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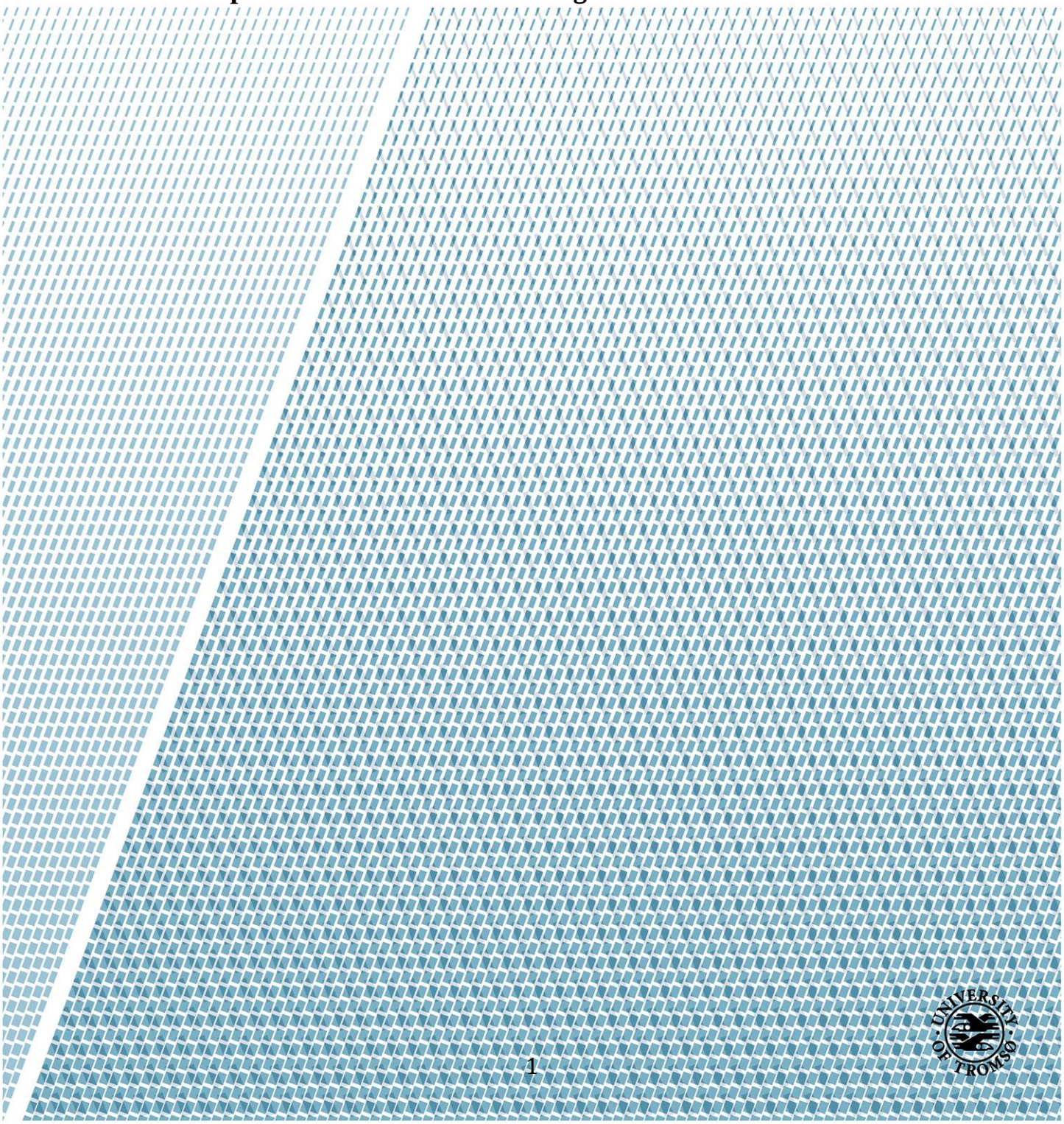

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Neha Pradhan

Telemedicine and e-health

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LIST OF ABBREVIATIONS

WHO	World Health Organization
GOe	Global Observatory for e-health
PDAs	Personal digital assistants
BCC	Behavior change communication
HIV	Human immune deficiency virus
MMR	Maternal Mortality Rate
IMR	Infant Mortality Rate
SDG	Sustainable Development Goal
TBAs	Traditional Birth Attendants
EMR	Electronic Maternity Record
AMR	Assistive Maternity Care
ART	Antiretroviral Therapy
ACT	Acceptance and Commitment Therapy

GWG	Gestational Weight Gain
BMI	Body Mass Index
PMTCT	Prevention of Mother-To-Child Transmission
HAART	Highly active antiretroviral therapy
MoMTECH	Mobile Technology
SMO	Support Message Only
SGR	Scheduled Gradual Reduction
KAB	Knowledge, Attitude, and Behavior
IPTp	Intermittent preventive treatment for malaria during pregnancy
IOM	Institute of Medicine
PCR	Polymerase chain reaction
LGA	Large for gestational age

ABSTRACT

Introduction: Mhealth is a medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices. Mhealth technology has many important usage in obstetric care such as access to emergency obstetric response and point of care support, health promotion, maternity records into a mobile application, and mhealth apps connected to biomedical device. **Methodology:** A non-systematic review was conducted with the aim to identify the obstetric issues faced by pregnant women, the type of mhealth applications used in obstetric care and its effectiveness. **Results:** Twelve studies published from 2012 to 2015 were found mainly focusing on obstetric issues such as health promotion and disease prevention (n=3), obesity and overweight (n=2), HIV prevention from mother to infant (n=3), smoking cessation (n=2), antenatal attendance (n=1), antenatal health knowledge and awareness (n=1). Text messaging was the only intervention used as mhealth application. Seven studies used a unique mhealth app such as Text4baby, Quit4baby, MoMTECH, Preg CHAT TEXT, and Wired Mothers while five studies used a simple mobile device SMS function to send text messages to pregnant women. Overall, all the reviewed studies showed potential positive impact of mhealth application to reduce the antenatal obstetric challenges. However, only six studies showed statistically significant effect on at least one outcome measure whereas two studies didn't demonstrate significant effect on any outcome measures and four studies couldn't test for statistical significance due to small number of participants. **Conclusion:** Thus, more high quality researches with large study population and long follow-up period should be conducted to expose evidenced based long term effects of different mhealth applications in obstetric care.

CHAPTER I

INTRODUCTION

1.1 Background of the study

Mobile health:

Spread of mobile technologies and continued innovations in their application has left an impression on the whole world. Mobile devices can be regarded as one of the if not the fastest adopted technology in human history which offers low-cost communication creating tremendous impact on the society as a whole (1).

According to the International Telecommunication Union there are now close to 5 billion mobile phone subscriptions in the world, with over 85% of the world's population now covered by a commercial wireless signal (2). These technologies are also used to address health priorities, which has evolved as a new field of e-health, known as mobile health or mhealth. Today, the world faces many health challenges from carrying double burden of diseases i.e. communicable and non-communicable diseases to critical shortage of health workers affecting millions of people worldwide. The World Health Organization (WHO) statistics shows that 57 countries need at least 2.4 million health workers in different parts of the country resulting in millions of citizens worldwide being affected by this deficit of health professionals, especially vulnerable groups like women and children. Thus, mhealth technologies, based on wireless communication platforms are available to improve public health (3).

According to WHO Global Observatory for e-health (GOe), mhealth is a medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices (3).*''Mobile health (mhealth) components of e-health span a broad spectrum of technologies. Mhealth includes*

technology that is wireless, mobile, or wearable (e.g., sensors, medication pumps, or wristbands that monitor physical activity). Mhealth also includes thousands of health apps designed for mobile devices. The market for mhealth apps is anticipated to grow 25% per year with no foreseeable end in sight. mhealth is a 'disruptive innovation' providing entre´e to Internet-based health resources'' (4).

Mhealth applications mainly cover 12 areas as suggested by WHO (5):

Table 1. Twelve Common mhealth Applications

1) Client education & behavior change communication (BCC)	7) Provider-to-provider communication
2) Sensors & point-of-care diagnostics	8) Provider work planning & scheduling
3) Registries/vital events tracking	9) Provider training & education
4) Data collection and reporting	10) Human resource management
5) Electronic health records	11) Supply chain management
6) Electronic decision support	12) Financial transactions & incentives

Source: World Health Organization

In recent years, mhealth has expanded its application to address many health issues like data collection, adherence to medication, booking appointments with the health professionals, receiving medical test result, health information communication, upgrading communication between patient-provider, remote diagnosis, tracking emergency and disease, building electronic patient record, and access to personal health records (6, 7). With the growing notion of mhealth, a South African project enlarged the platform of tuberculosis and Human immune deficiency virus (HIV) testing and counseling using text message (8). On a similar note, the CellPhone Project invented an optical imaging platform by utilizing mobile phone to analyze

body fluids (9). A video mobile messaging project presented soap operas to educate about HIV to young women (10). In Uganda, a mobile-phone based data collection and records access tool also helped to minimize the data entry errors and increased cost efficiency (3).

Along similar lines, mhealth has emerged as one of the potential solution for a wide range of health care services across the wider world. It possesses the capability to expand access to communications and to transmit voice and data at the precise time it is needed. This will ultimately enable health care workers to provide appropriate and improved diagnoses to the patients who seek it the most.

Obstetric Care in general:

Obstetric care generally refers to the care given to the mother and her developing child. This includes the care given to the pregnant women during pregnancy (antenatal care), childbirth, and after delivery (postpartum care). The postpartum care is generally given to new mothers until 6 weeks after delivery depending upon the health status of both mother and child. If the mother suffers from health complications such as opening of incisions, blood clot formation, infections etc. or the baby has unstable health, the obstetric care may be extended more than six weeks (11).

The fundamental concept of providing obstetrical care is to protect the health of the mother and the child by providing proper antenatal care and eliminating any associated complication. Despite having the national strategies of proving obstetrical care to each pregnant woman, the maternal (MMR) and infant mortality rates (IMR) are still high till date. According to WHO, about 830 women die from pregnancy or childbirth-related complications around the world every day. Approximately 2.7 million newborn babies die every year, and an additional 2.6 million are stillborn (12) In fact, only 58% of pregnant women receive at least four antenatal care service globally (13). In 2006, hemorrhage and hypertensive disorders were reported as the leading causes of maternal mortality in developing regions (14). Maternal and neonatal

mortality are usually higher is rural areas than in urban areas. In areas with little or no obstetrical services, delays in care of early labor complications becomes prevalent since women have to travel to a distant place that provide basic prenatal care as well as delivery (15). Therefore, reducing the global total of 3.82 million neonatal deaths, and particularly the 3 million who die in the first week of life (the early neonatal period), is crucial to meeting Sustainable Development Goal (SDG) (2). The solutions to reducing neonatal deaths, and especially in an early period, are intimately linked to maternal health and to the provision of effective maternal and neonatal health services. Thus, addressing current global gaps for care at birth is critical to achieving SDG 3, which are to reduce MMR to less than 70 per 100,000 live births and end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births by 2030 (16).

Mhealth in Obstetric Care:

Mhealth technologies have the potential to create a high impact in obstetric care. The following chart reveals the potential benefits of mhealth application in obstetric care (17).

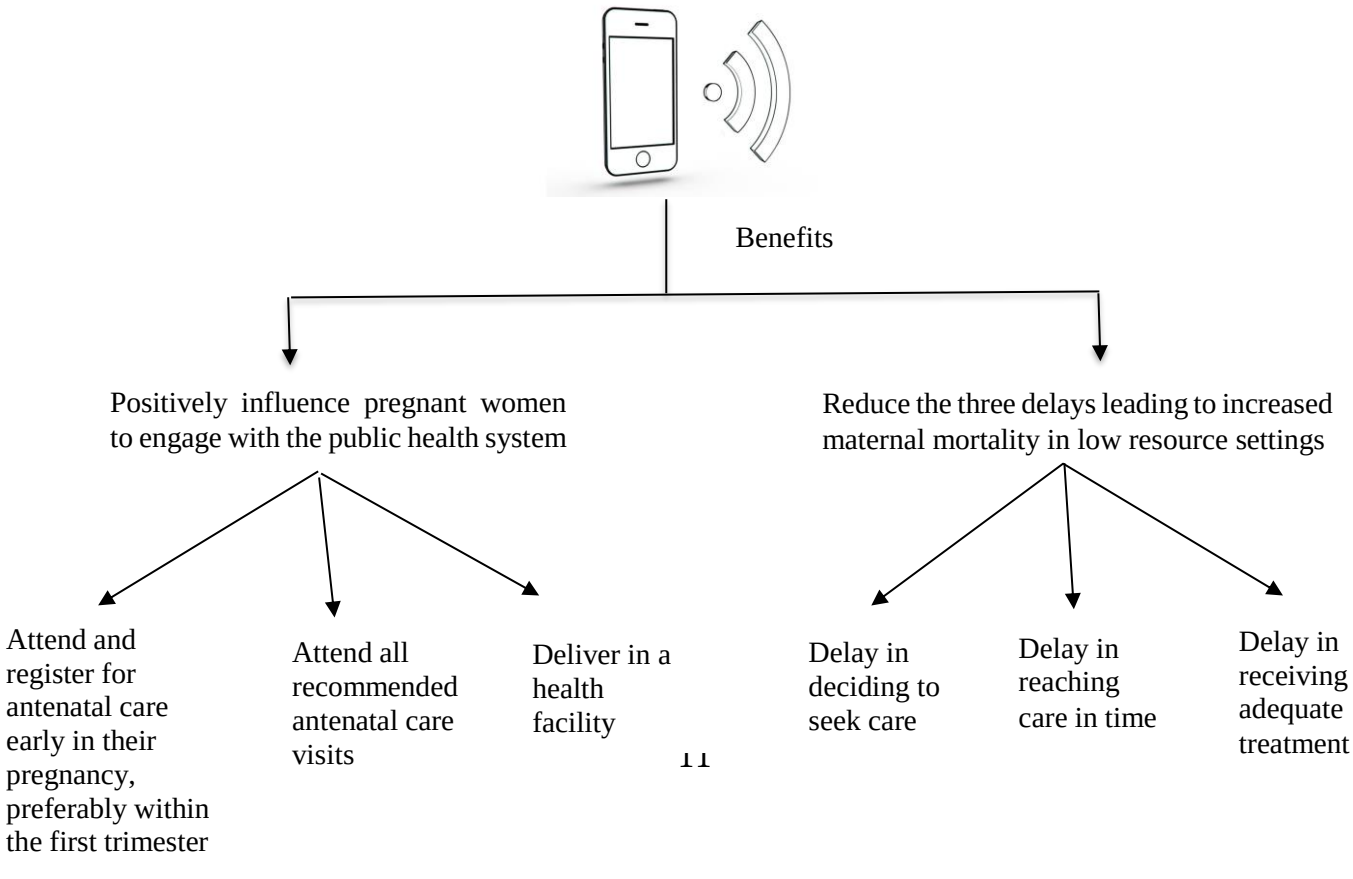

Figure 1: benefits of mhealth applications in obstetric care

On the similar note, Boston University School of Public Health points out that following two facts should be considered to believe that mhealth can create an impact on maternal health:

- Half of all mothers and children are devoid of access to lifesaving health care. Thus, the key maternal and child health services coverage should be increased in order to improve the health outcomes by expanding access to and improving the quality of these services (18).
- By 2019, there will be 9.3 billion mobile phone subscriptions and over 5 billion of these will be mobile broadband subscriptions. Of those, it is anticipated that 1 billion with cell phones will continue to have very limited access to health care. Thus, mobile phone platform provides a great potential for provisioning of greater access to health services for wider population and, also increase demand and improve quality and accountability of health services (18).

As discussed earlier, the objective of fulfilling the SDG goals requires a new dynamic. Some investments in private sectors have been seen in mhealth projects involving women health issues. For example, the U.S. government launched in May 2011 a $10 million partnership project with USAID and the Johnson & Johnson pharmaceutical company called "Mobile Alliance for Maternal Action", to provide health information to future or young mothers using mobile phones in India, Bangladesh and South Africa (19).

Some of the main uses of mhealth application in obstetric care is further discussed in a detailed manner:

- Use of mobile phone for access to emergency obstetric response and point of care support:

  The RESCUER program launched in 1996 in rural Uganda trained traditional Birth Attendants (TBAs) and midwives and were equipped with walkie-talkies, enabling them to contact supervisors and ambulances when facing difficult situation. Following the intervention, the maternal mortality rate in the study locations decreased by approximately 50% due to increases in referrals to health facilities. Likewise, a UNICEF-funded program in Madhya Pradesh, India offered pregnant women a health telephone helpline, complimentary ambulance system along with drivers equipped with mobile phones in the effort to reduce delays in seeking obstetric care. Moreover, World Vision's 2005 mobile-midwives project in Aceh Besar, Indonesia evidently proved how mobile technology strengthen point-of-care support by equipping midwives with mobile phones and phone credit to consult with specialists while providing obstetric care in remote locations (20, 21).

- Use of mhealth application for health promotion and empowering women to contact health services and access information: Using mhealth application for the exchange of information for health promotion to empower women to contact health services and access information has been pointed out as one the twelve mhealth functions by WHO. Such service can be achieved through an asynchronous modality generating SMS. To illustrate, the ''Wired Mothers'' project in Zanzibar, Tanzania used mobile phones to connect pregnant women with health institutions, provide reminders on their antenatal care appointments, facilitate access to skilled attendants for obstetric care and provide health education. Furthermore, MoMTECH, a project in Ghana utilizes mobile phones

to increase the quantity and quality of antenatal care. The Beba Dolazi program in Serbia also sends weekly health education messages via SMS to pregnant women on based on the progression of their pregnancy (20, 21).

- Integrating electronic maternity records (EMR) into a mobile application: EMR is a form of electronic health records for maternity service. Normally, when pregnant women visit a clinic for antenatal care, they are handed over a maternity health handbook that contains information about their health record. However, various issues with paper records such as issue of accuracy, susceptibility to misplace, lack of durability, risk of patient dignity and confidentiality, and poor record management, electronic records are preferred over paper records nowadays in many countries. In such case, integrating EMR into a smartphone will not only allow health professionals to access the information but also allow pregnant women to check their health reports on their preferred time. This way pregnant women can gain full access to their maternity status information which will enable them to feel more content and informed (22). Hoang et al. also developed the assistive maternity care (AMC) system to transform the paper-based system into EMR and provide a pregnancy care loop to initiate effective communication between health professionals and pregnant women. The system comprised of EMRs, PDAs and web system for users to access their health information via computers (23).

- Mhealth apps connected to biomedical device: Taking measurement of vital signs during pregnancy is very essential as it gives a clear picture of any signs of danger at an early stage and commence prompt actions. Such monitoring activities are usually done in antenatal clinics or hospitals. However, hindrances such as bad weather, traffic, and

long waiting hours can be inflicted to pregnant women, as they must endure it many times during the regular checkups. In another scenario, home-based sensors could be used to avoid such obstacles for monitoring purpose, yet without proper medical knowledge, accurate vital signs cannot be recorded (24). Therefore, a combination of medical device and mobile application can serve as a complete solution to such situations by linking monitoring device, users, and health care personnel. To illustrate, Megalingam et al. created a system that shows ultrasound scan of the pregnant women along with storing vital signs information such as blood pressure, ECG temperature, and heartbeat rate in a memory card. The mobile application can assess the information to check for any emergency issues and send a text message to the doctor with details of patient's critical condition if such case arises. In case of a desktop application, the reports and videos of ultrasound are displayed in the screen and the doctors can generate updated medical checkup data (25).

- Mhealth apps: There are plenty of mhealth apps available in the market that helps women to remain healthy and fit during pregnancy so that any complication is eliminated and healthy baby is born. Such apps include fitness apps, nutrition apps, and pregnancy journey apps. Some of the examples are Pear Fitness, which acts as a virtual personal trainer. The app guides through fitness for the entire pregnancy i.e. pre-pregnancy, trimester-by-trimester and post-baby workouts (26); What-to-expect, an app that guides pregnant women through pregnancy from hour-to-hour to day-by-day and week-by-week, on Apple based products such as iPhone, iPad, and Apple Watch. It also provides the latest parenting news and health information, and access to a tight-knit community of other parents and moms-to-be (27).

1.2 **Rationale of the study:**

The incidence of maternal and child mortality and morbidity has been key issues in many countries. Most of the women die of causes resulting from interaction between pre-existing medical conditions and pregnancy such as hemorrhage, hypertension, infections, and indirect causes. All these could be avoided and prevented if basic resources were available. Various programs are being conducted on national and international levels to halt the trend of double burden of obstetric issues in women and children. The growing interest in mhealth innovations have led to many mhealth studies conducted in many countries. Few studies implemented to test the efficacy and use of mhealth on behavior change, drug and treatment adherence, health care solutions have found the usefulness of such application in health promotion and adherence to treatment outcomes (28, 29). Very few studies have been carried out to identify the use of mhealth applications in obstetric care. In fact, only few reviewed studies (both systematic and non-systematic) on use of mhealth application by pregnant women can be established. In view of high prevalence of MMR and IMR in various regions, particularly in Sub-Saharan region and South Asian region, there is an urgency to change the situation worldwide. There is also an added requirement to apply mhealth programs in maternal and child health area and examine its feasibility and acceptability.

In this way, many research studies would be executed and the best mhealth application approach can be constructed which will shape the future projects. Furthermore, by identifying the obstetric issues faced by pregnant women, the type of mhealth application and its effectiveness, a platform for development and implementation of future mhealth interventions would be unlocked.

1.3 **Objectives of the study:**

General objective:

- To review the use of mobile health application in obstetric care.

Specific Objectives:

1. To identify the obstetric issues faced by pregnant women.
2. To explore the type of Mhealth application used.
3. To describe the effectiveness of the mhealth application used for obstetric care.

For Objective 1 and 2, the obstetric issues faced by pregnant women, type of mhealth application, the methods of delivery including study characteristics, participants' characteristics, intervention and follow-up duration will be discussed in the findings section. For objective 3, effectiveness of the mhealth application will be discussed based upon the author's findings and conclusion. Statistical tests and quality appraisal to assess the effectiveness of the mhealth application will not be conducted.

CHAPTER II

METHODOLOGY

Operational definition:

Mhealth application refers to the mobile health technology used by smartphone, tablet or computers to deliver preventive health care services.

A structured non-systematic review of literature was conducted for this dissertation. An extensive literature search was conducted between August – December 2015. The relevant literature was identified and collected through structured searches of 5 databases namely Pubmed, CINAHL, Embase, SCOPUS and Science direct. Cochrane library was also used as search engine to identify peer-reviewed literature. Likewise, hand searching of the reference lists and journal relevant to the research topic was done. Google scholar and UiT library database (BIBSYS) was used to find any additional relevant research articles. Grey literature was searched using WHO and other organizational websites to obtain an overall background literature for this dissertation on the use mobile health application in obstetric care.

Table 2: Schematic overview of the search strategy

Search engine	Journal databases	Grey materials	Hand search
• The Cochrane Library • Google • Google scholar • BIBSYS	• Pubmed • EMBASE • SCOPUS • Science direct • CINAHL	• UN Agencies • WHO • Relevant websites	• References • Relevant journals • Google • Google scholar • BIBSYS

Search Strategy:

The database search strategy of this review mainly focused on peer-reviewed literatures. Initially, the search strategy started with a broader aspect such as "use of mobile health application in obstetric care" to get an overview of the topic and identity past researches in the interest area. This comprised of both peer-reviewed as well as grey literatures. Later, one of the important inclusion criteria of this review i.e. focusing only on pregnant women receiving antenatal care was added in the search strategy. The search terms used were mobile health, mhealth, application, apps, pregnant women, pregnancy, prenatal care, antenatal care, and obstetric care. These terms were all used in various combinations in order to confirm that all of the appropriate articles were identified. Since the review has no desired location, country or region specific searches were not made. Thus, in this way peer-reviewed articles were sought. The review was limited to following inclusion and exclusion criteria:

Inclusion criteria:

- Studies conducted among pregnant women during their antenatal care were only included.
- Studies that focused on use of mhealth application by pregnant women during their antenatal phase were included.
- Studies reporting effectiveness of such mhealth applications were included.
- Studies published only in English from 2005 to 2015 were included.

Exclusion criteria:

- Studies involving mhealth application used by mothers in the postnatal care were excluded.

- Studies that included other study population other than pregnant women were excluded such as health care workers, post-partum mothers.
- Studies published in any other language other than English were excluded.
- Studies without full text access were excluded from the review.

Limitation of the review:

The review has some limitations. First, due to time and resources constraints, the review couldn't be done in a systematic way. As a result, quality appraisal of the studies and assessment of risk of bias couldn't be performed which might affect the actual data on effectiveness of mhealth application. Secondly, very few studies met the inclusion criteria, which may make it difficult to generalize the study. Lastly, articles published in different languages other than English and articles with no full access couldn't be included in this review. This displays a small chance of missing out relevant articles for this review.

CHAPTER III

FINDINGS

After screening and reading full text relevant articles, altogether 12 studies were finally included in this review. These 12 studies met all inclusion criteria, the objective of the review and focused on the use of mhealth application by pregnant women in antenatal obstetric care. Detail description of mhealth application and a summary of studies have been described in Appendix 2.

Study characteristics:

Out of 12 reviewed articles, 6 studies were conducted in the United States, 3 in South Africa, and 1 each in Nigeria, Zanzibar and England. Although the review searched for the studies from 2005 to 2015, articles published from the year 2012 to 2015 were only found. The review included different types of study designs in which 6 studies were randomized controlled trial (RCT), 2 were cross sectional, 1 study was non-RCT followed by 3 mixed studies (1 cross sectional and non-RCT and 2 RCT and pretest posttest intervention study). The study also found 5 pilot studies conducted on use of mhealth application. All the studies (n=12) were conducted in the antenatal clinics/hospitals where pregnant women visited for their regular prenatal checkup.

Obstetric issues faced by pregnant women

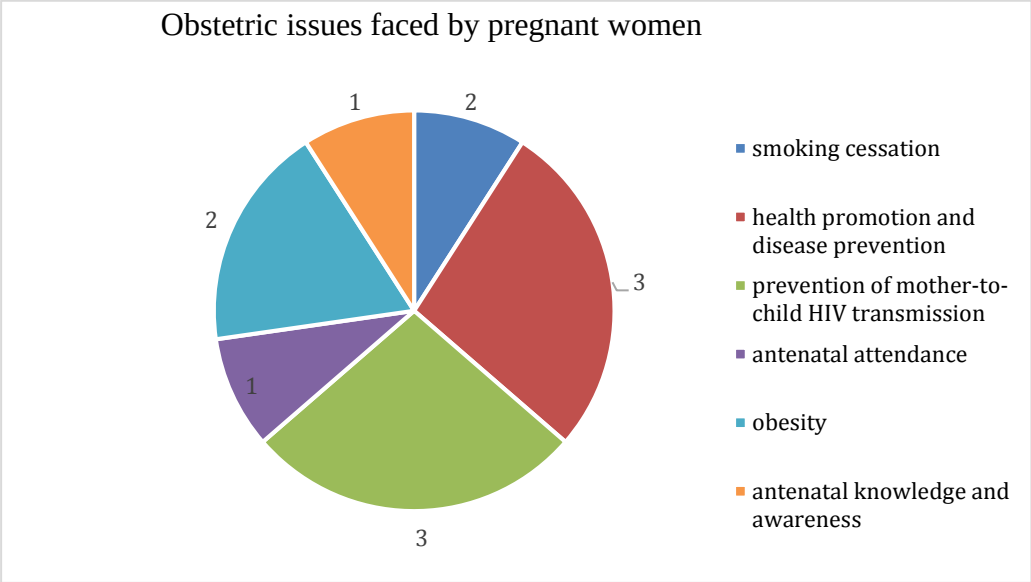

Figure 2 Different types of obstetric issues faced by pregnant women

The pie-chart depicts the various obstetric care pregnant women face during their antenatal phase of pregnancy. The review included three studies performed by Evans et al. focusing on health promotion and disease prevention with the aim to identify the effectiveness of mhealth application on pregnant women's health attitudes and beliefs on antenatal care and to increase healthy behaviors and decrease risk behavior and improving the antenatal behavior such as adequate antenatal visit attendance, following healthy diet, consumption of vitamins and folic acid, avoiding alcohol and smoking etc. (30-32)

Three studies focused on the use of mhealth application to prevent the transmission of HIV from mother-to-child during pregnancy by encouraging pregnant women to follow antiretroviral therapy (ART), retaining mother and infants from an option B+ program *(providing lifelong ART to all pregnant and breastfeeding women living with HIV regardless of CD4 count or clinical stage)* (33) and delivering acceptance and commitment therapy (ACT) (34-36).

Furthermore, two studies conducted in US and England aimed at using mobile technology to help obese and overweight pregnant women to limit gestational weight gain (GWG) and promote healthy GWG with healthy lifestyles (37, 38)

Likewise, two mobile smoking cessation program were carried out to help women quit smoking during pregnancy (39, 40). Only one study emphasizing on increasing antenatal attendance of pregnant women (41) and one study focusing on dissemination of antenatal health knowledge and awareness information for pregnant women (42) were found in this review.

Participant characteristics:

The review encompasses a range from 7 to 2550 (n=12) pregnant women visiting antenatal clinic/hospital during pregnancy. The mean age of the participants varied from 21.8 to 32.1 years and participants' pregnancy week ranged from 1st to 3rd trimester. 9 studies had gestational week and age eligibility criteria of 18 years and above (31, 32, 34, 35, 37-40, 42) while 3 studies didn't have any gestational week and age eligibility criteria (30, 36, 41).

The studies had diverse characteristics of participants depending upon the obstetric issues faced by the pregnant women. To illustrate, two trials conducted on obesity and overweight had participants with body mass index (BMI) of 25-40 or BMI> 30 (37, 38). One evaluation study particularly focused on low-income pregnant women for health promotion study (30). In the same way, studies focusing on prevention of mother-to-child transmission (PMTCT) involved HIV pregnant women diagnosed with the infection during the current pregnancy or receiving Highly active antiretroviral therapy (HAART) at the time of pregnancy or not yet received (34, 35). Two studies counted pregnant women who were current smoker or had quit smoking within last four weeks, have smoked at least 100 cigarettes in their lifetime or smoked 5 or more cigarettes per day in the 7 days prior to the study (39, 40)

Type of mhealth application used (intervention approaches):

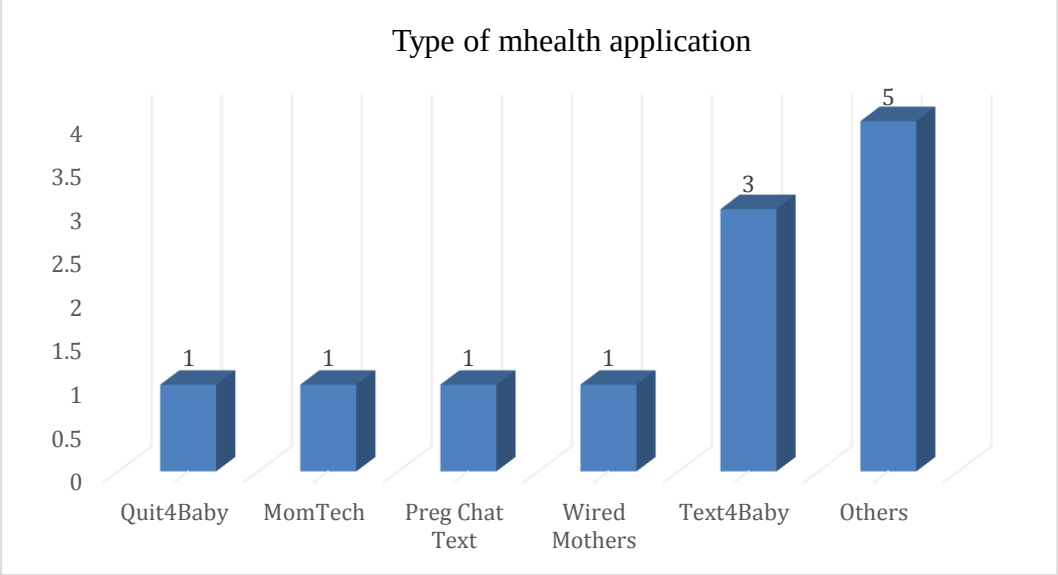

Figure 3: The type of mhealth application used in obstetric care

This column chart represents the different kinds of mhealth application used by the pregnant women during antenatal care of pregnancy. One common factor among all the applications is that all the applications are used for text messaging/SMS. Seven studies had a unique name for the text messaging application (30-32, 37-39, 41) whereas 'others' refers to the SMS text system using the normal mobile phone with no specific application developed; however, served the same purpose of sending messages to the participants (34-36, 40, 42).

Evans et al. implemented three studies on the effects of text4baby mobile health program out of which one was a pilot evaluation study to understand the effectiveness of the application. The researchers randomized the participants into two groups, exposure and control groups. The exposure group received usual antenatal care and counseling and in addition to received text messages from the Text4baby program while the control group only received usual care and counseling. Participants' mobile phone number, pregnancy due date, zip code and individual

identification code was entered in the database to send automated health messages. Telephone interview was conducted with 24-item questions with the participants. In the pilot study, follow-up was done 2-3 months after the initial antenatal visit to observe the differences in behavior in both groups (30) whereas follow up was done 4 weeks after intervention period to describe initial outcome of text4baby (32) and at 4 weeks, 28-weeks gestation and at the time of first postpartum visit to detect the dose-effect of the application (31).

Maternal obesity related studies used mhealth application such as Preg CHAT Text and mobile technology (MomTECH) to limit GWG and promote appropriate pregnancy weight gain. Pollak et al. randomized eligible women in a 2:1 ratio to either intervention group (Preg CHAT text) or a control group (Text4baby). The intervention group received text messages 3 days a week, which generally included 4 goals related to proper health eating habits and exercising and based on their goals the participants were asked to send their weekly health data. On the other hand, control group received 3 text messages per week which was very much related to mother and child health information and less of eating and exercising goals related messages (38). In the study undertaken by Soltani et al., participants who initially agreed and provided consent were included in the intervention group whereas all those participants who initially verbally agreed but declined later were included in the comparison group. Intervention group received one text messages per day and one week food and activity diary at consultation 1 and 2 text messages one with preference to dietary goals and the other in line with physical activity per day at consultation 2. Two follow-up appointments were made during 28 and 36 weeks in order to further collect diet and activity record and reflect on their ongoing progress (37).

Moreover, in Quit4baby study, participants were asked to set a quit date for smoking within 2 weeks of enrollment and received 1-5 messages per day. The quantity of texts increased on the quit date. The content of the message was based on prequit, postquit and notquit protocols.

Participants who couldn't quit on the time set were directed to notquit protocols where they received texts to remind about the benefits of quitting smoking for both mother and a child and advised to set a new quit date again. At 2 and 4 weeks, post-enrollment follow-up surveys through telephone interviews were conducted. Further, interactive text message survey was done, for example, the app would send text "*please be honest, did you quit today?"* and the responses would be *"Yes" or "No"* or keywords *"CRAVE"* requesting for help (39). Pollak et al. randomized participants to two groups i.e. one was support message only group (SMO) and the other was Schedule gradual reduction (SGR) group. Participants in SMO group were asked to set their quit date within 2-3 weeks and were sent support messages 5 times a day for 5 weeks. They received messages based on themes like reasons for quitting, getting ready for the quit date, partner smoking, and handling slips. On the other hand, SGR participants received alert messages planned to gradually cut the number of cigarettes to zero by 4th week rather than setting quit date. Participants were allowed to smoke only when they received alert texts at scheduled time. The number of cigarettes was reduced by one third each week resulting in long interval between cigarettes (40).

A study conducted in Zanzibar used Wired Mother mhealth application to collect information such as gestational age, date, and mobile phone number during first antenatal care visit. The messages sent were mainly about health education and the appointment reminder of their antenatal visits. Before gestational week 36, participants received two messages per month and from 36 weeks, two messages per week. Women were given mobile phone vouchers to have two-way communication with their local health care provider. This also gave quick access to emergency obstetric care (41).

On contrary, three studies based on PMTCT used text messages from mobile phone as an intervention approach but without specific application developed. A Nigerian study used Solomon four group design where there were 2 intervention groups and 2 control groups. The

intervention group received standard post HIV test counseling along with three session of ACT using weekly health messages for 3 months while control groups received only standard post HIV test counseling (36). A pilot study used two-way interaction SMS intervention. Participants received messages that comprised of medical information as well as psychosocial support messages. While, participants sent messages regarding their fear about the HIV transmission to baby from mothers, necessary nutrition and infant care (34). Similarly, Schwartz et al. sent messages to retain mothers and child from Option B+ program for PMTCT. Participants received 1 text message per week and 1 pre-delivery phone call after enrollment. This was followed by 1 text message per week and 2 post-partum phone calls from delivery to 6-week post-partum and eventually reminder calls/messages to mothers who did not bring their child for 6-week visit till 10 weeks post-partum. Messages sent contained pregnancy and infant related health information, reminders for appointments and medication, and motivational support. Another pre-intervention group of 50 HIV infected pregnant women were also selected retrospectively from the clinic file based on the same eligibility criteria during the period instantly preceding the intervention (3 months) who also received standard option B+ treatment to contextualize the intervention results (35).

Following the same approach, antenatal health promotion study sent antenatal SMS to the pregnant women based on their week of pregnancy. To illustrate, a participant booking at 10 weeks would have 16 weeks' gap before third trimester and the frequency of the messages were three to four times a week. Likewise, one message was sent daily for the participant booked at 19 weeks was there was only 8 weeks left of second trimester. SMS was sent in three different language based on participants' preference (42).

Intervention duration, follow-up rate, and postpartum follow-up:

The intervention duration ranged from five weeks to two years. Most of the studies had intervention time less than a year. The shortest intervention period was five weeks in the pilot SMS study (40) whereas the longest time interval was two years from the Text4baby studies (31, 32).

The follow-up rate ranged from 24.5% to 97% in the reviewed studies. Post- partum follow up was done only in five studies (31, 35, 37, 38, 41) while rest seven studies did not follow up the participants after the delivery of the child (30, 32, 34, 36, 39, 40, 42). Among the post-partum follow up, four studies followed up participants six weeks after the delivery at the first post-partum visit (31, 37, 38, 41) and one followed up till one year after delivery (35).

None of the studies reported any adverse health effects caused by the interventions.

Outcome measures:

Among the studies about health promotion and disease prevention, the outcome measures were pregnant women's knowledge, attitude, and behavior (KAB) towards text messages, antenatal care, proper nutrition and physical activity, substance use, vitamins and folic acid, immunization and flu shots, health risk avoidance behavior and health promotion, and high and low exposure to text messages (30-32).

Among the PMTCT studies, the outcome measures were knowledge of HIV, adherence to ART, efficacy, acceptability and feasibility of the mhealth app, maternal (at least one of more ARV pickups after delivery, actively engaged in HIV care at 10-weeks or transferred to another site, ART retention at 12-months post-delivery) and infant (known to have received PCR at 6 weeks

and 10 weeks) engagement in care, and psychological flexibility (mental health outcome) (34-36).

The outcome measures for reviewed studies about maternal obesity were gestational weight gain, and efficacy, acceptability and feasibility of the mhealth application. The studies used Institute of medicine (IOM) defined cut-off limits for gestational weight gain limit of 9 kg (37, 38).

Although the study in Zanzibar was similar in method, the outcome measures were different. It used number of women receiving four or more antenatal care visits, number of women receiving anti-tetanus vaccinations, preventive treatment for malaria, gestational age at last antenatal care visit, antepartum referrals and the timing of the mentioned services in gestational age as outcome measures (41).

Mobile smoking cessation study had feasibility, acceptability, efficacy of the intervention, average number of cigarettes, abstaining from smoking, and biochemically validated 7-day point prevalence abstinence at follow up as outcomes measures (39, 40).

Lau et al. emphasized on antenatal health and clinical procedures knowledge and impact of the intervention on the healthy behavior (42).

All the reviewed studies (n=12) used questionnaires to measure the outcome of the intervention. Most of the studies used only structured questionnaires, two studies used questionnaires and in-depth interview (34, 37), one used questionnaires and focus group discussion (FGD) (42), one used closed-ended and open-ended questions for qualitative feedback (39), and one used multiple choice questionnaire (42) (see appendix 2).

Effectiveness of mhealth application (effects on outcome measures):

All the reviewed studies displayed positive effect of the mhealth application to tackle the obstetric issues faced by pregnant women during the prenatal phase. However, only six studies showed statistically significant effect on at least one outcome measure (30, 31, 35, 36, 38, 41) whereas two studies didn't demonstrate significant effect on any outcome measures (32, 42) and four studies couldn't test for statistical significance due to small number of participants (34, 37, 39, 40) (see appendix 2).

Among the Text4baby intervention, only pilot evaluation study was effective to detect behavioral changes in pregnant women (30). Text4baby study on military women's population had no behavioral change and no significant treatment effect on KAB and behavioral outcomes as targeted by the intervention. Although, the outcome indicated no significant effect, yet increase in strongly agreeing with some pre-natal attitudes was seen (31, 32). On the other hand, there was significant effect at $p< .10$ level ($p<0.098$) on respondents who smoked in the last 30 days which decreased from baseline to follow-up (5.8% to 1.2%) in the pilot text4baby study. Similarly, reduction in alcohol consumption (from 3.5% at baseline to 1.1% at follow-up) and increase in eating 3 or more servings of fruit by 3% was noted. The odds of preparedness for motherhood were nearly three times higher in intervention group than the control group (OR=2.73, CI=1.04, 7.18, p=0.042). Moreover, there was a strong effect of education level of participants. Participants with high school education level or more had significant higher agreement that drinking alcohol during pregnancy will have negative health impact on the child (30, 32). The dose-effect of text4baby study found participants receiving higher dosage of text messages reported lower alcohol consumption. The odds of consuming alcohol after delivery lowered (OR= 0.212, 95% CI 0.046-0.973, p= 0.046), thus stating a significant effect of intervention on self-reported alcohol consumption postpartum (31). The study of evaluation of

short-term effect of text4baby exhibited that the exposure of text messages had some positive improvement in some attitudes and beliefs such as importance of pre-natal care, taking pre-natal supplements, avoiding alcohol use during pregnancy (32).

All three studies regarding HIV positive pregnant women revealed that the text message mhealth application to be feasible and highly acceptable because of reasons like safe, confidentiality, emotional support, educational information, and reminders for taking medication, and time saving. It was recommended for offering the service in the future as well. The intervention was successfully used as the participants increased their knowledge about PMTCT for e.g. how the baby will be HIV negative even when mother is HIV positive and what are the risks if ART is not taken during pregnancy and shared their psychological concerns with the people who cared. All the participants adhered to the treatment during the end of their pregnancy and one participant started ART after initially declining because of the intervention (34). The South African study found all live birth and no infant deaths or infant infection in the intervention group whereas in the pre-intervention group, there was one stillborn and one infant diagnosed with HIV. In terms of maternal engagement, no significant effect was found in 12-month maternal retention in ART in both groups. Nonetheless, in both pre-intervention and intervention group, all HIV infected pregnant women receiving HAART prior to pregnancy collected their medication at least once by 10 weeks post-delivery as compared to women who received HAART during pregnancy (100% vs 88%). Likewise, 91% of women on HAART prior to pregnancy engaged in the ART care 12 months' post-partum whereas only 62% of women on HAART during pregnancy or soon after pregnancy ($p<0.01$). On contrary, infants receiving polymerase chain reaction (PCR) in the intervention group was significantly higher than the pre-intervention group at 6 and 10 weeks (76% vs 45% and 90% vs 63% respectively, $p<0.01$) (35).

The Nigerian trial found significant psychological flexibility improvement following ACT intervention (t=3.4, p=0.001). A significant increase was seen in the pretest and posttest scores in Group 1 intervention group whereas there was significant decrease in the scores in the Group 2 control group (36).

Obese and overweight pregnant women reflected the feasibility, acceptability and efficacy of SMS intervention in achieving recommended weight during pregnancy and promoting healthy lifestyle. The Soltani et al. study showed that the participants in the intervention group had lower mean GWG than the comparison group i.e. 5.6 kg versus 9.7 kg. Also, only 28% of participants in the intervention group exceeded IOM upper limit of 9 kg GWG for obese women as compared to 50% in the comparison group. There was no occurrence of large for gestational age (*infant whose weight is greater than 90th percentile for gestational age)(43)* and small for gestational age (*infant whose weight is lower than 10th percentile for gestational age)(44)* in both groups (37). On a similar note, a South African study discovered mean gain of six less pounds in participants using Preg CHAT Text (intervention) than participants using Text4Baby (control) (95% CI −15.9, 4.0; $p = 0.24$) at 40 weeks gestation. Estimated mean weight at 40 weeks gestation was 214 lbs in the control group while it was 208 lbs in the intervention group. significant and positive effects were found in women who were quick in reporting their weekly goals. However, no significant effect for physical activity level (moderate: 95%CI (−3.5, 0.3), $p = 0.71$; light: 95%CI (−2.6, 0.4), $p = 0.08$) and nutrition score (95% CI (−1.1, 6.9), $p = 0.15$) outcome was found at 32 weeks gestation (38).

In Abroms et al. study, all participants agreed the intervention was very effective as it encouraged and gave ideas on quitting smoking. The average confidence level rating of quitting smoking increased from 3.6 at baseline to 3.8 in 2-week follow up and 4.8 at 4-week follow up. In addition, average cigarettes smoked per day decreased from 7.6 at baseline to 4.7 at 2-week

follow up and 2.4 at 4-week follow up. About half of the participants (54%) reported abstaining from smoking for the past week at the last follow up (39). Furthermore, Pollak et al. found that 7-day point prevalence abstinence favored SGR to be effective as it discovered the differences 13.4% in SMO versus 7.5% in SGR. The reduction of smoking rate at follow-up was higher in SGR (M = 16, SD = 11) as compared to SM group (M = 12, SD = 7) which proved feasibility, acceptability, and efficacy of text messaging intervention (TMI) for smoking cessation during pregnancy, SGR being more efficacious despite the fact that most of the participants in that group were heavy smokers and less likely to quit smoking sooner (40).

Increase in antenatal attendance was reported by Lund et al., which proved the benefit of mhealth application. The odds of receiving appropriate antenatal care were two times higher for intervention women (OR, 2.39; CL, 1.03-5.55). Moreover, more than half of the participants stated that the SMS systems educated them about danger signs in pregnancy and encouraged them to attend the antenatal care as per the guideline (41).

On the other hand, no significant effect was found on antenatal health knowledge level at the post-test between intervention and control group ($p > 0.05$). However, positive healthy behavior was reported in the intervention group despite lower knowledge score such as regular antenatal check-up, adherence to treatment of STDs, eating healthier, exercise and taking supplements of folic acid and vitamins (42).

Cost-effectiveness and feasibility:

None of the studies conducted cost-effectiveness analyses. It is also not known if such analysis was performed prior to the studies. However, four studies mentioned mhealth application as a cost-effective method (31, 32, 37, 41). Lau et al. specifically mentioned that the main purpose

of doing the research was because of the cost-effective nature of text messages intervention (42). The other seven studies didn't have any information about it (30, 34-36, 38-40).

Six studies mentioned about the feasibility of the program (34, 35, 37-40) while the rest didn't cite that the text message intervention was feasible for targeting pregnant women during antenatal phase. Among those six studies, Dean et al. suggested that the intervention would be more feasible if the program was partnered with the telephone company to avoid any technological problem and reduce the cost of the texts.

CHAPTER IV

DISCUSSION

The review on the use of mhealth application in obstetric care integrated altogether 12 studies that met the inclusion criteria. About 75% of studies were carried out in the US and African countries. This may be because pregnancy related deaths in US is higher among most high-income countries (45) and the maternal deaths in Sub-Saharan region is the highest in the world (46) and the pregnant women attending antenatal care is also in decreasing rate (47). On the other hand, no studies from Asia or Europe have been published. One of the contributing factors could be low maternal deaths rate in Europe for e.g. in Norway, only 3 maternal deaths were reported in 2015 (48) and decreasing trend of maternal mortality rate in Asia (49). Also, all studies reviewed in this dissertation were published after 2011. This indicates that the use of mhealth application and its importance has moved forward to gain progress in the obstetric care sector as well.

Studies with different study designs were discovered in the review. However, the review couldn't include any systematic or non-systematic reviews because of the inclusion criteria. Most of them involved pregnant women as well as new mothers or mothers with previous children which didn't match with the review's inclusion criteria (studies which focused on use of mhealth application by pregnant women during their antenatal phase). About 42% of the studies were pilot study designed to evaluate the effectiveness of the mhealth application.

The review covered six main obstetric issues faced by pregnant women during the antenatal phase. The Text4baby studies focused on the health promotion and disease prevention by detecting behavioral changes and KAB towards antenatal care during pregnancy phase. Similar

behavioral study by Higgins et al. found 18 health behaviors changes by women during pregnancy mainly dietary and exercise, smoking habits, alcohol use and, intake of vitamin supplements (50).

HIV infected pregnant women receiving ART, HAART and Option B+ treatment to prevent the transmission of HIV from mother to the child were centered in three studies. They stressed the importance of accepting HIV status, adhering, and committing to the treatment (34-36). According to WHO, good adherence to the treatment will increase its efficacy and suppresses the viral count to lower level, thus reducing the chance of HIV transmission to the child (51). The absence of treatment would rise transmission rates from 15% to 45% and could be minimized to below 5% if the women are treated during her pregnancy, delivery, and breastfeeding period (52).

Two trials promoted healthy weight gain during pregnancy for obese and overweight pregnant women (37, 38). A systematic review by Marchi et al. revealed the risks associated with obesity in pregnant women such as gestational diabetes, hypertension, preeclampsia antenatal and postpartum anxiety and depression, preterm birth and, neurodevelopmental problems or malformations in the children (53).

Likewise, Abroms et al. and Pollak et al. highlighted the smoking problem among pregnant women and implemented mobile cessation program as many pregnant smokers do not receive smoking cessation counseling as recommended (54).

Two African studies pointed out the importance of educating pregnant women about the antenatal knowledge, clinical procedure involved, and improving the antenatal attendance. WHO recommends at least four antenatal care visits that starts from 16 weeks of gestation, (9) A pregnant woman completing at least four antenatal visit to health facility will not only promote her own health by preventing obstetric complications, receiving tetanus toxoid

immunization and intermittent preventive treatment for malaria during pregnancy (IPTp), and identifying and managing of infections including HIV, but also protects her child by using skilled attendance at birth, breastfeeding, early postnatal care, and planning for optimal pregnancy spacing (55).

Participants' characteristics varied from one study to another depending on the obstetric issues dealt on the research study i.e. pregnant women with BMI of 25-40 or BMI> 30 for obesity management study, HIV pregnant women diagnosed with infection or receiving *HAART* for PMTCT study, and pregnant smokers for smoking cessation program. About 67% of the studies had eligibility criteria of gestational week and age 18 years and above. One study emphasized promoting health preventing disease in low-income pregnant women as they tend to receive less antenatal health information than others and face health inequality and insufficient antenatal access required during pregnancy (30). Also, two studies targeted female military health beneficiaries such as female militaries and spouse and family members of male militaries (31, 32). The targeted population face extra stress and female service personnel should balance between personal life and service towards country and probably be a single parent which ultimately may influence maternal and child health outcomes (56). The sample size of the study population was vastly diverse. Four studies confirmed that the sample size was too small and affected the study result by not being able to perform statistical powered analyses to detect any changes and generalize the result to diversity of women (34, 37, 39, 40).

The only mhealth application found to be used in this review was text messaging. 100% of the studies used the medium of text messaging as the mhealth intervention to resolve most of the obstetric problems. Approximately 64% of the studies had specific application developed such as Text4baby, Quitbaby, MomTECH, Wired Mothers, Preg CHAT Text while rest used a simple mobile phone SMS service to perform the same function. The reason behind discovering only text messages application is because of its easy, secure, quick, and cost-effective nature.

Text message intervention can be used to reach a larger group of people with fewer personnel required. A systematic review on mobile text messaging for health found the effectiveness of TMIs on health improvement and behavioral change in areas such as diabetes self-management, weight management, physical activity, smoking cessation, and medication adherence for ART (57).

On the contrary, studies on specific pregnancy mobile apps, EMR, and bio medical devices connected to mobile apps couldn't be explored in this review. The possible explanation could be that such apps require a lot funding on research and development to demonstrate expected benefits and mhealth program implementers would have to take a risk on spending both money and human resources to prove its questionable benefit (58).

The intervention duration of the TMI fluctuated from minimum five weeks to maximum two years. Although none criticized about the shorter intervention period effects on the final results, Schwartz et al. expressed the possibility of extending intervention duration to obtain greater impact on long-term maternal retention in ART (35). Lau et al. found drop in follow-up rate; however, didn't spot differential loss to follow-up amongst the demographic variables which allowed compromise with the validity of the results (42). On the other hand, Quit4baby and pilot Text4baby study benefited from the advantage of high follow-up rates (65% and 73% respectively) (30, 39). Only few studies were found to be following up participants at postpartum period, which is important as the long-term follow-up would bring potential and expected mhealth application effects.

All studies used questionnaires to measure numerous outcomes based on the obstetric difficulties of the participants. The review found the positive effect of TMI in obstetric antenatal care. Nevertheless, only 27% of the studies exhibited significant effect on at least one outcome measure.

Evans et al. conducted series of researches to test the effectiveness of Text4baby for health promotion for women in their pregnancy period. The pilot Text4baby study found behavioral changes in pregnant women for e.g. significant decrease rate of respondents smoking in the last 30 days from baseline to follow-up (30). The result was similar to the dose-response effect study in which respondents receiving higher dose of messages reported significantly lower alcohol consumption at postpartum phase ($p=0.046$) (31). A RCT on mobile phone text messaging found significant behavior changes in smokers at 6 and 12 weeks follow-up by increasing prevalence of non-smoking users (59). The productive nature of text messaging for behavior change in disease prevention was also found in the systematic review by Cole Lewis and Kershaw (28). However, no behavioral changes were found in short-term effects study of Text4baby. Although, the intervention duration (4-week effects) didn't prove to show the projected result, it revealed positive improvement in the attitudes and beliefs such as importance of taking vitamins supplements, prenatal checkup, and avoiding alcohol use (32). Pilot evaluation of the application also showed strong effect of education level as pregnant women with higher education and above agreed that alcohol use would harm their child's health which indicates that women who are more educated have ability to implement informed decision thus hinting the need of exploring the literacy status for further evidences for mhealth (30).

The TMIs used for adhering, accepting and using ART for preventing the HIV transmission from mother to child successfully helped pregnant women in providing medical information, emotional and psychological support and lifting mental health outcome. A pilot study increased the knowledge of the participants by disseminating information as to how the virus transmits from mother to child and the risks of not signing up for ART in pregnancy. No drop out was monitored in the ART during the intervention and one of them even initiated HIV treatment due to TMI after initially declining (34). According to two RCTs, text messages not only

increased ART adherence but also extended viral suppression (60, 61). United Nation Foundation's Project Masiluleke also reached one million HIV patients via mobile phones for prevention, test, and treatment purpose (8).

Retention to Option B+ program with the aid of TMI brought no infant deaths or infant infection in the intervention group as compared to one infant infected with HIV and one stillborn in comparison group. Although infant testing for PCR reduced to 63% by 10 weeks in intervention group, it was still higher than comparison group. A study in Malawi found increased high infant testing rate using community health workers with no comparison group and no assessment of long-term retention of mothers in ART (62). Ciampa et al. enhanced referral process in order to increase infant testing rate by three times in rural Mozambique. This process only worked if women returned to the health facility in postpartum phase (63).

A Nigerian study determined that the application of messages results in better psychological flexibility in HIV infected pregnant women and assist them to accept their HIV status and commit to the treatment (36). Fear of exposing to the society, late first appearance, denying HIV diagnosis and test, fear of treatment side-effects and difficulties in accepting a lifelong commitment to treatment are some of the main encounters to ART initiation identified by Stinson and Myer (64).

MomTECH and Preg CHAT Text were two mhealth applications used for the management of maternal obesity and overweight by promoting appropriate GWG. Both studies used the IOM recommended defined cut-off limit of 9 kg GWG. The MomTECH study couldn't perform statistical analysis due to small no. of participants (n=14), however, it showed that the intervention worked successfully. The mean GWG was lower in intervention group as compared to comparison group (5.6 kg vs 9.7 kg) (37). The result was similar to Pollak et al. study where the mean weight at 40 weeks gestation in intervention group was 208 lbs whereas

it was 214 lbs in the comparison group (38). Patrick et al. also found TMI resulted in more weight loss in the obese intervention group than in the obese comparison group (-1.97 kg difference, 95% CI −0.34 to −3.60 kg, $P = .02$) after adjusting for age and sex (65). An Australian trial compared comprehensive lifestyle intervention to standard care to deduce the probability of large for gestational age (LGA). The trial followed few similar protocols like MomTECH and Preg CHAT Text such as dietary and physical recommendations and goals, self-monitoring in a workbook, but contacted participants only via meetings and phone calls. The study didn't show any significant result in the reduction of LGA, proper GWG, and number of participants exceeding the IOM guidelines (66). This also illustrates that TMI is very effective because both MomTECH and Preg CHAT Text constantly reminded the participants of their physical and dietary goals and sent supportive and motivating messages to engage them to fulfilling their goals.

Two studies emphasized on aiding pregnant women to quit smoking by applying TMIs. Pregnant women in both studies found the intervention to be helpful, supportive and encouraging in the process of quitting smoking. Quit4baby saw a rise in self confidence level of quitting smoking habit from baseline to follow up (39). MiQuit study in United Kingdom also found higher quitting level of self-efficacy (67). Whittaker et al. believed that TMI can cover many smokers at a time with less necessity of personal contact (68).

Additionally, number of cigarettes per day reduced from 7.6 from baseline to 2.4 at follow-up in Quit4baby. This is comparable to pilot study of SGR program where the smoking rate was minimalized at the follow up survey. SGR gradually reduces the smoking habit by unlinking smoking from cues. In case if it does not assist in quitting completely, it will still reduce the number of cigarettes, thus reducing nicotine exposure ultimately benefiting the baby (69, 70).

The use of mhealth application has been beneficial to increase the antenatal attendance of at least four visits. In the Zanzibar study, the reminder text messages were sent which increased the attendance rate in the intervention group as compared to comparison group. The study also uncovered the results of intervention group receiving preventive health services (two doses of tetanus vaccination and IPTp) more than the comparison group although the timing of the service wasn't statistically significant (41). In rural Tanzania, 20% of maternal morbidities are credited to sub-standard antenatal services. Nyamtema et al. describes that significant no. of such morbidities could be averted by polishing this program (71). Two studies discovered that TMI increases the chances of attending antenatal clinics (72, 73). Previously, many studies were conducted to test the efficacy of reminder system of mhealth application for health promotion. However, due to increment in the interest in mhealth, the focus has been expanded. Lund et al. stated that the growth in antenatal attendance is not only due to reminder messages but also health education messages such as information about risk or danger signs in pregnancy (41).

Lau et al. conducted a study to measure antenatal knowledge of pregnant women by sending them messages based on their trimester like Getting Ready and healthy living during pregnancy in 1st and 2nd trimester and getting ready for birth and mothering at 3rd trimester. No significant effect was found on antenatal knowledge at exit between intervention and comparison group. This may be due to low message delivery rate because not every participant received messages and even if the messages were delivered, there is no guarantee participants read the message. Nonetheless, participants exhibited positive healthy behaviors despite low scores for e.g. regular antenatal check-up, adherence to treatment of STDs, eating healthier, exercise and taking supplements of folic acid and vitamins (42). This result also matches with the Text4baby results where pregnant women reported healthy behaviors (30).

Recommendations:

Based on the findings of the review and studies' own limitations, following recommendations were summed up:

- Long term follow up and large study population size is required to identify the long-term effects and foresee the feasibility of the mhealth application.

- Evans et al. expressed the need of future studies to realize the ideal dosage and timing of messages sent to the participants to gain prospective on key advantages of mhealth programs in relation to cost-effectiveness.

- Modification in the intervention by creating automated system to send messages to reduce human and money resources, and extensive training to health staffs during recruitment process is essential.

- Participants should be allowed to change the frequency and the type of text messages during the intervention if the messages stopped working for them or if the goals have been altered to diminish drop-out rates for e.g. in maternal obesity management.

- Mhealth programs could be incorporated with the telephone companies, which could solve any technological problems and reduce the burden of costs.
- Future studies should strive to explore the utilization of such mhealth application to tackle many other obstetric problems faced by pregnant women.

- High quality researches are desirable to draw more attention in the significance of mhealth applications especially in developing countries where maternal and child mortality and morbidity is high.

- Policy experts should consider merging mhealth programs in the national health agendas to achieve SDG goals and targets and reduce maternal and newborn mortality and morbidity rates.

CHAPTER V

CONCLUSION

The organizations like WHO and UN have reported that preventable pregnancy related complications have accounted for many deaths for women and children. Improvement in obstetric care will help achieve SDG 3 too. Mhealth serves many applications in obstetric care such as health promotion, health information access, emergency obstetric care access, EMR, mhealth apps for pregnancy and apps connected to biomedical devices. This review was executed with an objective to explore the use of mhealth applications in antenatal obstetric care. Only 12 studies met the inclusion criteria and were included in this review. Most of them were conducted in US and African region like South Africa, Zambia, Zanzibar, and Nigeria. Some of the serious obstetric issues faced in pregnancy were health promotion, disease prevention, prevention of HIV transmission from mother to infant, obesity and overweight, smoking problem, antenatal knowledge and attendance.

The only mhealth application found in this review used was text messaging. Seven studies developed an app to send text messages to the pregnant women while five studies used a simple mobile phone to perform the same task. Text4baby app was used to send text messages to the participants concerning antenatal care, proper nutrition and physical activity, substance use, vitamins and folic acid, immunization and flu shots. Preg CHAT text and MoMTECH sent dietary and physical activity related messages and helped participants choose diet and activity goals to limit GWG. Quit4baby and one unnamed TMI sent supportive and informative messages to assist pregnant smokers to quit smoking. Similarly, Wired Mothers app sent reminder messages and antenatal messages to increase antenatal attendance in Zanzibar. Three PMTCT studies sent text medical and psychological support messages to help HIV pregnant women to accept, follow and commit to the HIV treatment to halt the transmission of the virus

to the child. One study used mobile phone to send text antenatal health messages to increase antenatal knowledge.

All the studies stated that the mhealth application was very effective to see changes in knowledge and health outcomes of pregnant women. Text4baby found pregnant women with higher education level and receiving high dosage of messages agreed that drinking alcohol would harm the baby. Many participants showed positive agreement towards antenatal attitudes. PregCHAT Text and MoMTECH also disclosed the evidence of appropriate GWG in participants receiving text message than in control groups. Quit4baby and one unnamed TMI found smoking quitting rate decreasing from baseline to follow-up at the end of intervention. SGR way was found to be more effective than sending supportive message and setting quit date. Wired Mothers project was successful in increasing antenatal attendance by two times in intervention group. Moreover, HIV infected pregnant women displayed great result by adhering and obliging to the treatment. HIV pregnant women were discovered to be engaging themselves and the infant to HIV tests even after 1 year of birth. Although no significant effect was found on antenatal knowledge level between exposure and control groups, intervention participants still showed positive healthy behavior.

Therefore, more high quality researches, particularly RCTs with large study population and long follow-up period should be conducted to expose evidenced based long term effects of different mhealth applications, not being confined to only text messaging. This way, mhealth may grab more attention and policy makers could give mhealth priority in the international health programs.

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APPENDIX 1

Letter of Approval

UiT
NORGES
ARKTISKE
UNIVERSITET

Department of Clinical Medicine
Our ref.: 2016/7332-18
Date: 01.09.2016

Neha Pradhan
Email: npr006@post.uit.no

Approval of Contract of Supervision for Master's Thesis in Telemedicine and E-health (Health) – Neha Pradhan

According to the regulations of the University, the board of the department offering the Master Program must approve the credits and other conditions governing the thesis.

The Case IKM F14-16 is handled by authority at the Department of Clinical Medicine with the following result:

"Institutt for klinisk medisin godkjenner den fremlagte veiledningskontrakten for TLM-3902 Closing Master's Thesis for Neha Pradhan under forutsetning at det ikke er behov for innkjøp av utstyr utover det som er tilgjengelig. Det henvises for øvrig til de utfyllende bestemmelsene for mastergradsutdanningen for telemedisin og e-helse ved fakultetet.

Hovedveileder:	*Prof. Gunnar Ellingsen, IKM, UiT*
Studieprogram:	*Master of Science in Telemedicine and e-health*
Studieretning:	*Health field of study*
Foreløpig tittel:	*Use of Mobile health application in obstetric care in Norway: A Review*
Antall studiepoeng:	*60*
Arbeidssted:	*Forskningsparken*
Eksamensform:	*Sensur av skriftlig innlevering*
Evalueringsform:	*Bokstavkarakter A-F*
Utleveringsdato:	*1.9.2016*
Innleveringsdato:	*15.5.2017"*

Your Master's Thesis has the preliminary title, *"Use of Mobile health application in obstetric care in Norway: A Review"*, and is supervised by Prof. Gunnar Ellingsen. The number of credits for this thesis is 60 ECTs/studiepoeng and the deadline for delivery is the 15th May, 2017. It will be graded from A-F by an appointed examination board that composes of internal and external examiners. The grading of Master's Theses in Mathematics, Science and Technology (MNT) subjects will also be applied.

The Master's Thesis must be submitted electronically in MUNIN (www.ub.uit.no/munin/).

Yours sincerely,

Judy Yu Ying Au
Advisor

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Copy: Prof. Gunnar Ellingsen (supervisor)

Dokumentet er elektronisk godkjent og krever ikke signatur

APPENDIX 2
LITERATURE TABLE

S. N	First Author, Year, country, Reference no,	Objective	Study characteristics		Intervention		Summary of interventions	Outcome measures	Results
			Design	No. of participants	Type of intervention	Duration, Postpartum follow			
1	Soltani, 2015, England (37)	Evaluate the feasibility of text messaging based complex intervention designed to support obese women with healthier lifestyles and limit GWG	Non-RCT	29	Text message/ MoMTECH	32 weeks, 6 weeks after delivery	At Consultation 1 (14-16 weeks), participants received one motivational text message from the series of messages per day at any specific time they chose and started one week food and activity diary. Likewise, during the Consultation 2 (16-18 weeks), women were asked to discuss their dietary and physical activity behavior from consultation 1 and were further requested to select	Structured questionnaires and in-depth interview, gestational weight gain, birthweight, gestational age, Institute of medicine defined cut-off limits for gestational weight gain limit of 9 kg	participants in the intervention group has lower mean GWG than the comparison group i.e. 5.6 kg versus9.7 kg. Also, only 28% of participants in the intervention group exceeded IOM upper limit of 9 kg GWG for obese women as compared to 50% in the comparison group. There was no occurrence of large for gestational age

							one out of five health eating goals and one of three physical activity goals. After consultation 2, pregnant women received two text messages a day(one with preference to dietary goals and the other in line with physical activity) on their preferred time. Messages included texts for motivation, specific planning of their diet and physical activity, overcoming barriers, and self-monitoring.		and small for gestational age in both groups.
2	Pollak, 2014, US (38)	Promote healthy GWG among overweight and obese women.	RCT	35	Text message/ Preg CHAT TEXT	22 weeks, 6 weeks after delivery	Preg CHAT TEXT group received text messages 3 days a week which generally included 4 goals related to proper health eating habits and exercising and the participants were asked to send their weekly health data based on their goals. Text4baby group received 3 text messages per week which was very much related to mother and	Structured questionnaires, gestational weight gain, Institute of medicine defined cut-off limits for gestational weight gain limit of 9 kg	Mean gain of six less pounds in participants using Preg CHAT Text than participants using Text4Baby (95% CI −15.9, 4.0; $p = 0.24$) at 40 weeks gestation. Estimated mean weight at 40 weeks gestation was 214 lbs in the control group while it was 208 lbs in the intervention group. Significant and positive

							child health information and less of eating and exercising goals related messages		effects were found in women who were quick in reporting their weekly goals. No significant effect for physical activity level (moderate: 95%CI (−3.5, 0.3), $p = 0.71$; light: 95%CI (−2.6, 0.4), $p = 0.08$) and nutrition score (95% CI (−1.1, 6.9), $p = 0.15$) outcome was found at 32 weeks gestation
3	Evans, 2012, US (30)	Assess the efficacy of Text4baby	RCT	123	Text message/ Text4baby	12 weeks, no postpartum follow-up	Exposure group received usual standard antenatal care and counseling in addition to text messages while control group only received usual care and counseling. Participants' mobile phone number, pregnancy due date, zip code and individual identification code was entered in the database to send automated health messages.	Structured questionnaires, Pregnant women's knowledge, attitude, and behavior towards antenatal care, proper nutrition and physical activity, substance use, vitamins and folic acid, immunization and flu shots, health risk avoidance	No significant effect yet increase in strongly agreeing with some pre-natal attitudes. There was significant effect at $p< .10$ level ($p<0.098$) on respondents who smoked in the last 30 days which decreased from baseline to follow-up (5.8% to 1.2%). Similarly, reduction in alcohol consumption (from 3.5% at baseline to 1.1% at follow-up) and increase in eating 3 or more servings of fruit by 3%

								behavior and health promotion	was noted. The odds of preparedness for motherhood was nearly three times higher in intervention group than the control group (OR=2.73, CI=1.04, 7.18, p=0.042). Moreover, there was a strong effect on education level of participants.
4	Evans, 2015, US (31)	Evaluate treatment effects, dose-response effect of text4baby on behavioral outcomes	RCT	943	Text message/ text4baby	2 years, 6 weeks after delivery	Exposure group received usual standard antenatal care and counseling in addition to text messages while control group only received usual care and counseling. Participants' mobile phone number, pregnancy due date, zip code and individual identification code was entered in the database to send automated health messages. The follow up was done after 4 weeks at 28-weeks gestation and at the time of first postpartum visit	Structured questionnaires, pregnant women's knowledge, attitude, and behavior related to text messages, high and low exposure to text4baby messages.	no significant treatment effect on KAB and behavioral outcomes as targeted by the intervention. The study found the dose-effect of text4baby in which participants receiving higher dosage of text messages reported lower alcohol consumption. The odds of consuming alcohol after delivery lowered (OR= 0.212, 95% CI 0.046-0.973, p= 0.046).

5	Evans, 2014, US (32)	Evaluate text4baby to improve antenatal behaviors	RCT	943	Text message/ text4baby	2 years, no postpartum follow-up	Exposure group received usual standard antenatal care and counseling in addition to text messages while control group only received usual care and counseling. Participants' mobile phone number, pregnancy due date, zip code and individual identification code was entered in the database to send automated health messages. The follow up was done only after 4 weeks.	Structured questionnaires, pregnant women's knowledge, attitude, and behavior related to text messages	No behavioral change was found. The exposure of text messages had some positive improvement in some attitudes and beliefs such as importance of pre-natal care, taking pre-natal supplements, avoiding alcohol use during pregnancy
6	Dean, 2012, South Africa	Investigate the feasibility of text messaging to promote adherence to ART	Cross sectional study	7	Text message	12 weeks, no postpartum follow-up	Participants received messages which comprised of medical information as well as psychosocial support messages. Furthermore, participants sent messages regarding their fear about the HIV transmission to baby from mothers, necessary nutrition and infant care	Structured questionnaires and in-depth interview, knowledge of HIV, adherence to ART	Successfully used to increased participants' knowledge about PMTCT. All the participants adhered to the treatment during the end of their pregnancy and one participant started ART after initially declining because of the intervention.

7	Schwartz, 2015, South Africa	Assess acceptability and feasibility of a mobile phone intervention to retain HIV infected pregnant women on Option B+ program	Cross-sectional study and non-RCT	50	Text message	1 year, till 12 months after delivery	Participants received 1 text message per week and 1 pre-delivery phone call after enrollment. This was followed by 1 text message per week and 2 post-partum phone calls from delivery to 6-week post-partum and eventually reminder calls/messages to mothers who did not bring their child for 6-week visit till 10 weeks' post-partum. Pre-intervention group of 50 HIV infected pregnant women were also selected retrospectively from the clinic file based on the same eligibility criteria during the period instantly preceding the intervention (3 months) who received standard option B+ treatment.	Structured questionnaires, acceptability and feasibility of the mhealth, maternal (at least one of more ARV pickups after delivery, actively engaged in HIV care at 10-weeks or transferred to another site, ART retention at 12-months post-delivery) and infant (known to have received PCR at 6 weeks and 10 weeks) engagement in care.	Feasible and highly acceptable because of reasons like emotional support, educational information, and reminders for taking medication. All live birth and no infant deaths or infant infection in the intervention group whereas in the pre-intervention group, there was one stillborn and one infant diagnosed with HIV. No significant difference in 12-month maternal retention in ART between pre-intervention and intervention group. PCR in the intervention group was significantly higher than the pre-intervention group at 6 and 10 weeks (76% vs 45% and 90% vs 63% respectively, $p<0.01$)
8	Ishola, 2015,	Deliver acceptance and commitment	RCT and pretest posttest	132	Text message	3 months, no postpartum follow-up	The intervention group received standard post HIV test counseling along	Structured questionnaire to measure	A significant psychological flexibility improvement was found

	Nigeria (36)	therapy in PMTCT using mobile phone messages	interventi on study				with three session of ACT using weekly health messages for 3 months while control groups received only standard post HIV test counseling.	psychological flexibility (mental health outcome)	following ACT intervention (t=3.4, p=0.001). A significant increase in the pretest and posttest scores in Group 1 intervention group whereas there was significant decrease in the scores in the Group 2 control group.
9	Abroms, 2015, US (39)	Demonstrate the feasibility and acceptability of Quit4baby	Cross sectional study	20	Text message/ Quit4baby	6 weeks, no postpartum follow-up	Participants were asked to set a quit date for smoking within 2 weeks of enrollment. They received 3 messages per week. Follow-up surveys were conducted by taking telephone interviews on 2 and 4-week post-enrollment. Interactive text message survey was done, for example, the app would send text "*please be honest, did you quit today?"* and the responses would be *"Yes" or "No"* or keywords *"CRAVE"* requesting for help.	Open-ended and closed ended questionnaires, feasibility and acceptability of quit4baby, average no. of cigarettes, abstaining from smoking.	All participants agreed that the program was very effective. The average confidence level rating of quitting smoking increased from 3.6 at baseline to 3.8 in 2-week follow up and 4.8 at 4-week follow up. Average cigarettes smoked per day decreased from 7.6 at baseline to 4.7 at 2-week follow up and 2.4 at 4-week follow up. About half of the participants (54%)reported abstaining from smoking for the past week at the last follow up.

10	Pollak, 2013, US (40)	To assess feasibility and acceptability of a SMS text-based intervention for pregnant smokers and obtain preliminary efficacy data for SMS text-based SGR to promote cessation during pregnancy.	RCT	31	Text message	5 weeks, no postpartum follow-up	Participants in SMO group were asked to set their quit date within 2-3 weeks and were sent support messages 5 times a day for 5 weeks. SDR participants received alert messages planned to gradually cut the no. of cigarettes to zero by 4th week rather than setting quit date. Participants could smoke only when they receive alert texts at scheduled time.	Structured questionnaires, feasibility, acceptability and efficacy, mean level, biochemically validated 7-day point prevalence abstinence at follow up.	7-day point prevalence abstinence favored SGR to be effective as it discovered the differences 13.4% in SMO versus 7.5% in SGR. The reduction of smoking rate at follow-up was higher in SGR (M = 16, SD = 11) as compared to SM group (M = 12, SD = 7).
11	Lund, 2014, Zanzibar (41)	Evaluate association between mobile phone intervention and antenatal attendance	Clustered RCT	2550	Text message/Wired Mother	26-32 weeks, 6 weeks after delivery	SMS system such as gestational age, date, and mobile phone number were collected during first antenatal care visit. The messages sent were mainly about health education and the appointment reminder of their antenatal visits. Before gestational week 36, participants received two messages per month and from 36 weeks, two messages per week.	Structured questionnaires, number of women receiving four or more antenatal care visits, number of women receiving anti-tetanus vaccinations, preventive treatment for malaria, and the timing of the mentioned	The odds of receiving antenatal care more than four times was two times higher for intervention women (OR, 2.39; CL, 1.03-5.55). pregnant women in the intervention also showed improved timing and quality of antenatal care services although it wasn't statistically significant for e.g. no. of pregnant women receiving two doses of tetanus vaccination and

								services in gestational age	IPTp was more in intervention group as compared to the comparison one (72% vs 56% and 65% vs 52% respectively)
12	Lau, 201, South Africa (42)	Increase antenatal knowledge and awareness by disseminating text messages	Controlled clinical trial and pre-test and post-test intervention study	206	Text message	27 weeks, no postpartum follow-up	Antenatal SMS was sent to the pregnant women based on their week of pregnancy. A participant booking at 10 weeks would have 16 weeks' gap before third trimester and the frequency of the messages were three to four times a week. Likewise, one message was sent daily for the participant booked at 19 weeks as there was only 8 weeks left of second trimester. SMS was sent in three different language based on participants' preference.	Multi choice questionnaires and FGD to measure the antenatal health and clinical procedures knowledge	No significant effect found on antenatal health knowledge level at the post-test between intervention and control group (p> 0.05). However, positive healthy behavior was reported in the intervention group despite lower knowledge score.