

Summary

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Chapter 1 provides the introductory context and premises upon which we have structured our research. It describes the rationale and research questions behind the three main pillars of the studies in this study: maternal health, human resource for health with a focus on community health workers (CHWs), and mobile health (mHealth) applications.

This chapter states that maternal mortality remains a major challenge to health systems worldwide and improving maternal health has been on the global health agenda for years. One of the eight millennium development goals (MDGs) is improving maternal health (MDG5). This MDG targets to reduce the maternal mortality ratio (MMR) by 75% between 1990 and 2015. The World Health Organisation's maternal mortality trend analysis issued in 2012 showed an overall decline of 47% in maternal deaths globally, however, in relation to achieving the MDG target, the decline is insufficient. Many countries have made insufficient or no progress and are likely to miss the MDG5 targets unless accelerated interventions are implemented. In 2010, an estimated 287,000 maternal deaths occurred worldwide. Women in developing regions were at 15 times the risk of dying than women in developed regions because of pregnancy and pregnancy related complications.

With the aim of achieving MDGs amidst the critical shortage of skilled human resources for health, many developing countries have focused on increasing production and distribution of CHWs to provide basic and essential health services to their underserved and rural populations. Since 2003, Ethiopia has been rigorously accelerating access to primary health care (PHC) through its community-based health extension program (HEP) and primary health centers. Under the umbrella of the HEP and as part of PHC acceleration and revitalisation, approximately 34,000 new CHWs, given the title 'health extension workers' (HEWs) were trained and deployed in around 15,000 newly constructed health posts between 2003 and 2010. One health post was constructed for each of the 15,000 kebeles (villages) in the country. The acceleration of access to PHC in Ethiopia has not only resulted in a significant increase in the number of health centres but also with a remarkable increment in trained and deployed midlevel health professionals at health centers. The number of operational health centers in the country has increased by 413%: from 519 in 2004 to 2,660 in 2011. In the same timeframe, the number of deployed health officers increased (from 683 to 3702), as did the number of midwives (from 1,274 to 2,416) and all nurses including midwives (from 15,544 to 29,550).

Despite the few studies with published findings on the effectiveness of HEWs, and the need for rigorous and systematic evaluation of the impact of this acceleration and

expansion of the primary health care in Ethiopia, improvements in maternal and child health care indicators for the country over the past few years is highly likely attributed to this extensive and aggressive expansion. In this chapter it is highlighted that between 2005 and 2011, the contraceptive prevalence rate (CPR) increased from 15 to 29%, antenatal care (ANC) coverage increased from 28 to 43%, while infant and under-five mortality declined from 77 and 123 deaths per 1,000 live births, to 59 and 88 deaths per 1,000 live births, respectively. However, even with these achievements, the maternal mortality ratio remained the same and among the highest figures in the world: 673/100,000 live births in 2005 and 676/100,000 live births in 2011. In a similar period of time, increases were seen in the percentage of pregnant women who were assisted for birth by skilled birth attendants (from 6% to 10%), gave birth at health institutions (from 4% to 10%), and received PNC within the first two days of delivery (from 5% to 7%).

Given that HEWs are the primary and key health service providers to the grassroots population – particularly in remote and rural areas; and that globally there is insufficient evidence to justify recommendations which can guide policies and practices, investigations as to the effectiveness of such CHWs and potential solutions which improve their performance and competency are imperative. Taking these rationales into consideration, the studies in this thesis investigated three main research questions. First, we investigated the role of HEWs in improving utilisation of maternal health care services by rural women in Ethiopia. Second, we assessed the knowledge and performance of these community health workers and assessed their barriers and facilitators in providing quality maternal health care. Third, based on the findings of the aforementioned studies and review of literature, we believed mobile phone based solutions could be one potential avenue to improve the performance of HEWs and other primary health care workers in Ethiopia. Hence, we explored the feasibility and usability of implementing mobile health (mHealth) applications for maternal health care service delivery at primary health care in Ethiopia among midwives and HEWs over a period of approximately 22 months. Under this main research question, we formulate and investigated four sub-research questions: 1) We identified HEWs' and midwives' mHealth technical needs and considerations for maternal health care services delivery; 2) we qualitatively explored the feasibility of introducing and implementing an mHealth application for routine health data collection and patient assessment regarding maternal health care at PHC settings in Ethiopia in terms of acceptability, demand, practicality, implementation and integration dimensions; 3) we assessed the extent of use of electronic forms on smartphones by HEWs and midwives, and the barriers and facilitators met by health workers in using electronic such interface; and 4) we

investigated whether using electronic forms on smartphones for routine collection of health data would improve data quality in terms of completeness and accuracy.

Overall, the six separate studies accompanying the aforementioned research questions are presented in Chapters 2-7 of this thesis.

Chapter 2 presents a study on the role of health extension workers (HEWs) in improving utilisation of maternal health services in rural areas in Ethiopia. This study investigated women's utilisation of family planning, antenatal care, birth assistance, postnatal care, HIV testing and use of iodised salt and compared our results to findings of a 2005 national survey. This study showed HEWs have contributed substantially to the improvement in women's utilisation of family planning, antenatal care and HIV testing. However, their contribution to the improvement in health facility delivery, postnatal check-up and use of iodised salt seem insignificant. Women who were literate (OR: 1.85), listened to the radio (OR: 1.45), had income generating activities (OR: 1.43) and had been working towards graduation or graduated as model family (OR: 2.13) were more likely to demonstrate good utilization of maternal health services. The study commends for more effort in the improvement of the effectiveness of HEWs in promoting skilled birth attendance and institutional delivery, for example, strengthening HEWs' support for pregnant women for birth planning and preparedness and referral from HEWs to midwives at health centers. In addition, women's participation in income-generating activities, access to radio and education could be targets for future interventions.

We conducted a cross-sectional assessment among the Ethiopian HEWs to assess their knowledge and performance on antenatal and delivery care. This study is described in **Chapter 3**. A total of 50 HEWs working in 39 health posts, covering a population of approximately 195,000 people, were interviewed. Descriptive statistics were used and a composite score of knowledge of HEWs was produced and interpreted based on the Ethiopian education scoring system. Our interpretations revealed more than half (27, 54%) of the HEWs had poor knowledge on contents of antenatal care counseling, and the majority (44, 88%) had poor knowledge on danger symptoms, danger signs, and complications in pregnancy. With regards to the performance of the HEWs, a HEW assisted in an average of 5.8 births within 6 months. Only a few births (10%) were assisted at the health posts; the majority (82%) were assisted at home and only 20% of HEWs received professional assistance from a midwife. Based on these findings, the study suggested interventions to improve the performance of HEWs by enhancing their knowledge and competencies, while creating appropriate working conditions.

Detailed technical descriptions of the set of appropriate smartphone mHealth applications developed using open source components, including a local language adapted data collection tool, the health worker and manager user-friendly dashboard

analytics and maternal-newborn protocols are described in **Chapter 4**. This chapter also highlights the major lessons learned and considerations made during the period of the mHealth research project life. Taking into account staff replacements, overall 20 HEWs, 12 midwives and 5 supervisors participated in our mHealth research which ran from August 2011 to May 2013. This chapter includes all the steps we followed during the pre-implementation phase (August 2011 – November 2011) and the actual implementation phase (December 2011 – May 2013), as well as the real patient encounters recorded during the actual implementation phase. Within this period, a low level of smartphones breakage (8.3%, 3 from 36) and loss (2.7%) were reported. This significantly low figure is mainly attributed to the unrestricted use of smartphones which might have generated a strong sense of ownership and empowerment among the health workers.

Chapter 5 presents qualitative findings of the feasibility analysis we conducted at the beginning of the study (August 2011 – May 2012). It concerns the feasibility of introducing mHealth applications, smartphones, and electronic forms at PHC in Ethiopia for routine collection of health data and patient assessment as relevant to maternal health. During this study, a total of 14 health workers selected from 12 PHC facilities were trained and recruited to use an mHealth application for six months. Qualitative approaches comprising in-depth interviews and field notes were employed to document the users' initial perception and experience in using the application and forms. Feasibility of introducing the mHealth application was explored in terms of acceptability, demand, practicality, implementation and integration dimensions. Findings of this assessment showed that introducing our mHealth application and electronic forms for data collection and the provision of feedback for health workers on their performance was feasible at a small scale. Health workers' actual use of the application and forms was promising; they found the electronic forms helpful and expressed their intention to continue using them. Nonetheless, implementing a system of assigning unique and consistent patient identifier, standardization of health services and improving mobile network coverage would be pre-requisites for usage of such applications at a larger scale.

In **Chapter 6**, a quantitative assessment of usability of the mHealth application by HEWs and midwives for maternal health care service delivery is presented. This study evaluated a six month period (October 2012 – March 2013) use of electronic maternal health care forms among the health workers. Twenty-five HEWs and midwives, working in 13 PHC facilities participated in this study. A pre-tested semi-structured questionnaire was used to assess health workers' experiences, barriers, preferences, and motivating factors in using the forms and smartphone. Health workers' monthly mobile top up use for voice call, internet connection, and short message services was collected from telecommunication service provider, Ethio-Telecom. Findings of this

evaluation showed that health workers used the electronic forms on smartphones in more than half (1,122 women or 59.1%) of the cases for the total expected number of pregnant women. Almost three quarters (73.7%) of the records were submitted by midwives and the remainder (26.3%) by HEWs. Health worker's use of the forms was generally consistent across the six months. Health workers used about 90.2% of their mobile top ups for making voice calls. With 9.0% of the total mobile top up used for mobile internet connectivity, only a very small fraction (0.13%) was needed to submit the records. Similar to the feasibility assessment (Chapter 5), this study also found the actual use of the mHealth application was encouraging. However, considering health workers' high use of mobile top ups for making voice calls, the study recommended implementers of such interface for soliciting a mechanism of securing free airtime for health workers from telecommunication service providers or putting restrictions on health workers' mobile top up use.

Chapter 7 presents a study that specifically evaluated the quality of routine health data collection using electronic forms on smartphones. In conducting this evaluation, a structured paper checklist was prepared to assess the completeness and accuracy of 408 electronic records completed and submitted to a central database server using electronic forms on smartphones by 25 health workers. The 408 electronic records were selected randomly out of a total of 1,772 submitted by the health workers to the central database server over a period of six months (October 2012 – March 2013). Data quality in terms of completeness and accuracy was compared to their respective paper records. This comparison showed that the use of electronic forms improved data completeness by 209 (8%) entries. A very small margin of error, which was easily identifiable, occurred in both electronic and paper forms although the error rate in the electronic records was more than double that of paper records (2.8% vs 1.1%). More than 50% of errors in electronic records concerned entering a text value. This study attested that with minimum training, supervision, and without any incentives, health care workers were able to use electronic forms for patient assessment and routine data collection appropriately and accurately with a very small margin of error.

In the final chapter, **Chapter 8**, we discuss the overall major findings, conclusions and methodological considerations of the presented studies in this thesis. We highlight the implications of our findings for practice and further research. The major discussions of the studies in this thesis are presented in four major areas; 1) Role of HEWs in improving maternal health services utilisation by rural women in Ethiopia, 2) Knowledge and performance of HEWs in maternal health care provision, 3) Barriers and facilitators for HEWs in maternal health care delivery, and 4) Feasibility and usability of electronic forms on smartphones by the Ethiopian HEWs and midwives. Possible reasons for the discrepancies in the role of HEWs in improving different aspects of maternal health care services are also discussed in this chapter. With due emphasis, the

poor knowledge and performance of the HEWs are discussed as possible reasons for the low achievement of the health workers in improving health facility delivery and facilitation of referral. Major barriers such as workload, level of knowledge and lack of opportunities for the HEWs to upgrade their career are discussed. Recent efforts of the Federal Ministry of Health of the government of Ethiopia are also highlighted. The final section of this chapter focuses on introducing mHealth application at PHC settings in Ethiopia, in three main themes: 1) feasibility and usability, 2) data quality, and 3) cost implications of using electronic forms on smartphones at the PHC settings in Ethiopia. The chapter concludes with 10 take-home messages and strategies which might be useful for the optimum use of electronic forms on smartphones by primary health workers in resource-poor countries.