SARAH KIM

Northwestern ‘22

Major in Biological Sciences *(Concentration in Neurobiology)*

Minors in Global Health and Computer Science

My name is Sarah Kim and I am in the Class of 2022 at Northwestern University. I am majoring in Biological Sciences with a concentration in Neurobiology and minoring in Global Health and Computer Science. I am interested in the uses of technology to address global health issues and to improve health systems.

Q&A

In short, what is your research about?

The application of mobile health technology, or mHealth, in reducing maternal mortality and improving maternal health.

How did you come to your research topic?

I’m minoring in global health and computer science and was interested in looking into the ways these two fields are interconnected. I have always found technology fascinating and I think it is one of our greatest tools to empower individuals and to address global health disparities. Additionally, the problem of maternal mortality is becoming increasingly recognized in the area of global health.

Where do you see the future direction of this work leading? How might future researchers build on your work, or what is left to discover in this field?

Mobile health technology is nearly boundless in its application and will only become increasingly relevant as practices such as telemedicine become more popular. Future researchers should continue to record and analyze the role of mHealth in reducing health disparities. The ethics of mHealth technology should also be researched and scrutinized.

Where are you heading to after graduation?
After graduation, I plan to complete a Masters in Public Health and to study geriatric healthcare systems.

The Applications of Mobile Health Technology (mHealth) in Reducing Maternal Mortality and Improving Maternal Health

Abstract

Technology is developing at a rapid pace, serving as an invaluable resource in various disciplines — especially healthcare. This technology can be utilized in low-resource settings such as in rural areas or developing countries where there are high rates of maternal mortality. Most maternal deaths are preventable with proper antenatal care during pregnancy, as well as skilled care during and after childbirth.

Mobile technology used for health, otherwise known as mHealth, comes in the form of mobile apps, wearable devices, or cloud databases. mHealth is an emerging resource that serves all sides of the healthcare system: healthcare workers, mothers, and governments. Healthcare workers can utilize mobile technology to improve training and to quickly search protocols and instructions for various emergencies that arise at childbirth. Mobile technology also assists in creating an accurate nationwide database of pregnancies and other medical records for countries.

Additionally, mobile health apps empower mothers to take control of their pregnancies and find resources, by sending out informative messages and reminders about nutrition, doctor visits, and other timestamps during their antenatal periods. This has led to improved communication between health workers and mothers, especially in rural areas, and led to a positive attitude towards postnatal care. This paper will review the research on mHealth technology in developing countries and its role in reducing maternal mortality rates.

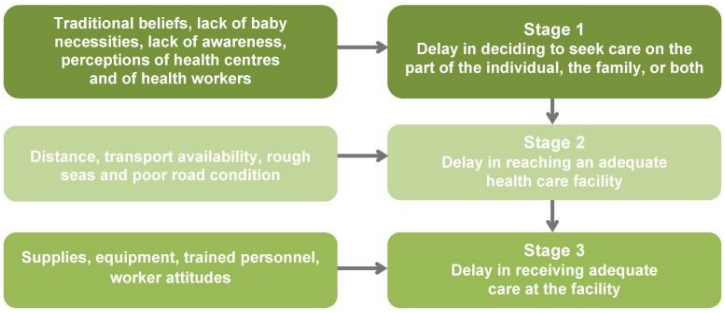
Introduction

The global maternal mortality rate remains high, with an estimated 303,000 women dying during pregnancy or childbirth in 2015 — most from preventable causes (UN, 2017). High maternal mortality rates are disproportionately aggregated in developing countries, with sub-Saharan Africa and South Asia accounting for 83.8 percent of maternal deaths worldwide (Say et al., 2014). According to Mbuthia et al. (2019), within lower- and middle-income countries, there is a large disparity between urban and rural areas, in which mothers in rural areas tend to receive lower and weaker post-natal care (PNC). PNC is linked to improving maternal and neonatal health. Additionally, delivery with the presence of a healthcare worker or at a clinic also helps to reduce maternal mortality rates as they can respond to obstetric emergencies such as hemorrhaging. This is specifically addressed in a joint statement by WHO, ICM, and FIGO:

> There is now a global consensus on what must be done to eliminate the menace of maternal deaths once and for all. Already in 1999, a joint WHO/UNFPA/UNICEF/World Bank statement called on countries to ‘ensure that all women and newborns have skilled care during pregnancy, childbirth and the immediate postnatal period’ (2004).

Skilled care is defined as getting attendance from an accredited health professional including doctors, nurses, and midwives. As outlined by the WHO, their presence during delivery is critical to reducing maternal mortality rates and mHealth can help communication between mothers and health professionals.

Maternal deaths often have preventable causes but occur due to delays in the mother receiving care, which can be organized in the Three Stages of Delay model. This model is utilized by Watson et al. (2015), whose diagram is included below. This model depicts the three stages of delay and each stage's corresponding factors: delay of the individual or family in choosing health care, delay in reaching an adequate healthcare facility, and delay in receiving adequate care at the facility itself. The first delay of the individual or family in choosing to receive medical care usually stems from cultural beliefs, lack of awareness, or mistrust in the healthcare system. The second delay of receiving treatment is the barrier of reaching an adequate health care facility, usually due to long physical distances. The third form of delay occurs when the health clinic itself lacks the proper equipment or training for health workers to address the problems mothers face during and after pregnancy, as well as during delivery.



Technology is becoming increasingly important in the day-to-day function and is developing rapidly — especially in the field of health. Mobile health technology, or mHealth, has a more nuanced reach in its various forms as mobile apps, wearable devices, and cloud

databases than traditional medical equipment. Mobile devices are light, portable, and can provide one-way or two-way communications in the forms of pictures, SMS text messaging, voice calls, video calls, and software applications. In this review, the focus will be on mobile apps and cell phones for patients and healthcare workers as well as cloud databases for medical records.

mHealth is an opportunity to lower disproportionate rates of maternal mortality in rural areas and developing countries that lack accessible healthcare centers. It assists in solving each of the Three Stages of Delay by increasing communication between health workers and medical records, rural health workers with urban specialists, and mothers and the healthcare system, thus overall reducing maternal mortality rates and improving maternal health.

Methods / Sources of Data

A literature review was conducted by searches through various databases including, but not limited to, PubMed, Google Scholar, and NUsearch. The searches were guided by the question, in what applications does mHealth work to reduce maternal mortality rates and improve maternal health? Additional supportive facts and data were gathered from in-class lectures and articles.

Articles came from projects in low- or middle-income countries with high maternal mortality rates, analyzing either the current use of mobile health technology or the difference after implementation of free mobile health technology to mothers or health workers. Additional sources include other literature reviews or case studies on the use of mHealth in improving maternal health. Notably, studies oftentimes took a mixed-methods approach and included

interviews to understand the role of mHealth, oftentimes because of limited qualitative data. Thus, many studies do not report specific qualitative data in their results and findings.

Information was systematically organized by aggregating common themes from the articles and categorized in a flow-chart to three categories in which mHealth addresses the maternal mortality issue: creating nationwide databases, increasing medical worker training, and empowering mothers with access to outside knowledge as well as to the healthcare system.

Summary of Research Findings

Creates databases of medical records

Medical records are important for tracking previous patient medical histories and integral for documenting trends in a geographic region. Oyeyemi and Wynn (2014) mention that reliable medical records were not available to analyze in Nigeria, making it hard to accurately measure maternal mortality rates. mHealth technology makes the record-keeping process easier for healthcare workers. In Kenya, the adaptation of digital records resulted in "shortened patient visits by 22 percent, doctor time per patient was reduced by 58 percent, and patients spent 38 percent less time waiting in the clinic" (Mungai, 2015, as cited in West, 2015, p. 12). Lowering the wait time for patients also lowers the risk time for delivering mothers. The use of mobile technology makes the process of recording medical information more time-effective and less error-prone, streamlining patient visits. The CliniPAK system in Nigeria, which helps to document medical information using mobile tablets, recorded over 50,000 patient visits in a year (West, 2015). Like the study in Kenya, they found that the CliniPAK program helped health workers save time for each patient (West, 2015). Thus, there was a shorter waiting time for

mothers, assisting in the reduction of maternal mortality rates. Additionally, it helped record the percentage of skilled birth attendants present during delivery in different regions of Kenya such as how Ondo had 87 percent of its deliveries with a skilled birth attendant compared to Kano with 100 percent (West, 2015). This collection of data helps future studies with understanding regional trends and target higher-risk areas. The creation of databases helps to reduce the third mode of delay, in which increased efficiency in the part of the health care clinic itself leads to a lowered risk of maternal mortality.

Increases access to health knowledge and consultations for health workers

The use of mHealth also helps in increasing the training of midwives and rural health workers who are the primary workers in contact with pregnant mothers in remote areas. Lee et al. (2011) conducted a statistical analysis of a questionnaire survey they conducted in 2006 to assess midwives' knowledge, health practices, self-efficacy, and the use of technology. They found a positive effect between midwives' cell phone use and health knowledge as well as midwives' access to institutional and peer resources which correlated to an increase in self-efficacy (Lee et al., 2011). This is an important factor in a healthy delivery as midwives are the primary source of providing maternal health care services — it is critical they have an accurate knowledge of maternal health for a safer delivery.

A similar correlation was found for rural health workers in a study in Papua New Guinea, although through a more direct method of phone calling urban health workers with specific questions. This study recorded several interviews with health workers who were given free phones to a line at a hospital with more maternal specialists. Rural health workers were able to

communicate with these specialists earlier on because they had an easier mode of relaying information through the use of digital devices rather than their previous one-way radio system; a rural health worker reported, “I talked to the labour ward staff and I got advice on what to do. Had I not, you know, if this project [of implementing free-calls to the labour ward] was not here and I didn’t have any means to communicate, we could have lost this mother because she was already septicaemic” (Watson et al., 2015). In one hundred percent of the interviewees, the rural health workers reported that implementation of the Childbirth Emergency Phone with the large Alotau Provincial Hospital helped resolve conflicts especially in obstetric emergencies (Watson et al., 2015). The immediate relay of instructions and advice on handling these life-threatening complications helped to save a mother’s life on multiple occasions — a quantitative result of how mHealth reduces maternal mortality rates.

Similarly, a study in Mongolia found that networking between urban and rural health workers improved through the use of mobile phones (Baatar et al., 2012). Since many patients in Mongolia live in a rural setting, mHealth helped bridge the gap between the two parties, allowing rural workers to get remote consultations. Ultimately, this helped in getting second opinions on prenatal diagnostics, as well as in reducing pregnancy and delivery complications. With the assistance of mHealth technology, the number of childbirth complications decreased dramatically from an estimated 25.7 percent in 2007 to 9 percent in 2009 (Baatar et al., 2012). This is another case exemplifying how mHealth successfully increases the quality of health care the mothers receive and reduces the third stage of delay.

Reduces referral rate to secondary health care

The implementation of mHealth also reduces referral rates to secondary health care clinics because primary clinics are better equipped to deal with various arising issues. Baatar et al. (2012) found that the implementation of telecommunication for health workers in Mongolia helped to reduce the referral rate of mothers to urban health clinics from 1,546 referrals in 2005 to 1,343 referrals in 2009. This is thought to be because rural clinics had a greater capability to diagnose and solve issues relating to maternal health (Baatar et al, 2012). This was important in reducing the risk level for mothers who would have had to travel a far distance to receive upper-level care in an urban hospital.

A similar finding emerged in a study in Nigeria by Oyeyemi and Wynn (2014) that health workers decreased referrals to secondary clinics, possibly because they had a better means of communication through phones: "fewer patients and health workers felt the need to visit (or recommend) the General Hospital… the implication of this is that the Abyie cell phones [free one-way cell phones given to mothers to contact health clinics] may have strengthened the primary healthcare system in the LGA and reduced inequalities in accessibility to healthcare facilities" (Oyeyemi and Wynn, 2014, pg 6). Thus, increased access to knowledge for health workers via mHealth also helped in reducing the second stage of delay by circumventing the physical barrier of mothers having to travel to receive medical help at a secondary health clinic located in an urban setting. Additionally, this allowed secondary health clinics to open up more spots for more urgent patients that have high-risk deliveries (Oyeyemi and Wynn, 2014), further helping to drive down maternal mortality rates.

Strengthens trust between mothers and the healthcare system

Additionally, mHealth technology helps to strengthen the trust between mothers and the local healthcare system — a solution to the first stage of delay in which traditional beliefs and perceptions of health centers and health workers were a barrier for mothers deciding to seek care. In the Oyeyemi and Wynn study in Nigeria, a project area was given free cell phones connecting them directly to a primary health clinic. They found a significantly higher utilization rate of health facilities in the project area (43.4 percent) compared to the control area (36.7 percent) (Oyeyemi and Wynn, 2014). This meant mothers were more likely to go to a health care center to deliver their babies rather than at home, which reduces the first stage of delay. It is important to note that there was not a significant difference in maternal mortality rates between the project and control area, which could be due to a multitude of different factors such as that the effects could emerge at a later stage (Oyeymi and Wynn, 2014). However, the transition to using health clinics where deliveries occur in the presence of a trained health worker is still a good indicator of improving maternal health.

Additionally, in a systematic review conducted on mHealth communication's role in strengthening PNC in rural areas, the authors found that some studies indicated positive attitudes change towards the use of PNC services. The review mentions a study in Ethiopia in which mHealth helped influence mothers to deliver with a trained health extension worker present and also to use PNC immediately afterward (Mbuthia et al., 2019). The mentioned study found that antenatal care follow-ups at mothers' homes increased from 5.21 percent at baseline to 29.75 percent after thirteen months of intervention (Atnafu et al., 2017). Thus, mothers were more likely to trust the healthcare system and utilize the resources available to them, improving their maternal health.

Empower mothers with access to information and increased self-efficiency

Mothers also utilized mHealth to empower themselves with medical knowledge, thus reducing health risks for both pre- and postnatal periods. Mbuthia et al., (2019) reviewed a study in India in which mothers were able to recognize and self-report complications in the postnatal period because they had mHealth communication in the form of text messages from health clinics. They also mention a study in Cameroon, where mothers who had mHealth communication gained the confidence to attend appointments for HIV care after delivery (Mbuthia et al., 2019). This shows that mothers felt empowered by the support that mHealth provided them to increase their self-efficiency to follow practices that would help them heal post-delivery.

More recently, mHealth in the form of mobile apps also helps to connect mothers with information. The Grameen Foundation, a global nonprofit organization, launched an app called "Mobile Midwife" in Ghana, which provides free health information to pregnant women (Grameen, 2010). The app helps the process of maternity in a multitude of different ways, such as reminding mothers about various appointments and maternal care; an app user reported, "with Mobile Midwife I receive useful information concerning my nutrition and reminders to visit the clinic for antenatal care and to take my drugs regularly" (Grameen, 2010). Another feature of the app was to message husbands and encourage them to help with household chores, reducing the physical demand of pregnant mothers and improving their maternal health. The design of these apps is to generally increase maternal health by filling in gaps of knowledge, informing mothers about the process of their pregnancies so that they are more aware of their bodies and the

resources available to them. This exemplifies another application of mHealth technology in working to solve the factors leading to the first stage of delay: by increasing the awareness mothers have about the healthcare system and their pregnancies.

The role of mHealth as additional support instead of the solution

mHealth technology alone is not enough to reduce maternal mortality rates. A study by Ruton et al. (2018) looked into the role the Rwanda RapidSMS system, a nationwide mHealth program connecting designated community health workers in a village with the Ministry of Health, played in the role of utilizing health services. They found that the RapidSMS system alone was not effective and that rather the mHealth intervention in conjunction with increased training and upgraded equipment in health clinics increased the use of health services (Ruton et al., 2018). This connects to the study in Mongolia previously mentioned because the success of the project in reducing maternal mortality rates through the implementation of a telecommunications system also credits the "hands-on training service model, a respect for local practices, and the knowledge base of local doctors" (WHO Telemedicine, 2010, pg 17). Oftentimes, mHealth technology is a tool for a larger initiative to improve maternal mortality rates and is not the sole contributor to improving maternal health nor the sole solution to reducing maternal mortality rates.

Discussion/Conclusions/Recommendations

It is important to keep in mind that technology in developing countries differs in its reach and use and there are several socio-cultural, technological, infrastructural, and economic barriers

to the implementation of mHealth technologies that must be addressed. Often, there is a lack of standardized software and medical equipment across regions which lowers the efficiency and quality of consultation for remote doctors (West, 2015). Additionally, unreliable software and internet connection slow the efficiency of technology in the medical system. For example, West (2015) mentions how slow bandwidth lowers picture resolutions in video calls and limits the diagnostic capabilities of remote doctors. Additionally, both patients and medical workers have to overcome the lower computer literacy rates among the population to utilize the resources, although touch screen technology is more intuitive for people with low computer literacy rates (West, 2015).

There are many other applications of mHealth not mentioned in this review and the extent to which it is helping the medical field goes beyond just rural and developing countries. This includes the remote health clinics that can diagnose patients through live video messaging systems and wearable health technology in preventative medicine. The role of technology in the field of medicine is rapidly broadening — but to utilize these tools to the fullest, countries must focus on developing poor infrastructure in rural and developing areas. This especially applies to people of lower socioeconomic status in developing countries, who have the lowest rate of access to mobile technology according to a study in IT&Society (Chen and Wellman, 2004). The United Nations has recognized the Internet's important role in the progress of developing countries: the 2030 Agenda for Sustainable Development specifies in goal 9.c to provide universal and affordable access to the internet in the least developed countries by 2020 (UN General Assembly, 2015). This goal is an ample opportunity to expand upon the emerging use of mobile technology as a method to improve maternal health and reduce maternal mortality rates.

Another area of investigation is the possible privacy and security vulnerabilities of medical databases in developing countries. This is already a problematic issue for countries that heavily rely on mobile technology. Developing countries have fewer regulatory systems and programs which allow for more flexibility and faster implementation speed of the internet and other technologies (West, 2015). This was exemplified in the Ruton et al. (2015) study in which the Rwanda RapidSMS system was adopted to connect communities with health workers on a nationwide scale — something not possible in other countries. However, it is important to ensure that there are various policies and security checkpoints to ensure that no one's information is unknowingly being taken advantage of. Privacy International, an organization that fights for privacy rights, states that "communication technologies in developing countries must be more ethically aware… we must ensure that even our more noble intents do not result in developing infrastructures that can enable miscarriages of justice" (Privacy International, 2012). Future studies can look into the regulations and policies as well as the possible long-term detriments of the rapid implementation of mHealth technology.

Overall, mobile health technology has been shown to help establish medical databases, increase medical knowledge and resources for health workers, reduce referrals to secondary clinics, strengthen trust between mothers and the health care system, and empower mothers with information and self-efficacy. In these ways, mHealth is working to lower maternal mortality rates and overall improve maternal health. As mHealth technology continues to rapidly develop and expand its role, further studies must be conducted to continue an updated record of its role and effectiveness.

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