where high-speed internet access is not widely available [5]. However, while developing countries may lack high-speed Internet access, affordable mobile phone service is widely available and used [6][7]. For this reason, mobile communication technologies hold great promise in improving access to and affordability of eHealth services even to the poorest areas [5][6].

mHealth uses mobile wireless devices, such as cell phones and PDAs to improve health outcomes. Mobile communications have all the potential to radically transform healthcare services –"even in some of the most remote and resource poor environments [8]." Studies have shown the potential for mHealth to improve healthcare outcomes and facilitate public health services [5][6][9][10]. For example, 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 [9]. Li et al. [5] illustrated how a mobile phone SMS-based application can be used to mHealth, potentially facilitating influenza pandemic surveillance in developing countries. However, researchers conclude that larger prospective studies are still necessary before large-scale services rollout [11].

The objective of this paper is to illustrate how a simple and inexpensive mHealth application can be used to facilitate the TB/HIV treatment. The system leverages SMS facilities of mobile phones that are widely available as a common personal item in resource-limited settings (e.g., developing countries). The rest of the paper is organised as follows: Section II discusses background information and the motivation to apply mHealth in the TB/HIV treatment; Section III discusses the potential use of mHealth. Section IV discusses how mHealth can be applied to combat TB/HIV; Section V discusses the design of an mHealth system; Section VI describes the features of the system and illustrate how it can be applied for the TB/HIV treatment; Section VII concludes with a summary of our study and future work.

## II. BACKGROUND

India, the third highest HIV- burdened country, had an estimated 2.31million (0.36% of adult population in the country) people living with HIV and AIDS in 2006. With such large numbers of HIV-positive individuals in India, it is likely that HIV may worsen the TB epidemic. TB is the most common opportunistic infection in people living with HIV virus. HIV- infected people are at greatly increased risk of TB, with HIV being the strongest risk factor for progression of latent TB infection to active TB [12] and recurrent TB [13]. Without HIV, the lifetime risk of developing TB in TB-infected people is 10%, compared to at least 50% in HIV co-infected. TB in turn accelerates the progression of AIDS and reduces the survival chance of patients with HIV infection. TB in HIV-infected persons is also a transmission risk to non-HIV affected persons and can accelerate the TB epidemic. Thus, TB and HIV are closely interlinked [14].

Directly Observed Treatment, Short-course (DOTS) for TB treatment is as effective among HIV- infected TB patients as among those who are HIV negative. TB control through DOTS is complicated by many factors such as treatment adherence (successful treatment requires multiple drugs under direct supervision for a long duration), lack of adequate number of healthcare workforce and social stigma. Stigma is increasingly recognized as part of the experiences of people living with TB, often in association with HIV [15][16][17]. TB has been and still is often considered a ‘‘dirty disease’’, ‘‘a death penalty’’ or as affecting ‘‘guilty people’’ [17]. When TB patients are treated as socially inferior or discriminated against, this often results in a sense of inferiority, shown by patients hiding their diagnosis from others, or feeling ashamed of having TB [18]. Despite the benefits of DOTS therapy, the rigid supervision of treatment may also increase the stigma associated with the disease, as it implies distrust of the patient. Patients often isolate themselves to avoid infecting others and to avoid uncomfortable situations such as being shunned or becoming the subject of gossip.

Inspired by the growth of mobile communication technologies, global health policy-makers and providers are strengthening mHealth as a new tool to tackle the global crisis in inadequate workforce and patient monitoring [19]. Also, mHealth in the follow up and management of TB/HIV patients can provide a secondary benefit in addressing the issue of stigma by the avoidance of face to face contact [20], and as a result better expected results of the treatment. The massive penetration of mobile phone networks, especially in developing countries, (i.e., about 4 billion people have mobile phones) potentially enhances access to ubiquitous healthcare services [11]. This is an encouraging sign for the use of mHealth with mobile phone networks as a cost-effective alternative to the more traditional Web based eHealth applications to facilitate the TB/HIV treatment.

The Asia-Pacific ubiquitous Healthcare research Centre (APuHC-www.apuhc.unsw.edu.au) at the University of New South Wales, Australia has been leading an evidence-based study on the Assessment of eHealth for Health Care Delivery (eHCD) for WHO since 2006 in a number of Asia Pacific countries including India and China (see www.apuhc.unsw.edu.au - Program 3). It has been decided to build upon this expertise to launch a new global cooperative project involving 12 countries all over the world (including India and Bangladesh in the subcontinent) to assess the impact of mHealth in terms four factors of health outcome, namely Access, Quality, Acceptance to physicians/healthcare workers and Cost (AQAC). The work reported in this paper is part of the mHealth global study.

## III. POTENTIAL USE OF MHEALTH

mHealth describes the application of mobile telecommunication and multimedia technologies in mobile and wireless health care delivery systems [5]. In broad, it involves using wireless technologies to transmit and enable various data contents and services which are easily accessible through mobile devices such as mobile phones, smart phones, PDAs, laptops and tablet PCs [21].

Health services are inadequate in many developing countries because they are often neither accessible nor affordable, compounded by a critical shortage of health workers [5]. When health services are available, they are often dysfunctional, low quality, and unresponsive to the needs of patients [22]. The poor condition of healthcare in developing countries is widely documented as shown in Table I. The statistical figures indicate the dire situation of primary health care in developing countries [23].

| Countries | Infant Mortality rate (per 1000) in 2006 | Maternal Mortality (per100000) in 2005 | Years of life lost due to communicable disease (%) in 2002 | Births attended by skilled health personnel (%) | Hospital beds (per 10000) | Total Health workers (per 10000) |
|---|---|---|---|---|---|---|
| India | 57 | 450 | 58 | 47 (2006) | 9 (2003) | 14 (2003) |
| Pakistan | 78 | 320 | 70 | 54 (2006) | 12 (2005) | 12 (2003) |
| Bangladesh | 52 | 570 | 60 | 20 (2006) | 3 (2001) | 5 (2001) |
| UK | 5 | 8 | 10 | 99 (1998) | 39 (2004) | 75 (2001) |
| USA | 7 | 11 | 9 | 100 (2004) | 32 (2005) | 125 (1999) |

TABLE I - HEALTH INDICATORS OF COUNTRIES

Five percent of the population has access to computers whereas 43% of the population own mobile phones [21]. Indeed, mobile phones, as an ICT platform, have far greater penetration than computers, and are potentially capable of meeting the underserved health needs of patients [5][8]. A recent study of United Nations Foundation and Vodafone Foundation (2009) shows that there are fifty-one mHealth programs that are being operated in 26 developing countries around the world. These programs are gaining strong support across regions as well as from different stakeholders like technology providers, government and academia [21]. Different types of mHealth services are in practice, which include text (SMS) & video contents and voice (medical call centres) services [5].

## IV. MHEALTH TO COMBAT TB/HIV

One of the major issues with diseases like HIV/AIDS and Tuberculosis is the social stigma attached to them. In many villages in India, these diseases are considered to be death warrants for the patients. This leads to patients becoming demotivated and losing their will to battle the disease. Similarly, in order to be accepted by society, many patients are hesitant to approach health workers in public to discuss their problems as they fear ridicule. In order to tackle these problems, mHealth can be of great help. We can utilize the huge mobile phone penetration in the country by sending regular awareness and motivational messages to educate the people about the diseases. We also send regular reminders to the patients to take medications on time. One important point to note here is that most people in rural India cannot read or write in English; therefore for the system to be successful, communication in local languages is a must.

## V. SYSTEM DESIGN AND DEVELOPMENT

This section discusses the application requirements, the system architecture, and the required technologies to create it.

### A. *System Requirements*

Server:

- A WAMP (Windows, Apache Server, MySQL Database and PHP) system with Frontline SMS
- A supported mobile phone connected to the system via USB

Client: (Patient)

- Mobile phone which supports UCS2 (UTF-16) character encoding

### B. *Technologies Used*

The system is built on AMP (Apache Server, MySQL and PHP) and is completely open source. This helps us reduce the cost of the system which is an important factor as the project is distributed to more locations. Due to the lack of existing infrastructure, the systems will be deployed with local databases. A centralized database is not required for this system as the patients will continue to receive messages from his home system regardless of where he lives once he has registered himself. If, the patient changes his address or phone number, all he has to do is SMS the new contact details to his home system.

This program also uses FrontlineSMS – a free, open-source software, which is used for Non-Government organizations, mostly in the developing world, as the mobile gateway. FrontlineSMS requires a computer, and a phone with a SIM card connected to the computer via data cable. The program uses FrontlineSMS to send and receive SMS messages. The messages and responses are then ported to and from the main program.

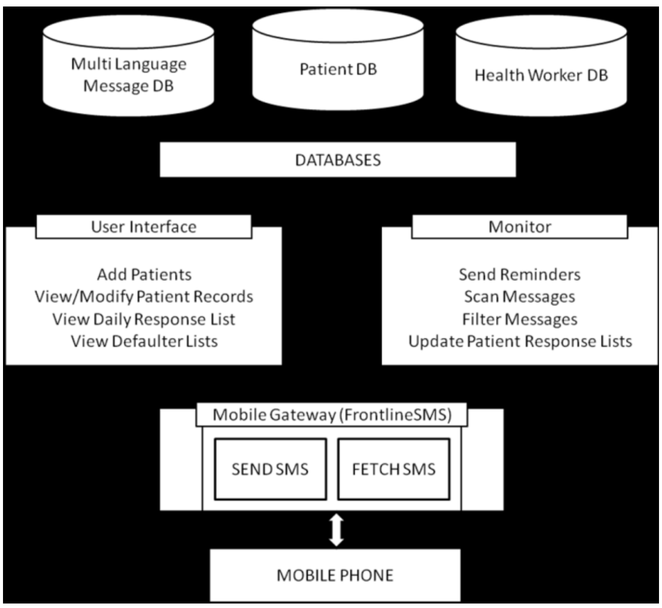


Fig 1: System Architecture

The interface is kept simple keeping in mind that the users of the system might have very basic knowledge of using computers**.**

### C. *System Components-*

Fig 1. Shows the architecture of the system. The system is comprised of the following components.

1) *Databases*:

Message Database - The Message database contains awareness and reminder messages in different languages that are sent to patients periodically in the language of their choice. Currently the system supports Hindi, Bengali and Tamil. The message columns in the database are set to UCS2 (UTF -16) encoding which allows us to store the messages in all the languages specified above. While this adds a lot of flexibility to the system in terms of language support, it also requires the users of the system to have access to mobile phones that supports non-English character set. Most basic Nokia mobile phones, which are popular among rural mobile users support these character sets

Patient Database - Patient Database contains basic personal information about the patient along with this contact details and available medical history. It will also contain the patient's preferred language of communication.

Health Worker Database - The health worker database contains information about the public health workers involved in the program. It also stores the responsibilities and amount of work allocated to each health worker

2) *User Interface (UI):*

The UI allows authorized users to access the database and perform functions like entering and accessing records, running queries, configuring the Monitor and sending SMS.

3) *Monitor:*

The monitor handles the task of scheduling and handling messages that are sent and received by the system. The monitor is programmed to automatically fetch the correct message at the right time and send it to the appropriate receiver. The monitor must also handle and filter the messages that are received by the system at any time. Fig 2 shows the activities and workflow of the monitor.

*4) Mobile Gateway (FrontlineSMS)*

The mobile gateway is a tool which provides an interface between a computer and a mobile phone. This gateway links the monitor and UI to the mobile phone to send and receive messages. We use FrontlineSMS as our gateway. Frontline SMS interacts with the monitoring program using a HTTP Trigger. The HTTP trigger function allows the transfer of HTTP commands to FrontlineSMS through a free HTTP Port (Fig. 3)

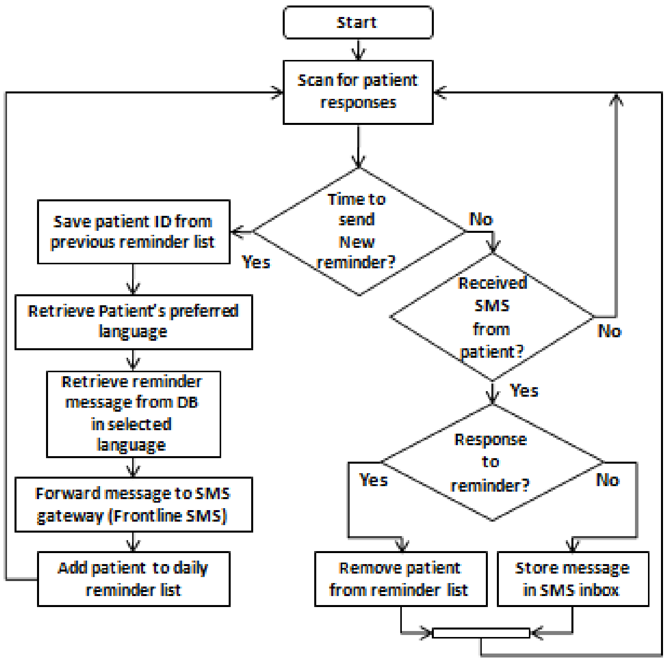


Fig 2: Activity Flow of the Monitor

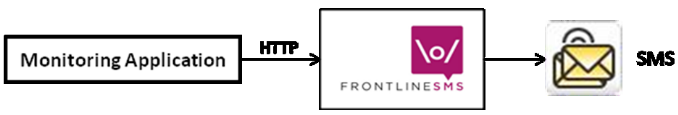


Fig 3: HTTP Trigger for Mobile Gateway

## VI. Application Functions

In this section we discuss the functional units of the system. A) *Patient Registration* - The TB/HIV patient registration form (Fig 4.) is a very simple form where the data entry operator or health worker enters the basic personal details of the patient along with the preferred language of communication. It is vitally important that local languages are supported in non-English speaking developing countries like India as majority of the population will not be able to make use of the system otherwise. All medication reminders will be forwarded to the patient in their selected language and the health workers will also try and communicate other instructions to the patients in their selected language whenever feasible. Once the patient is registered, a unique patient identification number is generated. The registration form is kept very simple as we assume that the health workers and operators might not have prior exposure to handling computer systems. In case of any data entry error during registration, a 'modify records' (Fig 5.) option is provided to quickly change or correct the information.

B) *Reminder Generation and Response Tracking* - Each day the monitor will send the medication reminder messages to all the registered patients in their preferred language of communication. For the rest of the day, the monitor will track responses from the patients. Throughout the day the monitor will scan the phone for messages from patients containing a pre-defined keyword to signal that they have taken the medicine. The response list (Fig 6.) is updated such a message arrives from a particular patient. All other messages and patient queries are transferred to the inbox (Fig 7.) and the health workers can respond to the messages instantly by clicking the 'Reply' button from the inbox. All new messages in the inbox are highlighted in yellow.

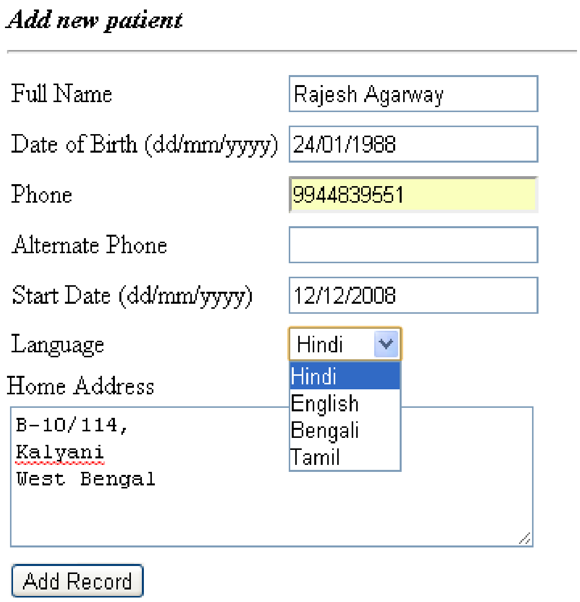


Fig 4: Patient Registration Form

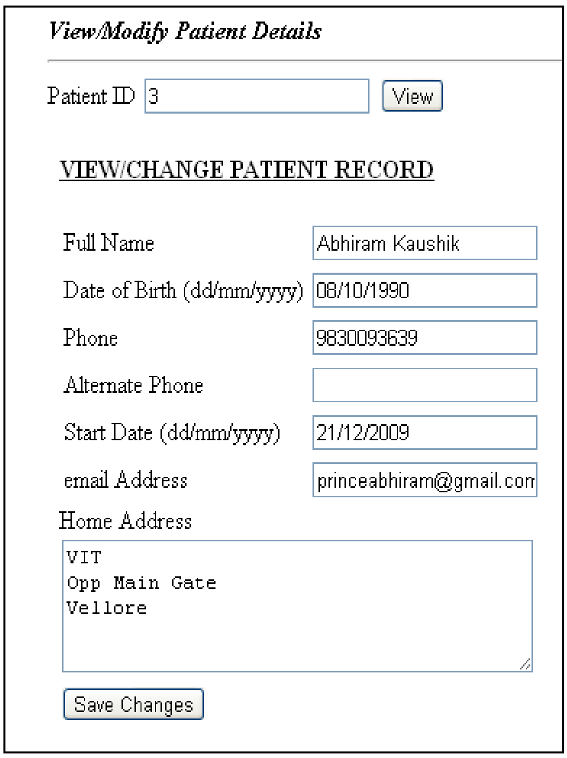


Fig 5: Patient information Modification Form

Before fresh reminder messages are sent out at the start of the day, the monitor records the patient identification numbers of all the patients who failed to respond the previous day. This list of patients can be found under the defaulters list (Fig 8.). This will help health workers to instantly track the patients who have been avoiding their medications. For the first time a patient appears on the list, the health worker can find the phone number of the patient from the database and call the patient to understand the reasons for him avoiding medication.

The health worker will also explain the effects of stopping medication and try to convince the patient to restart his medication. . If a patient's name appears repeatedly in the defaulter's list, the health worker can find the address of the patient from the database and pay him/her a visit to understand and resolve the problems. All these problems and solutions should be documented for analysis and future use.
At the end of each week, month, and year, statistics related to drug adherence can be generated using the following formula. Over any given period of time:

$$\textit{Individual Drug Adherance Ratio} = \frac{\textit{Total number of responses}}{\textit{Total number of reminders sent}}$$

$$\textit{Average Drug Adherance Ratio} = \frac{\sum \textit{Individual Drug Adherance Ratio}}{\sum \textit{Number of patients}}$$

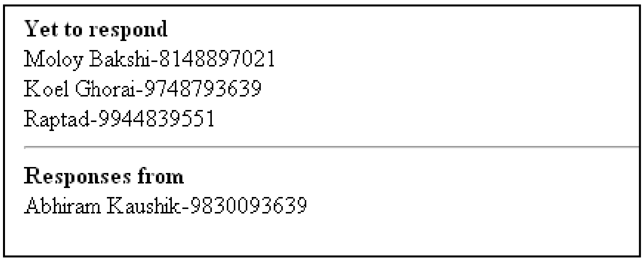


Fig 6: Medication Response List

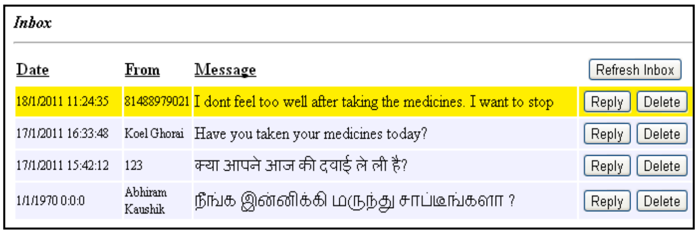


Fig 7: SMS Inbox with Quick Reply Option

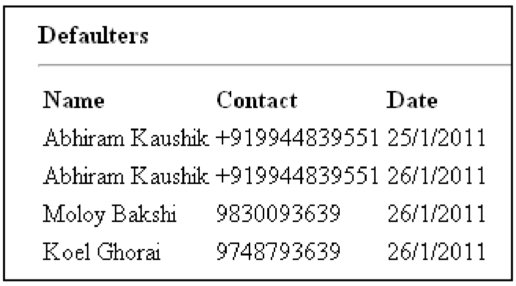


Fig 8: Patients Who Did Not Respond (Defaulter List)

## VII. CONCLUSION

This paper has demonstrated the uses of mHealth for the TB/HIV treatment. This mHealth application has used the FrontlineSMS platform that appears to have a number of advantages in the context of developing countries, such as low start up cost, no need for an internet connection and the ability to run for several hours without a power source. It leverages technology (regular mobile phones) that is already widespread in the population; and the program itself is extremely user friendly and requires little training.

In 2011, the program is being implemented to assess the effectiveness of such a program in two states of India (eastern state West Bengal and southern state Tamil Nadu) that have completely different cultures and languages. Two regional towns, Vellore in Tamil Nadu and Kalyani in West Bengal, host the servers with about 100 patients using the system from each location. We are testing the success of the system in India by comparing the medication adherence rates, mortality levels, and relapse rates of TB/HIV patients with access to mobile phones and using the m-Health system, with those who do not have access to a phone. Further, surveys will be conducted to assess patient health status and satisfaction; periodic feedback collected from the users for the improvement of the program.

The study will be extended to other countries in Asia-pacific as part of the mHealth global study.

## REFERENCES

[1] World Health Organisation. (2010). Global tuberculosis control: surveillance, planning, financing: WHO report 2010.
[2] J. Figueroa-Munoz, K. Palmer, M.R. Poz, L. Blanc, K. Bergstrom and M. Raviglione, The health workforce crisis in TB control: a report from high-burden countries. Hum Resour Health, 2005; 3(1), 2.
[3] RNTCP. RNTCP Status report. New Delhi: Central TB Division, DGHS, Ministry of Health and Family Welfare2010.
[4] Eysenbach, G. (2001). What is e-health? J Med Internet Res, 3(2), E20.
[5] J. Li, N. Moore, S. Akter, S. Bleistein and P. Ray. (2010) mHealth for Influenza Pandemic Surveillance in Developing Countries, The 43 Hawaii International Conference on System Sciences (HICSS), 5-8 January, 2010 Hawaii, United States.
[6] UN. (2010). Barriers and Gaps Affecting mHealth in Low and Middle Income Countries: Policy White Paper. In C. U. Center for Global Health and Economic Development Earth Institute (Ed.).
[7] P. Ray, N. Parameswaran, V. Chan and W. Yu, (2008) Awareness modelling in collaborative mobile e-health. J Telemed Telecare, 14(7), 381-385.
[8] P. Mechael. (2009) The case for mHealth in developing countries, Innovations, MIT press.
[9] W. Curioso and A. Kurth, (2007). Access, use and perceptions regarding Internet, cell phones and PDAs as a means for health promotion for people living with HIV in Peru. BMC medical informatics and decision making, 7(1), 24.
[10] U. Strandbygaard, S. Thomsen and V. Backer, (2009) A daily SMS reminder increases adherence to asthma treatment: A three-month follow-up study. Respiratory medicine.
[11] J. Puccio, M. Belzer, J. Olson, M. Martinez, C. Salata, D. Tucker and D. Tanaka, (2006). The use of cell phone reminder calls for assisting HIV-infected adolescents and young adults to adhere to highly active antiretroviral therapy: a pilot study. AIDS Patient Care & STDs, 20(6), 438-444.
[12] H. Rieder, G. Cauthen, G. Comstock, Jr D. Snider. Epidemiology of tuberculosis in the United States. Epidemiologic Reviews. 1989;11:79.
[13] E. Korenromp, F. Scano, B. Williams, C. Dye, P. Nunn. Effects of human immunodeficiency virus infection on recurrence of tuberculosis after rifampin-based treatment: an analytical review. Clin Infect Dis. 2003:101-12.
[14] J. Chretien, Tuberculosis and HIV. The cursed duet. Bulletin of the International Union against Tuberculosis and Lung Disease. 1990;65(1):25.
[15] E. Johansson, N.H. Long, V.K. Diwan and A. Winkvist, (2000) Gender and tuberculosis control: Perspectives on health seeking behaviour among men and women in Vietnam. Health Policy, 52, 33-51.
[16] F. Karim, AM.R. Chowdhury, A. Islam and M.G. Weiss, (2007) Stigma, Gender,and their Impact on Patients with Tuberculosis in Rural Bangladesh. Anthropology & Medicine, 14(2), 139 - 151.
[17] N.H. Long, E. Johansson, V.K. Diwan and A. Winkvist, (1999) Different tuberculosis in men and women: beliefs from focus groups in Vietnam. Social Science & Medicine, 49(6), 815-822.
[18] S.V. Eastwood and P.C. Hill, (2004) A gender-focused qualitative study of barriers to accessing tuberculosis treatment in The Gambia, West Africa. International Journal of Tuberculosis and Lung Disease, 8( 1), 70-75.
[19] VitalWaveConsulting V. mHealth for development: the opportunity of mobile technology for healthcare in the developing world. Washington,

DC and Berkshire, UK: UN Foundation-Vodafone Foundation Partnership. 2009.

[20] S. Akter, J. D'Ambra and P. Ray, (2010) "A Hierarchical Model of Trustworthiness in mHealth Information Services: Model Development and Validation Using Partial Least Squares (PLS)", Accepted (Sept 2010) Journal of the American Society for Information Science and Technology

[21] United Nations foundation & Vodafone foundation 2009, mHealth for Development: The opportunity of mobile technology for healthcare in developing world, [Internet] Available: http:// www.vitalwaveconsulting.com/insights/ mHealth.htm (Accessed 3 April 2009)

[22] World bank report, 2004 as cited by UN foundation & Vodafone foundation 2009, mHealth for Development :The opportunity of mobile technology for healthcare in developing world, [Internet] Available: http://www.vitalwaveconsulting.com/insights/mHealth.htm (Accessed 3 April 2009).

[23] G. Ivatury, J. Moore and A. Bloch. (2009) A doctor in your pocket: Health hotlines in developing countries, Innovations, MIT press.