

Maternal Complications: Nuances in Mobile Interventions for Maternal Health in Urban Pakistan

Amna Batool*, Samia Razaq*, Maham Javaid*, Beenish Fatima*, Kentaro Toyama**

*Department of Computer Science
Information Technology University
Lahore, Pakistan
{amna.batool,samia.razaq,maham.javai
d,mscs13017}@itu.edu.pk

**School of Information
University of Michigan
Ann Arbor, Michigan, United States
toyama@umich.edu

ABSTRACT

We present a three-phase exploration of mobile messaging to address the high rate of maternal mortality in low-income, urban Pakistan, with a focus on identifying deviations from previously published findings about mobile interventions in developing-world health.

Phase 1 was a qualitative study of healthcare staff and pregnant mothers. It found that while the deeper medical challenges of maternal mortality were beyond the reach of ICT interventions, many of the problems could be partially addressed through a mobile-phone system that issued health-related information and reminders. In Phase 2, we ran a randomized controlled trial of 180 pregnant mothers split into four arms based on the mode by which the messages were sent – (1) no messages (control), (2) SMS text messages, (3) recorded voice messages, and (4) a combination of SMS and voice messages. Consistent with prior research, we found that mothers receiving messages exhibited dramatic gains in knowledge about pre-natal care, though whether the messages increased follow-up hospital visits was not clear.

Phase 3 involved follow-up phone interviews with the participants of the Phase 2 evaluation. Complex family dynamics involving husbands and mothers-in-law mediate the impact of mobile information interventions, with both positive and negative effects.

CCS CONCEPTS

• Information systems ~ Information systems applications • Human-centered computing ~ Field studies

KEYWORDS

Maternal Health, mHealth, Mobile intervention, randomized controlled trial, interactive voice response, pregnancy, Pakistan, Expecting Mothers

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from Permissions@acm.org.

ICTD '17, November 16–19, 2017, Lahore, Pakistan © 2017 Association for Computing Machinery.

ACM ISBN 978-1-4503-5277-2/17/11...\$15.00

<https://doi.org/10.1145/3136560.3136573>

1 INTRODUCTION

The formal, globally accepted definition of maternal mortality is “the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes” [1].

Women in developing countries have, on average, many more pregnancies than women in developed countries, and their risk of death due to pregnancy is higher. In 2015, the maternal mortality rate in developing countries was estimated to be 239 per 100,000 live births compared with the much lower developed-country rate of 12 per 100,000 live births [2]. Worldwide, roughly 303,000 women die each year due to pregnancy or childbirth [2]. 99% of these deaths occur in developing countries, of which Pakistan alone is responsible for an estimated 30,000 deaths [3]. Maternal mortality figures prominent in the United Nations’ Millennium Development Goals, and Pakistan hoped to do its part by reducing maternal mortality by 75% in 15 years, from 410 per 100,000 in 1990 to 140 per 100,000 by the end of 2015. This goal was not reached, with the latest maternal mortality rate at 273 per 100,000 [3]. (The UN’s newer Sustainable Development Goals aims to reduce the maternal mortality ratio even further to less than 70 per 100,000 [4].)

The medical causes of maternal mortality are similar around the world. They include hemorrhage, anemia, obstructed labor, sepsis, eclampsia, and severe bleeding [2]. In Pakistan, one study revealed that the majority of maternal deaths are due to post-partum hemorrhage, followed by pregnancy-induced hypertension or eclampsia and non-obstetric causes [5] [6]. These medical problems, however, are just the proximal causes. Higher maternal mortality is associated with poverty, low literacy, lack of skilled birth attendants, high fertility rate, early marriages, malnutrition, superstitious beliefs, poorly implemented health policies, and delays in seeking or receiving proper medical care [7] [8] [9].

This paper describes a three-year, three-phase exploration of an attempt to reduce maternal mortality among low-income mothers in urban Pakistan with a mobile-phone-based intervention. Phase 1 was a qualitative investigation into what both the medical staff and pregnant mothers perceive to be the obstacles to healthy pregnancy and birth, as well as a brief analysis of which challenges appear amenable to an ICT-based solution.

The conclusions of that initial study led us to Phase 2, involving a system to deliver SMS text messages and interactive voice response (IVR) calls that provided information relevant to pregnancy and issued reminders to make hospital visits. The evaluation involved a four-arm RCT of the system's effectiveness under different modes of usage, and found that both SMS and IVR messages were helpful in increasing knowledge about pregnancy and childbirth.

Finally in Phase 3, we performed follow-up phone interviews with the Phase 2 participants.

Our intervention was the result of a human-centered design paradigm focused on input from mothers and medical staff. However, in being true to stakeholders, the final system we developed was not novel in itself. And, while our results are novel with respect to increased knowledge among mothers, they are not surprising, as they confirm findings from similar studies in other developing-world contexts [10] [11] [12] [13]. Thus, in this paper, we highlight insights we gained throughout the three-phase study, in which our findings deviate from published results about mobile health.

The paper makes the following novel contributions. First, our qualitative explorations represent the first attempt to develop an understanding of the challenges of maternal mortality in urban Pakistan – a unique context in which high-end medical care meets deeply held traditional Muslim social norms. Second, our evaluation presents what is to our knowledge the first experimental trial of a maternal health intervention in which low-income pregnant mothers see significant gains in antenatal care knowledge through a mobile intervention. Third, in all three phases, we paid close attention to the realities of maternal health in Pakistan which deviate from existing literature about mobile interventions for women in the developing world. These findings offer a nuanced view of mobile health interventions and spotlight issues requiring attention in future projects.

In Section 2, we overview related work. Section 3 provides background to the state of maternal healthcare in Pakistan. Section 4 presents our initial qualitative study. Section 5 explains the design of the intervention. Section 6 presents the experimental methodology and its results. Discussion occurs in Section 7.

2 RELATED WORK

Maternal healthcare has seen many applications of information and communication technologies (ICT). However, relatively little of it has taken place in the unique context of Pakistan, and a lack of hard evidence about impacts has made it difficult to arrive at clear generalizations about the relative value of text and voice messaging. In this section, we overview the existing literature on ICTs to address maternal mortality

2.1 Mobile Information for Health

Recent years have seen a proliferation of projects in which various types of health information are provided to members of low-income communities through their mobile phones [10] [12] [13].

Disseminated information tends to take one of two forms. One category provides information for education, for example, with respect to HIV/AIDS [14]. Another category issues reminders to take medication or administer other treatment. Researchers have used SMS reminders to improve hypertension treatment medication intake [15], adherence to iron supplements among expecting mothers [11], and diabetes management in young diabetic patients [16]. These interventions often take the form of SMS text messages, but others have used voice calls. One study used voice calls to disseminate information about iron supplements to increase pill adherence specifically by non-literate users [17].

Maternal health, perhaps because of its prominence in the Millennium Development Goals, has received considerable attention, with a range of projects mobile phone technology. Many of these are projects run by non-profits: Motech [18], MAMA [19], liga inan [14], Gifted Mom [20], and Medic Mobile [21]. Increasingly, some of these and other interventions have been studied and published in peer-reviewed journals. Reviews of this work find that while most “studies showed at least some evidence of effectiveness at changing behavior to improve antenatal care attendance, postnatal care attendance,” rigorous evaluations are very few. There have been only two randomized controlled trials of mobile interventions connected to maternal health (both showing increased antenatal care visits to hospitals [22] [23], and none examine the potential for such interventions to increase maternal knowledge of good pregnancy practices.

The work reported in this paper extends this line of work to address maternal mortality in the context of urban Pakistan, and it adds to the body of evidence for the value of mobile health interventions. To our knowledge, the impact evaluation described in this paper is the first to show increased knowledge of antenatal care among low-income mothers through a mobile intervention.

2.2 Other ICT for Pregnant Mothers

Apart from direct delivery of health information to patients, there are at least two other forms of ICT use intended to benefit pregnant mothers: counseling and monitoring/screening.

Community health workers form a core component of the health system in developing world. In order to boost their role as health counselors, several interventions have used ICTs to support health workers and reduce their workload [24] [25] [26]. One study in rural India used mobile videos as a basis for healthcare conversations with mothers [27]. An extension of that work found that counseling sessions were improved by the inclusion of dialogic messages that provoked responses from expecting mothers [28].

Monitoring and screening tools help identify health abnormalities and complications at an earlier stage. One example is the digitization of the partograph – a graph used to monitor labor progress to identify fetal and maternal complications. The Partopen helps midwives better monitor the progress of labor, and it has been demonstrated to make monitoring easier in low-resource settings [29]. In another study, the availability of low-cost ultrasound machines to assist village midwives supported the early detection of complications among expecting mothers [30].

As above, existing research on mobile interventions for maternal health tends to focus on direct health-related outcomes improved counseling, more hospital visits, and improved health. These are important impacts to be sure, but rigorous evaluations of them are few. In our study, we confirm that related impacts can be

evinced [13] in urban Pakistan with a randomized controlled trial. In addition, we investigate some of the less understood surrounding issues with regard to mobile maternal health: What are the unique concerns of Pakistani households? How exactly do mothers in low-income urban Pakistan use their phones? How do mobile interventions affect family dynamics? These are questions that have not been highlighted in the existing literature.

3 THE CONTEXT

Urban Pakistan presents a unique social context, much like that of urban India but with a Muslim flavor. On the one hand, it is firmly in the developing world: Pakistan's per capita income is around USD 1,430, and the country has an overall literacy rate of 54% [31] [32]. Gender inequalities are severe: 75% of its girls and women have no education; 11% have some primary education; and only 6% have more than secondary education [31] [32]. Most women do not work outside of the home; only 20% of women hold formal jobs. With respect to pregnancy, 65% of Pakistani women give birth at home with only 8% of these homebirths supervised by a trained birth attendant [3]. Social norms are dominated by Islamic tradition, with 95-98% of the population being Muslim [31].

At the same time, urban Pakistan is connected to a cosmopolitan culture through its global elite. Cities like Karachi and Lahore are increasingly ranked among the top cities worldwide in terms of their economic potential and growth [13] with an educated middle class and strong universities. On this foundation, Pakistani cities also house quality hospitals with modern medical care.

As with other developing countries, Pakistan's social strata tend to remain siloed with few routine interactions among them except those that occur between employers and employees. Urban healthcare, however, and maternal care in particular, is one of the few contexts in which low-income households come into close interaction with modern urban practices.

3.1 Research Site

All of our research was conducted in partnership with Lady Willingdon Hospital, one of the largest public obstetrics and gynecological care facilities serving underprivileged communities in Lahore. The hospital comprises 832 medical personnel, 235 beds, and 3 independent teaching units headed by three different administrators. Each unit has its own medical resources, operating facilities, and patients' departments.

Each unit runs its out-patient department (OPD) on different weekdays with an estimate of 250 patients visiting the antenatal care OPD per day.

4 PHASE 1: QUALITATIVE INTERVIEWS AND FIELD OBSERVATIONS

To understand the current situation of maternal health in Pakistan, both from the perspective of the medical staff as well as expecting mothers, we conducted a qualitative field study in 2014 consisting of semi-structured interviews with various health personnel and expecting mothers, as well as field observations at several healthcare facilities.

A total of eighteen in-person interviews were conducted with medical personnel from all levels of Pakistan's health delivery

system, as well as 93 in-person interviews with expecting mothers. All interviews were conducted in Urdu and detailed notes were taken on paper. Each interview took between 20-60 minutes.

4.1 Findings from Medical Staff Interviews

The interview protocol for medical personnel focused on how hospital personnel perceived the current maternal health situation in Pakistan; what they perceived as the key determinants of maternal mortality; and what, if anything, could be addressed with an ICT-based intervention.

4.1.1 Misinformation or Lack of Information. One theme which occurred repeatedly was a general lack of basic knowledge about health and pregnancy among low-income mothers in Pakistan. They were unaware of the value of routine checkups during pregnancy; iron supplements; pre-natal supplements; ultrasound appointments; high-risk indicators; or even the value of hospital births. This unawareness was noted by medical personnel and was confirmed by pregnant mothers, often through their recitation of misinformation.

A male gynecologist at a public hospital noted the following about his patients:

"There is no concept of routine health checkups in Pakistan... They don't know that they can be deficient in blood because of their menstrual cycles if they don't get proper iron intake. They are not aware that they should meet the iron deficiency before they get pregnant again."

A gynecologist from a public hospital said this of ultrasound:

"I see many patients who think that ultrasound rays are harmful for their fetus, hence they never get an ultrasound."

One mother – surprisingly, a PhD candidate in a public university in Lahore – confirmed:

"I have heard that ultrasound rays are harmful for the fetus. Hence I have not performed this test yet. Although I am doing research on brain cancer but when it comes to oneself, you become suspicious of things like that."

The consequences of this ignorance can be devastating. One 7-month pregnant mother was admitted to the hospital for abortion because of fetal abnormalities which were revealed to her only at the 7th month when she performed her first ultrasound. According to the doctors:

"It would have been much less painful, both physically and emotionally, if she had performed an ultrasound at an earlier stage."

A senior gynecologist at a public medical college said,

"Expecting women are unaware of all the high-risk indications in pregnancy, in which case they should visit the hospital and consult a doctor. If we can make them aware of what these high risk indications are and how they have to tackle these situations, we can surely make some difference."

4.1.2 Reliance on Non-Medical Advice. Another prominent theme was the reliance on advice from people without proper medical training, including traditional midwives ("daai") and relatives, particularly mothers-in-law.

A senior gynecologist mentioned that she often saw sepsis cases caused by midwives' mismanagement.

"I have seen midwives who have kept one big nail of their little finger to cut the baby's cord; this is the level of hygiene of these

midwives... They have unsterilized surgical equipment and all they use to sterilize it is Dettol [an over-the-counter disinfectant]."

Other medical personnel noted that mothers-in-law play a powerful role in determining what mothers do:

"They have their mothers-in-law who don't allow them to come to hospital unless they have complications."

Mothers say mothers-in-law provide folk advice such as

"We have given birth to children without any doctors or hospitals in our time and our kids turned out to be OK. So there is no need to go to hospital for regular checkups."

Pregnant mothers, in fact, do not control the decision about hospital visits on their own. During one visit, a mother said:

"Don't put next week's date for test, I want to get all my tests done today as I am not sure if my family would allow me to come again next week."

Most women are unaware of the methods of contraception and family planning. Even when there is familiarity, they have little say in family planning and fall in line with their husbands' and mothers-in-law's wishes. One mother who was expecting for the second time in a year, with low hemoglobin when inquired by the doctor about reasons for not waiting longer before the second child said the following:

"My husband had to go out of the country and my mother-in-law wanted me to be pregnant again before he left."

4.1.3 Unhealthy Home Practices. Other themes that emerged in the interviews include the frequency of pica (a disorder in which mothers eat coal, soil, raw rice, and other non-foods); self-medication with counterfeit pharmaceuticals; and lack of immunization against tetanus.

Pica. Pica is the practice of craving substances with little to no nutritional value. Some speculate that pica cravings are body's attempt to obtain vitamins or minerals missing from normal food consumption [33]. In our visits we have seen doctors actively and regularly advising patients to adopt healthy eating habits and avoiding any kind of pica during pregnancy by saying:

"Bibi (lady), do not eat koyla (coal), chawk (chalk), mitti (mud/soil), kache chawal (raw rice) when you feel nausea as it affects you and your baby badly."

Self-medication: Since there is a tendency in the population to take pregnancy or the symptoms around pregnancy as an illness, the women, when faced with such symptoms, look for medication to overcome them. While interviewing a gynecologist from a public hospital, we heard that some mothers have a self-medication habit, as when doctors don't prescribe medicines in pregnancy, they go to some xyz dispenser at a pharmacy and asked for medicines, she said:

"Expecting women, especially low literate, often tell us that they are taking some xyz tablet recommended by their brother in law who is a dispenser at a pharmacy."

To conclude, our interviews with medical personnel pinpoint what they thought were the main causes of maternal mortality. One observation prevalent in all of the interviews was that along with many other factors, misinformation or lack of information among expecting women is playing a major role. Some went as far as to suggest that most of maternal deaths are preventable and can be addressed inexpensively through increasing mothers' knowledge during and after pregnancy.

4.2 Findings from Expectant Mothers

We also conducted semi-structured interviews with 93 expecting mothers when they visited the hospital. The interviews were undertaken at Lady Willingdon Hospital between July and August, 2014. Most of the interviews were short – between 5 to 7 minutes – because we could not impose too much on the women. Our questions focused on their literacy level, their gravidity (the number of previous pregnancies) and parity (the number of previous births), their preference for home/hospital birth, their current source of antenatal care information and the communication technologies they have access to.

Around half of the interviewed women were semi-literate or low-literate. Majority (79%) were in their third trimester, followed by women in their second trimester (19%) and a very small number (2%) were in their first trimester. The women in their third trimester had visited the same hospital at least twice before on average.

When inquired about their existing sources of information for maternal and antenatal health, majority (60%) of the women mentioned their mothers-in-law, mothers, and/or relatives as their source of antenatal care information, (12%) relied on Lady Health Workers (LHWs) for pregnancy-related information whereas more than a quarter (28%) had no source of pregnancy-related information.

More than half of the interviewed women (54%) had their previous delivery at a hospital and they mentioned low-cost public hospitals as their preferred hospitals.

Most of the women had access to cellphones in one form or the other with different ownership models: 25% had their own cellphones, 20% used their husband's cellphone for communication and 30% had access to a phone shared by the whole family. The women were used to both voice and text (57%), though some used only voice (40%), and a very small number relied only on texts (3%). The majority of the mothers interviewed preferred Urdu and were comfortable with reading, listening, and understanding Urdu.

These findings suggest that many women rely on the women around them (mothers, mothers-in-law or LHWs) as a source of information. And while women with prior hospital-birth experiences prefer hospitals; most women rely on secondary sources of information and often waiting late in their pregnancy to make a visit.

4.3 Field Observations

In our visits to the hospitals, for both patient and doctor interviews, we also made many observations about doctor and patient behavior, some of which seem relevant to maternal health and maternal mortality.

4.3.1 Poorly Informed Mothers. One clear observation that emerged from our interviews was the striking deficiency in mothers' knowledge about good measures during pregnancy.

Since the women's visits and information about pregnancy are dependent upon mothers-in-law, many mothers question the information from doctors if it conflicts with their prior knowledge. Many mothers continue to pursue the traditional conventions. The

reasons for this appeared to stem from lack of decision-making power, social pressure, and infrequent interaction with doctors.

One such incident occurred with a mother who was diagnosed with gestational diabetes and was advised by the doctor to avoid fatty, oily, and sweet foods. The mother, however, argued that the advice of her mother-in-law was different:

"But can I take milk with clarified butter since my mother in law told me that it is good for the baby's growth?"

Many patients we interviewed and observed during our qualitative research neither know about their Last Menstrual Period (LMP) nor about their Expected Date of Delivery (EDD). Many patients cited several miscarriages in their history, and hardly anyone had any idea why they might have had them. Those who lost their babies after birth did not know if it's was a stillbirth or if the baby died after birth. When we asked one mother about the reason for miscarriages, she simply said:

"It is something to be known by the doctors not by the patients."

4.3.2 Large Patient Turnout. Low-income communities prefer public health facilities over private health facilities due to their low cost. As a result, hospitals are understaffed and underfunded. The effect of this is that patient turnover is high and doctors' behavior and performance with patients is affected. This behavior in turn makes the patient not only uncomfortable to ask follow-up questions, but also increases their confusion about medication intake, required tests, follow-up visits etc.

According to official government statistics, there are 127,859 doctors in Pakistan to cater for a population of over 180 million which accounts to a doctor patient ratio of 1 doctor per 1329 patients. Similarly, the availability of hospitals beds in all medical facilities has been estimated at 98,684 which comes to population bed ratio of 1536 persons per bed as compare to USA public health services with a general average of 200 persons per bed. This huge disparity between the number of human resource/facilities at the hospitals and the large number of patients' influx leads to difficult situations for the doctors [34].

The doctors are overburdened and have to interact with a large number of patients using whatever resources and facilities they have. This leads to behavioral issues and negative attitude from the doctors.

At Lady Willingdon, the doctor-patient ratio is about 1 to 50, where each doctor is required to do a medical checkup of 50 mothers during an 8-hour shift. This would translate to just under 10 minutes per patient, if all of the doctors' time could be spent with patients, but because of other demands on the doctors' time, actual time spent by OPD doctors according to our observations was about 3 minutes per patient on average.

During these 3 minutes, even the best doctors are only able to discern if the pregnancy is normal or if there are any high-risk indications. Given the lack of time, there is little time for patient education. Patients hear little advice or information about what they should expect in the coming weeks. Most are not even told about the dos and don'ts in pregnancy, their EDD, the physical changes that might appear in the following weeks, and the next visit date for a follow-up visit.

When necessary, doctors prescribe medication and tests by writing the medicine's name and dosage along with the tests to be

conducted. They do this on the mother's hospital card without explaining the reason or requirements of the medicines, the benefit and importance of the tests or even the office where the tests could be conducted.

With time neither for explanation nor follow-up questions, patients leave confused, intimidated, and no more knowledgeable about their pregnancy than when they entered the hospital. Hence, most of the mothers do not focus on taking such medicines, and the risk of health problems for them and their baby remains high.

4.3.3 Intimidation of Patients. Because physicians are pressed for time, their attitude appears to make mothers afraid of asking questions. We found that mothers opened up to us during our brief interview with them, only because we strived to establish a rapport with them. They seemed relaxed and they started discussing maternity-related problems with us, which we suggested they raise during the doctor visit. But during their visit, they seemed intimidated by the doctor and failed to raise issues important to them.

5 PHASE 2: MOBILE INTERVENTION

Based on our interviews with doctors, patients and our direct observations, pregnant mothers' lack of good information seemed to be a prominent issue that an ICT intervention could target. In addition, our interviews with mothers confirmed that they had access to mobile phones and were comfortable with their use. Thus, we decided to design a mobile-information system that focused on providing short, simple messages during and after pregnancy via SMS text messages, automated voice calls, or both. Following the theory of technological amplification, the system would have to have a clear association with the hospital to be effective [35].

5.1 Content Source

The first task in designing the information system was to decide on the source of content. The content had to be appropriate for Urdu-speaking expecting mothers from low-income settings.

Much of the content available online for maternal health is targeted for developed-country use. One exception is material from the Mobile Alliance for Maternal Action [19] which specifically created and distributed content in developing countries. However, physicians at Lady Willingdon Hospital suggested that the content was written for very low-resource settings which did not apply to their care. Instead, they recommended a book written by a local Pakistani physician that was also being used at the hospital. It is written in simple language intended for pregnant Pakistani women. We used that book as the basis for our messaging system.

5.2 Content Adaptation

Because our source book did not contain material in snippets suitable for text messaging or voice recording, we first finalized a list of themes in consultation with the hospital physicians. The topics included: reminders of follow-up visits, adherence to iron and calcium supplements, tests to be performed during pregnancy, healthy diet and healthy lifestyle, high risk indications, baby movements, delivery preparations, newborn care and birth spacing. We further split each topic into subtopics, e.g., high-risk indications

were subdivided into multiple indications and what actions to take for each.

A total of 110 different messages were prepared that cover all the necessary information required during pregnancy. These were then adjusted to fit the two message-delivery paradigms of SMS and automated voice calls.

5.2.1 Length of Message. Message length was important because (1) users could only remember a limited amount of information on audio-calls without any visual cues; (2) longer messages required two or more text messages; and most importantly (3) mothers did not feel comfortable with the idea of multiple phone calls or SMSs in a day due to negative attitudes attached to frequent phone usage.

Therefore, for SMS text messages, we tried to restrict message length to 140 to 160 characters (one message), except for a handful of messages where the doctors requested longer two-text versions so as to maintain key information. For automated calls, we restricted all recordings to fit within 30 seconds.

5.2.2 Association with the Hospital. It was critical to make clear an association with hospital for several reasons: (1) An early disclaimer of association with the hospital could be helpful for women whose families might not otherwise permit frequent phone usage; (2) the mention of the hospital prepares the women about the nature of the message, thus alerting them to pay attention to the information; (3) the hospital name could also strengthen the women's relationship with the hospital.

For the SMS messages, recipients are informed once at the time of the registration about the association with the hospital with a message that says, "This message service is from Lady Willingdon Hospital." For automated calls, a welcome note is placed at the start of each call saying that "This message is from Lady Willingdon Hospital" followed by the information message and an ending note.

5.2.3 Content Language. As per our initial discussion with the expecting mothers about their need for information, we learned that the mothers want the content to be in simple Urdu and preferably using the same technical language or terminologies used by the doctors.

5.2.4 Timing of Content Delivery. The timing of content delivery for informational messages (explained in Section 5.3.3) vary with the stated preference of each mother and is also dependent upon their phone ownership model. Women who have their own phones or can read on their own were more flexible with timing and prefer morning time for message delivery. Women who either share the phone with their husbands or families or cannot read the messages on their own prefer evening for messages. Individual timings for the message depends upon the message type as explained in the following section. Note that these options were provided in the same way for all four arms of the trial.

5.3 Content Type

Three message types are sent by the system.

5.3.1 Registration Confirmation Message. A one-time message is sent at the start to all the expecting women, using SMS or automated calls (depending on which trial group), once they register with our system:

"Assalamualaikum (Hello), this message service has been introduced by Lady Willingdon Hospital. The purpose of this service is to guide the expecting mothers about proper antenatal

care during pregnancy. Following these messages and visiting hospital regularly is highly recommended for the health of mother and the baby. Thank you!"

5.3.2 Reminder Message. Reminders about follow-up visits and medicine intake are also sent as messages to the expecting mothers. For the follow-up visits, reminder messages are sent one day before the visit day. The preferred day for sending reminder messages was decided after consultation from doctors and expecting mothers. Morning was selected as a suitable time for sending follow-up visit reminder messages since the women can inform their husbands about their visit the next day, before the husbands leave for the day's work. The content for follow up visit reminder is as follows:

"Assalamualaikum (Hello), this message is from Lady Willingdon Hospital to remind you that you have your follow-up hospital visit tomorrow. Kindly get all your tests done and remember to show all your reports to the doctors at hospital. Do not forget to bring your file and hospital card along. Thank you!"

Similar reminders are sent to mothers once every week to remind them about taking medications as per doctor's prescription.

5.3.3 Informational Message. Three times a week, informational messages are delivered to expecting mothers on the basis of their gestational age, customized to the week and the month they are in. Timings of these messages are adjusted according to the preference of mothers as explained in earlier section. A sample informational messages content is as follows:

"Hello, this message is from Lady Willingdon Hospital. Ultrasound test is very important to know about the fetus growth. Its rays are not at all harmful. Hence doctors recommend that you get your ultrasound and other tests done on time and show reports to the doctors regularly. Thank you!"

5.4 Technical Implementation

To send out SMS messages, an API from a local SMS service provider (SMSAll.pk) was used. The messages were sent via a provider short code. An acknowledgement that the message was saved is recorded.

For sending automated calls to expecting mothers, we used open source telephony software (Asterisk) with a Primary Rate Interface line with 5 channels. Asterisk uses routes calls to the PRI channels, which in turn use the PSTN lines to reach the telecom networks and recipients' numbers. It also saves the positive (call answered) or negative (busy, no answer, phone off) response to the database to show that the number of calls successfully made.

The algorithms for message selection and timing was the same for both SMS and automated calls: Messages were selected based on the mothers' gestational age, so participants would all receive the same message when they were exactly, say, six months pregnant. Since our participants were at different gestational ages, in any given week, the outbound messages are diverse.

6 EMPIRICAL TRIAL

6.1 Methodology

To evaluate the effectiveness of the messages, and to see how they performed comparatively, we conducted a randomized control trial. A total of 180 pregnant mothers participated in the trial, with 45 mothers registered in each of four groups: (1) a control group, (2) an SMS group, (3) a voice message group, and (4) a group that received both SMS and voice messages. The impact of the intervention was assessed through before and after tests of knowledge as well as by tallies of follow-up visits.

6.1.1 Enrollment Procedure. We enrolled 180 expecting women in our trial over 11 visits to the hospital from August to October, 2015. Patients were registered while they were waiting their turn with a hospital physician. Patient consent was sought through a written form. In cases where the patient could not read, the form was read aloud, with additional explanation provided. (A thumb print was taken from assenting patients who could not sign.)

All of the women enrolled in the trial had to fulfill the following criteria:

- 1) Be in their first or second trimester of pregnancy;
- 2) Know their last menstrual period date, which identifies the month and week of pregnancy, and the expected date of delivery;
- 3) Have access to a mobile phone, either their own or a family members';
- 4) Understand and accept the consent form; and
- 5) Agree to receive SMS and/or automated calls.

For each registration, we requested basic demographic details, medical history including gravidity (number of previous conceptions), parity (number of previous births), age of marriage (all of the participants were married), current age, mobile phone ownership, phone number details, and preferred time for information delivery. The participants were also asked to undergo a baseline test of knowledge which included 15 questions that tested their knowledge about antenatal care.

All participants were then randomly assigned to one of the four arms of the study. Depending upon the group allocation, participants were informed about whether they would receive SMS or voice calls. The participants were also provided printed sheets that summarized our discussion with them and included information about our system and numbers from which they might receive SMS or automated calls.

We encountered a few mothers who agreed to be a part of our study but only if they could be part of one of the message-receiving groups (i.e., not the control group). We registered them in our system as they requested, but we did not include them in the study, as they may have presented a selection bias. We encountered six such patients.

Initially, we planned to use the hospital cards as a means of patient identification and visit tracking. But our visits to the hospital revealed that most patients often lose or forget to bring their hospital cards. Thus, all participants were provided with hardcover files with the hospital logo on one side and printed information pasted on the other side. The unique ID of each participant was also written on the information page. The

participants were asked to bring their file with them upon each visit, so that we could recognize them on future visits.

6.1.2 Data Collection. To assess impact, we administered a test of knowledge at the time of enrollment, a test of knowledge two months after enrollment, and additionally tracked the women's visits to the hospital.

The WHO recommends a minimum of four antenatal care visits during pregnancy [36]. However, doctors at Lady Willingdon Hospital recommend six to nine visits depending upon the condition of the expecting mother. Upon registration, participants were asked to mark attendance upon each visit to the hospital. However, because this marking was voluntary, and some visits were due to high-risk indications, not all of the visits were recorded this way. To supplement self-reported attendance data, phone calls were made to all patients a week after each scheduled follow-up appointments. In these phone calls, participants were inquired about any visits since the last call, reasons for visits (scheduled appointment, recommended medical test, or other) and any high-risk indications, if observed.

In a separate follow-up survey administered two months after enrollment by phone, participants were asked the same 15 test-of-knowledge questions we asked during the baseline survey. The responses were recorded on paper and later entered in a database.

6.2 Baseline Information

Baseline demographics: 27% of the women registered in our intervention did not have any formal education, some had a primary school education (through the 5th grade; 13%), a plurality had secondary school education (through 10th grade or more; 37%), and some had additional education ("intermediate college" through 12th grade or university; 23%). The majority of the registered women were married after 18 years of age (74%) whereas a minority were married before age 18 (26%). This is significantly more education compared with Pakistan's average, confirming that urban mothers are somewhat more educated than women in rural areas.

6.2.1 Baseline Health. At the time of registration, 23 out of 180 (13%) were in their first trimester of pregnancy, 80 (44%) were in their 2nd trimester, and 77 (43%) were in their 3rd trimester. 21% of registered women had one or more miscarriages in their maternal history. 12% preferred home births without any trained birth attendant. More than a third of the women (35%) registered had some sort of pre-existing condition such as anemia, pre-eclampsia, or diabetes.

6.2.2 Phone Ownership. With respect to mobile phone ownership, 48% of the participants claimed that they have their own mobile phones. All of them preferred morning messages. (Incidental comments suggest they preferred to receive messages while husbands were out of the house.) 41% said that they have access to their husbands' mobile phones in the evening; all of them preferred receiving messages in the evening. The rest (11%) shared a mobile phone with the whole family and did not request a particular time of day. The four arms of the trial were balanced.

They did not show significant differences in any of the variables noted above.

6.3 Results

Overall, our evaluation showed that all three types of messaging had a large, statistically significant effect on mothers' knowledge about pregnancy. In addition, the two groups receiving text messages appeared to have a tendency toward increased follow-up visits, though this result was not statistically significant.

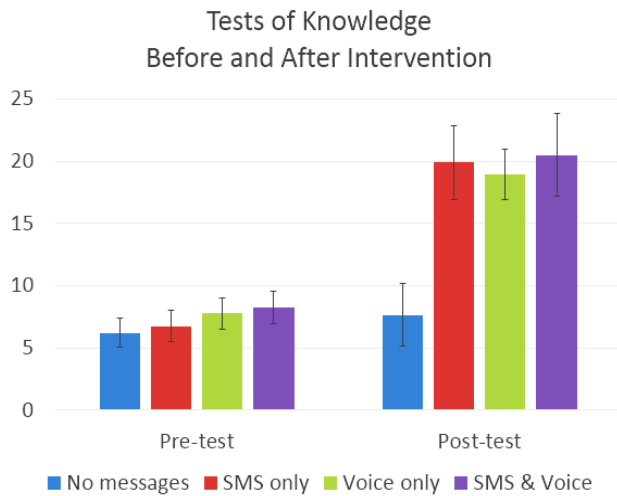


Figure 1: Impact of awareness level before and mid intervention. Error bars show 95% confidence interval.

6.3.1 Gains in Knowledge. The impact on knowledge of pregnancy showed dramatic gains among all three modes of messaging, with gains averaging 12-13 points on a 31-point test. For SMS messages, mothers scored higher ($M = 19.9$, $SD = 10.1$) after two months of informational messages compared to when they started ($M = 6.7$, $SD = 4.3$), $t(45) = 1.65$, $p < 0.001$. For voice messages, showed a similar increase in score ($M = 18.9$, $SD = 6.9$) over ($M = 7.8$, $SD = 4.3$), $t(45) = 1.57$, $p < 0.001$. And for combined SMS and voice, the increase was ($M = 20.5$, $SD = 11.5$) over ($M = 7.2$, $SD = 4.5$), $t(45) = 1.69$, $p < 0.001$. In comparison, the control group showed no statistically significant gain in knowledge: ($M = 7.7$, $SD = 8.4$) versus ($M = 6.2$, $SD = 4.0$), $t(45) = 1.08$, $p = 0.14$.

These results are shown graphically in Fig. 1 with error bars showing 95% confidence intervals.

6.3.2 Increased Follow-up Visits. We saw no statistically significant gains in the number of follow-up visits due to the reminders, but the mothers who received SMS text messages (without or with voice messages) made slightly more doctor-advised follow-up visits over the two-month window in which we tracked them. Fig. 2 shows the data graphically. This is suggestive that the messages had some effect – in any case, none of the groups

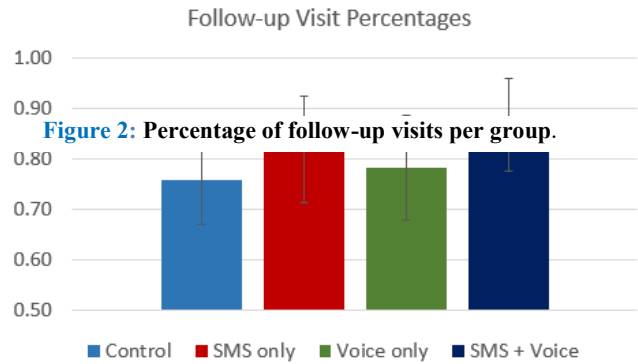


Figure 2: Percentage of follow-up visits per group.

receiving messages showed a lower likelihood of making follow-up visits.

6.4 Qualitative Observations

When we made calls to ask about follow-up visits, we observed some unexpected behavior and heard a range of comments from mothers, separate from the questions we asked.

6.4.1 Requests to Change Mobile Number. During registration and data collection, we came across some patients who received messages for a week or two and approached us at their follow up with a request to change their mobile number. Some mentioned that they had submitted a shared number, but after receiving messages they felt the need to acquire a personal mobile phone. Others said that the original number was their husbands' mobile number and their husbands did not want to receive the messages.

Some patients asked us to register other expecting mothers in their family as well and gave us their mobile numbers. We registered them in our system but they are not included in our study sample. We enrolled 7 such women. These requests suggest that for some participants, there was considerable trust in the system.

6.4.2 Inability to Differentiate between Automated and Human Calls. During our phone surveys, some patients complained that the person on the informational voice calls hangs up without listening to the participants. Although the nature of the calls was explained at the time of registration, some participants appeared not to understand this.

6.4.3 Husband's answering of Phone. Many of the calls made to ask about follow-up visits were answered by men – presumably the women's husbands – whose typical response was to inform us that their wives were at work. Upon our insistence that the call concerned hospital business, we received one of three reactions: (a) the husband gave us another number to contact their wife; (b) the husband recommended another time to call again; (c) the husband handed the phone to their mothers or sisters for verification. On average – and in a culture that almost always answers a phone call – it took about two calls to reach the registered mother.

6.4.4 Husbands' Indifference to Hospital Visits. When husbands answered, we would ask them if they knew about their wives' hospital visits. The majority of them said that they had no idea when their wives visited the hospital or when they would go again for follow-up.

6.4.5 Doctors' Callous Attitude. We heard one frequent complaint when polling participants: The women noted that they had not made a follow-up visit because they did not like their experience with doctors. Those who complained felt that the doctors were abrupt and dismissive of their concerns.

6.5 Information Feedback from Mothers

In our last round of calls to track follow-up visits, we also asked the participants if they had comments about the system. Overall, the women mentioned that they found the information system very useful. First-time mothers were particularly enthusiastic. Most of the participants in one of the treatment groups wanted to continue with the message service until the end of their pregnancy.

Participants also reported that they verified the information in the messages by speaking with their mothers-in-law, who tended to say positive things about the messages.

Upon inquiring if the participants would be willing to pay PKR 5.00 (USD 0.05) or PKR 10.00 (USD 0.10) per month for the service, the majority of women said that they would pay.

7 PHASE 3: FOLLOW UP INTERVIEWS

Fourteen months after our evaluation, in February-March 2017, we called all of our participants in an attempt to determine whether our intervention had any direct effect on health, and to ask follow-up questions about the study and their health. We were, however, only able to make contact with 30% of our participants, and as a result, we could not establish any statistically significant differences between the groups in terms of successful births and maternal health. On the other hand, we gained a number of qualitative insights about family dynamics that inform mobile-based health interventions.

Some mothers reported that the messages improved their standing in their families. In some cases, the messages provided support for things the mothers needed (e.g., sufficient rest). In others, the mother was taken more seriously as a source of information. Both of these effects can be seen in the following comment by a mother:

"My mother-in-law pays more attention to my health after these messages. She thinks that if the hospital is paying attention to me by sending me messages on a regular basis, she, too, has to pay attention. Now, she asks me almost daily if I have taken my iron tablets or not."

There were limits to this effect, however. Although our messages advised birth spacing of 18 months or more between children, mothers continued to have little to no say regarding family planning. 10 out of the 42 mothers we were able to contact were expecting again. They said that their voices are overridden by mothers-in-law and husbands, who decide when to conceive again. One mother suggested a possible solution:

"These awareness and family planning messages must also be sent to my husband's phone, too, so that he also understands the importance of birth spacing. I gave birth to twin daughters, and I want a gap of 3 years before the next child."

8 DISCUSSION

Our findings are scattered across the three phases of our study, so we pull them together here to highlight the key issues.

8.1 Value of Simple Interventions

First, we confirm that both SMS text messages and automated voice calls can be effective as a means to increase health knowledge among pregnant mothers. Particularly as a means to transmit bite-sized information, weekly text messages, automated voice calls, and a combination of the two saw dramatic increases in basic knowledge among urban Pakistani mothers. On the one hand, this is the first experimental trial to demonstrate increased knowledge among low-income mothers through a mobile intervention; on the other hand, the finding is not surprising – it is consistent with a large body of existing literature in a range of health contexts that shows that text messages and automated voice calls can improve health outcomes [14] [17] [12] [13].

Somewhat surprisingly, we did not see evidence that automated voice calls outperformed text messages or vice versa. A larger trial might show differences, but even if so, we expect that they would be muted in their effect at least among urban Pakistani mothers. Two possible explanations for this are that given some base level of education in which literacy is commonplace, there is no benefit to voice messages over text messages. Another is that the benefit of voice messages is countered by the fact that text messages are asynchronous and can be read at leisure. In any case, the question of the relative value of voice versus text remains.

Thus, the primary value of our Phase 2 experiment is to add to the growing body of evidence demonstrating that simple ICT interventions can have positive impact on maternal health.

8.2 Caveats

Despite evidence of positive outcomes, we suspect that the success of our trial also depended upon a number of conditions that were not themselves tested in the experiment. These points were raised through qualitative observation and interviews with the participants.

We believe, for example, that the relationship with Lady Willingdon Hospital was critical for the messages to work. Consistent with the theory of technological amplification [35] our mobile intervention was trusted because of the participants' existing relationship with the hospital. It was evident in our in-person and phone interactions with the women that they were aware that the messages were associated with the hospital, and that the association was important. We believe that the messages would not have had as much of an effect without that association.

Another contributing factor to success was a base level of education among the mothers. As noted in earlier sections, in contrast to the 75% of Pakistani women who have no formal education, about three quarters of our participating mothers had at least a primary-school education. Especially for the text message intervention, literacy is useful (though perhaps not strictly necessary if other family members can read [37], and for either type of message, formal education is helpful in allowing consistent absorption of the information transmitted [38]. We expect that in contexts where mothers have less education, the same mobile intervention would not be as effective.

It should also be mentioned that the conditions of pregnancy are unique – it is one of the few times when healthy individuals (i.e., not sick patients) are motivated to interact with the formal medical system. The combination is unusual – much of antenatal care is preventative in nature but taken up with the same urgency as when treating an illness – mothers and their families are deeply vested in a healthy birth. What this means is that internal motivations among care recipients are aligned with the goals of medical staff. This is not necessarily true with, say, disease prevention, where potential patients are notoriously lax about preventative measures.

Finally, we note that while our study provided evidence of increased knowledge among mothers, it did not show a measurable increase in antenatal visits to the hospital, as other studies have found [22] [23]. Here, we suspect that there are social norms and resource limitations that suppressed impact: As we heard repeatedly from mothers in our interviews, women's movement outside of the household is restricted; even their occasional visits to the hospital were not fully supported. This fact, combined with the transport cost of such visits (small, but not negligible for low-income families), raised barriers that mobile reminders alone could not overcome.

8.3 Family Dynamics

A recurring theme across all three phases of our study was the significant presence of husbands and mothers-in-law in the lives of wives and mothers. This is an everyday observation in Pakistan and taken for granted in the country's popular entertainment. Nevertheless, it is striking to see its effect – largely negative – in the context of maternal care. In our Phase 1 exploration, we often heard that mothers learned about pregnancy through their mothers-in-law, with much of it being misinformation. Even among a population that had ultimately consented to hospital visits, there seemed to be residual suspicion about modern medical care. Mothers also repeatedly and matter-of-factly reported that whether and when they became pregnant was up to husbands and mothers-in-law, with the women themselves having little say. This was in spite of our messaging intervention which noted that birth spacing is important both for the health of the mother and any future children.

In Phases 2 and 3, we also found that the mobile messaging intervention had mediating effects on family dynamics by empowering mothers both with reliable information and a source of status. Husbands and mothers-in-law of participants appeared to take the intervention messages seriously, and in some cases they would appropriate the authority of the information for themselves, as when one mother-in-law assigned herself the role of iron tablet monitor. More interestingly, the fact that the hospital appeared to bother with participants gave the participants themselves a boost in status within the family. Young mothers in particular are typically the lowest ranking adult in Pakistani households. And, while their relative position in the hierarchy may not change, they nevertheless seem to gain some respect within the family from the visible attention of a credible medical authority.

8.4 Mothers' Access to Phones

Another theme with respect to family dynamics is the household politics of phone ownership and use. Previous work has noted gender disparities in phone ownership and use in the developing world, with the finding that even when women have physical access to a mobile phone, use is limited [39] [40] [41]. Our study confirms

this high-level finding and builds on it with heretofore unreported details.

Among our participants – all from lower-income urban Pakistani households – we found two groups: One group appeared to have personal ownership and control of their mobile phones – they consistently answered the phone themselves when we called. Another group shared a mobile phone with other members of the household, with great variability in the degree to which the women themselves had access. Frequently, husbands were the primary owners and users of the phone, and even when women reported these numbers as “their” phone, they rarely answered them. We believe that many of these women read a request for their phone number as “a way to contact the family”; and women assume that it is their husbands who will speak for the family.

We also found that even when women owned their own phones, they did not feel completely free to use them. When we asked women when they would like to receive informational messages, it came out that they often preferred receiving calls when they knew their husbands would be out of the house. Some women explicitly mentioned that their husbands did not like it when the women were on their phones.

The gender boundaries with phones was very clear among our participating households. Though mothers-in-law had a lot of decision-making power with respect to what their daughters-in-law do, they themselves never answered when we called. At most, husbands would pass the phone to their (own) mothers to speak on behalf of pregnant mothers.

These issues of women's mobile ownership and use complicate interventions targeting mothers. As we discovered, when women provide mobile phone numbers, they are not guaranteed to have access to them; and not all of the women who consented to participate ultimately received messages because they were intercepted by indifferent husbands. Future work might consider the value of messages sent to or tailored for husbands of pregnant mothers.

8.5 Other Possibilities

Given the hold of religion-based norms in our context, it may be worthwhile to consider messages piggybacking on religious values, as was done recently in a study to increase donations to Bangladeshi mosques [42]. For example, might pregnant women and their husbands be more responsive to messages that suggest that “Allah seeks a healthy birth. Be sure to take your iron tablets.” One challenge here is in ensuring that religious dogma does not impinge on the integrity of medical science.

8.6 Policy Implications

We note several policy implications of our study.

First, our study suggests that SMS and automated-voice interventions should be widely used by hospitals and clinics which treat pregnant mothers. As long as there are trusted medical institutions, even these very simple ICT interventions can improve knowledge among mothers.

Second, ICT interventions alone may not be sufficient for bringing about more impactful changes such as increasing the number of antenatal visits to the hospital. These changes require additional resources (e.g., transport vouchers) to clear bottlenecks to impact.

Finally, much of what seems to hold back mobile interventions are complex family dynamics, both with respect to mothers and

their ability to make their own choices as well as their practical access to mobile phones. Though we find that mobile messages with medical information can raise a woman's status in her home, other mechanisms seem necessary to cause the significant shifts in gender-related social norms. The nature of such interventions is well beyond the scope of this paper, but we note that any action to reduce gender disparities is likely to improve outcomes for all mobile interventions addressed to women.

9 CONCLUSION

We presented a three-phase exploration to understand and address the high rate of maternal mortality in low-income, urban Pakistan. We find that while the deeper medical challenges of maternal mortality are beyond the reach of ICT interventions, many of the problems could be partially addressed through a mobile-phone system that issued health-related information and reminders. In a randomized controlled trial of 180 pregnant mothers split into four groups receiving none, one, or both of SMS text messages and automated voice calls, we found that mothers receiving messages exhibited dramatic gains in knowledge about pre-natal care. We also found that complex family dynamics involving husbands and mothers-in-law mediate the impact of mobile information interventions. Though the messages appear to increase the status of mothers within their households, we believe that overall family dynamics inhibits the impact of mobile messaging on maternal health.

Our study made several novel contributions. To our knowledge, it is the first randomized evaluation of mobile messaging to increase knowledge about pregnancy among expecting mothers, and the only rigorous study of mobile interventions for maternal health in the unique context of urban Pakistan. More generally, the study offers confirmation of past work that shows the efficacy of simple mobile interventions on health. Our study also uncovered a range of detailed complications regarding mobile use and ownership in the context of urban Pakistan. Women, even when they owned their own mobiles, feel restricted in their use. More often than not, women reporting access to a mobile phone really mean that their husbands have a phone. And finally, future work should explore the possibility of customized messages to husbands of pregnant women as a way to improve maternal health.

ACKNOWLEDGEMENTS

We would like to thank the medical superintendent and the doctors from Unit 3 of Lady Willingdon Hospital, for their support and encouragement throughout. We are also grateful for all of the healthcare staff we interviewed as well as the participants in our study.

REFERENCE

- [1] Wikipedia, "Maternal death," Wikipedia, [Online]. Available: https://en.wikipedia.org/wiki/Maternal_death.
- [2] WHO, "Maternal Mortality," WHO, November 2015. [Online]. Available: <http://www.who.int/mediacentre/factsheets/fs348/en/>.
- [3] Y. P. Khan, S. Z. Bhutta, S. Munim and Z. A. Bhutta, "Maternal health and survival in Pakistan: issues and options," *J Obstet Gynaecol Can*, vol. 31, pp. 920-929, 2009.
- [4] U. Nations, "Sustainable Development Goals," 2015. [Online]. Available: <https://sustainabledevelopment.un.org/?menu=1300>.

- [5] A. Bashir, M. Aleem and M. Mustansar, "A 5-year study of maternal mortality in Faisalabad City Pakistan," *International Journal of Gynecology & Obstetrics*, vol. 50, pp. S93-S96, 1995.
- [6] R. Rahim, T. Shafiqat and N. R. Faiz, "An analysis of direct causes of maternal mortality," *Journal of Postgraduate Medical Institute (Peshawar-Pakistan)*, vol. 20, 2011.
- [7] Z. Batool, "Socio-cultural factors affecting anemia and its effects on mother child health in the rural areas of district Faisalabad, Punjab, Pakistan," Faisalabad, Pakistan, 2010.
- [8] G. Mahmud, F. Zaman, S. Jafarey, R. Khan, R. Sohail and S. Fatima, "Achieving millennium development goals 4 and 5 in Pakistan," *BJOG: An International Journal of Obstetrics & Gynaecology*, vol. 118, pp. 69-77, 2011.
- [9] N. Lalji, A. M. Thaver and A. Kamal, "Maternal neonate and child health (MNCH) research in Pakistan: trend and transition," *J Pak Med Assoc*, vol. 60, pp. 401-403.
- [10] P. N. Mechaal, "The case for mHealth in developing countries," *innovations*, vol. 4, pp. 103-118, 2009.
- [11] R. Lester and S. Karanja, "Mobile phones: exceptional tools for HIV/AIDS, health, and crisis management," *The Lancet infectious diseases*, vol. 8, pp. 738-739, 2008.
- [12] T. Tamrat and S. Kachnowski, "Special delivery: an analysis of mHealth in maternal and newborn health programs and their outcomes around the world," *Maternal and child health journal*, vol. 2012, pp. 1092--1101, 16.
- [13] J. L. Watterson, J. Walsh and I. Madeka, "Using mHealth to improve usage of antenatal care, postnatal care, and immunization: A systematic review of the literature," *BioMed research international*, vol. 2015, 2015.
- [14] "Liga Inan," [Online]. Available: <http://www.ligainan.org/>.
- [15] M. R. Khorshid, P. Afshari and P. Abedi, "The effect of SMS messaging on the compliance with iron supplementation among pregnant women in Iran: a randomized controlled trial," *Journal of telemedicine and telecare*, 2014.
- [16] D. A. Hanauer, K. Wentzell, N. Laffel and L. M. Laffel, "Computerized Automated Reminder Diabetes System (CARDS): e-mail and SMS cell phone text messaging reminders to support diabetes management," *Diabetes technology & therapeutics*, vol. 11, pp. 99-106, 2009.
- [17] N. Pai, P. Supe, S. Kore, Y. Nandanwar, A. Hegde, E. Cutrell and W. Thies, "Using automated voice calls to improve adherence to iron supplements during pregnancy: a pilot study," in *Proceedings of the Sixth International Conference on Information and Communication Technologies and Development: Full Papers-Volume 1*, 2013.
- [18] B. MacLeod, J. Phillips, A. E. Stone, A. Walji and J. K. Awoonor-Williams, "The architecture of a software system for supporting community-based primary health care with mobile technology: the Mobile Technology for Community Health (MoTeCH) initiative in Ghana," *Online Journal of Public Health Informatics*, vol. 4, 2012.
- [19] "MAMA: Mobile Alliance for Maternal Action," [Online]. Available: <http://www.mobilemamaalliance.org/>.
- [20] "Gifted Mom," [Online]. Available: <http://www.giftedmom.org/>.
- [21] "Medic Mobile," [Online]. Available: <http://medicmobile.org/>.
- [22] T. Fedha, "Impact of mobile telephone on maternal health service care: a case of Njoro division," *Open Journal of Preventive Medicine*, vol. 2014, 2014.
- [23] S. Lund, B. B. Nielsen, M. Hemed, I. M. Boas, A. Said, K. Said and M. H. a. R. V. Makungu, "Mobile phones improve antenatal care attendance in Zanzibar: a cluster randomized controlled trial," *BMC pregnancy and childbirth*, vol. 14, p. 29, 2014.
- [24] J. Sherwani, N. Ali, S. Mirza, A. Fatma, Y. Memon, M. Karim, R. Tongia and R. Rosenfeld, "Healthline: Speech-based access to health information by low-literate users," in *Information and Communication Technologies and Development, 2007. ICTD 2007. International Conference on, 2007*.
- [25] B. DeRenzi, N. Lesh, T. Parikh, C. Sims, W. Maokla, M. Chemba, Y. Hamisi, M. Mitchell and G. Borriello, "E-IMCI: Improving pediatric health care in low-income countries," in *Proceedings of the SIGCHI conference on human factors in computing systems*, 2008.

- [26] S. Grisedale, M. Graves and A. Grunsteidl, "Designing a graphical user interface for healthcare workers in rural India," in *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems*, 1997.
- [27] D. Ramachandran, J. Canny, P. D. Das and E. Cutrell, "Mobile-izing health workers in rural India," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2010.
- [28] D. Ramachandran, V. Goswami and J. Canny, "Research and reality: using mobile messages to promote maternal health in rural India," in *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development*, 2010.
- [29] H. Underwood, S. Sterling and J. K. Bennett, "The design and implementation of the PartoPen maternal health monitoring system," in *Proceedings of the 3rd ACM Symposium on Computing for Development*, 2013.
- [30] W. Brunette, W. Gerard, M. A. Hicks, A. Hope, M. Ishimitsu, P. Prasad, R. E. Anderson, G. Borriello, B. E. Kolko and R. Nathan, "Portable antenatal ultrasound platform for village midwives," in *Proceedings of the First ACM Symposium on Computing for Development*, 2010.
- [31] "UNdata | country profile | Pakistan," Department of Economic and Social Affairs, United Nations, [Online]. Available: <http://data.un.org/CountryProfile.aspx?crName=PAKISTAN>. [Accessed 17 11 2015].
- [32] "The World Bank - Country Data : Pakistan," The World Bank Group, [Online]. Available: <http://data.worldbank.org/country/pakistan>. [Accessed 17 11 2015].
- [33] "Pica: Causes, Common Cravings and Risks During Pregnancy," American Pregnancy Association, [Online]. Available: <http://americanpregnancy.org/pregnancy-health/unusual-cravings-pica/>.
- [34] "Health Care in Pakistan," [Online]. Available: https://en.wikipedia.org/wiki/Health_care_in_Pakistan.
- [35] K. Toyama, *Geek Heresy: Rescuing Social Change from the Cult of Technology*, 2015.
- [36] World Health Organization, "Provisions of Effective Antenatal Care, Standards for Maternal and Neonatal Care," Department for Making Pregnancy Safer, WHO, 2006.
- [37] N. Sambasivan, E. Cutrell, K. Toyama and B. Nardi, "Intermediated technology use in developing communities," in *ACM*, 2010.
- [38] I. Medhi, S. R. Menon, E. Cutrell and K. Toyama, "Beyond strict illiteracy: abstracted learning among low-literate users," in *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development*, 2010.
- [39] J. Blumenstock and N. Eagle, "Mobile divides: gender, socioeconomic status, and mobile phone use in Rwanda," in *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development*, 2010.
- [40] A. Zainudeen, T. Iqbal and R. Samarajiva, "Who's got the phone? Gender and the use of the telephone at the bottom of the pyramid," *New Media & Society*, 2010.
- [41] J. Tacchi, K. R. Kitner and K. Crawford, "Meaningful mobility: Gender, development and mobile phones," *Feminist Media Studies*, vol. 12, pp. 528--537, 2012.
- [42] M. R. Rifat, J. Chen and K. Toyama, "Money, God, and SMS: Explorations in Supporting Social Action Through a Bangladeshi Mosque," in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 2017.