SUMMARY

The growth of mobile networks and access to mobile phones has led to the design of health interventions reliant on the utilization of existing infrastructure. The use of mobile phones to improve health outcomes is known as mobile health (mHealth). One health domain within which mHealth technology is currently used is in assisting community health workers in delivering maternal health care in low and middle-income countries (LMICs).

Community health workers (CHWs) are members of their community, although not qualified health professionals, chosen to receive varying amounts of training and consequently provide a range of health services to their communities, including maternal health information and advice. CHWs are often volunteers and are essential in rural areas of LMICs with nation-wide shortages of human resources for health. However, it is important to note that CHWs cannot replace professional health workers. Human resources for health are important for overall health outcomes including maternal health. Research has shown that the countries with the worst maternal health indicators are also some of those that have the least amount of health workers. In these countries, women of low socioeconomic status in rural areas are the most affected.

The presence of CHWs has helped improve the overall outcomes for women in rural communities; however, these health workers often have limited education and training and insufficient supervision, which leads to difficulties in conducting their tasks. The use of mHealth technologies can serve as a bridge between these gaps in education, training, supervision and communication (between CHWs and the communities and CHWs and other health workers).

This thesis aims to contribute to the evidence-base to develop solutions for solving maternal health problems related to maternal knowledge and health-seeking behaviors in rural settings in LMICs. Based on the overall research objective, four research questions were formulated:

1. What is the effect of mHealth interventions utilized by CHWs on maternal health?
2. How does mHealth program implementation influence the performance of health workers, including community health workers?
3. What contextual factors influence the effectiveness of a mHealth intervention utilized by CHWs on maternal knowledge and health-seeking behaviors?
4. How do program-targeting strategies influence observed outcomes of maternal mHealth interventions?
The thesis addresses the main objective and research questions in three parts.

**PART I: SETTING THE SCENE (CHAPTERS 1-4)**

In Chapter 1, a brief introduction to the overall thesis topic of the use of mHealth technologies by CHWs for maternal health is presented, as well as a discussion of the three delays model. The three delays model proposes that maternal mortality can be related to three key delays: a delay in the decision to seek care, a delay in reaching care and a delay in receiving adequate care at health facilities. In Chapter 2, the concepts presented in the previous chapter are expanded upon. This includes the challenges of human resources for maternal health and the role of CHWs in providing maternal health services. In this chapter, an overview of previous research on mHealth for maternal health is presented. This chapter also highlights issues around complexity in assessing interventions, which is fundamental for understanding the thesis. Simply put, a complex intervention is one in which there are multiple variable components, such as individuals and originsations, which the intervention attempts to influence, as well as the change which the intervention seeks to achieve. Interventions, which attempt to change human behavior, are complex, as there are many elements to be considered, such as the environment, cultural norms and the individuals' personal attributes. The chapter ends with a conceptual framework with four levels: mHealth interventions, individual level characteristics, health systems and context. The framework is represented visually and accompanied by narrative text that explains each level of the model. This framework guided the selection of interventions as well as the design of studies.

Chapter 3 deals with the research design of the thesis. The research comprised of both theoretical and empirical components. The theoretical component comprised of two literature reviews while the empirical part utilized case study design. The first review utilized a realist review methodology which aimed at understanding questions related to how do mHealth applications improve health workers performance, what applications work and for whom. The second review adopted a narrative analysis to understand who is targeted in community level health interventions and how targeting strategies of mHealth interventions influence the outcomes of the maternal mHealth interventions. Selection of case studies were guided by three key criteria which were: the existence of a maternal mHealth intervention which was utilized by community health workers; an ongoing CHW program which was already operational before the introduction of the mHealth technology; in a rural region of a low and middle-income country; implemented by a
non-governmental organization (NGO) which was interested in assessing their program. Based on these criteria two projects were selected in India and Uganda.

Chapter 4 was the realist review of the effects of mHealth on the performance of health workers in LMICs. The review showed that there was significantly more evidence on factors which influenced health workers’ acceptance and use of mHealth interventions, as opposed to the effect of these interventions on their performance. The results highlighted that at the initial introduction of an mHealth intervention, two factors influenced health workers’ acceptance of the intervention. These were the usability of the intervention and empowerment. The perceived usefulness, ease of use and their understanding of the content of the interventions influenced usability. Empowerment was often related to increased computer literacy skills, confidence in problem solving or enhanced self-efficacy. Continued use of the intervention after the initial adoption was influenced by infrastructural and technical resources, as well as the response from peers and patients to the use of the intervention. Although there was limited information on the performance of health workers, there were indications that the mHealth interventions improved knowledge and skills especially for workers in remote areas.

PART II: EMPIRICAL RESEARCH (CHAPTER 5-7)

In this section of the thesis results from the empirical case studies are presented.

Chapter 5 was a quantitative study that explored the effects of a mHealth intervention utilized by CHWs on maternal health, Mobile for Mothers (MfM), in improving maternal health knowledge, attendance at antenatal clinics and delivery at a health facility in Jharkhand, India. The study design was quasi-experimental and included three groups: an intervention group which received MfM in addition to NGO existing interventions; (2) a quasi-control group that received NGO programs nor including the mHealth intervention and (3) a standard care group that only received standard care government programs. The study was interested in understanding the differences and similarities between these groups on three main outcomes: i) maternal health knowledge ii) antenatal care attendance and iii) delivery at a health facility. To explore these outcomes across the groups, three comparisons were made: 1) MfM vs. standard care; 2) MfM vs those who received the NGO intervention and 3) NGO intervention versus standard care. After controlling for predictors, the women in the MfM group significantly performed better than both the NGO-intervention groups and standard care groups on all three outcomes variables (all p>0.05). The
results showed that mHealth interventions could be helpful in improving maternal health knowledge as well as practice of recommended maternal health behavior. However, the effectiveness was influenced by Individual characteristics such as education and caste. The study led to the conclusion that although mHealth interventions hold promise for improving maternal health, contextual factors need to be addressed.

Chapter 6 is the second study on the Mobile for Mothers (MfM) intervention in India. This mixed methods study (quantitative and qualitative methods) further explores the factors that influenced the intervention outcomes related to maternal health knowledge, health seeking behavior and facility delivery presented in Chapter 5. The study utilized quantitative data from 740 women who received the MfM intervention as well as 57 CHWs who utilized MfM. There were also semi-structured interviews and group discussion with CHWs, women and men. In this study, CHWs reported that MfM improved their confidence and performance of maternal health related tasks by providing a job aid. However, CHWs experiences with MfM varied based on their age and education levels. Factors that had an effect on women’s health seeking behavior included their responsibilities at home (cooking, needing to arrange child care), mothers-in-law and husbands as important decision makers and issues with transportation to the health center. This study highlights the need to understand the context within which the mHealth intervention is to be implemented and adapt interventions to these conditions.

Chapter 7 explores the implementation of an mHealth intervention utilizing Village Health Teams (VHTs) in Uganda. This study had two aims; the first was to understand the assumptions of program designers about their mHealth interventions, and the second was to compare these assumptions with evidence from the stakeholders (health professionals, village health teams, men and women) to better understand the results of the intervention. From interviews with program developers, three assumptions were identified. Assumption 1: VHTs with limited literacy would benefit from training sessions and be motivated and able to encourage their community to utilize the mHealth intervention. Assumption 2: When women with limited maternal health knowledge and poor utilization of maternal health services use the mHealth intervention, their maternal health knowledge would increase and this would subsequently lead to an increase in their utilization of maternal health services. Assumption 3: As mothers and health workers gained knowledge about maternal health rights and responsibilities, there would be increases in positive experiences at health centers and this in turn would encourage increased utilization of health facilities. Study results showed that for each of the program designers assumptions, there were multiple
additional factors which influenced the results of the intervention beyond those captured by the designers. These factors include VHTs perceptions of training, maternal health decision makers, mobile phone ownership, difficulties in reaching health centers and poorly equipped health centers. The results showed that examining stakeholder’s experiences of an intervention against program designer’s assumptions allowed for a deeper understanding of factors that influenced the achievement of intervention goals.

PART III THEORETICAL REVIEW AND DISCUSSION (CHAPTERS 8-10)

Chapter 8 presents the protocol that was utilized in the narrative review of Chapter 9. In conducting the realist review and research studies presented in Chapter 4-7, a question that was consistently raised was one regarding the role of targeting in the design and outcome of mHealth interventions. The questions of the review presented in the protocol underwent changes during the review process, and the final questions explore: 1) what are the targeting strategies employed in maternal health interventions and who do they target? 2) In what way do the targeting strategies affect sub-group outcomes? The review included 12 articles that fit the inclusion and exclusion criteria presented in the protocol. Of the 12 included articles, only two studies reported on their targeting strategies, the other articles describe the target groups and the characteristics of the groups. Interventions, which reported on sub-group difference in outcomes, noted that factors such as literacy, place of residence, ownership of mobile phones by husbands and age of participants influenced the observed outcomes. Overall, the review highlighted the limited attention given to socio-cultural factors in targeting strategies by mHealth intervention developers could influence observed maternal health outcomes. It would be interesting for future intervention development to pay more attention to creating programs that account for the socio-cultural context, through targeted interventions.

The concluding chapter of the thesis, Chapter 10, integrates the results from both the realist review and narrative review, as well as findings from both case studies including case notes and observations, and scientific literature. In this chapter, a revised conceptual framework is presented which represents a change in thinking that occurred during the thesis. The revised framework was guided by an understanding that the outcomes of a health system are crucial in the implementation of a technological intervention and the ultimate success of the intervention. For this thesis, it means that the broad context (e.g. rural community, health systems, etc.) and the functioning of the health workers (CHWs) must be well understood in order to implement an effective mHealth intervention. The chapter presents eight key messages, which highlight the importance of contextual, health system,
and mHealth factors in understanding the effectiveness of a CHW utilized mHealth intervention.

1. CHWs are increasingly utilized in providing care in rural LMICs. However, they are not substitutes for trained health professionals and do not solve issues related to the recruitment and retention of skilled health professionals to rural areas in LMICs. There is a need for mHealth intervention designers to acknowledge that human resources for health can be a limitation to achieving maternal health outcomes and modify their expectations accordingly.

2. While some maternal mHealth interventions, such as those studied in this thesis, are designed to reduce the impact of the shortage of healthcare workers and increase health-seeking behaviors; the effects of non-existent or poor infrastructure cannot be overcome by an mHealth application designed to improve knowledge. In such contexts, mHealth interventions can provide information that empowers women to demand services. It, however, does not overcome issues of limited infrastructure. Acknowledging this limitation can enable program implementers to adapt expectations accordingly.

3. Non-governmental organizations often play significant roles in the provision of maternal health care in rural areas of LMICs. However, CHW performance appears to be negatively influenced by the inconsistent provision of incentives by different programs in the same context. Consistent and context appropriate incentives to all CHWs involved in the intervention could minimize CHW demotivation.

4. Gender norms have significant effects on other determinants of health, such as autonomy in decision-making and education. mHealth interventions could address these by expanding the target groups to include decision-makers, such as men and mothers-in-law, and adapt the intervention to the literacy levels of the different target groups.

5. CHW programs are complex interventions, which are influenced by their program history and structure. Effective mHealth interventions need to be aware of these nuances in CHW program design and context and address them within the intervention and training design.

6. mHealth applications utilized by CHWs are often based on the assumption that CHWs have positive relationships within their communities and the pregnant women they serve, but the relationships are more complex. mHealth programs should take into account social hierarchies within communities as these might influence community members’ abilities to trust CHWs and consequently influence intervention and health
Although CHWs are formally considered a part of the health system in both contexts, this integration is in practice often less well functioning. This could be problematic particularly for systems in which CHWs are responsible for referrals to health centers, as CHWs feel disempowered and unable to perform their tasks properly. To address this, it is important that mHealth interventions also support the CHWs in navigating their position in the health system.

The effects of mHealth interventions are influenced by the contexts in which they are implemented. The results of this thesis suggest that mHealth interventions need to be adaptive to the needs of the target groups, and responsive to emergent context related factors.

Based on these key messages, three recommendations are made for policy and practice: the need to facilitate collaboration between CHWs and health professionals, as well as CHWs and communities; the impact of inconsistent incentives and NGO involvement in rural health and the need for different educational models to improve technological literacy of CHWs. This chapter also presents a reflection on methodological aspects of the thesis including complexity in research design, the role of the researchers, conducting research in rural settings and the process of collaboration between NGOs and academic partners.

In conclusion, mHealth interventions utilized by CHWs have significant promise for reducing first delays through delivery of accurate maternal health knowledge to CHWs and pregnant women. However, in order to achieve the global vision of long-term improvements in maternal outcomes, mHealth interventions should be adapted to the existing CHW programs and the wider context (both the hardware and software components). mHealth interventions would be most successful when embedded in a system-focused approach and designed to address contextual limitations.