

Mobile Health for TB



<http://zunia.org/typo3temp/pics/79b33cb598.jpg>

Amanda Spielberg

Capstone Advisor: Michael Zeilinger
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Introduction

The use of mobile phones in the developing world has increased dramatically over the past several years. Developing countries currently account for two thirds of mobile phone usage.¹ In Africa a surprising one out of 11 people are mobile subscribers.² Additionally cell phones are increasingly being used for more than communications, for example: transferring money, banking, research, and recently developing health purposes. Mobile health technology(mHealth), a new and expanding field, is working to bridge the gap between patients and health services by utilizing cell phone technology. This includes disease surveillance, appointment reminders, medication adherence, self assessment tests, treatment monitoring and other features all carried out through basic cell phone functions such as texting, automated messaging, and calendar features. This type of technology has the potential to be extremely instrumental in fighting infectious diseases that often require long treatment. In particular, Tuberculosis (TB) requires a standard treatment period of 6-9 months. In the developing world, for various reasons, many TB patients do not complete this treatment causing further sickness, spread of infection, and breeding drug resistance. Meeting the Millennium Development Goal of halving the prevalence rate of TB by 2015 is unlikely without new interventions. How, and to what extent can mHealth technology be used to increase surveillance, prevention and full and effective treatment of TB?

Purpose

Mobile health has the potential to help bring better health care to remote areas using what many of the poor consider to be one of their most important assets, their cell

¹ Jordans, Frank . "World's Poor Drive Growth in Global Cell Phone Use - ABC News." ABCNews. <http://abcnews.go.com/Technology/WireStory?id=6986939&page=1>

² LaFraniere, Sharon. "Cell phones Catapult Rural Africa to 21st Century." New York Times, August 25, 2005, International. <http://www.nytimes.com/2005/08/25/international/africa/25africa.html>

phone. Despite its tremendous promise and the numerous mHealth endeavors that have begun in the past decade, due to the newness of the mHealth field and the fact that many of the first mHealth programs are still in pilot phases, the scholarly literature on mHealth is almost nonexistent. Instead there exists a series of summary papers and recommendations, but even these take a general approach summarizing what mHealth is and all the initiatives that are currently in progress. As such, this paper seeks to take a more detailed approach by looking at how the components of mHealth can be structured to improve health care for a specific infectious disease, in this case tuberculosis. Tuberculosis still plagues the developing world, and is a disease where most components of mHealth technology may be fairly easily incorporated into National Treatment Programs (NTPs). Two TBmHealth programs that are being piloted now have shown up to 90% improvement in medication adherence (discussed in detail in Section 3). In this paper I will look at all sectors of mHealth and see how they can improve TB programs, as well as detail what a good mHealth initiative needs in order to be sustainable and most effective. This paper is merely a beginning look at how mHealth can be incorporated into current TB efforts, and also proves the need for more field research and data collection in this field.

Methodology

Research on using Mhealth in relation to TB treatment is very limited, as the few efforts that have been developed are still in trial phases. To overcome this lack of data and scholarly work I took a general qualitative approach in my research looking specifically at programming framework. In doing so, I first looked extensively at the Mhealth field as a whole including: its components, where it is being used, its future

potential and barriers to its success. Separately, I did widespread research on tuberculosis and the current global views and treatment efforts being used. Lastly, I objectively looked at mHealth and TB together, including assessing the efforts currently being undertaken, to gain an understanding of how mHealth may be incorporated into TB programs and to create a general framework for where and how this may be done. To narrow my scope of research, I focus the majority of the TB discussion on the Africa region, where the burden of tuberculosis is high and rapid cellphone penetration makes most countries in the region viable contenders for mHealth.

This paper is broken down into four major sections. The first section synthesizes and provides some assessment of the current status of mHealth by reviewing the relevant literature, looking at current programs and evaluating cases where mHealth is working and where there are still gaps that need to be addressed. The second section looks in detail at tuberculosis and provides a summary of the causes, prevention and treatment of TB in general, and secondly evaluates the current strategies and treatment plans that are being used (where they work and where there are gaps). The third section will present preliminary findings and explanations of four efforts that are using mHealth to address TB. Lastly, based on my research, the final section evaluates, where and to what extent mobile health technology can play a role in improving current TB efforts.

Section 1: Mobile Health

What is mHealth?

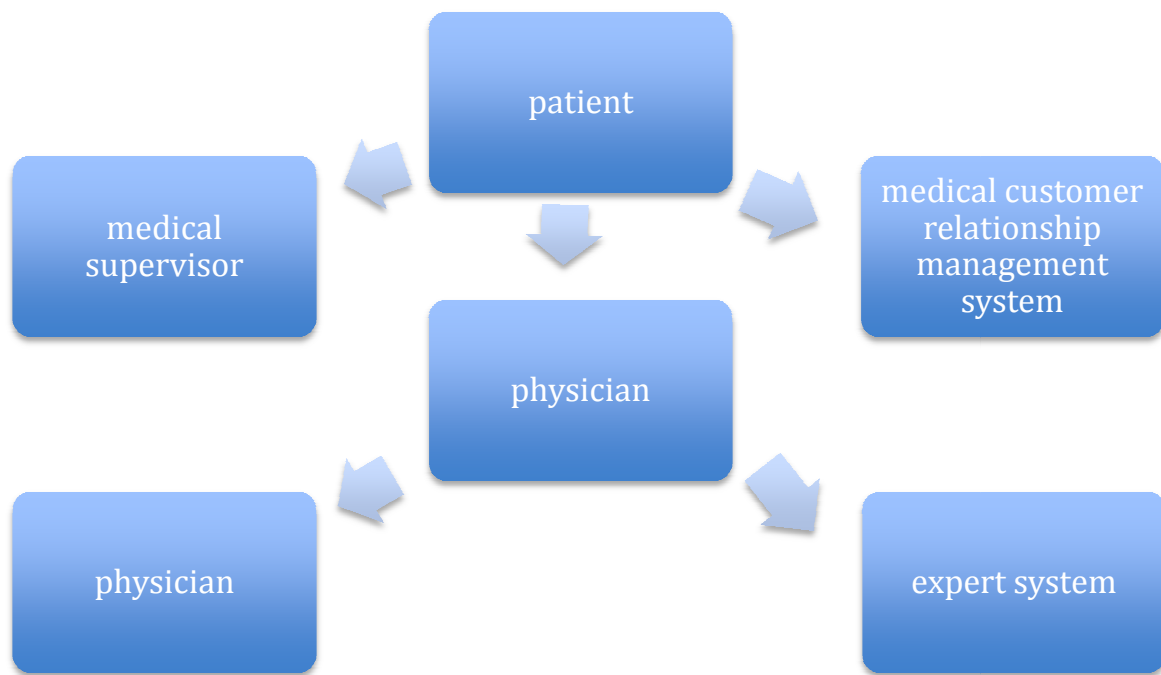
Mobile Health, more commonly referred to as mHealth, is currently defined as “Using mobile communications— such as PDAs and mobile phones—for health services and information”.³ In other words mHealth encompasses any form of health related service that is facilitated or aided with the use of a mobile device. The main idea of mobile health technology is to bridge the gap between patients and healthcare providers and broader health services. In doing this a series of relationship and health information flows are developed.

Figure 1 depicts the information flow within the health care umbrella that mobile phones facilitate.⁴ For example, one mobile health connection shown in the chart is physician-to-physician, which may refer to the sharing of patient records through a mobile device or receiving assistance with a diagnosis from another physician. Likewise, the patient-to-physician mHealth relationship may consist of a patient texting their symptoms to a physician in order to receive a prescription or medical advice. These relationships help to explain the simplest functions of, and need for, mHealth: communication. While in the developed world we may think of these communication relationships as an everyday occurrence in the healthcare industry, in many parts of the developing world it is the simplest breakdowns in (or complete lack of) communications within health systems that leads to ineffective healthcare.

³ Vital Wave Consulting. mHealth for Development: The Opportunity of Mobile Technology for Healthcare in the Developing World. Washington, D.C. and Berkshire, UK: UN Foundation-Vodafone Foundation Partnership, 2009.

⁴ Mishra , Saroj Mishra , and Indra Pratap Singh. "mHealth: A Developing Country ." (2008). ehealth--connection. <www.ehealth-connection.org/files/conf-materials/mHealth_%20A%20Developing%20Country%20Perspective_0.pdf>

Figure 1: Directions of Medical Information Facilitated by mHealth



Mhealth can be further broken down into different sectors of use, all of which encompass one or more of the above described relationships. While the field is new and evolving and classifications within mHealth vary, for the purpose of this paper I will use the UN Foundation's six sector form of classification: Education and Awareness, Diagnostics and Treatment Support, Remote Monitoring, Remote Data Collection, Tracking Epidemic and Disease Outbreaks, and Basic Training and Communication for health workers.⁵

Education and Awareness: Health and education are inextricably linked. Often health problems originate in large part from a limited understanding or awareness of

⁵ Vital Wave Consulting, 10

effective prevention methods, nutrition, testing for a disease, or purpose of treatment. Without accurate health knowledge people are often unwilling or unable to seek appropriate care and make informed health related decisions. Health education and awareness campaigns are one method for dealing with this imperfect information. In the past these campaigns have been carried out through a variety of means including: billboards, radio and TV ads, pamphlets and brochures.

In terms of mHealth, education and awareness usually consists of one-way text/SMS messaging from the health/campaign organization to a target group. “SMS messages are sent directly to users’ phones to offer information about testing and treatment methods, availability of health services, and disease management.”⁶ The purpose of these efforts is often to induce certain behavioral changes and increase awareness, with an overall long-term goal of improving public health. The benefits of using SMS/texting campaigns versus the standard tactics are widespread.

The UN Foundation ascertains that: “Formal studies and anecdotal evidence demonstrate that SMS alerts have a measurable impact on and a greater ability to influence behavior than radio and television campaigns”.⁷ For one, providing information through texts allows individuals to receive critical information privately, which becomes very important when dealing with stigmatized issues and diseases (such as HIV/AIDS).⁸ In addition with a growing cell phone penetration in remote areas, the texting campaigns offer a tool for providing education and awareness to typically hard to reach populations. This in turn affords financial benefits as time and travel costs are saved and the overall

⁶ Vital Wave Consulting, 7

⁷ Vital Wave Consulting, 7

⁸ Vital Wave Consulting, 7

“cost per impression” is significantly decreased.⁹

Diagnostics and Treatment Support: In the developed world this sector of mHealth is expanding rapidly as specialized mobile devices and phones are able to measure and monitor a patients blood pressure and pulse, detect certain breathing problems and more.¹⁰ These devices are however fairly new and expensive and are not likely a viable tool for developing countries, as of now.

In developing countries, this sector of mHealth consists of connecting healthcare workers to information databases or medical staff, through wireless mobile devices, in order to obtain treatment or diagnostic advice when needed.¹¹ Phones used for this sector typically need more specialized tools and software, making it slightly more costly than some of the other sectors of mHealth, but immensely beneficial. For example, software in the phone is able to take the health care workers through a series of diagnostic steps (in some cases including imaging) and then transfer this data to medical professionals who make the diagnosis and provide treatment advice.¹² Obviously this cannot work for all health problems and leaves room for error, but it has proven to be effective in many cases thus far. For example a recent small-scale John Hopkins University study found the precision of diagnosis when using imaging on smart phones to be extremely accurate. “In 125 reads of CT scans on iPhones, five medical residents made a total of just one error. In every other case, the residents agreed that 15 of the 25 patients whose records were

⁹ Vital Wave Consulting. “Sizing the Business Potential of mHealth in the Global South: A Practical Approach. (2009). P8 <www.mhealthalliance.org>

¹⁰ Mishra ,2

¹¹ Vital Wave Consulting, 14

¹² Vital Wave Consulting, 14

reviewed had acute appendicitis and 10 had a less-emergent issue.”¹³ As technology expands and projects like this scale up such methods and devices are likely to be more widely used and decrease in cost.

Remote monitoring: Remote monitoring, which refers to the ability to monitor a patient’s treatment and progress using cell phone technology, is one of the most promising areas of mHealth. This sector encompasses: “one or two way communication to monitor health condition, maintain caregiver appointments, or ensure medication regime adherence”.¹⁴ This is especially important for medication adherence, which is a major problem with numerous chronic and infectious diseases. In many cases a significant improvement of medication adherence can benefit the health of the overall population significantly more than improved medical treatments.¹⁵ Remote monitoring is one of the main tools that has the potential to play a large roll in tuberculosis treatment, as will be discussed in detail in sections 3 and 4.

Remote monitoring not only improves patients’ home care and medication adherence, but also cuts costs and adds to patient satisfaction. By receiving daily reminders or phone calls patients are able to maintain treatment at home, discounting them the costs of traveling to a clinic and taking time away from work (which decreases DALYS).¹⁶ It also helps them feel cared for when they receive personal reminders and medication tips. “Evidence shows that... monitoring patients at home for chronic

¹³ Versel, Neil. "Study: iPhone image quality adequate for diagnosing appendicitis " FierceMobileHealthcare. http://www.fiercemobilehealthcare.com/story/study-iphone-image-quality-adequate-diagnosing-appendicitis/2009-12-01?utm_medium=nl&utm_source=internal

¹⁴ Vital Wave Consulting, 12

¹⁵ Haynes RB, McDonald H, Garg AX, Montague P. Interventions for helping patients to follow prescriptions for medications. The Cochrane Database of Systematic Reviews 2002, Issue 2. Art. No.: CD000011. DOI: 10.1002/14651858.CD000011.

¹⁶ Vital Wave Consulting 2009, 8

conditions dramatically improves survival rates.”¹⁷ On the side of health care providers they save on the cost of having to visit outpatients to observe medication compliance and are able to make sure all patients are contacted in some form daily (or as needed).

Remote Data Collection: On the side of policy makers and healthcare providers, the lack of access to necessary information about the lifestyles, health problems, and current coping mechanisms of the poor, often

contributed to inadequate health policies and services. Data collection contributes to the monitoring and evaluation of current programs and policies, and provides a broader survey of the overall health situation in a country or region. Data collection of any sort is difficult to carry out among populations who may live in



This picture, taken in Indonesia, depicts a health care worker recording patient's health data on his cell phone through an electronic questionnaire.
*Source: <http://www.flickr.com/photos/unfoundation/3239149632/>

more remote areas and typically do not travel often to health facilities due to cost and distance. Thus, collecting information about these sectors of a population is costly and time consuming. Poor data recording and collecting contributes to certain health needs and problems being overlooked or misinterpreted.¹⁸

Mobile phones provide a new method of dealing with this. MHealth in relation to data collection refers to the use of mobile devices (including smart phones, PDAs or

¹⁷ Vital Wave Consulting, 12

¹⁸ Earth Institute at Columbia University. "mHealth in the Millennium Villages Project." The Millennium Villages Project. <[ghed.ei.columbia.edu/sitefiles/file/Mobile_Health_within_MVP %20\(1\).pdf](http://ghed.ei.columbia.edu/sitefiles/file/Mobile_Health_within_MVP%20(1).pdf)>, P4

mobile phones) by health workers to collect field data.¹⁹ This is more time efficient, cost effective, and accurate. Typically when data collection is done, paper surveys are used. Using mobile devices “allows the creation of customized questionnaires, which are distributed to the phones of health agents in the field...”²⁰ This cuts on the costs of paper, decreases the time spent on the survey (as the data is entered while being obtained and doesn’t have to be typed up and put in a database later), and improves data accuracy. When health workers have completed the surveys they send the data through their phones to a central analysis source. Because the data is being transferred directly from patient/individual to health worker it eliminates the steps of reentry and thus the chance of losing the data or creating miscommunications along the way. In an example from Uganda, the use of PDAs by health workers to collect field data decreased overall costs by 25%.²¹

Tracking Disease and Epidemic Outbreaks: All too often disease outbreaks and epidemics could have been halted if cases were appropriately recorded and monitored. Other than new mHealth initiatives in this area, outbreak monitoring often relies on radio communication, written recording systems and other efforts that often have a substantial time lag and no centralized analysis base. “Disease and epidemic outbreak tracking mHealth applications are being used in Peru, Rwanda, and India as an early warning system, allowing public health officials to monitor the spread of infectious diseases.”²² These systems and techniques are fairly straightforward and if used correctly and consistently have the potential to significantly improve disease surveillance. These types of activities require mobile devices with adequate memory space and battery life.

¹⁹ Vital Wave Consulting 2009, 8

²⁰ Vital Wave Consulting, 28

²¹ Vital Wave Consulting, 16

²² Vital Wave Consulting, 13

Communication and training for health care workers: In referring to the “communication” component of this sector, in many developing countries effective communication between different health service centers and hospitals are minimal to non-existent. Ensuring that mobile phones are available at these institutions and organizations, and setting up an agreed upon system of communication, can make a huge difference in patient health and health costs. For example, if a patient is referred to a higher health institution for treatment but shows up only to find that they are out of the medication or have no beds available, this patient incurs not only the financial and time costs but health costs as well, that could have been avoided by a simple phone call or text.²³ Improving the smallest communication factors can make a huge financial and health difference at little to no cost.

Training of health workers through mHealth is still a very new idea and is not as widespread as the other sectors, and thus will not be looked at in detail. In brief this sector refers to the provision of information to health workers through mobile devices or using mobile phones as a component to a training program.

The Need for mHealth and What Makes it Possible

Healthcare in developing countries faces many barriers in providing to the poor, including barriers to access, limited staff and training, financial capacity, lack of educational awareness, and much more. Shortage of health care workers is one of the biggest issues. The World Health Organization asserts a 2.4 million total deficit of healthcare workers worldwide.²⁴ For instance, the public health systems in many parts of Africa face huge human resource gaps. “Doctors, nurses, pharmacists and other health

²³ Vital Wave Consulting, 13

²⁴ Mishra, 7

care professionals are scarce. Those that are available are largely confined to urban areas leading to significant inequities in the provision and quality of health services between rural and urban areas.”²⁵ This limited capacity of health workers and the health inequalities it breeds often mean that the people who need health services the most have limited to no access to them.

In an article entitled “The Relationship among Economic Development, Health, and the Potential Roles of mHealth” by James G. Kahn et al., they classify these “constraints to improving health systems” into five different levels (see table 1).²⁶ For instance, the shortage of staff issue would fall into the “health service delivery” level. While mHealth cannot contribute to all of these constraints it does have the potential to play a role in each level. MHealth was developed as a tool to respond to many of these health care barriers in developed and developing countries, as discussed in the previous section.

Table 1: “Constraints to Improving Health Care”

(This table is copied from the footnoted source)

Level	Constraints to improving
Community and household	Lack demand for health services, physical, financial, social barriers to effective services
Health services delivery	Shortage of qualified staff, weak management of health systems, inadequate supply of meds and supplies, lack equipment and infrastructure
Health sector policy and strategic management	Weak system for planning and management, poor drug policies and supply systems
Cross-sectoral public policies	Lack of incentives to use inputs efficiently, reliance on donor funding
Environment and context	Gov corruption, weak rule of law, political instability, weak public accountability, climate geographical dispositions to disease, physical environment, unfavorable service delivery

²⁵ Regional Office for Africa. *DOTS in the African Region “A framework for engaging private health care providers.* (2004, April) World Health Organization. Regional Tuberculosis Program. P12 <[http:// www.afro.who.int/tb/res-pub/ppm_dots_framework_july_2006.pdf](http://www.afro.who.int/tb/res-pub/ppm_dots_framework_july_2006.pdf)>

²⁶ Kahn, James G. , Joshua Yang, and James S. Kahn. "The Relationship among Economic Development, Health, and the Potential Roles of mHealth." *ehealth--connection*. July 2008. <[http://www.ehealthconnection.org/files/conf-materials/Relationship%20among%20Economic %20Development_0.pdf](http://www.ehealthconnection.org/files/conf-materials/Relationship%20among%20Economic%20Development_0.pdf)>

However, while mHealth does fit well into these gaps, it is not just a construed response to need, it is an effort that looks at how what we have can be used to our full advantage. Most development economists use a livelihoods model in understanding and addressing the needs of the poor. I believe this model explains fairly well the overall theoretical justification for mHealth's potential.

The Household Livelihood Strategy is an effective approach for observing the poor's decisions and actions. In recognizing the poor as rational thinkers, their decisions have meaning and value behind them that provide key information about their needs. The livelihoods approach looks at four intertwining categories that influence a household's position in society²⁷:

- **Context-** natural forces, market conditions and access, state related services and regulations, and civil society
- **Assets-** monetary and nonmonetary, tangible and non-tangible (i.e. social connections) that a household or individual has
- **Activities-** how they use their assets i.e. jobs, service, migration...
- **Outcomes-** outcomes that arise from assets and activities (food, income, empowerment etc...)

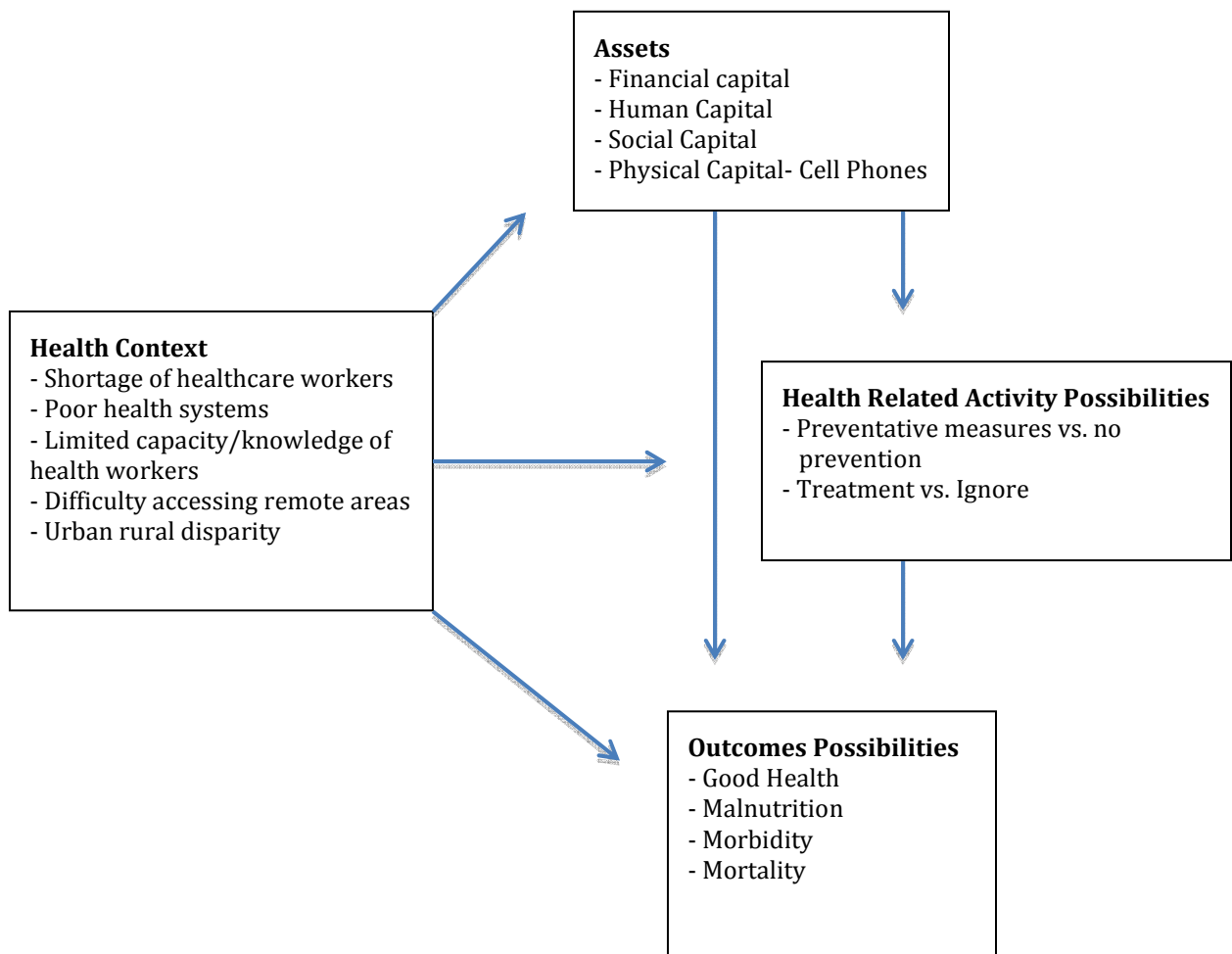
As a whole assessing the poor in this matter shows us: what context the poor live in, what the key assets of the poor are, the activities they partake in based on their assets and the context in which they live, and the outcomes of these activities (that then help determine future assets). Careful evaluation of this process, allows us to determine where problems exist that create poverty gaps and other failures that limit the livelihood of the poor.

In looking at only the health system through this lens, the health system, which encompass health facilities, healthcare workers, pharmacies, data collectors and other

²⁷ Krantz, Lasse . "The Sustainable Livelihood Approach to Poverty Reduction." *Swedish International Development Cooperation Agency (SIDCA)* (2001): 1-27.
<http://www.catie.ac.cr/CatieSE4/htm/Pagina%20web%20curso/readings/krantz.pdf>

related elements, represents the “context”. The “assets” of the poor may broadly include human capital, financial capital, physical capital, social capital and for this purpose cell/mobile phones (classified as physical capital). The “activities” of the poor (when only addressing the health context) would be any health related activity they engage in, such as seeking treatment or using preventative methods. Lastly, the “outcomes” are the specific health outcomes, broadly including morbidity, mortality, and good health (See Figure 2)

Figure 2: A Livelihood Strategy Approach to the Health Care System



In considering these components in terms of the livelihoods approach, it is apparent from common research that problem and breakdowns occur in: the “context” area, due to limited resources and rural urban healthcare disparities, and in the “assets” area in terms of poor health education/awareness (human capital) and limited financial capacity (financial capital). These breakdowns/problems in the assets and context lead to poor health activities and negative outcomes. In order to remedy this, we need improvements in the context situation and the asset situation.

MHealth provides one solution for both of these with little intervention. According to Oblageli Ezwesili, the vice President of the Bank for Africa, the poor consider mobile/cell phones to be one of the biggest assets in their lives.²⁸ “A full 64% of all mobile phone users can now be found in the developing world.”²⁹ By using this already present and important technology in everyday health operations we may be able to close these gaps in the health context and improve the asset position of the poor. MHealth is using this key asset of the poor (a cell phone) and expanding the scope of activities that they can use it for, such that, cell phones will no longer be used merely for communication, or banking (as has been a growing sector) but health.

Specifically, the context can be improved by using the mHealth sectors discussed in the previous section such as, Remote Data Collection, Remote Monitoring, Diagnostics and Treatment Support, Tracking Epidemic and Disease Outbreaks and Basic Training and Communication for health workers. The assets of the poor will be improved by the costs saved from transport, the improvement in work capacity associated with better health and directly from improved education if mHealth Education and Awareness

²⁸ mHealth Summit. 29-30 October 2009. Washington DC. Accessed online
<<http://www.fic.nih.gov/news/events/mhealthsummit.htm>>

²⁹ Vital Wave Consulting, 7

campaigns are initiated. “The rapid advancement in the technologies, ease of use and the falling prices of devices, make the mobile an appropriate and adaptable tool to bridge the digital divide”³⁰

Future Potential and Scalability

Based on the positive role that beginning mHealth efforts are playing, the future of mHealth in the developing world looks promising. The current mHealth efforts that have been carried out or are in trial phases have shown positive aptitude in bringing health and education to remote areas, as well as improvements in medication adherence and treatment. Though still in the beginning stages, disease tracking and diagnosis efforts also hold promise for the future. “The overall development of mHealth will be driven by the consumer demand, value added service by the mobile phone industry and health care policy makers in the near future.”³¹ In order to ensure that mHealth reaches its potential a multisector international approach is best.

Inline with this joint action approach, the global health community, at events like the Global Health Summit, have called for a policy of openness and shared ideas and technology in the field of mHealth. Thus, sites and organization such as the Open Mobile Consortium are already thriving. The Open Mobile Consortium is a leading group in this idea of technology and idea sharing. Their mission states that they are a “community of mobile technologists and practitioners working to drive open source mobile solutions for more effective and efficient humanitarian relief and global social development.”³² By developing mHealth as an internationally cooperative field rather than a competitive industry it can grow to be an important tool in development.

³⁰ Mishra, 1

³¹ Mishra, 8

³² "Open Mobile Consortium About." *Open Mobile Consortium*. Web. <<http://www.open-mobile.org/>>.

In terms of scalability, the potential scalability of mHealth varies by sector. For instance, the education and awareness sector efforts have the simplest technology requirements and are the easiest to implement, giving this sector a fairly high scalability potential.³³ On the other hand the diagnostic and treatment support sector requires more complex technology and coordination and will be much more costly and involved in scaling up.³⁴ Regardless most current mHealth initiatives are still fairly small and while scalability potential is there in varying degrees, it must remain a focus of the global mHealth effort (the joint venture approach can aid in this). “Without scale, the mHealth application will be evaluated as a corporate social responsibility initiative and its sustainability will be in question.”³⁵ How well this is done will determine the direction mHealth takes, who it benefits, and the impact it has on improving equality in healthcare. For example, if it does not reach a scalable potential, mHealth may evolve into a service that is paid for (as part of cellphone plan).³⁶ In this way it would only benefit consumers who could afford it, providing no direct benefit to improving health equality. Alternatively, it could evolve into a substantial aspect of everyday health services, perhaps maintained by government funding. In another viewpoint, the growing field of mobile services in general (including mBanking and mCommerce), may increase the scalability potential and market sector for mHealth. “Packaging such services with mHealth solutions creates economies for operators and takes advantage of shared resources and best practices.”³⁷ The direction it takes will largely depend on governments, health care providers, donors, developers and consumers.

³³Vital Wave Consulting, 8

³⁴ ibid, 8

³⁵ Vital Wave Consulting, 35

³⁶ Mishra

³⁷ Vital Wave Consulting, 34

It is also important to look at the target markets demand and the technological capacity when gauging mHealth's scalability potential. The growing cell phone penetration in the developing world speaks to the growing market that mHealth has the potential to reach. "Estimates reveal half of all individuals in remote areas of the world will have mobile phones by 2012".³⁸ Adding to this, like other public health initiatives such as vaccines, even people who don't have cell phones (like people who don't receive a vaccine) may be able to benefit passively from the improved public health and services and increased community awareness.³⁹ Just as important as cell phone penetration, is the way in which the software and mHealth efforts are developed. In this case ease of use is essential for consumers and must be appropriately balanced with technological capacity.

Financial Considerations and Potential Barriers

Along with assessing scalability, it is essential to determine financial sustainability, as well as potential problems and product barriers. Many efforts report cost savings through mHealth (as discussed in the section on the disease tracking and surveillance sector of mHealth). However indirect costs to mHealth must also be considered. These costs may include: training costs for health workers to use the technology accurately centralized software where needed for data analysis, and providing cellphones and devices when not already available.⁴⁰ It is too soon to tell in many current mHealth efforts what the cost gains versus losses are, this is something that will need to be further studied as current pilots and field studies come to a close.

In terms of finances, while donor support is growing, to ensure sustainability, long-

³⁸ Engelbrecht, Lezette . "Mobile heralds healthcare revolution." *Web Telecoms* [Johannesburg] 16 Nov. 2009. *ITweb*. Web.

³⁹ Anta, Rafael. "The potential of mobile telephony to bring health care to the majority." (2009 February) *Inter-American Development Bank*. Innovation Note <<http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=1861959>>.

⁴⁰ Mishra, 7

term plans must be made. The best way to achieve a sustainable initiative is to incorporate mHealth programs into international or governmental efforts. Incentive programs to encourage mHealth innovation through “tax rebates to telecom providers for provision of mHealth services and funding for universities and research institutes studying mHealth solutions” are also beneficial when possible.⁴¹

In terms of nonfinancial related issues, current cellphones and mobile devices present various shortcomings. Technologically, the mobile devices battery life, memory, screen size, bandwidth and other basic components will determine to what extent and in what form mHealth can be used.⁴² For example if a health worker is using their mobile device for diagnosis assistance and sends an image to a medical professional. If the quality of the imaging is poor it could lead to misdiagnosis. “Whenever health care professionals make a clinical judgment [through mobile devices] they must be satisfied that they have sufficient information to form such a judgment and that the information itself is of appropriate quality and reliability.”⁴³ For another example, when collecting data or surveying, short battery life or inadequate memory space could cause a loss of data or incomplete data collection.

In encouraging mobile health to be a joint multisector field, it is necessary to develop common practices and standards. MHealth gives the power of increased health communication, but if the information is not standardized and easily interpretable by all sectors, institutions, and people involved, the exchange of such information cannot be reliable. Thus, there is a need for “the integration and exploitation of heterogeneous scientific information databases in a seamless way, so as to enable the storage, updating,

⁴¹ Vital Wave Consulting, 36

⁴² Mishra, 7

⁴³ Ibid

search and retrieval of useful information.”⁴⁴ As such, a major challenge for mHealth is not only standardizing the new systems and techniques being developed, but addressing already present medical differences in areas that could present a problem and creating a centralized access point for consistent records and data keeping.

Stepping away from the institutional issues, using mHealth for patients also has several barriers that will need to be addressed in the future. Language, cost and infrastructure challenges prevent mobile health technologies from being accessible to all. “...In the short-term patients with low health literacy will not benefit as much.”⁴⁵ Therefore, ensuring that the technology is user friendly and that its target market can interpret the information provided through the technology correctly, must be addressed specifically in each area. This could entail running training sessions in a community or doing mHealth campaigns in a variety of local languages (which requires specific information about mobile users in an area). Overall we will need to see a balance of technological capabilities, cost efficiency and ease of use when moving forward with mHealth devices.⁴⁶

Moving Forward

In moving forward in the field of mHealth the challenges presented in the previous sections, as well as the successes, should be avidly addressed. Much more field research is needed to gain a clearer understanding of where and when certain components of mHealth work and where they don't (including looking at financial benefits and costs). In terms of program development preliminary research on current mHealth efforts have provided some preliminary suggestions. The UN Foundation in partnership with the

⁴⁴ Mishra, 8

⁴⁵ Engelbrecht, Lezette. Clearing m-health hurdles. 18 Nov 2009.

<http://www.itweb.co.za/index.php?option=com_content&view=article&id=28146>

⁴⁶ Vital Wave Consulting (2009), 7

Vodafone Foundation summarize important considerations for mHealth program development as follows⁴⁷:

- Multi-sector approach- develop strong partnerships-multi sector approach
- Accessibility-information should be “tailored” to local culture, age, ethnic, social groups
- Ease of use is essential
- Funding- need long term funding plan—best if integrated with a National/Government health program
- Set measurable goals
- Collaborate with other mHealth organizations

⁴⁷ Vital Wave Consulting, 21

Section 2: Tuberculosis

Before diving into a discussion on mHealth specifically for TB, which is the topic of this paper, it is first essential to provide a backdrop on the global burden of tuberculosis and the disease itself. As such, this section seeks to provide a detailed background on tuberculosis, a disease that in my opinion could largely benefit from mHealth.

The World Health Organization (WHO) estimated in 2007, that 9.27 million new cases of tuberculosis occurred globally, with 44% of these being smear positive (the most contagious form of TB).⁴⁸ This represents about a .32% increase from 2006. Moreover, 13 out of the 15 countries with the highest TB incidence are in Africa.⁴⁹ The challenges of controlling TB in Africa, are widespread and include the HIV/AIDS epidemic (which leads to a large rate of co-infection), widespread poverty and malnourishment, poor civil society, weak public health system, lack of trained health workers, poor education, corrupt and unstable governments, poor DOTS implementation and more.⁵⁰

What is Tuberculosis?

Tuberculosis, commonly referred to as TB, is an airborne disease that is caused by an infection with *Mycobacterium Tuberculosis* (MTB).⁵¹ Tuberculosis has the potential to affect any part of the body (extra pulmonary TB), though it most commonly attacks the lungs (pulmonary TB).⁵² When MTB infects the lungs or another part of the body tuberculosis infection develops. However, if a person becomes infected with TB they

⁴⁸ World Health Organization. *Global Tuberculosis Control*. (2009). WHO publication. P 7
<http://www.who.int/tb/publications/global_report/2009/pdf/report_without_annexes.pdf>

⁴⁹ World Health Organization, 9

⁵⁰ Regional Office for Africa, 11

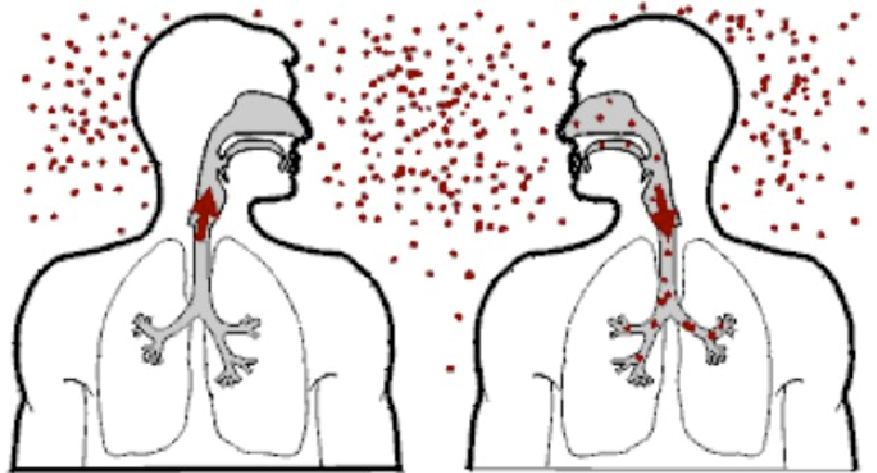
⁵¹ "CDC | TB | Basic TB Facts." *Centers for Disease Control and Prevention*. <<http://www.cdc.gov/tb/topic/basics/default.htm>>

⁵² "TB DOTS". Sandoz, Web. 2006 <www.tbdots.com/site/en/index.html>

will not necessarily develop TB disease. In fact, one third of the worlds population is infected with Tuberculosis, yet on average only 5-10% of these people are known to develop TB disease.⁵³

When someone has TB infection but not TB disease, the bacilli germs are dormant in the body and the person will not experience symptoms and cannot spread the germs to others. A person is at risk for developing TB disease if their immune system is weakened. As such, people who are HIV positive, malnourished or otherwise immuno-compromised are more susceptible to developing TB disease. When the infection progresses into TB disease the Tb bacteria are active and the immune system is unable to prevent the TB bacteria from growing.⁵⁴ When a person has TB disease they can infect 10-

20 people a year and will experience symptoms.⁵⁵ As an airborne disease TB infection may be transmitted through coughing, spitting, sneezing, and even talking if infected droplets are inhaled (see picture).⁵⁶



<http://web.njcu.edu/dept/hwc/Uploads/aerosoltransmission.jpg>

Extra pulmonary TB, refers to any TB infection not in the lungs, and more commonly infects parts of the body such as: lymph glands, bones and joints, the spine, the coverings of the brain (meningitis) or the GU tract. Depending on the area that is infected the symptoms may present as swelling at the sight of infection, mobility damage,

⁵³ World Health Organization, 3

⁵⁴ "CDC | TB | Basic TB Facts."

⁵⁵ Mallozi, Jennifer. "Tuberculosis: an airborne disease." *UN Chronicle* XXXV. Department of Public Information (1998). <<http://www.un.org/Pubs/chronicle/1998/issue2/0298p73.htm>>

⁵⁶ Mallozi, Jennifer.

or neurological dysfunction if the brain is infected.⁵⁷ Pulmonary TB is an infection of the lungs and is highly contagious. Symptoms of pulmonary TB include a severe cough, fever, weight loss, and appetite loss.⁵⁸ Public health is most concerned with this form of TB because of its infectious nature; as such this will be the primary focus in this paper. In all forms of infection, death may occur if TB disease goes untreated.

Diagnostic tests and their effectiveness

There are a variety of common and up-and-coming tests and methods for diagnosing TB, but this is an area where a lot of research and attention is still needed. Table 2 summarizes the most common forms of TB diagnostic tools, how they work, and their effectiveness. Newer tools are not provided in this table, as they are still undergoing research and testing. The first method in the chart, Sputum Microscopy, is the preferred method of testing by the DOTS program (discussed later in detail). This method helps to prioritize patient treatment, as patients who are smear positive may infect 10-14 people a year if untreated and are more likely to die if untreated.⁵⁹

⁵⁷ "TB DOTS", extra pulmonary TB

⁵⁸ "TB DOTS", Symptoms

⁵⁹ "Tuberculosis in Developing Countries ." *Centers for Disease Control and Prevention*. Version 39:33. CDC, n.d. Web. <<http://www.cdc.gov/mmwr/preview/mmwrhtml/00001729.htm>>

Table 2: Tuberculosis Diagnostic Tools

*(info adopted from http://www.tbdots.com/site/en/doctor_section_tb_diagnosis.html except where noted otherwise)

Diagnostic tool	Description	Accuracy	Notes
Sputum Smear Microscopy (SSM)	Examines sputum (from the lungs) for specific bacteria ⁶⁰	Detects about 50% of patients with active TB and as low as 20% for children and HIV+ patients ⁶¹ -Difficult to detect non-pulmonary TB	Inexpensive Only takes a few minutes
Tuberculin Skin Test (TST)	Matoux test: inject small amount of TB into arm and look for red swelling (positive response)	False positives may result from BCG vaccine or presence of other bacterial infections similar to TB -Estimated that 1/3 of patients test false positive -Misses 30% of infected people and up to 70% for immuno-compromised people.	Painful for patient
Chest X-ray	Look for abnormalities in the lungs if patient presents with TB symptoms	-40% over diagnoses -Plus about 10% misdiagnosis (class notes-can not confirm if active TB -Difficult to determine if scarring is from previously cured TB	
Culture	Live bacteria grown on plate in laboratory	-Extremely sensitive -Can detect pulmonary and extra pulmonary TB - Bacteria is not always obtained in the sample-so results sometimes unreliable	- 2-6 week time to results - need adequate lab

Delay in, or complete lacks of, diagnosis in many areas of Africa are common. The basic reasons for this can be broken down into two groups: Provider factors and patient factors. Provider contributions to this include inadequate health infrastructure (including poor diagnostic tools) and limited knowledge and skills of health workers. On the patient side factors for delay in or not seeking diagnosis at all include: distance from a

⁶⁰ "TB DOTS". Diagnosis

⁶¹World Health Organization Stop TB Partnership. *New Laboratory Diagnostic Tool for Tuberculosis Control*. (2008). WHO Publication. P 5 < http://www.tb-evidence.org/documents/tbdxpl/Diagnostic_Brochure_Print_Dec_22_3_3.pdf>

diagnostic facility, lack of knowledge about the disease and testing, stigma associated with the disease and the financial and opportunity costs of getting tested (including transport, missing work and stigmatization).⁶² The length of time before a diagnosis is made (as shown in the chart) also contribute to this, as some patients who do get tested may never come back to find out the results.⁶³

Prevention

While TB is a non-vaccine preventable disease, there is a vaccine available (BCG vaccine) that has been proven to provide some protection and is used widely in areas of high TB prevalence. The BCG vaccine is somewhat unpredictable as in eight major studies it has shown effectiveness rates varying from 0% and 76%.⁶⁴ The vaccine also may produce false positives in certain TB diagnostic tests such as the TST.⁶⁵

Treatment Strategies

For the purpose of this paper I will not go into the details of the different Tb drugs, but I will discuss some treatment specifics. Total treatment for TB disease lasts between 6-9 months and if not completed or done correctly can cause relapse cases and drug resistance. Once diagnosed, treatment is given in two phases. The first phase usually lasts about two months and consists of a combination of intensive drugs. After this phase symptoms typically decline dramatically and a person may no longer feel ill. Despite this it is essential to continue phase 2 of the treatment, which lasts about 4-6 months but requires fewer and milder drugs. If phase 2 of the treatment is not continued the patient

⁶² Regional Office for Africa, 13

⁶³ World Health Organization Stop TB Partnership, 9

⁶⁴ "Chapter 10: CDC Core Curriculum: BCG Vaccination." *University of Medicine and Dentistry of New Jersey*. CDC, n.d. Web. <<http://www.umdj.edu/~ntbcweb/corebcg.htm>>.

⁶⁵ "CDC TB Basic Facts"

may relapse or breed resistance to the drugs. Depending on the types of drugs and dosage used, patients will either take drugs daily or 3 times weekly.⁶⁶

The DOTS Strategy

The lengthy complex treatment regimes for tuberculosis have been one of the major barriers in fighting TB. The WHO developed treatment program called DOTS (Directly Observed Therapy Short-course) has become the most cost effective method in improving TB testing and treatment worldwide. The five components of DOTS, summarized below, are the key to its success.⁶⁷

- Political commitment with increased and sustained financing: There must be a government and general public commitment to fighting TB and commitment to a National Treatment Plan. Support for TB control in all forms must be a priority. □
- Case detection through quality-assured bacteriology: Prioritize smear + cases (most infectious, ensure timely and accurate results)
- Standardized treatment, with supervision and patient support: Directly observed treatment for all patients to ensure drugs taken accurately and consistently □
- An effective drug supply and management system: ensure adequate supply of drugs for every patient prior to begging treatment □
- Monitoring and evaluation system, and impact measurement- monitor and evaluate program and patient outcomes at all levels in order to identify problematic areas and record data. □

The success of DOTS in many areas has led it to be included in almost every major global TB strategy. The WHO Stop TB strategy initiated in 2006, provides specific TB targets and strategies in line with Millennium Development Goal number 6 (Have halted by 2015 and begun to reverse the incidence of

Text Box 1: WHO Stop TB Strategy

1. Pursue high-quality DOTS expansion and enhancement
2. Address TB-HIV, MDR-TB, and the needs of poor and vulnerable populations
3. Contribute to health system strengthening based on primary health care
4. Engage all care providers
5. Empower people with TB, and communities through partnership
6. Enable and promote research

⁶⁶ World Health Organization. "Treatment of Tuberculosis Guidelines" (2003). Third ed. WHO. Geneva. P27
<http://whqlibdoc.who.int/hq/2003/WHO_CDS_TB_2003.313_eng.pdf>

⁶⁷ "The five elements of DOTS." WHO. World Health Organization, Web.
<<http://www.who.int/tb/dots/whatisdots/en/index1.html>>

malaria and other major diseases) and the DOTS strategy (refer to text box 1 for Stop TB strategy summary).⁶⁸ Efforts include a strong focus on the five components of DOTS (as discussed) and addressing specific high-risk groups as well as a MDR TB and HIV-TB co-infection. The strategy suggestions also speak to the need for stronger communication and continued research.

Problems with DOTS

While in theory DOTS is an extremely effective strategy to fight TB, and has worked in practice in many regions of the world, the expansion and stability of DOTS in many parts of the developing world is still not adequate or present. “The MSF report recognized that DOTS programs achieved greater treatment success (82%) than treatment without DOTS (67%). But, it argued, it was difficult to implement DOTS in all but the most stable settings.”⁶⁹ Developing countries are often unable to expand DOTS as needed to reach global TB targets. This has often led to poor DOTS penetration in rural areas.⁷⁰

Despite the implementation of DOTS in the majority of the African region. It has not had the desired effects. While in 2006 the treatment success rate for patients enrolled in a DOTS program was 75% in the African Region.⁷¹ This still means 25% of DOTS enrolled participants were not successfully treated in addition to the people who did not have access to DOTS at all.

One of the major constraints in the effectiveness of the DOTS strategy in Africa

⁶⁸ World Health Organization. “Treatment of Tuberculosis Guidelines”, 6

⁶⁹ Mudur, Ganapati . "Medical charity criticises shortcomings of DOTS in management of tuberculosis." *National Center for Biotechnology Information*. BMJ Publishing Group Ltd., 3 Apr. 2004. Web.
<<http://www.ncbi.nlm.nih.gov:80/pmc/articles/PMC383398/>>

⁷⁰ Leshen, Elizabeth. *X Out TB: A Strategy for Remote Monitoring of TB Patient Compliance* (Powerpoint)

⁷¹ World Health Organization, 29

comes from the “direct observation of treatment” component. While this aspect of DOTS is what makes it so successful and effective, the limited staff, poor understanding of the disease, demographics and hard to reach populations in many parts of Africa, make this almost unfeasible on a large scale. “...Implementing the practice of direct observation of pill swallows on a wide scale for the ambulatory treatment of TB is a daunting task and many TB control programs in Africa have difficulties practicing it”⁷² Another issue in the region is the primary confinement of DOTS to the public health sector which is not able to support it alone.⁷³ In a broader sense, other constraints to DOTS include financial limitations, demography, inadequate drug supply, lack of qualified medical personnel, inadequate education and knowledge about TB and DOTS and inadequate health systems and laboratory resources.⁷⁴ A majority of these reasons relate to the overall problems with the health systems in the developing world shown in Table 1 on page 13.

Growing problems

Before moving on it is essential to at least mention two growing problems that contribute to the extent of tuberculosis in Africa: TB-HIV/AIDS co-infection and Multi-drug resistant TB. Firstly the HIV epidemic in Africa has a strong almost inseparable impact on the magnitude of tuberculosis in the region. People with HIV/AIDS are immuno-compromised and thus at high risk for contracting TB disease if exposed to the bacterium. In addition “HIV is the strongest risk factor for reactivation of latent TB and it promotes rapid progression to disease of new infection.”⁷⁵ While co-infection is not a

⁷² Regional Office for Africa, 13

⁷³ Regional Office for Africa, 8

⁷⁴ World Health Organization. “Treatment of Tuberculosis Guidelines”

⁷⁵ Regional Office for Africa, 8

main focus of this paper, it is an important distinction to make in treatment consideration and barriers to TB program effectiveness.

Secondly multi drug resistant (MDR) and extensively drug resistant (XDR) TB arise when the improper use of anti-TB medications breeds drug resistant strains of tuberculosis. “MDR-TB rates have been rising, and countries are faced with the need to both access second-line drugs and conduct MDR-TB surveys to assess the true extent of the problem.”⁷⁶ This is both a partial result of inadequate DOTS programs and a call for better DOTS or other mechanisms to combat this. “MDR-TB rates have been rising, and countries are faced with the need to both access second-line drugs and conduct MDR-TB surveys to assess the true extent of the problem.” In order to get this problem under control, there is a need for better DOTS programs, more effective drugs, and overall more data on where this is a problem.

Moving Forward

The millennium development goals have set fourth a goal of halting and reversing the “incidence, prevalence, and death rates associated with Tuberculosis” by 2015. In addition global targets seek to cut the 1990 prevalence and mortality rates in half by 2015, reach 70% case detection for smear positive cases and successfully cure 85% of these.⁷⁷ While there has been positive movement towards these goals in many parts of the world, there are many countries and regions, particularly in Africa, that have seen little to no improvement in TB incidence.

MHealth is an up-and-coming strategy and proven effective tool in combating some of the shortcomings discussed with DOTS and other TB efforts. The following

⁷⁶ USAID. *East Africa: Tuberculosis Profile*.

<http://www.usaid.gov/our_work/global_health/id/tuberculosis/countries/africa/eastafrica.pdf>

⁷⁷ World Health Organization, 8

section briefly discusses four current efforts that are using mHealth strategies to improve medication adherence among TB patients.

Section 3: mHealth for TB-what is being done so far?

In this section I will talk briefly about the four initiatives that are using mHealth for TB thus far. All of these efforts focus on improving medication adherence among TB patients. While they are all mostly in trial phases they are already showing tremendous potential and provide a good insight into where this field could lead.

Phone call reminders in Thailand: In 2007, a three month long pilot program involving 60 TB patients in Chiang Mai, Thailand tested the effectiveness of daily phone call reminders on medication adherence.⁷⁸ Each patient was provided with a cell phone that could only receive calls. Every day trained volunteers, who were all former TB patients, called to remind the patients to take their pills. Using former TB patients as volunteers was considered a key factor in the programs success, as these people had experience with the disease and treatment. “The daily call is not just a good reminder to those patients who forget to take the drug, but it also comes in a way that makes them feel cared about and supported,”⁷⁹ The consistency in drug taking was over 90%.⁸⁰ The cost per person of this program is only USD\$3.⁸¹ The low cost and simplicity of this program shows extreme potential.

⁷⁸ Khwankhom, Arthit. “Phoned Pill Reminders Make Inroads Against TB”. The Nation (Bangkok), January 28, 2007. <<http://listmanager.bps-lmit.com/read/messages?id=49295>>

⁷⁹ Ibid

⁸⁰ Vital Wave Consulting. 53

⁸¹ Khwankhom, Arthit.

SIMpill solution in South Africa: The SIMpill solution was piloted in 2007 in South Africa with 130 TB patients.⁸² In this program⁸³: all TB patients are given a pill bottle equipped with a SIM card and transmitter. When the patient opens the bottle to take their medication an SMS is automatically sent to a designated health worker. If the patient does not take their pill within a certain time, an automatic text message reminder is sent to them. If they still don't comply, the health worker is alerted and will either call the patient or travel to see them in person. The study showed an increased compliance from 22-60% (without the SIMpill) to 90% (with the SIMpill), a dramatic improvement.

The cost of the program is about USD \$16.17,⁸⁴ which is more expensive than some of the other efforts but the drastic increase in compliance (which means less peoples are infected and need to be treated and less drug resistance) may make it worth it. The SIMpill solution is now globally available for use.

Video Phones in Kenya: Recently in Nairobi, Kenya a very small scale pilot was done using video mobile phones to improve medication adherence. The study spanned 30 days and involved 13 TB patients who each had an "assistant" (family member/friend).⁸⁵ Each patient was given a video mobile phone and their "assistant" was instructed to video record the patient taking their medication each day. The video message was automatically sent to a central location where trained nurses observed it on screen. The patient and

⁸² Planting, Sasha . "SIMpill Solutions for TB." *FM*. 2 Mar. 2007. Web.
<<http://free.financialmail.co.za/innovations/07/0302/minn.htm>>

⁸³ Vital Wave Consulting, 54

⁸⁴ Planting, Sasha

⁸⁵ Goedert, Joseph. "Cell Phones Monitor TB Drug Compliance." *Health Data Management*. 23 Mar. 2009. Web.
<http://www.healthdatamanagement.com/news/cell_phone-27912-1.html>.

assistant satisfaction with the program were 4.36 and 4.33 respectively (out of 5).⁸⁶ Full results will be presented at a conference in Nairobi at the end of March.

Using video messaging to directly observe medication adherence will save time and money associated with sending field workers out to observe in person, and could potentially reach more people. However this will need to be weighed against the cost of providing video phones to patients, training both patients and health care workers in the technology, ease of use, and other constraints that may arise if the trial is done at a larger scale.

X OutTB: X Out TB, is an innovative program idea that was developed by a team of students and professionals at MIT's Poverty Action Lab. Field tested in Nicaragua, this program incentivizes patients to take their medication by rewarding compliant patients with cell phone minutes. The basis of this program rests on the fact that providing incentives, in conjunction with daily reminders, is the most effective way to increase medication compliance.⁸⁷

The X Out TB program process is as follows⁸⁸: patients are given a cell phone (if they don't already have one), a set of urinalysis test strips, and a storage dispenser for the urinalysis strips. All cell phones are set with a daily reminder to take the medicine. Each day, a patient is reminded to take their pill. Once they take their medicine they complete the urinalysis test. Within a few minutes a number code is revealed on the test strip. The patient then texts this code to the central database location. Patients who reach a high enough compliance are given a reward of 300 cell phone minutes.

⁸⁶ Goedert, Joseph.

⁸⁷ Trafton, Anne. "Eradicating TB with...cell phone minutes?." *Tech Talk: serving the MIT Community*. 52:28. June 4, 2008.

⁸⁸ Leshen, Elizabeth. *X Out TB: A Strategy for Remote Monitoring of TB Patient Compliance* (Powerpoint)

The dispenser for the urinalysis strips, which only dispenses one strip in a given time period, cost \$7. The urinalysis strips are not reusable and cost 1cent per strip.⁸⁹ The cost of phones was not specified. In the pilot the organization also paid the cell phone company for the minutes it gave out.

The results of the field test have not yet have been published but the team is now planning for a clinical trial in Pakistan which will hopefully provide insights into the role of incentives in TB medication adherence.

Section 4: Proposed program implementation and Conclusion

While mHealth cannot take over all functions of health servicesand facilities (at least not yet), it has the potential to improve them. In order to create scalable and sustainable TB related mHealth efforts, it is my suggestion that rather then develop a whole new program, current mHealth efforts should work with the DOTS strategy, or other strong national treatment plans, to evaluate where and how the DOTS program can take advantage of mHealth in its efforts.

After reviewing the current status and programs of mobile health technology, assessing where the barriers to effective TB control and DOTS programming are, and looking at the current TB related mHealth efforts, I have determined that mHealth has significant potential to improve the global fight against TB. In the following section I provide my own suggestions for where and how mHealth might be able to combat these barriers.

In order to demonstrate where mHealth can fit into current TB strategies in an organized way, I have created two tables. The first (Table 3) lists all of the barriers to effective TB

⁸⁹ Ibid

control that have been presented in this paper. These are divided into provider side issues and patient side issues to permit a clearer understanding of where efforts need to be targeted. In the second table (Table 4) I classify each of these problems into one of the five sectors of mHealth (as well as an Other/General section) in order to see where each of these mHealth sectors can play a role. Also in table 4, I provide my suggested mHealth programs in correspondence the most of listed problems, based on lessons learned from current mHealth initiatives where possible. Refer to these tables below.

Table 3: Barriers to effective TB control (including problems with DOTS and its implementation)

Provider side issues	Patient side issues
• Requires quite stable environment	• Limited education and awareness- •
• Problems with DOTS expansion-	• No incentives-after phase 1 begin to feel better
• Poor rural penetration-costly and difficult to reach remote areas-	• Side affects of meds-
• Costly in time and finances to implement large scale DOT in remote areas-	• Stigma-
• Shortage of medical personnel-	• Don't take meds accurately or consistently-
• Lack of qualified medical personnel-	• Costly to miss work
• Confinement of DOTS to public health sector	• Length of time to diagnose-
• Inadequate labs and diagnostic equipment-	• Distance from treatment/diagnostic centers-
• Weak public health systems	• Poverty
• Inadequate health resources-	• Malnourishment
• Poor communication networks between health institutions-	• Co-infection-
• Corrupt and unstable government	
• Lack of adequate data-esp. on MDR TB-	

Table 4: Problems and Proposed mHealth Solutions for combating TB: Sorted by mHealth Sectors

Problems	Potential Solutions
Education and Awareness	
Limited education and awareness	- SMS/Text TB awareness campaign-text facts about TB to cell phone holders - Similar to an HIV/AIDS effort in South Africa: SMS a short survey testing patients knowledge of TB, provide correct answers, phone number for more information, and locations of test sights (provide incentives like cell phone minutes for completing survey if necessary) - Promoting awareness decreases stigma, also by providing info in confidential manor (through texts) people will not be worried about stigma associated with accessing the information - Awareness campaigns should be fit to the specific area and population and seek the advice and participation of local leaders to ensure language, cultural, ethnic, and age sensitivity of messages. (This will also increase community and local involvement in TB efforts)
Stigma	
Remote Data Collection	
Lack of adequate data-especially on MDR	- Simple text surveys, discussed above can provide basic info on peoples knowledge and awareness - to improve data on TB and MDR especially in hard to reach areas tactics discussed in the section on Data Collection (P 9) could be implemented
Tracking Epidemic and Disease Outbreak	
Shortage of medical personnel	- Tracking disease outbreak is always important, if tracking of TB outbreaks was improved using mHealth tactics discussed on P 10, outbreaks could be halted limiting the number of people infected (and thus decreasing the amount of people needing treatment and care)
Inadequate health resources	
Poor communication networks between health institutions	
Remote Monitoring	
Problems with DOTS expansion	- Remote monitoring, discussed in detail in section 3, is one of the most promising sectors of mHealth in DOTS. The types of efforts that work best in this area are likely to vary depending on the target population and funding capacity. For a low literacy population, a program such as the one carried out in Thailand with simple phone calls might be best. The SIMpill could also be useful in this case, but is much more costly as is the videophone program. - Using former TB patients to call current patients, as done in Thailand, gives patients an outlet to ask questions about the drugs and there side affects
Poor rural penetration-costly and difficult to reach remote areas	
Costly in time and finances to implement large scale DOT in remote areas	
Shortage of medical personnel-	
Patients don't take meds accurately or constantly	
Side affects of meds	
Diagnostics and Treatment Support	
Inadequate labs and diagnostic equipment	- Because of the complex diagnostics of TB, it is difficult to use mHealth for diagnostics. However when personnel can

Lack of qualified medical personnel	conduct a test, but may not be qualified to diagnosis, digital imaging may be sent to qualified medical personal for diagnosis (technology for this is more expensive than basic cell phones and still needs to undergo more testing –but could save on costs of providing drugs to those wrongly diagnosed to have TB disease).
Length of time to diagnose	-Because many of the diagnostic tools may require more than one visit or take time to reach a diagnosis, patients will often not return to find out their diagnosis or may not get tested at all. Although mHealth cant do anything to bring diagnostic centers closer, it might be possible for patients to text in their symptoms and be told whether or not they should come in to get tested (this is being done with other health issues in parts of Uganda). -In addition patients who come in to get tested should be asked to provide a telephone number (theirs or a friend/family members) so that they can be contacted about their results and wont have to make the trip back unless for treatment.
Patients distance from treatment/diagnostic centers	
Basic Training and Communication for Health Workers	
Lack of qualified medical personnel	As discussed in section 2, training through mHealth has not been widely tested. As more efforts emerge this may present future possibilities in improving training of health workers
Poor communication networks between health institutions	- Ensuring that all health facilities have phones and develop a system for coordination and communication when necessary could dramatically save patient costs (of being transferred) and improve the cohesiveness of the health system. - There is also a need for standardization of terminology and process to make this work effectively
Other and General	
No incentives-after phase 1 begin to feel better	Current TB efforts don’t consider incentive needs. If we acknowledge the poor as rational thinkers, they likely have good reasons for not completing treatment. Assuming access to drugs is not the problem, issues could be lack of understanding about the medicine, they forget, or they feel better. Education campaigns and phone reminders can address the first two. The third is what X out TB is trying to combat, rationally when people begin to feel better they don’t see the need for continued drugs. Because with TB drugs patients start to feel better after phase 1 of treatment, this often becomes a problem. Thus providing incentives for continued medication adherence (such as X-Out-TB does with cell phone minutes) could prevent this.
Confinement of DOTS to public health sector	-By involving mHealth organization, NGOs, CBOs, and locals in all levels of mHealth the burden of TB control can be more effectively managed across sectors (rather than having a large burden solely on treatment and testing facilities)
Costly to miss work	Refer to suggestions under remote monitoring and diagnostic and treatment support

Weak public health systems	Refer to “Basic Training ad Communication for Health Workers” suggestions
DOTS requires quite stable environment	Nothing can directly be done by mHealth to stabilize a countries political or social environment, but hopefully the combined use of mHealth efforts can help to stabilize the health environment enough to ensure better DOTS implementation
Corrupt and unstable government	
Poverty, Malnourishment, HIV co-infection	These problems contribute to the likelihood that someone will develop TB infection. mHealth efforts separately targeted at these issues may be able to improve them.

In referring to the table 4 above, it is clear that many mHealth efforts can be intuitively aligned to combat many of the problems associated with the burden of TB and the problems with DOTS. It is not my suggestion that every single effort be carried out concurrently, but rather that they be evaluated in each separate location and determine where certain efforts may be beneficial based on region/area specific challenges. However, all such efforts need to undergo a great deal of field testing and financial analysis to evaluate the actual effectiveness in all areas. None of this is knowable without further research and field-testing.

Theoretically, while the above table looks to be a daunting set of solution efforts, many of these could be combined and executed jointly. From my research and based on suggested TB improvement given by the Stop TB strategy (refer to text box 1), I personally believe that improved communication efforts, education campaigns, remote monitoring, and an incentive program are most essential in terms of TB (refer to the table 4 for specific program suggestions). Secondly disease tracking and diagnostics are very important, but may be a bit harder and more costly to implement, especially on a large scale.

In terms of overall costs, potential costs for most of these programs will likely include: cell phones and mobile devices for patients and health workers (this will vary

depending on the cell phone penetration, type of activity and technical capacity of the mobile device needed), minutes for incentive programs, training for community and staff, and other varying elements depending on each initiative. Most mHealth efforts thus far have proven to be cost saving on their small scale. If this is in fact true, costs that are saved can be used towards efforts that mHealth cannot serve such as improving laboratories, equipment and medications. Barriers to any of these programs relate to the potential problems of mHealth as previously discussed, such as mobile/cell phone battery life and technological capacity, as well as patient literacy. In all of these efforts, the suggestions for an effective mHealth program should be implemented (see P22) and continued DOTS strategy should still be followed strictly.

Conclusion

In conclusion, it is evident from the research that while Mhealth may be able to play a large role in the global fight against Tuberculosis, much research is needed to determine where and how this can be done most effectively. This being said, as the current mHealth pilot programs begin to show data on the effects of using mHealth, donors, program developers, and governments should look thoroughly at where mHealth has worked and has the potential to benefit the improvement of TB surveillance, prevention, diagnosis, and treatment. From this preliminary report, in my own opinion, TB programming should particularly focus on incorporating the discussed mHealth components into their surveillance, education, data collection, and treatment support. It is my recommendation that more research be done on the most cost effective way to implement these programs and that continued diagnostic research keep mHealth in mind for the future. Mobile Health technology is a powerful tool using the assets of the poor to reach a broad

population and bridge the gap between healthcare providers and their patients in all parts of the world.

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