The Nurse Assistant App

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Development and evaluation of an electronic decision aid to improve the quality of antenatal care in Magu district, Tanzania

Sandra van Pelt

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Sandra van Pelt

Promoters:
Prof. Dr. Robert A.C. Ruiter
Prof. Dr. John B.F. de Wit, Utrecht University

Co-promoters:
Dr. Karlijn Massar
Dr. Laura Shields-Zeeman, Trimbos Institute (Netherlands Institute of Mental Health and Addiction)

Assessment Committee:
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Prof. Dr. Jelle Stekelenburg, Rijksuniversiteit Groningen

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CHAPTER 1

General introduction

Maternal mortality remains one of the major healthcare challenges globally. Current best estimates show that in 2017, 295 000 women died globally due to pregnancy- or childbirth-related complications (World Health Organization et al., 2019). The burden of maternal mortality is not carried equally, as the magnitude of the problem is higher in low- and middle-income countries (World Health Organization, 2019) with sub-Saharan Africa accounting for 66% of global maternal deaths (Alkema et al., 2016).

Maternal death is defined by the World Health Organisation as "*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 unintentional or incidental causes*" (World Health Organization et al., 2019). Maternal death is most widely measured as the maternal mortality ratio defined by the World Health Organisation as "the number of maternal deaths per 100 000 live births". This ratio makes comparisons between countries and regions easier because it quantifies the risk of maternal death relative to the number of live births. Worldwide, the maternal mortality ratio in 2017 was 211 maternal deaths per 100 000 live births while for sub-Saharan Africa this was estimated to be 542 per 100 000 live births (World Health Organization et al., 2019). As a comparison, the maternal mortality ratio in Europe in 2017 was calculated at 10 per 100 000 live births (World Health Organization et al., 2019).

Maternal health globally

Improving maternal health remains an important issue worldwide. High quality maternal health is an important indicator of a country's well-functioning healthcare system (Miller & Belizán, 2015; Family Care International, 2005). The consequences of maternal death and morbidity go beyond the individual tragedy of the death or degradation of a mother's life, and also impact the life of their children, families, communities (Miller & Belizán, 2015; Reed et al., 2000) as well as society as a whole (Sachs, 2012). Apart from the direct health costs related to maternal death and morbidity, national economic development is also impacted, through productivity loss of the family. Furthermore, the long term-effects of maternal death and morbidity extend to their children, both in terms of increasing the risk of death for the new-born child, and negatively impacting educational attendance and attainment and nutrition (Family Care International, 2014; Koblinsky et al., 2012; Reed et al., 2000). Importantly, many of these complications and their consequences are preventable.

Global efforts to improve maternal health

Improving maternal health for low- and middle-income countries was put on the global agenda in 1987 during the Alma Ata conference followed in 1987 by a global campaign of the United Nations - the Safe Motherhood Initiative. Both initiatives raised awareness

about the high maternal death rates and challenged the world to take action to fight this issue (Family Care International, 2005; Starrs, 2006). In 2015, the United Nations established the Sustainable Development Goals, where Goal 3 "Ensure healthy lives and promote well-being for all at all ages" aims to reduce the global maternal mortality ratio to less than 70 per 100 000 live births by 2030 (United Nations, 2021). Significant improvements have been made and the global estimated number of maternal deaths has declined by 44%, from 526 300 in 1980 (Hogan et al., 2010) to 295 000 in 2017 (World Health Organization et al., 2019); however, the distribution of progress has been unequal geographically as the burden or the problem is still highest in low- and middle- income countries. To achieve a similar reduction in maternal death rates in these countries, one key intervention is universal access to high-quality maternal healthcare services (Koblinsky et al., 2016; Miller et al., 2016; World Health Organization, 2019), among which antenatal care is an important service.

The importance of antenatal care

High quality antenatal care is especially urgent in areas where the burden of maternal mortality is highest. Most maternal deaths are caused by complications related to pregnancy or childbirth, such as severe bleeding, infections, high blood pressure, unsafe abortion, and complications during labour (World Health Organization, 2019). These causes are often preventable and can be detected during pregnancy, therefore antenatal care is a crucial component of maternal healthcare to promote maternal health (Callaghan-Koru et al., 2016; Kerber et al., 2007; Mrisho et al., 2009; World Health Organization, 2016). Quality antenatal care should be provided by skilled healthcare workers and consists of essential interventions that help to reduce maternal and infant morbidity and mortality (Mrisho et al., 2009; World Health Organization, 2016) by detecting high-risk pregnancies and managing pregnancy-related complications (Finlayson & Downe, 2013; Gupta et al., 2014; Mrisho et al., 2009). For example, if necessary, pregnant women should receive preventive interventions such as iron supplements and routine screening for complications such as high blood pressure or sexually transmitted infections (World Health Organization et al., 2006). Furthermore, during antenatal care, health education can be provided to inform women about danger signs and urge them to seek help when such signs occur (World Health Organization, 2016). In addition, research has shown that women who receive antenatal care are more likely to deliver their baby in the presence of a skilled birth attendant, which is considered to be the most effective intervention in reducing maternal mortality (Afnan-Holmes et al., 2015; Bishanga et al., 2018; Campbell & Graham, 2006; Campbell et al., 2016; Ministry of Health, Community Development, Gender, Elderly and Children [MoH], 2016).

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Maternal health in Tanzania

One of the countries with the highest maternal mortality ratio is Tanzania, with 524 maternal deaths per 100 000 live births (World Health Organization et al., 2019). It is not solely the high maternal mortality ratio in Tanzania that poses a burden on society, but also the impact it has on economic development. For example, due to the central role women play in Tanzanian households – including provision of food and income – the death of a mother disrupts households, and can bring families into poverty for many generations (Miller & Belizán, 2015).

In Tanzania, one of the lowest performing regions in terms of maternal health indicators is Mwanza Region, where only 54% of deliveries take place in the presence of a skilled birth attendant and only 21% of women receive a post-partum check-up (MoH et al., 2016). In addition, Mwanza is among the regions with the highest number of maternal deaths. In 2009, 176 maternal deaths were reported in Mwanza region (Shoo et al., 2017) and the lowest coverage of quality antenatal care services (Ministry of Health and Social Welfare [MoHSW], 2016), especially in rural areas. The current project took place in Magu district, one of the rural areas of Mwanza region. To understand the challenges Magu district faces with respect to maternal health, I will now briefly illustrate the socio-cultural context of Tanzania and Magu district.

Country and district profile

Tanzania became independent from Britain in 1961, and in 1964 the *United Republic of Tanzania* was established by President Julius Nyerere (National Bureau of Statistics, 2020). The country is located in East-Africa, bordering Kenya, Mozambique, Malawi, Zambia, the Democratic Republic of the Congo, Burundi, Rwanda, and Uganda (MoHSW et al., 2016). Magu district is in the north of Tanzania in Mwanza region, known as the 'lake zone' of Tanzania due to its proximity to Lake Victoria, see Figure 1 and 2.

Tanzania has a fast growing population which was estimated at 55.9 million in 2019 with an annual growth rate of 3.1 percent (National Bureau of Statistics, 2020). This growth can be explained by the high total fertility rate of 5.2 children per women, combined with a decrease in total adult mortality levels (MoH et al., 2016). However, the life expectancy at birth remains low at 62 years and despite decreasing poverty, estimates show that in 2018, 26.4% of the total population in Tanzania experienced 'basic needs poverty' (National Bureau of Statistics, 2020). Most of the population lives in rural areas and gains their income via agricultural activities such as crop production, fishery, and keeping livestock. In Magu district, 97% of household income is earned by farming activities such as growing cassava, cotton, and rice, as well as fishing and other petty trade activities (Kishamawe et al., 2015). In Magu district, fertility rates are comparable with the country's average and decreased

from 6.6 children per women in 1998 to 4.7 in 2013 (Kishamawe et al., 2015). The major cause of death in Magu is complication related to HIV/AIDS, followed by Malaria and other non-communicable diseases.

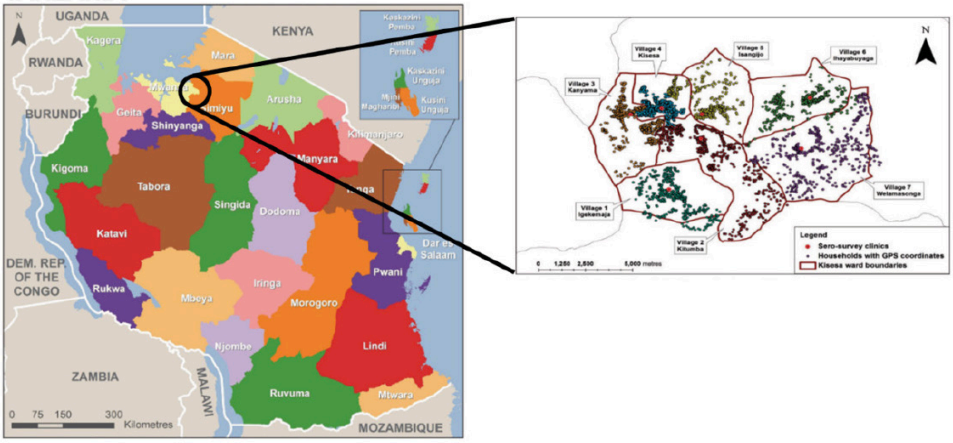

Figure 1 (left): Map of Tanzania, showing Mwanza district (yellow) in the North (MoHSW et al., 2016)
Figure 2 (right): Map of Magu district, where the study was conducted (Kishamawe et al., 2015).

National (maternal) health system

The Tanzanian health system aims to achieve access to quality primary healthcare for all inhabitants and includes quality reproductive health services (MoH et al., 2016). As a result, the primary healthcare services follow a pyramid structure (Figure 3). At the base of this pyramid are community-based health activities for people living in rural areas, where dispensaries provide preventive and curative outpatient services of any kind. Dispensaries also provide maternal and child health services such as antenatal and postnatal care and assist with uncomplicated deliveries. At the next level of referral are health centres, which provide small surgical services such as uncomplicated caesarean sections and which have a small ward to admit patients. This level of care is followed by the district hospitals, referral hospitals and national hospitals which serve referred patients from lower levels. These hospitals provide specialist medical care appropriate to their level, such as emergency obstetric care and x-ray diagnostics (Kwesigabo et al., 2012; National Bureau of Statistics & Macro International Inc, 2007).

Figure 3: The pyramid structure of the healthcare system of Tanzania (Kwesigabo et al., 2012)

These different levels of health facilities vary in the number of healthcare workers and their different positions. In dispensaries, services are provided by healthcare workers of different education levels ranging from to clinical officers (the highest level) to medical attendants (the lowest level). Clinical officers received three years of medical training after finishing secondary school. Their training consists of anatomy, physiology, hygiene, diagnostic methods, and treatment of common illnesses (Kwesigabo et al., 2012; O 'shea et al., 2009). Clinical Officers are assisted by Registered Nurse Midwifes and Enrolled Nurses who respectively studied three and two years after finishing secondary school. Medical Attendants only recently were offered a short medical training by the government and often continue to work without any formal training (Kwesigabo et al., 2012; O 'shea et al., 2009). Due to the shortage of healthcare workers, patients presenting a broad variety of complaints are treated (or referred) by the healthcare worker who is available at that time regardless of the education level or specialisation of the healthcare worker.

The health system in Tanzania faces major healthcare worker shortages, especially in rural areas (MoHSW et al., 2013). Overall, the country has one of the lowest physician-population-ratios worldwide. In 2014, Tanzania had a Medical Doctor Density of 0.25 per 10 000 population and a Nurse Density of 3.03 per 10 000 population. Comparatively, the Netherlands had 33.47 Medical Doctors per 10 000 population in 2014 (World Health Organization, 2021). Mwanza region is one of the regions with the lowest health worker density (MoHSW et al., 2013), which will continue to decline taking into account the rapidly growing population and the country's relatively limited training availability for health workers.

Antenatal care in Magu district

In Magu district, at the time of the research, reproductive health services were provided at one of the 31 government health facilities, 26 dispensaries scattered over the district, four health centres and one district hospital in the district town (Solnes Miltenburg et al., 2017b). All health facilities in Tanzania provide focussed antenatal care since 2002, in line with the model of the World Health Organization (Kearns et al., 2014). According to this model, it is recommended that the initial visit should occur in the first trimester of pregnancy, and that women receive a minimum of four consultations that contain all essential interventions. Results from the Tanzanian Demographic and Health survey show that 98% of women in the reproductive age received antenatal care at least once during their last pregnancy (MoH et al., 2016). However, only 24% schedule their initial antenatal care consultation in the first trimester of their pregnancy and only 51% received four or more antenatal care visits (MoH et al., 2016).

In Magu district, the antenatal care clinic is open for pregnant women on specific days, from eight in the morning until two in the afternoon. The morning often starts with a group education session provided by a Medical Attendant or Nurse who chooses the topic based on a predefined schedule. Topics discussed are, for example, related to diet and nutrition; rest and exercise; personal hygiene; HIV; danger signs; or signs of labour. After the education session, the individual antenatal service provision starts in a private room of the dispensary where the registration is performed followed by a measurement of the vital functions such as weight, blood pressure and fundal height. Depending on the availability of materials, diagnostics are performed such as tests for malaria, HIV or syphilis and prophylactic medication is provided such as iron supplements, deworming, and tetanus toxoid immunisation. Visits last between 20 minutes (for an initial visit) and five minutes (for repeat visits); whereas the World Health Organization recommends visits to last 40 to 20 minutes, respectively (Villar & Bergsjo, 2002).

Antenatal care services are provided by all healthcare workers active at the dispensary but should be supervised by the Clinical Officer. In Magu district, there are approximately 4.6 healthcare workers per dispensary, with one Clinical Officer. The workload is influenced by the catchment area of villages surrounding the dispensaries, which results in some dispensaries serving on average 10 pregnant women per day for antenatal care, while other dispensaries are serving more than 70 pregnant women. Due to personnel shortages, services are sometimes provided without proper supervision, and tasks are often divided between healthcare workers, for example one Medical Attendant is performing the diagnostics to screen for diseases, while one Nurse is registering the women in the government registration books.

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Healthcare workers must register all pregnant women in the government registration books and record demographic characteristics of each woman, such as number of children and number of pregnancies as well as services provided and its results. In addition, pregnant women receive a paper-based antenatal care card during their initial visit that they need to keep and bring with them to the next visits, see Figure 4. The card is used for extra documentation and guidance for the healthcare workers and contains the information relevant to their pregnancy.

Figure 4: The antenatal care card to be brought to the dispensary by the pregnant woman.

The quality of antenatal care in Tanzania

A major key national policy in combatting the high rates of maternal mortality in Tanzania is the availability of high-quality antenatal care (MoH, 2016). Unfortunately, it is widely known that the quality of antenatal care in Tanzania is low (Solnes Miltenburg et al., 2017a; Nyamtema et al., 2012), and that healthcare workers do not adhere to antenatal care guidelines and skip essential interventions (Boller et al., 2003; Conrad et al., 2012; Gross et al., 2011; Solnes Miltenburg et al., 2017a; Mubyazi et al., 2012; Nyamtema et al., 2012; Pembe et al., 2010; Sarker et al., 2010). The National Demographic and Health survey found that fewer than 50% of health facilities that provide antenatal care offer a urine check, syphilis screening or haemoglobin testing, only 47% of women visiting antenatal care received information on danger signs, and 29% had no blood pressure taken (MoH et al., 2016). Compared to the rest of the country, the Mwanza region has health facilities that are the least well equipped with (basic) instruments needed for antenatal care such as a stethoscope or measuring tape and are the least likely to have guidelines on antenatal care available (MoHSW et al., 2016). Several studies conducted on women's perception on antenatal care have shown that long waiting times (Mahiti et al., 2015), poor communication about the return schedule for follow-up visits (Callaghan-Koru et al., 2016), and the low quality of care (Mahiti et al., 2015; Mubyazi et al., 2010; Tancred et al., 2016) are perceived as barriers to seek care (Mselle et al., 2013; Solnes Miltenburg et al., 2016).

In Tanzania, a substantial body of research has focused on reasons for low quality of antenatal care. These studies have demonstrated that shortage of staff and equipment, as well as the absence of clear guidelines and lack of knowledge on these guidelines among healthcare workers are important contributors to the low performance of essential interventions for antenatal care (Conrad et al., 2012; Gross et al., 2011; Mrisho et al., 2009; Nyamtema et al., 2012; Sarker et al., 2010; Van Pelt et al., 2020). However, some studies have found that even when necessary equipment to perform antenatal care-related tasks is available, some interventions were not provided (Solnes Miltenburg et al., 2017a; Nyamtema et al., 2012). Challenging working conditions for healthcare workers, such as high workload, poor infrastructure (e.g. lack of dependable electricity and water supply), low salaries, and delay in payment might also contribute to this low performance and motivation (Conrad et al., 2012; Gross et al., 2011; Solnes Miltenburg et al., 2017a; Mrisho et al., 2009).

The low adherence to antenatal care guidelines by the healthcare workers combined with the low attendance at antenatal care of pregnant women is worrisome: Women who do not attend the recommended four antenatal care visits are likely to miss essential information and interventions (Callaghan-Koru et al., 2016; Gross et al., 2012). Furthermore, women who do not initiate antenatal care in their first trimester, receive interventions later during the pregnancy that are then less effective, which increases the risks of adverse health outcomes (Callaghan-Koru et al., 2016; Gross et al., 2012). Research has shown that approximately

20% of severe maternal morbidity could be avoided by improving the quality of antenatal care, including more rigorous prevention and management of severe anaemia and the early detection and management of hypertensive disorders in pregnancy (Nyamtema et al., 2012).

Efforts to improve the quality of antenatal care in Tanzania

The commitment of the Tanzanian Ministry of Health, Community Development, Gender, Elderly and Children to improve the quality of antenatal care focuses on the improvement of service provision, for example by training healthcare workers and creating (more) efficient supply-chains for basic equipment (MoH, 2016). Despite these national efforts, enhancing antenatal care services and linking strategic plans to practice remains a challenge (MoHSW et al., 2013). The total government expenditure on health as a percentage of the total government expenditure remained stable around 10% since 1995, and does not meet the international target for low-income countries to spend 15% of their total budgets to health (Sachs, 2012).

The practical translation of the national strategic plans in Magu district was reflected in increased opportunities to follow in-service training for healthcare workers (MoHSW et al., 2016; MoHSW, 2013; Shoo et al., 2017), health facility upgrades (such as the provision of a water tank, the construction of a basic toilet and wooden furniture) (MoH, 2016), and rotation of healthcare workers to increase exposure to new work standards. In practice however, this meant that only a few healthcare workers were able to follow additional training, which temporarily increased the shortage of staff due to the traveling from the dispensary to the training location. These efforts were also implemented in an attempt to increase the work motivation of healthcare workers since inadequate working conditions may influence work motivation (Gross et al., 2011; Mrisho et al., 2009; Mubyazi et al., 2012; Nyamtema et al., 2012; Pembe et al., 2010) and less motivated healthcare workers may not provide the highest quality care (Ntoburi et al., 2008). To date, despite these efforts, overall performance of essential antenatal care interventions has not improved.

Digital health tools for quality of care improvement

Given that government expenditures are unlikely to increase, and that staff motivation to follow antenatal care guidelines in the context of the difficult working conditions seems to be the biggest challenge, innovative tools are needed that can improve adherence to antenatal care guidelines, increase workers' motivation, and subsequently improve service provision of antenatal care. Digital health tools may be promising tools in enabling better quality care in low- and middle-income countries (Blaya et al., 2010; Lewis et al., 2012; World Health Organization, 2011). Digital tools have shown promising results related to extending geographic access to care (Kahn et al., 2010; Lewis et al., 2012), improving communication between patients and health providers (Kahn et al., 2010; Lewis et al., 2012), and monitoring and increasing treatment

adherence (Blaya et al., 2010). However, digital health should not be perceived as the "silver bullet" to solve health systems challenges (Battle et al., 2015a; Eze et al., 2016), but rather as an enabler to reach better health outcomes for patients (Mechael et al., 2010).

With respect to maternal healthcare, research has shown that a specific type of application known as an electronic clinical decision and support system (hereafter: electronic decision aid) can improve healthcare workers' performance and adherence to guidelines (Adepoju et al., 2017; Agarwal et al., 2015; Horner et al., 2013; Oluoch et al., 2012), and enhance the motivation of healthcare workers (Adepoju et al., 2017). To date, most research conducted to electronic decision aids were not designed to be used by healthcare workers, but outside the health facility, targeting community health workers or other community users. Only few studies have examined the use of electronic decision aids by healthcare workers in low-resource settings (Benski et al., 2020). Information on perceived benefits of digital health tools by patients and providers in low-income countries in particular is limited (Mahiti et al., 2015; Tamrat & Kachnowski, 2012).

Gaps in the current literature

Although an electronic decision aid may be promising to help enhance motivation of healthcare workers (Adepoju et al., 2017), improve communication between patients and healthcare workers (Kahn et al., 2010; Lewis et al., 2012), and potentially improve the overall quality of care, more empirical and experimental studies are needed (Piette et al., 2012) to contribute to the evidence base on the impact of digital health tools on quality of care. To narrow this evidence gap, this dissertation aimed to assess whether an electronic decision aid might be a useful tool to improve the quality of antenatal care in Magu district, Tanzania. Since most research on perceptions and experiences with digital health tools have been conducted in high-income countries (Strayer et al., 2010; Wilson et al., 2007), there is a need to explore to what extent the introduction of digital health tools in maternal healthcare in low- and middle-income countries would be perceived as beneficial by healthcare workers and pregnant women. Yet, there is a need for research focussing on the development and implementation of digital health tools (including process evaluation) and the adoption of such tools in low- and middle-income countries. Having this understanding would help in optimising processes of developing, evaluating, and implementing digital health tools in low-and middle-income-countries, that are tailored to local needs and generate solutions and strategies to address local contextual factors that hinder implementation.

In an effort to contribute to building this evidence base, this dissertation aims to 1) gain insight into the perceptions and experiences of healthcare workers and pregnant women on antenatal care, 2) understand to what extent digital health tools are perceived as potentially

beneficial by healthcare workers and pregnant women for use during antenatal care consultations, 3) systematically evaluate the development and implementation process of an electronic decision aid to contribute to a greater understanding of factors that help a digital health tool to be meaningful for end-used, and 4) assess the impact of an electronic decision aid on workflow and quality of antenatal care.

The current project

This study was part of the Woman Centered Care Project of the African Woman Foundation, which had as the primary objective to improve maternal and neonatal health in Magu district (Solnes Miltenburg et al., 2019). This Dutch non-governmental organisation played an active role in Magu district from 2012 until 2017. The project conducted research activities in collaboration with local partners and established community groups to increase health-seeking behaviour and demand for quality services. Guided by the research activities, the Nurse Assistant App, an electronic decision aid was developed and implemented (Figure 5). The Nurse Assistant App is a tablet-based application, written in Kiswahili, to create a step-by-step guide for healthcare workers to systematically guide antenatal care consultations based on international recommendations and guidelines. The Nurse Assistant App consists of a comprehensive questionnaire to be filled in by a healthcare worker during the antenatal care consultation categorised into history taking, physical examination, laboratory tests, medication provision, and health education. After completing all steps, the Nurse Assistant App generates a clinical summary and provided the healthcare worker with advice on treatment, referral, and follow-up according to national and international evidence-based guidelines. The Woman Centered Care Project was active in thirteen dispensaries and in seven dispensaries the Nurse Assistant App was implemented.

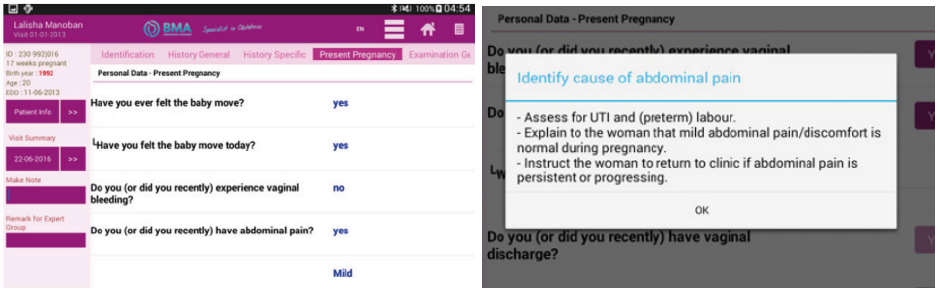

Figure 5: two screenshots of the Nurse Assistant App

Overview of the dissertation

This dissertation will present finding on the use of an electronic decision aid by healthcare workers during antenatal care service provision in Magu district, Tanzania. **Chapter two** explores how healthcare workers perceive the delivery of antenatal care in rural Tanzania and explores their opinion on working with an electronic decision aid. **Chapter three** presents the findings from interviews with pregnant women on their experiences with receiving antenatal care and their opinions on the use of an electronic decision aid during service provision. **Chapter four** evaluates the development and implementation of the Nurse Assistant App – an electronic decision aid aimed at improving the performance of healthcare workers providing antenatal care. This chapter uses Intervention Mapping to assess the theoretical and empirical foundation of the development and implementation process and to discuss the necessity of such an approach. **Chapter five** presents the findings from a mixed-methods study to assess how the Nurse Assistant App impacts care delivery and explores possible reasons in varied uptake of the Nurse Assistant App in practice. **Chapter six** provides a general discussion combining the results of the four studies presented in this dissertation combined with a reflection on the methodological choices and practical implications.

CHAPTER 2

"If you don't have enough equipment, you're not going to provide quality services": Healthcare workers' perceptions of improving the quality of antenatal care in rural Tanzania

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Abstract

To reduce maternal mortality in rural Tanzania, improving antenatal care remains an urgent priority. Therefore, the availability of qualified and motivated staff providing antenatal care is an essential precondition for high-quality maternal healthcare. However, it is still unclear which factors affect the performance of healthcare workers in this setting, and what they perceive is necessary to improve the quality of antenatal care. The aim of this research was to identify factors that could, according to healthcare workers, improve their performance and thereby improve the quality of antenatal care in rural Tanzania. Semi-structured in-depth interviews were conducted with sixteen healthcare workers of different education levels and from different health facilities in Magu district, Tanzania. Questions were asked about their experiences, opinions, and motivations related to the provision and quality of antenatal care, as well as their perceptions of the value of using an e-health application during consultations. Healthcare workers possess a positive attitude towards antenatal care and acknowledge its importance. Despite the existing social pressure from both colleagues and clients to perform well, this study identified differences in the quality of antenatal care provision and the level of motivation between healthcare workers. In addition, participants felt capable of providing antenatal care but complained about the poor working conditions (e.g. lack of electricity, equipment or medication), and indicated a need for more training and better supervision. Furthermore, when asked whether an electronic clinical decision and support system could improve the quality of antenatal care and their working conditions, healthcare workers expressed a positive attitude towards such a system. In order to change the status quo in antenatal care provision in Tanzania, attention should be paid to reducing the work challenges experienced by healthcare workers. This could be achieved through providing training opportunities, supportive leadership, and the improvement of physical working conditions, for example by the implementation of an electronic clinical decision and support system.

Introduction

Maternal mortality remains a major issue globally; 810 women die from pregnancy- or childbirth-related complications every day (World Health Organization, 2019). Of these deaths, 66% occur in sub-Saharan Africa (Alkema et al., 2016) and one of the countries with the highest maternal mortality ratio is Tanzania with 410 maternal deaths per 100 000 live births (World Health Organization et al., 2014). For nearly two decades, the United Nations have been focussing on the reduction of maternal mortality. In their Sustainable Development Goals (United Nations, 2019), the United Nations set the target to reduce the global maternal mortality ratio to less than 70 per 100 000 live births by 2030 (Alkema et al., 2016; World Health Organization, 2015). To achieve such a reduction in maternal and infant death rates, one key intervention is universal access to high-quality maternal healthcare services (Koblinsky et al., 2016; Miller et al., 2016; World Health Organization, 2019).

Antenatal care is a key component of maternal healthcare, as these services identify high-risk pregnancies, and provide an opportunity to prevent and manage (pregnancy-related) diseases, as well as to provide health education to women and their partners (Kerber et al., 2007; Lawn et al., 2010; World Health Organization, 2016) which contribute to maternal and child health. Antenatal care involves the provision of essential interventions such as tetanus toxoid immunisation, iron supplements, malaria prophylaxis, and deworming, as well as screening and treatment for complications, such as sexually transmitted infections (Lassi et al., 2014; MoH, 2016; Mrisho et al., 2009; World Health Organization et al., 2006). In Tanzania, attendance at antenatal care at least once is 96% and therefore offers an important entry point to other maternal healthcare services for a large proportion of women (Conrad et al., 2012). Receiving antenatal care has been also associated with uptake of facility-based childbirth which is still considered as the key intervention to reduce maternal mortality (Afnan-Holmes et al., 2015; Bishanga et al., 2018; Campbell & Graham, 2006; Conrad et al., 2012; Lassi et al., 2014; MoH, 2016; Mrisho et al., 2009).

Despite the importance of antenatal care for maternal and child health, research has shown that the quality of antenatal care in Tanzania is low (Solnes Miltenburg et al., 2017a; Nyamtema et al., 2012). In general, healthcare workers show poor adherence to antenatal care guidelines and low provision of essential interventions (Boller et al., 2003; Conrad et al., 2012; Gross et al., 2011; Solnes Miltenburg et al., 2017a; Mubyazi et al., 2012; Nyamtema et al., 2012; Pembe et al., 2010; Sarker et al., 2010). For example, fewer than 50% of health facilities that provide antenatal care offer a urine check, syphilis screening, or haemoglobin testing (MoH, 2016), and only 67% of women visiting antenatal care received information on danger signs (Conrad et al., 2012). Reasons for not performing these tasks include staff and equipment shortages, as well as a lack of knowledge on guidelines and procedures among healthcare workers (Conrad et al., 2012; Gross et al., 2011; Mrisho et al., 2009; Nyamtema et al., 2012;

Sarker et al., 2010). Some studies have found, however, that even when necessary equipment to perform antenatal care-related tasks is available, some interventions were not provided (Solnes Miltenburg et al., 2017a; Nyamtema et al., 2012). Researchers have posited that challenging work conditions for healthcare workers in Tanzania, such as a high workload, poor infrastructure and low incentives (Conrad et al., 2012; Gross et al., 2011; Lugina et al., 2001; Solnes Miltenburg et al., 2017a; Mrisho et al., 2009) might be underlying these findings. Since inadequate working conditions may influence work motivation (Gross et al., 2011; Mrisho et al., 2009; Mubyazi et al., 2012; Nyamtema et al., 2012; Pembe et al., 2010), and less motivated healthcare workers may not provide the highest quality care (Ntoburi et al., 2008), there is a need to investigate healthcare workers' perceptions of antenatal care provision, and in particular to understand their working conditions and motivation to provide antenatal care.

In Tanzania, several solutions have been implemented in an effort to increase the work motivation of healthcare workers. Among these are higher (financial) incentives, improved working conditions, better training opportunities, and supervision (Manzi et al., 2004; Mrisho et al., 2009; Mselle et al., 2013; Oka et al., 2018). Unfortunately, these strategies have not yet resulted in high-quality antenatal care. One innovative solution might be the implementation of an electronic clinical decision and support system (hereafter: electronic decision aid) in health facilities. Research has shown that this can improve healthcare workers' performance and adherence to guidelines (Adepoju et al., 2017; Agarwal et al., 2015; Horner et al., 2013; Oluoch et al., 2012) which results in better services for pregnant women. For example, a systematic review on electronic decision aids in sub-Saharan Africa showed, despite several health system barriers, that the implementation of an electronic decision aid led to increased healthcare worker motivation, better adherence to evidence-based guidelines, and improved training opportunities (Adepoju et al., 2017). Moreover, a pilot study in Tanzania and Ghana implementing an electronic decision aid revealed high uptake during antenatal care consultations and positive attitudes of healthcare workers towards the use of an electronic decision aid (Sukums et al., 2014).

Although an electronic decision aid may be one promising tool to enhance the motivation of the health workforce providing antenatal care, for such a tool to enable outcomes there remains a need to first understand the determinants that influence healthcare workers' performance of essential antenatal care interventions as well as their usage of electronic decision aids. Changing the work motivation of healthcare workers – and thereby, ultimately the quality of the services they provide - requires understanding what influences it, i.e. the determinants (Kok et al., 2016). In this study, the Theory of Planned Behaviour is used as a framework to understand the behaviour of healthcare workers providing antenatal care services in Tanzania. The Theory of Planned Behaviour has been successfully applied to understand many types of health behaviour and provide insight into the determinants of

behaviour (Ajzen, 1991, 2011). The theory predicts that behaviour is influenced primarily by the motivation or intention to perform the behaviour, which in turn is influenced by three determinants: attitude, subjective norms, and perceived behaviour control. Attitude refers to the positive or negative evaluation of performing the behaviour. Subjective norm means the perceived social pressure to perform (or not perform) the behaviour. Finally, perceived behaviour control is the perceived capability to perform the behaviour (Ajzen, 1991, 2011). The aim of this research was to identify perceptions of healthcare workers about antenatal care in rural Tanzania, and the factors that influence their performance. Specifically, sixteen semi-structured in-depth interviews were conducted with healthcare workers responsible for antenatal care about the quality of their provided services and focused on their attitudes, subjective norms, and perceived behavioural control; further, healthcare workers' motivation and their opinions on the utility of an electronic decision aid were explored.

Methods

Study design

Data for this research were collected utilizing a qualitative study design, specifically, individual semi-structured in-depth interviews. The aim was to gain insights into the perceptions and opinions of healthcare workers providing antenatal care.

Study site

This study took place in Magu district, Mwanza Region, which is part of the Lake Zone of Tanzania, one of the regions in Tanzania where maternal mortality is highest (Shoo et al., 2017). The Tanzania Demographic and Health Survey report of 2016, shows that the Lake Zone has the lowest percentage of assistance at birth by a skilled birth provider (MoH, 2016; MoH et al., 2016) as well as the lowest coverage of quality antenatal care in the country (MoH et al., 2016).

This study was part of the *Woman Centered Care Project*, a project run by the African Woman Foundation from 2013 until 2016. The project aimed to improve maternal healthcare in Magu district through three main activities: community groups to raise awareness on maternal health issues and increase health-seeking behaviour (Solnes Miltenburg et al., 2019); upgrading health facilities and providing training to healthcare workers; and developing and implementing an electronic decision aid (the Nurse Assistant App) to enhance antenatal care services in rural dispensaries. In Magu district, reproductive health services are provided at different levels of care ranging from the district-level dispensaries providing basic healthcare services (26 scattered over the district) to tertiary care offered at the district hospital (one in the district town). In rural areas, dispensaries are the main access points for reproductive health services, including antenatal care. They serve as first-level primary healthcare and

provide services mainly on an outpatient basis. For this study, thirteen dispensaries were selected using purposive sampling based on different geographic factors to represent the district as adequately as possible. The current study was conducted among healthcare workers of six of these dispensaries that were allocated to be control facilities. (Further information on the Woman Centered Care Project and an overview of its published papers; see supplemental material of this chapter)

Sampling

Antenatal care is provided by healthcare workers of different disciplines and seniority levels, e.g., clinical officer, assistant clinical officer, nurse midwife, enrolled nurse, and medical attendant. Although medical attendants are not officially trained to provide antenatal care services, the circumstances in the dispensary require them to provide this care. Therefore, we decided to apply purposive sampling to include healthcare workers from all types of disciplines and seniority levels. All healthcare workers responsible for providing antenatal care in their health facility were eligible for inclusion and were approached at their health facility. In total, from the healthcare workers who offered to volunteer in the research, sixteen healthcare workers were selected, in which care was taken to include as many differences as possible. The healthcare workers were invited for the interview at their health facility. Among them were five clinical officers, four enrolled nurses, and seven medical attendants.

Data collection

An interview guide was developed, based on the determinants of the Theory of Planned Behaviour (Ajzen, 1991, 2011) and tailored to the local setting. To maximise content validity, the researchers discussed the guide with the team members of the Woman Centered Care Project while taking the context of the data collection into account and made sure to base the phrasing of the Theory of Planned Behaviour questions on the original recommendations by Ajzen (1991, 2011). The interview guide (see Appendix A of this chapter) was further adapted during the data collection using an iterative approach to acknowledge healthcare workers' input (ensuring ecological validity).

Healthcare workers were asked about their attitudes towards antenatal care services, perceptions of social norms towards antenatal care in their social environment (e.g. by other healthcare workers), and opinions on the level of control they experienced in their jobs, as well as their job satisfaction. Moreover, to probe whether an electronic decision aid could contribute to improvements in both the quality of care as well as healthcare workers' motivation and performance, questions using an electronic decision aid during antenatal care were included. Example questions are: What do you think about providing antenatal care? Do you feel you had enough training to provide antenatal care? Do you like working at this facility?

The interviews were conducted in March and April 2016 in Kiswahili and the regional language Sukuma. English translations were provided by a translator who was present with the researcher conducting the interview. The translator and researcher are extensively trained and experienced in conducting qualitative research. Prior to the commencement of data collection, interview skills were practised and refreshed during training meetings with the principal researcher. Interviews took approximately 30 minutes and were conducted in a private, quiet area in or around the health facility. All interviews were tape-recorded with the consent of the participants and transcribed verbatim using *F5transcription v3 software*. Field notes taken by the researcher were informally discussed with the translator at the end of each data collection day and were used to supplement the transcripts. Any discrepancies or disagreements in the field notes or transcripts were discussed in a follow-up meeting with the principal researcher.

Data analysis

Analysis was performed by the principal researcher using MAXQDA 12 software, employing a directed content analysis approach (Hsieh & Shannon, 2005). After reading all interviews once, the text was coded and revealed prior defined categories of the Theory of Planned Behaviour, as well as newly formed categories that emerged from the text. After this, the categories were checked by reading the interviews for a second time and grouped into five themes whereby the categories consisting of variables from the Theory of Planned Behaviour (attitude towards antenatal care services; social norm; perceived behaviour control) were combined into one theme called psychosocial variables. To maximise inter-rater reliability, part of the analysis was repeated by one of the team members. Inter-rater reliability refers to the interpretation of data and the likelihood that the same themes emerge from similar data (Green & Thorogood, 2011). Therefore, any discrepancies in codes and categories were discussed until consensus was reached. The three final themes - psychosocial variables, inhibiting factors to provide antenatal care, and opinions on an electronic decision aid - will be discussed separately in the result section below.

Ethical considerations

Ethical clearance for this study was obtained from the National Institute of Medical Research in Tanzania (MR/53/100/103-244-245-349-399) and Maastricht University in the Netherlands (OZL_188_10_02_2018_S32). A research permit was granted by the Tanzanian Commission for Science and Technology (No.2015-227-NA-2013-32). This study was discussed and approved by the local (medical) authorities and conducted in collaboration with the district coordinator for Reproductive and Child Health. Verbal information about the purpose of the study and the content of the interview was provided to the respondents before written informed consent was obtained from all healthcare workers. Healthcare workers were informed about their right to withdraw at any time. Data were only accessible to the research team.

Results

Theme 1: Psychosocial factors

Attitude towards delivering antenatal care services

All healthcare workers expressed a positive attitude toward providing antenatal care. They stated that they like helping pregnant women and their unborn child by checking their health status and providing them with the required services. In general, healthcare workers indicated that the provision of antenatal care services is important, explaining that antenatal care reduces pregnancy-related problems and that the provided services reduce maternal and child mortality rates.

Some participants pointed out that the health education provided during antenatal care is important because they felt it increases women's awareness of the possible danger signs during pregnancy. Others also stated that health education helps pregnant women understand the advantages of a facility birth:

> *"First you have a health education on how to manage your pregnancy and preparations during pregnancy* […] *The importance for antenatal care visits, it helps the mother to understand the advantage of attending to the health facility* (for delivery) *and counselling provided by the medical personnel which is very necessary."* (Clinical Officer, Age: 32, Male)

Besides providing health education, most healthcare workers mentioned other important components of antenatal care, such as HIV testing, foetal heart rate monitoring, blood pressure measurement, abdominal examination, urine testing, and medication provision. Although a few participants viewed certain components as more important than others, all healthcare workers indicated they felt that all aspects of antenatal care are important.

Social norms

All healthcare workers interviewed expressed that they care about the opinions of their co-workers and supervisors about their performance. However, the majority of the participants had difficulties in providing reasons why they felt this was important. The few who were able to do so explained that the quality of their work reflects on their colleagues and the whole facility. One clinical officer stated that it is important to reduce the number of complaints from pregnant women and to satisfy colleagues with his performance. He further stated that his co-workers come to him for help when they face challenges, which gave him the confirmation that they must be content with his manner of providing antenatal care services. In addition, all healthcare workers expressed that it is important that their clients are satisfied with the care provided but struggled to cite reasons for this. Instead, they mentioned things that contribute to client satisfaction, for example receiving the service they expect, receiving the service for free, providing weight measurement of the new-born, and being provided

with a *clean delivery pack* (in Tanzania, women are expected to bring their equipment to the health facility when they deliver). The *clean delivery pack* contains the basic equipment required to conduct a safe delivery and is provided to women attending antenatal care as part of a campaign supported by the Ministry of Health to reduce the financial burden for women. One healthcare worker explained that it is important that pregnant women are satisfied with antenatal care services because without clients she would not have a job. Another one stated that the satisfaction of his clients encourages him to do his work well, and he stated that he believes that women would not come back to the facility if poor quality care was provided. One clinical officer gauged the quality of antenatal care services by her clients' satisfaction:

> *"And I see that they are happy because if you do something good to somebody, and somebody says thank you for your services, means that they have appreciated your services."* (Clinical Officer, Age: 28, Male)

Interestingly, although they all indicated their own work should be of good quality, the healthcare workers were not unanimously positive about the quality of antenatal care provided by their co-workers. About half of them expressed that the service of their colleagues was the same, or just as good as the service they provide themselves. Several explained that this is because they all use the same guidelines and two participants indicated that they work as a team and assist each other. However, some healthcare workers commented on differences in the quality of antenatal care provided by their colleagues. Most of them expressed that these differences were due to the level of education these colleagues received, which often results in lack of skills, knowledge, and experience. For example, one clinical officer asserted that medical attendants do not receive enough antenatal care skills training:

> *"Eh they are working but these healthcare workers who are available here they don't have much experience and knowledge on antenatal care* […] *so they are not trained in antenatal care."* (Clinical Officer, Age: 58, Male)

In addition to lack of experience and knowledge, shortage of healthcare workers as well as the heavy workload was cited as another factor influencing provider behaviour:

> "*If you don't have enough equipment, you're not going to provide the quality service to the pregnant mama* […] *So the shortage of healthcare workers and also lack of working equipment are the main barriers* […] *Because she won't have enough training, it affects the quality of antenatal care to the pregnant mama, because she can do something wrong because she doesn't know maybe."* (Medical Attendant, Age: 52, Female)

Furthermore, one healthcare worker stated that another potential reason for poorer quality of antenatal care services is that specialised healthcare workers are not motivated to work in a department other than that of their specialisation, and that they refuse to provide certain services. She gave an example of seeing incomplete antenatal care records when clients came to give birth at the health facility. It was noted that co-workers failed to record important medical information, despite her instructions to do so, sometimes leading to complications that could have been prevented:

> *"*shaking her head (laughing) *It is out of my control. Other healthcare workers they are not working good* […] *Personal behaviour so cannot be able to changing that* (sic) *because I may ask that why don't you do this one, and again they don't fill this one, and again then I repeat it - so it's hard* […]. *They are not motivated to provide such services."* (Enrolled Nurse, Age: 29, Female)

Perceived behaviour control

The majority of participants expressed the need for additional training, supervision, and leadership; most felt that they had not received enough education to provide good quality antenatal care:

> *"I don't have (enough education). Eh I don't have because this information they change day after day so they need to visit seminar to up to date* (sic) *to get new things. Yes, that's why the quality is decreased."* (Clinical Officer, Age: 51, Male)

In general, healthcare workers were positive about the possibility of receiving more leadership and supervision; importantly, some of them thought that it would have a positive effect on the quality of care they provide. One participant noted they would feel more capable of doing the job if more experienced colleagues shared their experience and knowledge with them. Conversely, several healthcare workers expressed that they already receive enough guidance. The participants furthermore revealed different experiences about the level of supervision they received. For example, one medical attendant explained that the books at the facility provided her with guidance, whereas others indicated that they received sufficient leadership and supervision from the District Medical Office, and the clinical officers in charge. Some participants mentioned that supervision and guidance are particularly needed when doing rotations to other departments within a health dispensary. Rotation between departments of one dispensary is recommended by the District Medical Office to upgrade the different competencies needed to provide all healthcare services the dispensary offers. Some dispensaries rotate weekly while others rotate monthly and some infrequently do rotations. This healthcare worker explained that she and her colleagues rotate regularly and that this rotation system

teaches her how to manage all departments, and that she learns from experience:

> *"Yes, it helps me because I learn to work in every place and to manage all the departments maybe in the ward taking measurements* (sic). *No one is there to guide me or to show me because I just do due to the experience (sic)* […]*."*
> (Medical Attendant, Age: 44, Female)

Theme 2: Inhibiting factors to provide antenatal care

During the interviews, healthcare workers were asked to rate the quality of antenatal care they provide at the health facility on a scale from 0 to 100, with 0 being the lowest and 100 the highest. In general, the service was rated as being of high quality. The majority of the participants rated their performance as 70 or higher, and two outliers scored themselves as below 50 and over 90. Although they rated their performance as adequate, the majority of the healthcare workers elaborated further by pointing out barriers to high-quality antenatal care. First, all participants mentioned the lack of medical materials and equipment as an apparent barrier; second, half of them expressed a high workload as a result of insufficient medical staff; and last, three respondents commented on the infrastructure of the buildings which they deemed inadequate. Some participants came up with solutions to these barriers. As an example, pregnant women are informed when HIV tests are available again after being out of stock for some time and are invited for an extra antenatal care visit to get tested. To provide additional information, Table 1 describes these barriers in more detail, complemented with improvements suggested by the healthcare workers.

Table 1: Mentioned barriers in providing antenatal care

Barrier	Explanations of healthcare workers	Improvements suggested by healthcare workers
Lack of equipment	• Required items: an ultrasound machine; diagnostics (urine dipsticks, malaria, HIV and syphilis rapid tests); medication (folic acid, antimalarial, deworming) and the antenatal care card. • Caused by malfunctioning ordering system. Missing items and the time span during which these items were out of stock varied between health facilities and varied per item.	• Equipment, materials and medication should be available at all times. • Look for donors to receive equipment to increase healthcare workers' confidence in their ability to provide antenatal care services. • Government has to pay its debt to the Medical Stores Department (the department of the Ministry of Health responsible for distribution of medicines and supplies) • District authorities need to make a plan to supply the facilities with antenatal care equipment.
High workload	• Caused by insufficient medical staff and high patient load (up to 70 a day).	• More staff • Rotation and feedback sessions to increase knowledge • More training
Infrastructure	• Facilities are in a poor condition and too small to accommodate all clients: no toilets, floods due to heavy rains, strong scent of bats, lack of (running) water, lack of or unstable electricity.	• Water tank • Ambulance

Theme 3: Opinions on an electronic decision aid

During the interviews, an explanation was provided to participants about what an electronic decision aid is and how it could be used during antenatal service delivery. In this project an electronic decision aid was developed that runs on a tablet which was shown and shortly demonstrated to the participants in order to assist them to build their opinions. All but one of the healthcare workers expressed a positive attitude towards the use of an electronic decision aid, stating: "It's nice", "It's a good system" or "I really like it, I like it". The healthcare worker who did not express a positive attitude felt unable to use the program due to her eye problems. The majority thought it would be a good tool to use during antenatal care, and some of them added that it is better than their current paper-based documentation system. One clinical officer made an appeal to receive an electronic decision aid and expressed the wish to provide all health facilities in Tanzania with it in order to level the health situation in Tanzania with other high-income countries. All of them expressed that they would use an electronic decision aid if available, and were open to learning how to use it:

> *"Yea it is a good system […] I am capable to learn and even the others also they're capable to learn."* (Enrolled Nurse, Age: 40, Female)

Most healthcare workers mentioned that the ability to store patient information on a computer/tablet is the biggest advantage. In Tanzania, pregnant women are responsible for keeping their paper-based antenatal care card, which is used for documentation and contains the information relevant to their pregnancy. The woman brings this card to their antenatal care visit in the clinic. Participants explained that antenatal care cards sometimes get lost and therefore liked the possibility of the electronic decision aid to store all patient information digitally. This would allow them to quickly retrieve information about specific clients during antenatal care visits and reduce the risk of losing information:

> *"Yea so I like to using that* (sic) […] *if a pregnant woman has lost the antenatal care card it means it's going to be very difficult for them to found out previous information or previous records so if they're having another kind of or another means of keeping records rather than antenatal care card it's going to be very good ."* (Clinical Officer, Age: 28, Male)

A few participants also indicated that an electronic decision aid could improve their performance and the quality of care, as the aid prompts healthcare workers to ask additional questions to the patient, conduct examinations, and gives guidance on complication management or referrals. One healthcare worker mentioned the benefit of saving time with the registration of clients.

Critical remarks on the implementation of electronic decision aid were also discussed. The most commonly mentioned barrier was the lack of electricity, which hinders the feasibility of using an electronic decision aid when it needs to be charged. In addition, some of the participants were concerned with theft or damaging of the electronic device. One healthcare worker was concerned about the risk of running out of battery while providing antenatal care which would result in asking clients to come back the next day. Some participants mentioned that they do not know how to operate the tool and that not understanding it properly could cause problems. Nevertheless, several participants expressed that these doubts about the skills for and knowledge about using an electronic decision aid would be removed if proper training would be provided. Other participants either stated that they could not see any disadvantages, or that they were unable to assess disadvantages because they had never really used an electronic decision aid.

Discussion

The aim of this study was to investigate healthcare workers' perceptions of the quality of antenatal care services and barriers to providing high-quality antenatal care in rural Tanzania. In this light, the initial feasibility of implementing an electronic decision aid during antenatal care was also explored. From the semi-structured in-depth interviews conducted with healthcare workers from different education levels and with different positions, it was found that the performance of healthcare workers is influenced by several determinants.

Results indicate that the positive attitude of healthcare workers towards performing antenatal care, as well as their beliefs of its importance, seemingly contradicts their actual behaviour during antenatal care provision. Consistent with previous studies, healthcare workers acknowledge that avoiding important components of antenatal care occurs due to various factors, such as lack of materials and shortages of skilled healthcare workers (Conrad et al., 2012; Solnes Miltenburg et al., 2017a; Nyamtema et al., 2012; Sarker et al., 2010). Having a positive attitude towards certain behaviours positively influences the likelihood of performing that behaviour (Ajzen, 1991). However, these findings illustrate that knowledge and a positive attitude alone may not be sufficient to enable behaviour change, despite being important determinants in delivering high-quality antenatal care (Bartholomew Eldredge et al., 2016)).

Healthcare workers expressed the importance of being helpful to colleagues and performing well on the job, supporting overall performance of the healthcare team. Participants often stated that some of the differences in quality of care provided can be attributed to discrepancies in levels of knowledge, skills, experience, and motivation of different healthcare workers. To a certain extent, healthcare workers felt obliged to perform well because their actions

might be evaluated by co-workers, indicating that their motivation was externally driven. However, not all motivation was externally driven, since several healthcare workers also expressed varying levels of perceived responsibility for service provision and accountability for pregnant women's health outcomes.

Although some participants in this study attributed differences in the quality of provided care primarily to differences in healthcare workers' level of education and experience, this might not be the full explanation. For example, one Tanzanian study among healthcare worker performance found that medical attendants, the lowest cadre of health professionals, were providing more antenatal care services than their highly educated colleagues (Pembe et al., 2010). Therefore, it is more likely that this perceived variety in the quality of care is related to healthcare workers' motivation. Some of the participants in the current research explained that they were obliged to provide antenatal care services despite their deficiency in required knowledge and skills (e.g., they were specialised in a different medical field), which led to a lack of motivation to provide these unfamiliar services. Consistent with other studies, this indicates a critical shortage of qualified staff trained specifically to provide maternal health services in rural health facilities in Tanzania (Gross et al., 2011; Mselle et al., 2013; Nyamtema et al., 2012; Plotkin et al., 2012). Providing services without the required knowledge and skills can lead to frustration or even less motivation to perform (Feringa et al., 2018; Mathauer & Imhoff, 2006), which in turn may negatively affect the quality of care and ultimately increase pregnant women's and new-borns' health risks.

Moreover, previous studies have shown that there is a relationship between poor quality of care and the poor infrastructure of health facilities (Conrad et al., 2012; Gross et al., 2011; Solnes Miltenburg et al., 2017a; Mrisho et al., 2009; Nyamtema et al., 2012; Sarker et al., 2010) in rural Sub-Saharan Africa, which influence healthcare workers' motivation (Gross et al., 2011; Mosadeghrad, 2014; Mrisho et al., 2009). Being faced on a daily basis with challenges such as missing equipment and supplies, a high workload, the lack of reliable water, housing facilities, and electricity, can lead to a decrease in motivation and morale (Gross et al., 2011; Mosadeghrad, 2014; Mrisho et al., 2009; Penfold et al., 2013). In the current research, healthcare workers also mentioned these challenges as barriers to performing adequate antenatal care and their perception that these conditions may increase health risks for both themselves as well as their clients.

Interestingly, in the current study, participants reported that they valued their clients' satisfaction with the services they provided. This finding contradicts previous studies on (pregnant) women's experiences with maternal healthcare in Tanzania, which have reported negative encounters of clients with healthcare workers, including experiencing humiliation, sanctions, and abusive treatment (Bishanga et al., 2019; Kruk et al., 2018; Mrisho et al., 2009; Mselle et al., 2013; Solnes Miltenburg et al., 2018). Although the participants in the current

study indicated they answered truthfully, one explanation of this contrast between the current findings and the existing literature could be that the healthcare workers in the current study under-reported their negative attitudes and behaviours toward their clients, and responded in a socially desirable manner when asked about the pregnant women's satisfaction with their work. Given that some of the participants also mentioned they experienced pressure from their colleagues to perform well, this hesitation to report their true opinion might have been shaped by fear for criticism about their performance.

Despite barriers, it is interesting that most healthcare workers felt able to provide good quality antenatal care and rated their service as being of high quality. The majority of the participants attributed the challenges they faced to external factors, which they did not feel capable of solving, and reported waiting for governmental funds to resolve the problems. The findings also indicate that on the one hand, healthcare workers seem to have been able to adjust to the challenging working conditions. On the other hand, they expressed the need for change: healthcare workers asked for additional training opportunities, especially for medical attendants (the lowest cadre of health professionals), and additional supervision from the District Medical Office. Lack of training opportunities has been identified as a barrier in other studies on antenatal care practices in Tanzania (Gross et al., 2011; Manongi et al., 2006) in which healthcare workers expressed feelings of frustration because of the challenging working conditions and a lack of feedback, promotion opportunities, training, and supportive supervision – which according to them resulted in low quality of care (Manongi et al., 2006). In three other studies conducted in Tanzania, healthcare workers acknowledged their performance sometimes suffered and proposed to receive more education and better supervision to solve this problem of the low quality of care (Bremnes et al., 2018; Mkoka et al., 2015; Mubyazi et al., 2012). Overall, the interviews in this study show that healthcare workers may have requested education and supervision, did not receive it, and may not have felt in position of power to change this situation. Previous research has demonstrated that the lack of control and lack of supportive management reduces work motivation or performance of healthcare workers (Manzi et al., 2004; Mosadeghrad, 2014; Tibandebage et al., 2016). This lack of empowerment, which relates to healthcare workers' motivation and feeling of autonomy, may result in staff who perceive themselves as not capable of providing safe and good quality care (Harrowing & Mill, 2010; Lugina et al., 2002; Tibandebage et al., 2016). In this respect, the positive attitude of the healthcare workers towards electronic decision aid is promising, given prior research suggesting that use of a decision aid increases the motivation of staff to work under difficult conditions and provides opportunities for self-improvement (Agarwal et al., 2015; Thondoo et al., 2015). Furthermore, research demonstrates that the use of an electronic decision aid may help with providing correct guidelines, monitoring progress and condition of clients, as well as assisting inadequately skilled staff to comply with treatment guidelines (Agarwal et al., 2015).

In this study, healthcare workers identified more advantages than disadvantages of working with an electronic decision aid. It seems that an electronic decision aid enables in particular the less experienced healthcare workers to provide good quality care because of its structured guidance during the provision of antenatal care. An electronic decision aid has the capacity to guide healthcare workers in detecting high-risk pregnancies and assist in decision making during complications. Another perceived advantage is the ability to safely store clients' information, which participants indicated would be a large improvement compared to the current situation. These findings suggest that healthcare workers' attitude towards an electronic decision aid and the recognised advantages of its utilisation in antenatal care provision, may positively influence their decision to use it if it would be available to them. In addition, the healthcare workers' perceived ease to learn how to use an electronic decision aid may facilitate its implementation during antenatal care visits.

This study has some limitations that need to be taken into consideration. First, as healthcare workers providing antenatal care in rural Tanzania were interviewed, the findings may not be generalizable to urban settings or more well-resourced settings. Although the findings are likely to be similar in other rural areas, generalisation to all of Tanzania or low-income countries must be made with caution due to the narrow geographical scope of the study. Second, this study is part of the *Woman Centered Care Project,* which has made donations of equipment and materials to the health facilities of the participants. This might have increased the chance of socially desirable answers. Third, although the neutrality of the research was emphasised, it is likely participants were biased to self-rating their performance of antenatal care. Furthermore, the pilot implementation of an electronic decision aid at neighbouring health facilities might have influenced participants' opinions regarding such tools. Despite these limitations, this study reveals valuable insights into several determinants that influence the behaviour of healthcare workers during antenatal care provision, which help in understanding what healthcare workers might need to provide antenatal care in a different way, and what solutions might be feasible in the rural Tanzanian context.

The current findings suggest that the focus for improving antenatal care services in Magu district, Tanzania should be on resolving the work challenges experienced by healthcare workers. This could be attained through training opportunities, supportive leadership, improvement of the physical work environment, and the implementation of an electronic decision aid. As a result, this might also lead to increased work motivation and empowerment of healthcare workers. Training opportunities do not only have the potential to enhance the skills of healthcare workers (Nyamtema et al., 2012) but will also increase feelings of control and responsibility (Manzi et al., 2004; Mkoka et al., 2015; Prytherch et al., 2012). Working conditions have to be improved in order to reduce feelings of frustration and to trigger feelings of recognition and confidence (Manzi et al., 2004; Mubyazi et al., 2012). Practicing antenatal care with an electronic decision aid improves healthcare workers' performance

and adherence to guidelines (Adepoju et al., 2017; Agarwal et al., 2015; Horner et al., 2013; Oluoch et al., 2012) which have the potential to enhance their motivation. Moreover, through the use of an electronic decision aid, healthcare workers may be able to assess and reflect on their knowledge and performance. These actions, combined with supportive leadership, could empower healthcare workers to improve antenatal care (Tibandebage et al., 2016).

Conclusion

The results of the current research indicate that healthcare workers in rural Tanzania are willing to provide good quality antenatal care, but that several inhibiting factors prevent them from providing all essential antenatal care interventions. Therefore, attention should be paid to reducing the work challenges experienced by healthcare workers by providing training opportunities, supportive leadership, and improving physical working conditions, for example by the implementation of an electronic clinical decision and support system.

Appendix A – Interview guide in-depth interviews

Used in the health facilities which provided antenatal care (ANC) without the electronic decision aid

Introduction	The translator introduces him/herself, the research and the researcher The participant signs the informed consent form
Themes	**Questions**
Attitude ANC	How many years have you been providing ANC? What do think about providing ANC? • What are some of the reasons for why you like providing ANC? • What don't you like about providing ANC?
Importance of ANC	How important do you think is ANC? • Why? • What is in your opinion the most important part of ANC and why? • Is there any part of ANC that is less/not really important? How does ANC improve the health of pregnant women? • What do you think improves the health of pregnant women when she is provided with ANC? What are the reasons for the pregnant women to come for ANC?
Quality ANC	On a scale from 0-100, 0 being the lowest and 100 being the highest, how would you rate the ANC you provide? • What is it that you do that makes you provide this quality of ANC?
Barriers (perceived behavioural control)	What do you think are the main barriers to provide better ANC? • What makes you think that? • What kind of supplies are you missing the most? • Where do you get your water from? • Why do you think women come late in their pregnancy? • How could these barriers be minimized? • What do you think about male involvement? • What do you think of your workload at this facility? (# of pregnant mamas and other medical services)
Improvement	How can this be improved?
Social norm Quality others	What do you think about the quality of ANC the other HWs at your facility provide? • Is there a difference between the quality of ANC you and your colleagues provide? • How do your colleagues feel about that?
Co-worker satisfaction	Do you discuss ANC with each other? • Is it important to you that other HCWs at your facility are satisfied with the ANC you provide? Why? Is there a difference between the ANC provided at this facility and the hospital? • Why do you refer someone for ANC to the hospital?
Client satisfaction	What do the pregnant mamas think of the ANC in your facility? • What do they like? • Is it important to you that they are satisfied with the ANC at this facility? • What would they want to see improved?

Appendix A continued.

Themes	Questions
Knowledge, skills, leadership, supervision	Do you feel you had enough training to provide ANC? Do you feel like you have enough leadership? Do you feel like you have supervision? • Does that affect the quality of ANC that you are providing? How?
Job Satisfaction	Do you like working at this facility? • What do you like about it? • What don't you like about it? • Have you chosen to work at this facility or have you been assigned to it?
Experience with ANC card	How does the ANC card help you in providing ANC? • How does it help you in decision making? • Do you think it is important to document ANC visits? • What do you think about the availability of the ANC cards? • What do the pregnant mamas think about the ANC cards? • Is there something missing? • Would you like to change something about it? And what?
Attitude mHealth	Are there any other guidelines available? • Do you have them at work? • Do you use them? • Do you find them helpful? What would you think of having the guidelines on your phone or a tablet? In some clinics, healthcare workers providing ANC use mHealth tools such as a phone, tablet or laptop to assist and document the visits. • Would you like to use such a tool? • What do you like about it? • What are the disadvantages of using such a tool? • How difficult would be to use such a tool in this facility?
End Questions	• What do you think is the most important change that can be done to help you to make the quality of ANC better? • How would you change this? Would you like to say or add anything that we have not talked about?

Supplemental material

The Woman Centered Care Project was a collaborative project of the African Woman Foundation, a Dutch non-governmental organisation focused on women's health and empowerment projects in sub-Saharan Africa, and Crop Marketing Bureau, a Tanzanian organisation aimed at empowering small-scale farmers by using Information and Communication Technologies (ICT). The Project officially started with active participation from both community and district-level stakeholders in 2013 and ended in 2016. The project's primary aim was to improve maternal healthcare in Magu district through three main activities:

- Community group activities to increase healthcare seeking behaviour and demand for quality services (Solnes Miltenburg et al., 2019).
- Upgrading health facilities and providing training to healthcare workers to enable health facilities to provide appropriate, effective care.
- Developing and implementing a tablet based electronic clinical decision and support system (the Nurse Assistant App) to enhance service delivery in rural dispensaries.

The Nurse Assistant App has been conceptualised and developed by the African Woman Foundation in collaboration with a renowned Dutch health technology partner, ICT healthcare Technology Solutions (formerly Buro Medische Automatisering B.V.), as part of an integrated approach with the primary aim to improve efficiency and effectiveness of antenatal care service in low-resource settings at the grassroots level. The Nurse Assistant App is developed to assist healthcare workers during antenatal care provision by guiding them step by step through all essential interventions of each antenatal care visit and providing tailored advice or alarm bells when needed (in this case appropriate follow up actions are suggested).

The team of the Woman Centered Care Project performed a pilot study, representing the first step of implementation of the Nurse Assistant App in a rural area in Tanzania with the aim to evaluate acceptability and utility among healthcare workers and pregnant women in Magu district as well as evaluate the impact of the App on the quality of antenatal care. The pilot study was conducted from February 2016 until September 2016 at thirteen dispensaries, divided over seven wards of Magu district, selected through purposive sampling based on different geographic factors to represent the district as adequately as possible. The included dispensaries were divided into seven intervention facilities, where the App was implemented, and six control facilities, to establish the baseline for comparison with the intervention facilities. Selection for intervention and control facilities was done based on the availability of electricity. Since the Project was an active partner in the community and regular meetings with the ward leaders were conducted, local

stakeholders were aware that they needed to make sure a facility has electricity in order for them to receive the Nurse Assistant App. This approach was used to make sure that local leadership was continuously engaged and mobilised in their collaboration with the Project. For more information, please see one of the following publications: (Solnes Miltenburg et al., 2016, 2017a, 2017b, 2019; Vermeulen et al., 2016)

CHAPTER 3

Pregnant women's perceptions of antenatal care and utilisation of digital health tools in Magu district, Tanzania: A qualitative study

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Abstract

Antenatal care is essential to promote maternal health. Much research in recent years has focused on barriers women face to attend antenatal care. Improving the quality is seen as a precondition for better attendance. Digital health tools are seen as a promising instrument to increase the quality of healthcare. It is less clear to what extent the use of digital health tools in low- and middle-income counties would be perceived as beneficial by end-users. The aim of this research was to explore women's experiences with antenatal care, and whether digital health tools would change their perceptions of quality of care. This qualitative research consisted of thematic analyses on data from semi-structured in-depth interviews with nineteen randomly selected pregnant women from six different dispensaries in Magu district. Findings showed that the pregnant women are motivated to attend antenatal care and are grateful for the services received. However, they also articulated a need for improvements in antenatal care services such as availability of diagnostic tests and more interactions with healthcare workers. Participants indicated that a digital health tool could help in storing patient files and improving communication with health workers. Our results indicate that pregnant women are positive about the use of digital health tools during antenatal care but that the implementation of such a tool should be implemented in parallel to structural service delivery improvements, such as testing availability.

Introduction

It is widely recognised that antenatal care (ANC) is a key intervention to promote maternal health (Callaghan-Koru et al., 2016; Kerber et al., 2007; Mrisho et al., 2009; World Health Organization, 2016). In low- and middle-income countries where maternal mortality rates remain high, ANC contains crucial components that can help to reduce maternal and infant morbidity and mortality (Callaghan-Koru et al., 2016; Kerber et al., 2007; Mrisho et al., 2009; World Health Organization, 2016) and plays an important role in detecting high-risk pregnancies and managing pregnancy-related complications (Finlayson & Downe, 2013; Gupta et al., 2014; Mrisho et al., 2009). In addition, women who receive ANC are more likely to deliver with a skilled birth attendant (Gross et al., 2012; Gupta et al., 2014; Mrisho et al., 2009; Bishanga et al., 2018), which is considered to be the most effective intervention in reducing maternal mortality (Campbell et al., 2016; MoHSW et al., 2013).

In 2001, the World Health Organization recommended a minimum of four ANC consultations for all pregnant women, of which the initial visit should occur in the first trimester of pregnancy. These visits consist of several preventive interventions, such as tetanus toxoid immunisation, iron supplements, malaria prophylaxis, and deworming (Callaghan-Koru et al., 2016; Gupta et al., 2014; Kearns et al., 2014; Kerber et al., 2007; Nyamtema et al., 2012; World Health Organization et al., 2006). These interventions are supplemented with health education as well as screening and treatment for complications, such as sexually transmitted infections (Callaghan-Koru et al., 2016; Kearns et al., 2014; Kerber et al., 2007; Nyamtema et al., 2012; World Health Organization et al., 2006). Since 2017, the World Health Organization has shifted its focus to improve women's experience of care and recommends eight ANC visits (World Health Organization, 2016). However, many low- and middle-income countries have not yet implemented these new recommendations.

Tanzania implemented the model of four ANC visits recommended by the World Health Organization in 2002 (Kearns et al., 2014). The coverage of at least one ANC consultation in Tanzania is promising, with 96% of pregnant women aged 15-49 receiving ANC from a skilled provider (MoH, 2016; MoH et al., 2016). However, only 51% of women attended the recommended four ANC visits, and of these, only 24% schedule their initial ANC consultation in the first trimester of their pregnancy (MoH et al., 2016). This is worrisome, since women who do not attend the recommended four ANC visits may miss essential information and interventions (Callaghan-Koru et al., 2016; Gross et al., 2012; World Health Organization et al., 2006). In addition, women starting ANC late will receive interventions that are less effective as they are not provided in the right pregnancy trimester. For example, medication to prevent mother to child transmission of HIV loses efficacy if it is not started early in pregnancy (World Health Organization et al., 2006). As a result, women and their infants face an increased risk of adverse health outcomes (Callaghan-Koru et al., 2016; Gross et al., 2012).

Previous studies conducted in Tanzania examined the low uptake of the recommended four ANC visits, finding numerous barriers to attending maternal healthcare (Callaghan-Koru et al., 2016; Gupta et al., 2014; Mahiti et al., 2015; Mubyazi et al., 2010; Tancred et al., 2016). In general, it has been shown that women acknowledge the benefit of receiving ANC but value this as less important than the perceived barriers (Finlayson & Downe, 2013; Mahiti et al., 2015; Mubyazi et al., 2010): Barriers included difficulty in accessing health facilities due to bad road conditions (Gupta et al., 2014; Mahiti et al., 2015; MoH et al., 2016; Mubyazi et al., 2010), out of pocket expenditures (Mahiti et al., 2015; MoH et al., 2016; Mubyazi et al., 2010; Tancred et al., 2016), fear to undergo certain procedures (Callaghan-Koru et al., 2016), and lack of a male companion (Callaghan-Koru et al., 2016; MoH et al., 2016). In addition, it has been found that a pregnant woman's decision to seek ANC is influenced by the perceived quality of care they expect to receive (Bishanga et al., 2019; Mselle et al., 2013; Solnes Miltenburg et al., 2016). Women identify long waiting times (Mahiti et al., 2015), poor communication about the return schedule (Callaghan-Koru et al., 2016), and disappointment over the received quality of care (Mahiti et al., 2015; Mubyazi et al., 2010; Tancred et al., 2016) as barriers to seeking ANC. Therefore any effort aimed at increasing the uptake of ANC should also focus on improving the quality of ANC.

Digital health tools may be promising to enable better quality care in low- and middle-income countries (Blaya et al., 2010; Lewis et al., 2012; Noordam et al., 2011; World Health Organization, 2011). To date, patients' perceptions and experiences with digital health tools and interventions (including applications) have mainly been studied in high-income countries, where positive attitudes of patients about technology use – computer, tablet, smartphone – during their health consultation were reported (Lelievre & Schultz, 2010; Strayer et al., 2010; Wilson et al., 2007). For example, the use of a digital health tool that supported healthcare workers in decision making for patients with hypertension resulted in patients' perceptions of increased involvement in their consultation and facilitated discussions about their health status (Wilson et al., 2007).

Though still limited, the use of digital health tools and interventions in low- and middle-income countries is being increasingly explored. For example, digital tools have been used to extend geographic access to care (Kahn et al., 2010; Lewis et al., 2012), improve communication between patients and health providers (Kahn et al., 2010; Lewis et al., 2012; Noordam et al., 2011), and monitor and increase treatment adherence (Blaya et al., 2010). With respect to maternal healthcare, digital health tools have been shown to enhance the performance of healthcare workers (Horner et al., 2013; Mensah et al., 2015; Oluoch et al., 2012). However, digital health should not be perceived as the "silver bullet" to solve health systems challenges (Battle et al., 2015b; Eze et al., 2016), but rather as an enabler to reach better health outcomes for patients (Mechael et al., 2010). Therefore, careful evaluation of digital health tools is essential, since its feasibility, as well as benefits for both healthcare

workers and patients, need to be explored (Blaya et al., 2010; Kahn et al., 2010; Lewis et al., 2012; Noordam et al., 2011; World Health Organization, 2011). To date only few studies have examined the use of digital health by healthcare workers in low-resource settings (Adepoju et al., 2017; Agarwal et al., 2015; Oluoch et al., 2012; Sukums et al., 2014), and information on its perceived benefits by patients in low-income countries is limited (Mahiti et al., 2015; Tamrat & Kachnowski, 2012).

In an effort to contribute to digital tool uptake in maternal healthcare in Tanzania, The Woman Centered Care Project in Tanzania developed a tablet based digital health application to assist healthcare workers during ANC through step-by-step guidance through all necessary interventions and providing tailored advice and suggestions for follow up actions when needed. This type of application is known as an electronic clinical decision and support system (eCDSS) of which a prototype was used for this study. In Tanzania, a paper based ANC card is used for documentation and contains the information relevant to their pregnancy. The eCDSS could function as replacement for the ANC card.

The current research

Existing research on the use of digital health tools in healthcare consultations generally reports positive results on quality improvement and patient satisfaction (Kahn et al., 2010; Lelievre & Schultz, 2010; Lewis et al., 2012; Strayer et al., 2010). It is less clear to what extent the introduction of digital health tools in maternal healthcare in low- and middle-income countries would be perceived as beneficial by beneficiaries and end-users, and whether such tools would modify women's perceptions of (the quality of) ANC. To explore these perceptions, the aim of this study is two-fold: (1) to gain insight into the perceptions and experiences of pregnant women receiving ANC in Magu district, Tanzania and (2) to understand to what extent digital health tools are perceived as potentially beneficial for use during ANC consultations. To this end, we have conducted in-depth interviews with pregnant women attending ANC in Magu district, Tanzania. Specifically, interviews focused on reasons to attend ANC, their opinions about the healthcare workers, suggestions for improvement of ANC, and the women's perceptions regarding the use of digital health tools during ANC consultations.

Methods

Study design

This qualitative research employed an interpretative phenomenological approach (IPA) (Al-Busaidi, 2008; Smith, 2004), drawing on semi-structured in-depth interviews to gain insight into lived experiences and perceptions of pregnant women receiving ANC in Magu district, Tanzania. This method has been described as "[…] *a method which is descriptive*

because it is concerned with how things appear and letting things speak for themselves, and interpretative because it recognises there is no such thing as an uninterpreted phenomenon" ((Pietkiewicz & Smith, 2014), p.7). Here, we utilized in-depth interviews because it enabled for detailed exploration of the contextualised personal perspectives on ANC of pregnant women, and the possibility for the respondent to freely elaborate on issues that are important to her (Green & Thorogood, 2011).

Study setting

This study was conducted in Magu district, one of the seven districts comprising Mwanza Region, and part of the Lake Zone in Tanzania. The study setting has been described in detail elsewhere (Solnes Miltenburg et al., 2019; Van Pelt et al., 2020). In brief, the Lake Zone has the highest maternal mortality rates in Tanzania (a total number of 176 maternal deaths in 2009) and is one of the regions with the highest percentages of women (46.6%) reporting problems in accessing healthcare (MoH et al., 2016; Shoo et al., 2017). This study was part of the *Woman Centered Care Project* (hereafter: the project) of the African Woman Foundation, which had as the primary objective to improve maternal and neonatal health in Magu district[1]. The development of an eCDSS was part of this objective, and the current study formed part of the needs assessment phase of intervention development (Bartholomew Eldredge et al., 2016; Van Pelt et al., 2020).

In Magu district, health services are delivered by 26 dispensaries, four health centres, and one district hospital. These different levels of health facilities vary in services provided, with the district hospital acting as the referral centre for all lower-level facilities. Dispensaries are the lowest level of health facilities and provide services mainly on an outpatient basis. In rural areas, dispensaries are the main access point for reproductive health services, including ANC. This study took place in six dispensaries dispersed across five wards.

Participants

To gain insight into pregnant women's perception of ANC and their experiences with (the quality of) ANC in Magu district, in-depth interviews were conducted with pregnant women attending ANC care at the six dispensaries. These dispensaries were selected using purposive sampling based on geographic factors to represent the district as adequately as possible. In total, nineteen women were randomly selected during ANC visits by the two research assistants, to collect views and opinions of women representative of the population of pregnant women receiving ANC in the district.

Data collection

Data collection took place in the period January until March 2016 and in June 2016. The interviews took place in a private area allowing for a confidential discussion, either at the

1 The African Woman Foundation ended in 2017 since by that time, the goals of the *Woman Centered Care Project* were reached and evaluations had been performed. The project was handed over to local partners.

dispensary or at the participant's home, depending on the participant's preference. Interviews were conducted by two members of the research team; a foreign research assistant who asked the questions in English and a local research assistant who translated to KiSwahili or the regional language Sukuma. A number of local and foreign research assistants (who were volunteering or undertaking work placement in the local project organisation) were paired to conduct the interviews. As the foreign research assistants were aware of their outsider position, care was taken to allow the local research assistants they were paired with to explain the goal of the research and give clarifications in the local language as much as needed prior, during and after the interview. All research assistants worked in close collaboration with the principal researcher and the local team members of the project throughout the process of data collection and analysis to ensure insider perspectives were taken into account. Interviews took approximately 40 minutes. Participants provided informed consent to record the interview and transcribe the interview for subsequent analysis. After 19 in-depth interviews, no new information emerged from the interviews. Consequently, the research team decided that data saturation was reached and no further interviews were conducted.

Materials

Before the in-depth interview commenced, participants were asked to fill in a short demographic questionnaire about their age, level of education, occupation, marital status, number of children, number of pregnancies, gestational age of current pregnancy, number of current ANC visit, waiting time for current ANC visit, and estimated time spent in current ANC visit. For the in-depth interviews, a semi-structured interview guide was developed and discussed within the local research team of the project (see Appendix A of this chapter for the overview). Questions focussed on women's perceptions of (the quality of) ANC received in current and previous pregnancies, opportunities for improvement in ANC, their interpretation of digital health in relation to ANC, as well as their opinions about the use of such a tool during ANC. During the interviews, the prototype of an eCDSS was demonstrated on a tablet to ensure a basic understanding of digital health and help conceptualise the use of digital health tools during ANC.

Data analysis

Data were analysed following the 6 phases of thematic analysis (Braun & Clarke, 2006), which are presented in Table 1 accompanied by an example.

To enable familiarization with the data (Phase 1), each recording was attentively listened to and transcribed verbatim in English. Before analysis, each transcript was read thoroughly several times by the foreign research assistants and the principal researcher and initial ideas were noted down. To generate initial codes (Phase 2), transcripts were read again several times and coded line by line using an inductive approach to create initial codes, making use of Atlas.ti 8.0 software.

Table 1: Phases of thematic analysis

Phase	Description of the process	Example
1. Familiarizing yourself with data	• Interviews were transcribed verbatim • Transcripts were thoroughly read several times • Initial ideas were noted down	*"because the healthcare workers are speaking nicely, they are not speaking like shouting"*
2. Generating initial codes	• Transcripts were coded line by line • Initial codes were grouped • 15 codes were identified: *ANC card, most essential change, NAA, life circumstances, most important service, communication of HCWs, received services, husband, motivation to visit, improvements, comparison with hospital, opinion on received services, initiating ANC, advantages ANC, community health fund*	Initial code: communication of HCWs
3. Searching for themes	• Codes were grouped into potential themes • Four potential themes were created: *Norms and believes during pregnancy, Importance of ANC, Digital health ,and Remarks on ANC*	Potential theme: remarks on ANC
4. Reviewing themes	• Themes were checked for coherence • Individual work was compared and consensus reached • Themes were checked for accurate representation of data • Visual presentation of themes was made (Figure 1) • Themes were reorganised into 5 themes. Codes that did not fit within an existing theme and were not relevant for a new theme were discarded from the analysis	Theme: Healthcare worker communication Subtheme: Tone of voice
5. Defining and naming themes	• Specifics of each theme was decided on • Themes were checked for accurate content • Names were generated for each theme: (1) Experiences of receiving antenatal care (2) Perceived facilitators for antenatal care attendance (3) Perceived barriers for antenatal care attendance (4) Views on healthcare worker behaviours during antenatal care provision (5) Perceived utility of digital health tools in antenatal care.	Final theme: Views on healthcare worker behaviours during antenatal care provision
6. Producing the report	• Results were related to the research questions and literature • Quotes were selected from the transcripts to present in the report	

Subsequently, in Phase 3 initial codes were grouped into potential themes by looking at the mutual relationships between codes. For example, the initial codes *advantages of ANC* and *most important service* were grouped together in the potential theme *Importance of ANC*. This process resulted in four potential themes. Next, in Phase 4, the potential themes that were independently identified by the research assistants and the first author were compared, and adjustments were made until consensus was reached about the final set of themes. The codes were reorganised into the five final themes and codes that did not fit within an existing theme and were not relevant for a new theme were discarded from the analysis. For example, two potential themes were combined into one and another potential theme was split into three separate themes. Figure 1 presents a visual overview of the themes and how potential themes

evolved into final themes. In Phase 5, the interview parts that were related to each of the themes were read again to verify the essence of the topic and to check for accuracy in the specific story of the team, which ultimately resulted in 5 final themes: (1) Experiences of receiving antenatal care, (2) Perceived facilitators for antenatal care attendance, (3) Perceived barriers for antenatal care attendance, (4) Views on healthcare worker behaviours during antenatal care provision, and (5) Perceived utility of digital health tools in antenatal care. Finally, in Phase 6, the results of the analysis were related to the aims of the research and all interview parts forming the five themes were read again for writing the results. Quotes were selected to illustrate the results, making sure a variety of participants and perspectives were taken into account. The demographic questions were analysed to create an overview of the sample.

Ethics and consent

Approval for this study was obtained from the National Institute of Medical Research of Tanzania (MR/53/100/103-244-245-349-399) and Maastricht University in the Netherlands (OZL_188_10_02_2018_S32). The district medical authority gave permission to conduct the study in their area. Before each interview, the local research assistant explained the purpose of the study to the participant, and they were asked to read and sign a written consent form. In case the participant was not able to read, the consent form was read out loud by the local research assistant. Participants were assured of confidentiality and reminded that their participation in the study was voluntary and that they could stop the interview at any time or withdraw their consent to have their data used in the research.

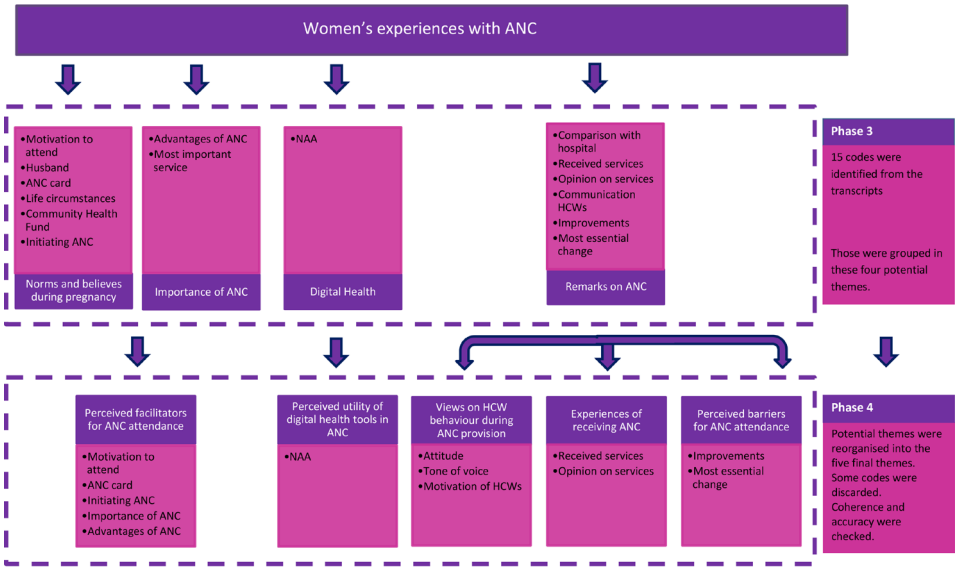

Figure 1: Visual presentation of the process moving from codes to potential themes (Phase 3) to final themes (Phase 4)

Results

Nineteen pregnant women, aged 16-38, participated in semi-structured in-depth interviews. The majority of participants were between 20 and 24 years of age, completed primary school, were married, were farmers or otherwise worked in agriculture, and already had children. Socio-demographic characteristics of the participants are summarized in Table 2.

Table 2: Socio-demographics of participants

Variable	Number of participants
Age in years	
Mean (SD)	23.79 (16-38)
16-20	3
20-24	10
25-29	4
> 29	2
Number of children	
Mean (SD)	1.67 (0-4)
0	3
1-2	10
2-4	5
unknown	1
Number of current ANC visit	
Mean (SD)	2.37 (1-6)
1	6
2	7
>2	6
Total number of ANC visits in the past	
Mean (SD)	7.21 (2-16)
1-2	3
3-4	1
5-6	6
7-8	3
>8	6
Marital status	
Single	1
Married	17
Divorced	1
Education	
Lower primary school	2
Upper primary school	16
Junior secondary school	1
Occupation	
Farmer	16
Housewife	1
Other	2

Theme 1: Experiences of receiving antenatal care

All participants felt grateful for the provided ANC services in the district, and most of them stated that they felt they received good care. When they were asked to explain what they meant with good care, the pregnant women defined this as the sum of services they received, such as weight measurement, blood testing, and abdominal examination:

> "The *treatment are* (sic) *good, there is nothing to add*". (Participant 2)
> "*For the facility, there are some services which are always provided to us. First is weight, height and also HIV tests and to observe the lie of the baby. These are the things we always get when we go there*". (Participant 3)

However, several women indicated that they felt they received poor ANC at the health facility. For example, one woman stated that she was refused services as she had not come with her husband. Others revealed that they felt that the care they received was not in line with the needs of pregnant women to ensure a safe pregnancy:

> "*In general the services is* (sic) *not good, is very poor for the pregnant mama* […] *there is only the testing for malaria and HIV and no other tests like blood pressure or blood group*". (Participant 12)

Moreover, although most women did not clearly express dissatisfaction with ANC, many described challenges related to the availability of materials in the ANC clinic, such as tests or medication. Other participants commented on being tested but not provided with the results of the tests or sufficient explanation of the test results:

> "*I don't know what's wrong but maybe they do not have time* […] *you can be tested only, and they are not going to give you the results, they just tell you, oh you can go, that way. I would like to know the results* […] *yes it is really important for me to know what is going on, rather than told* (sic) *me that I have to go home, only that is not enough, they have to explain to me*". (Participant 7)

Theme 2: Perceived facilitators for antenatal care attendance

Almost all participants expressed that the most important reason to attend ANC was to learn about their health status and the health of their unborn baby, as well as to be reassured about the progress of the pregnancy. Women also pointed out that they felt it was important for them to undergo blood tests, such as diagnostic tests for malaria and HIV, and to receive medication when needed:

> "*I go to test my health and to know the condition of the baby inside* […] *if there are any problems the healthcare workers can let me know* […]". (Participant 2)

Another important reason mentioned by participants, was the expectation of family members and relatives, women clarified that they are expected to go to the clinic when they become pregnant and that they follow the example of other women receiving ANC:

> "[…] *any other woman, when they realise they are pregnant, they always went to the clinic. I am not sure what's going on there but I am supposed to go there*". (Participant 8)
> "*Nurses and also in the radios they say about attending ANC early* (sic)". (Participant 17)

Furthermore, women stated that healthcare workers urge pregnant women to visit the ANC clinic either in the community or at healthcare facilities during other visits (e.g. during a previous pregnancy or non-pregnancy related visit). Several participants indicated that they were worried that healthcare workers get angry when they find out that women do not attend ANC. In addition, several women explained the need for receiving an ANC card (in Tanzania, a paper-based ANC card is used for documentation and contains the information relevant to their pregnancy) during their visit, because they believed it enabled them to get access to good delivery care and would appease the healthcare workers. Pregnant women are responsible for keeping and bringing their ANC card every time they visit the health facility:

> *"When I went for ANC, it is very nice because I am going to get an ANC card* […] *because if you do not have an ANC card, it is a problem* […] *they will provide you with services* (if you don't have an ANC card) *but in a harsh way, because they always ask why you didn't come for ANC* […] *that is why the card is very important because it may avoid all this situation*". (Participant 7)

Theme 3: Perceived barriers for antenatal care attendance

Most participants articulated the need for more free medication when needed and the availability of blood tests during ANC. For example, women described that medication was often prescribed and they were told to buy it at the pharmacy, instead of these medications being given to them for free[2].). Other participants indicated that they were told to come back the next month in order to receive medication and blood tests because they were out of stock. Several of the participants suggested they felt it was necessary to hire more healthcare workers since they acknowledged the high workload for healthcare workers and complained about the long waiting times:

> "*When there is an emergency during the night, a pregnant mama that wants to deliver during the night, there is only one healthcare worker. So when we go there to wake him up, he is not friendly because it is night* […] *mama is having a risky situation"*. (Participant 14)

2 In Tanzania, maternal healthcare is funded by the Ministry of Health and therefore free of charge for all pregnant women visiting governmental health facilities for ANC; this includes any necessary medication or supplements

Some women additionally expressed barriers related to building infrastructure, for example, having a reliable source of light, or more housing options close to the clinic to house healthcare workers, to ensure that someone would be present if a woman had to deliver their baby at the health facility in the night:

> "*The building is not enough, including houses for healthcare workers, and also for the other services including antenatal care* […] *you may find that maybe you have someone who is very sick and she needs an emergency services* (sic) *and you went there you find no one so you have to walk for a long distance to maybe to the houses* […] *it will be very difficult in such a situation* […] *there is a need to have enough buildings, enough houses for healthcare workers*". (Participant 4)

Theme 4: Views on healthcare worker behaviours during antenatal care provision

Women mentioned that healthcare workers provided 'good care', whereas some stated that healthcare workers can get angry when their rules are not followed by patients. One participant gave an example of a healthcare worker shouting at her because she did not bring her ANC card and another woman expressed that she was worried she had not complied with regulations:

> "*If you have a problem maybe, you didn't go maybe on the exact date, so you are going to feel like "ahh they are going to tell me today* […] *because they are going to shout at you a lot*". (Participant 2)

When participants were asked what they meant with healthcare workers providing 'good' care, they answered that they were treated in a nice and polite way and not scolded. Thus, they referred more to the manner in which the care was delivered rather than the nature of the care itself:

> "*Because the healthcare workers they speaking* (sic) *to them nicely, they are not speaking like shouting*". (Participant 17)

In general, women explained that they perceived that the healthcare workers were willing to provide good service within the existing environmental limitations of unavailability of medication and tests. They also indicated they felt that the healthcare workers were not the ones responsible for these problems. On the other hand, about one-third of the participants mentioned that healthcare workers should perform better. One of the participants questioned if blood tests were really not available, or that healthcare workers were just not willing to perform tests. Two participants indicated that they wished that healthcare workers worked harder in general, and three women stated they felt that the knowledge level of the healthcare

workers was not sufficient to monitor the health of pregnant women closely:

> "*No, I don't think that healthcare workers know enough* […] *it is a limit* (sic) *of their knowledge to provide such services* […] *this is because of the shortage of healthcare workers and the shortage of the tests* […] *they care and they are friendly*". (Participant 14)

Theme 5: Perceived utility of digital health tools in antenatal care

The overall response of women towards the use of digital health tools during ANC was positive, especially when they understood what the application could do after the demonstration of the prototype. Most of them stated that the use of digital health tools would result in better care in general, and about half of the participants expressed that they thought the application would enhance better record-keeping or would help the healthcare workers in their work:

> "*I would feel happy because the one* (the application) *with many questions is good, rather than now just lay there and they just measure and you go* […] *healthcare workers will increase their awareness on that they should do* […] *because it will bring information which is correct*". (Participant 17)

Several participants voiced that using digital health tools during ANC could stimulate the exchange of information between healthcare workers and women so that pregnant women are more informed about procedures and results of the tests. A few others mentioned that such a device would enhance the correctness of their health information, the comprehensiveness of this information, as well as make the visit shorter in duration:

> "*There is an exchange of information and even I will then be able to read it so now I know that what I am supposed to do according to the report that is coming from the app* […] *if they have this kind of things and healthcare workers try to explain to us, it would be OK*". (Participant 14)

Most women would give permission to the healthcare worker to work with the digital health tool, but when asked what they would choose when given a choice between the tool and the traditional ANC card, only half of them would choose the digital health tool. Most participants explained that this was because they needed the ANC card to read at home and to get access to other service points where no digital health application was used.

> "*I choose tablet, with also ANC card because they may fill maybe* (sic) *some of the information, to my ANC card. So even if I am home I can look and read and then at the same time the other or the same information will be found* (sic) *on the tablet*". (Participant 8)

The majority of the women had difficulties in formulating negative aspects of receiving ANC with the digital health tool because they had not seen it before. However, several women were able to explain what they thought was needed to make it a success: They suggested healthcare worker training, sufficient and reliable electricity at the health facility to charge the tablets, proper information about the application for the community, and a safe place to store the tablets to avoid damage and stealing.

Discussion

The main aim of this study was to explore pregnant women's perceptions and experiences on ANC in Magu district, Tanzania. Furthermore, we explored whether digital health tools are perceived as beneficial for use during ANC consultations. The results of this study indicate that in general, the pregnant women interviewed were positive about the importance of ANC, and they were grateful for the services received such as blood tests or vaccinations. However, they also expressed a need for improvements in ANC services, and they indicated that a digital health application could help in improving care.

Our results indicate that participants mainly utilized ANC for two reasons: to understand their health status and status of the pregnancy and because of societal expectations that dictate that attending ANC is an appropriate process to follow during pregnancy. In addition, there is an instrumental motive to attend ANC because they receive the ANC card, which gives them access to other services as well. These findings are in line with previous studies (Gross et al., 2012; Kawungezi et al., 2015; Mahiti et al., 2015; Mrisho et al., 2009). For example, in Tanzania, Gross et al. (2012) found that women's motivation to attend ANC was mostly due to norms and rituals, and less related to their personal health benefit. However, Gross et al (2012) also identified that the perceived poor quality of care of ANC was one of the reasons for women to attend ANC late (or not at all), which underscore that women take the quality of care they receive into account. The current study also found that participants expressed their concerns about the quality of care. Specifically, they noted poor availability of diagnostic tests, as well as the low motivation of healthcare workers. This is in line with findings of other studies on ANC (Callaghan-Koru et al., 2016; Finlayson & Downe, 2013; Mahiti et al., 2015; Mrisho et al., 2009; Mselle et al., 2013; Mudallal et al., 2017; Tancred et al., 2016). Previous research on healthcare workers' perceptions of the quality of ANC in Magu district indicated a lack of motivated healthcare workers providing ANC (Bremnes et al., 2018; Van Pelt et al., 2020), which is in line with the experiences of our participants. Furthermore, participants mentioned they were often obliged to buy medication, despite the policy of the Ministry of Health to provide free medication. Healthcare workers obliging women to buy their medication is a well-known issue in Tanzania, as also identified in other studies (Callaghan-Koru et al., 2016; Gross et al., 2012; Mahiti et al., 2015; Tancred et al., 2016).

In addition to the criticism of having to buy their medication, the women expressed diverging feelings towards healthcare workers. On the one hand, women stated that healthcare workers were polite, provided good care, and were perceived as willing to deliver quality care during the ANC visits. On the other hand, women described that healthcare workers were sometimes angry, unreliable, did not provide high-quality care, and did not give sufficient and relevant information to the pregnant women. For example, they sometimes did not provide test results to the women. These divergent views are consistent with previous research on interactions between women and healthcare providers in Tanzania (Mahiti et al., 2015; Mrisho et al., 2009; Tancred et al., 2016). One potential explanation for these diverging feelings might be that some women were reluctant to share their negative views during the interviews, reflecting socially desirable answers (Grimm, 2010). However, once the interview progressed, women often felt comfortable opening up (Grimm, 2010). Another possible explanation is the role and position of women in Tanzanian society. Women might feel that they need to accept and be grateful for the care they received (Solnes Miltenburg et al., 2016), or may not be aware of their (reproductive) rights and therefore do not easily express critique. As about half of the women in the current study were able to express their concerns about the perceived quality of ANC might be a sign of the urgent need to improve the situation.

We also explored women's perceptions of the possibility of including digital health tools in ANC services, with the aim to increase the quality of care. Participants in this study had little knowledge about the use of mobile technology in general, and poor access to tablets like the one used during the interviews to demonstrate the prototype. Despite this knowledge and experience gap, pregnant women generally expressed a positive attitude towards the use of such an application during the ANC visit. Women felt their care could be improved by the device due to its ability to store information and guide healthcare workers in care delivery. In addition, women reported expecting an increase in quality of communication with the healthcare workers, and in the correctness of the information they received. Similar findings were reported by Mitchell et al. (2012) in a study of the use of electronic protocols for the assessment of children younger than 5 years of age in health facilities in Tanzania. Caretakers whose children received care from healthcare workers using an electronic device, reported improved services, more thorough services, improved communication, and they considered healthcare workers to be more knowledgeable and able to provide better diagnoses (Mitchell et al., 2012).

In low-resource settings, digital health interventions are often implemented through patient's mobile phones to deliver health education and behaviour change communication. These interventions have been found to be effective in increasing ANC attendance (Feroz et al., 2017; Sondaal et al., 2016; Watterson et al., 2015). However, eCDSS has received less attention and its effects, as well as clients' and healthcare workers' experiences, are not yet established in the literature (Tamrat & Kachnowski, 2012). To our knowledge, the only study

investigating clients' perspectives on eCDSS has been conducted in Ghana and found diverse reactions of pregnant women to the use of an eCDSS during ANC (Abejirinde et al., 2018). Some women reacted with fear towards the device while others felt heard and listened to (Abejirinde et al., 2018). The study also indicated improved women-provider interactions due to the eCDSS. The current study shows similar findings in terms of women's perception of the use of eCDSS, substantiating the potential of the role of eCDSS in providing ANC.

Methodological considerations

Although the results of this study provide valuable findings that might be used as a starting point for the development of interventions such as an eCDSS to promote the quality of ANC, a number of limitations need to be considered. This study was based on a relatively small sample of pregnant women attending different dispensaries in Magu district selected using random sampling. Although similar results have been found in other rural areas, the findings may not be a clear representation of the entire population seeking ANC in Tanzania and transferability to all of Tanzania or low-income countries must be made with caution. Also, we sampled only women who had attended ANC consultations at the health facility, which excludes the valuable perception of women who do not seek ANC. This carries a risk of bias as included pregnant women already see the value of ANC and therefore may be more positive about the importance of ANC. Nevertheless, our sample represents a well-experienced group of pregnant women with a broad variety in the number of ANC consultations attended. Although we took care to select translators who were trained professionally in the translation between Kiswahili and English, and had a general understanding of the regional language Sukuma, different dialects of Sukuma between villages might have been possible. Most participants were of Sukuma ethnicity and spoke Sukuma as their first language, with Kiswahili second. In this study, it was evident that participants had poor understanding of and experience with digital health tools which might have caused participants to feel digital health provides better quality services due to the novelty effect of using new, high-cost technology (Abejirinde et al., 2018; Wells et al., 2010). However, this should not be used as an argument to view these perceptions as less value. Including the perspectives of end-users of digital health tools is essential in the process of developing and implementing digital health tools that fit local needs.

Conclusion

This study shows that circumstances in and around the health facility, like the availability of diagnostic tests and other materials, need to be improved to create a better environment for ANC provision for both women and healthcare workers. Although it is evident that these issues in infrastructure deserve attention, the study also found clear concerns of women related to the interaction with healthcare workers. In order to improve ANC in Magu district,

Tanzania, more attention should be paid to the attitude of healthcare workers by emphasizing the need for respectful care provision in education programs and providing local training for healthcare workers in the field. The usage of digital health tools in maternal healthcare seems promising, as this study found a positive view of pregnant women who believe digital health tools might improve the communication with healthcare workers. Further research is needed to examine if digital tools in ANC can help to increase ANC attendance and subsequently improve pregnancy and childbirth-related outcomes. Including end-users in such future research is important to ensure their voices are heard.

Appendix A: Interview guide

Themes	Questions
Antenatal care	> Why do you go for ANC? • In what way does ANC help you and your baby? > How do you decide when to go to the clinic for the first time? > How do you experience ANC visits? • What was done in your ANC visit today? > What is in your opinion the most important service that should be provided during ANC visits? > What do you think about the HCW who provide the ANC care? What do you like about the care they provide? • What don't you like about the care they provide? What can they do differently? • What is the difference between the care they provide here and at the hospital? > What do you think is needed to improve the quality of the ANC visits? • Are there any services you miss?
Antenatal care - new ideas	> What do you think about the ANC card? > Can you think of other methods of doing an ANC visit instead using the just the ANC card? > How would you feel about an ANC visit that involves more extensive questions and tests than the ANC visit you receive now? > How do you feel about the use of electronic devices to support ANC visits?
Digital health	> How would you feel about the use of an electronic device during ANC visits that contains a questionnaire with healthcare questions to determine your health status during pregnancy? (Show prototype) • What would you like about the tablet? • What would you not like about the tablet? > Would you give consent to use such a device during an ANC visit? > What should definitely be included in such an ANC visit? (Questions, explanations or tests) > What would you expect with regard to the quality of ANC care if HCW would use such an electronic device? > If you could choose to be seen during ANC by a HCW that did use the tablet versus one that did not use the tablet, which one would you choose, and why? > What is needed to make the implementation of this tablet successful?
End question	> If you could change one thing about ANC visits, what would it be? > Do you have any other remarks you feel are important about ANC or the HCW?

CHAPTER 4

The development of an electronic clinical decision and support system to improve the quality of antenatal care in rural Tanzania: lessons learned using Intervention Mapping

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Abstract

It is widely recognised that high quality antenatal care is a key element in maternal healthcare. Tanzania has a very high maternal mortality ratio of 524 maternal deaths per 100 000 live births. Most maternal deaths are due to preventable causes that can be detected during pregnancy, and antenatal care therefore plays an important role in reducing maternal morbidity and mortality. Unfortunately, quality of antenatal care in Tanzania is low: Research has shown that healthcare workers show poor adherence to antenatal care guidelines, and the majority of pregnant women miss essential services. Digital health tools might improve the performance of healthcare workers and contribute to improving the quality of antenatal care. To this end, an electronic clinical decision and support system (the Nurse Assistant App) was developed and implemented in Tanzania in 2016 to provide digital assistance during antenatal care consultations to healthcare workers. The current study systematically evaluated the development and implementation process of the Nurse Assistant App in Magu district, Tanzania, with the aim of informing future programme planners about relevant steps in the development of a digital health intervention. Desk research was combined with semi-structured interviews to appraise the development process of the digital health tool. We employed the criteria stipulated by Godin and colleagues (2007), which are based on the six steps of Intervention Mapping (IM; Bartholomew Eldredge et al., 2016). Findings indicated that five of the six steps of IM were completed during the development and implementation of the Nurse Assistant App. Tasks related to community engagement, adjustment to local context, implementation in the practical context in collaboration with local partners, and rigorous evaluation were accomplished. However, tasks related to identifying theory-based behaviour change methods were not accomplished. Based on the lessons learned during the process of developing and implementing the Nurse Assistant App, we conclude that programme developers are recommended to (1) engage the community and listen to their insights, (2), focus on clear programme goals and the desired change, (3), consult or involve a behaviour change specialist, and (4), anticipate potential problems in unexpected circumstances.

Introduction

Current best estimates from the United Nations show that one of the countries with a "very high" maternal mortality ratio is Tanzania, with 524 maternal deaths per 100 000 live births (World Health Organization et al., 2019). The consequences of maternal death are far-reaching, as it impacts women as well as their children, families, and communities (Reed et al., 2000). The death of a mother negatively influences schooling and nutrition for children, results in economic loss, and increases the chances of death for her baby (Family Care International et al., 2014; Koblinsky et al., 2012; Reed et al., 2000). Most maternal deaths are due to preventable causes that can be detected during pregnancy, such as haemorrhage, infection, unsafe abortion, hypertensive disorder, and obstructed labour (World Health Organization, 2019). Therefore, antenatal care (ANC) is a crucial intervention to promote maternal and child health (Callaghan-Koru et al., 2016; Kerber et al., 2007; Mrisho et al., 2009; World Health Organization, 2016) and identify issues early during pregnancy. ANC improves the survival and health of mothers through the prevention and management of pregnancy-related complications and by providing an entry point for health contact with pregnant women (Kerber et al., 2007; Lawn et al., 2010). In addition, ANC offers an opportunity to promote facility-based deliveries, which is considered as the key intervention for reducing maternal mortality in low- and middle-income countries (Afnan-Holmes et al., 2015; O. M. Campbell & Graham, 2006; Conrad et al., 2012; Lassi et al., 2014; Ministry of Health, 2016; Mrisho et al., 2009).

It is widely recognised that the quality of care in Tanzania needs to be improved since the majority of pregnant women miss essential services (Solnes Miltenburg et al., 2017a; MoH, 2016; Nyamtema et al., 2012; Stuart-Shor et al., 2017). A nationwide survey found that 47% of the women receiving ANC were not informed by the healthcare workers about danger signs (National Bureau of Statistics & ICF Macro, 2011), 29% had no blood pressure taken and 40% had no urine sample taken during the entire pregnancy (MoH et al., 2016). These results have been confirmed by multiple studies conducted in several districts of Tanzania (Hodgins & D'Agostino, 2014; Solnes Miltenburg et al., 2017a; Nyamtema et al., 2012; Pembe et al., 2010; Sarker et al., 2010; Urassa et al., 2002, 2003). It has been shown that ~20% of severe maternal morbidity could be avoided by improving the quality of ANC, including more rigorous prevention and management of severe anaemia and the early detection and management of hypertensive disorders in pregnancy (Nyamtema et al., 2012). Despite the commitment of the Tanzanian Ministry of Health, Community Development, Gender, Elderly and Children to prioritise maternal, new-born and child health by enhancing ANC services, reducing maternal death remains a challenge (MoH, 2016).

One innovative solution to improve the quality of ANC might be an electronic clinical decision and support system for use by healthcare workers during ANC, as it may have the

potential to guide and improve healthcare workers' performance and adherence to guidelines (Abejirinde et al., 2018; Adepoju et al., 2017; Agarwal et al., 2015; Mensah et al., 2015). A study conducted in Tanzania on the use of an electronic clinical decision and support system to improve HIV care, found high acceptability of healthcare workers to use the device (Thomas et al., 2020). In an effort to contribute to this solution, the Woman Centered Care Project – a project run by the African Woman Foundation between 2013 and 2017 to improve maternal health outcomes - conducted a needs assessment in Magu district, Tanzania. The aim of the needs assessment was to explore healthcare workers' and pregnant women's perceptions regarding ANC and the use of an electronic clinical decision and support system during ANC (Van Pelt et al., 2020; Van Pelt, et al., 2021).

The needs assessment undertaken through the Woman Centered Care Project consisted of semi-structured in-depth interviews with sixteen healthcare workers and nineteen pregnant women recruited from a sample of healthcare facilities in Magu district (Van Pelt et al., 2020; Van Pelt et al., 2021). Both healthcare workers and pregnant women expressed a positive attitude towards ANC and acknowledged its importance. However, they also expressed a need for improved ANC care delivery, particularly availability of diagnostic tests, and strategies to improve performance and strengthen motivation of healthcare workers to provide antenatal care (Van Pelt et al., 2020; Van Pelt et al., 2021). Healthcare workers explained that differences in healthcare worker's provision of antenatal care were due to differences in level of education, with some workers lacking experience, knowledge, and skills (Van Pelt et al., 2020). While the pregnant women were grateful for the care received, one-third of the participants felt that healthcare workers should perform better and questioned healthcare workers' willingness to perform or explain certain procedures (Van Pelt et al., 2021). Regarding the use of an electronic clinical decision and support system during ANC, the interviews found positive views among both healthcare workers and pregnant women (Van Pelt et al., 2020; Van Pelt et al., 2021). Both expressed that an electronic clinical decision and support system could improve the quality of ANC due to improved record-keeping, improved performance of healthcare workers, and improved communication between healthcare workers and pregnant women. Healthcare workers expressed that an electronic clinical decision and support system could improve their performance because the structured guidance it offers would make it easier to ask additional questions, detect high-risk pregnancies and know what to do in case of any complications (Van Pelt et al., 2020).

Guided by these findings of the needs assessment, a Nurse Assistant App (NAA) was developed as part of the Woman Centered Care Project. The Nurse Assistant App was developed to create a step-by-step guide for healthcare workers to systematically guide antenatal care consultations based on international recommendations and guidelines. Specifically, the NAA consisted of a comprehensive questionnaire to be filled in by a healthcare worker during the ANC consultation, based on results obtained through observations and/or responses of the

pregnant woman. The NAA offers a step-by-step guide through the essential interventions of an ANC visit, categorised into history taking, physical examination, laboratory tests, medication provision, and health education. Abnormalities in any of these sections were signalled to the healthcare worker through automatically generated 'alarm bells'. After completing all steps, the NAA generated a clinical summary and provided the healthcare worker with advice on treatment, referral, and follow-up according to national and international evidence-based guidelines. For an example of one of the sections of the NAA, see Figure 1.

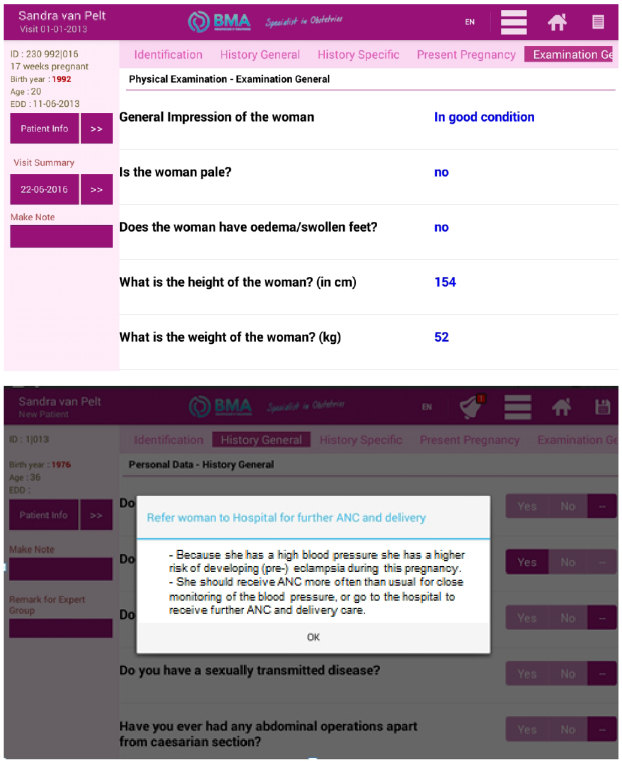


Figure 1: Two screenshots of the Nurse Assistant App with example 'alarm bell'

The NAA was developed by professionals in practice, and at the time of its development in 2014, little was known about the process of successfully developing and implementing digital health interventions in low- and middle-income countries. To our knowledge, this knowledge gap persists and available evidence focuses on the outcomes of digital health interventions and much less on process optimization in the development or implementation phase (R. Braun et al., 2013; Lewis et al., 2012), which is critical to a digital tool having an impact on health outcomes. Evaluating the development process of a digital health intervention such

as the NAA allows for identification of lessons learned to inform future programme planners in low- and middle-income countries on important considerations and pitfalls to avoid when developing a digital health intervention.

This paper evaluates the development and implementation process of the NAA, using Intervention Mapping (Bartholomew Eldredge et al., 2016) as a guide to assess whether a systematic and theory- and evidence-based approach was employed in the development of the digital tool. In addition, models and matrices, which are essential parts of Intervention Mapping, where retrospectively created to evaluate the scientific base of the choices made during the development and implementation process of the NAA. The findings of this study will help to inform future programme planners in low- and middle-income countries developing a digital health intervention as well as contribute to a greater understanding of factors that can help a tool like the NAA to be meaningful for end-users and be sustained in practice after the pilot phase.

Methods

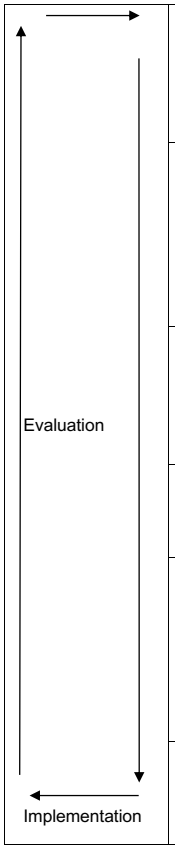
Design

This qualitative study draws upon two sources of data: documents describing the development and implementation process of the NAA, complemented by semi-structured interviews designed to verify the results of the desk research.

Evaluation framework

This evaluation is guided by Intervention Mapping, a six-step protocol for theory- and evidence-based intervention development that can also be used for the post-hoc evaluation of the soundness of digital health interventions, such as an electronic clinical decision and support system (Godin et al., 2007). Intervention Mapping provides systematic guidance to programme developers that facilitates making sound decisions during the process of intervention development (Bartholomew Eldredge et al., 2016). In step 1 of Intervention Mapping, the health problem is analysed through a needs assessment and the subsequent development of a logic model of the problem to specify the causes and contributing factors related to the health problem. Step 2 focusses on what behaviour and underlying personal determinants need to change in order to reduce the health problem, visualised in a logic model of change. In step 3, an intervention is designed, based on behaviour change theory and relevant change methods. In step 4, intervention materials, activities, and protocols are designed and pre-tested and the final intervention is produced. In step 5 an implementation plan is developed to ensure adoption and full and correct use of the intervention and aim for long-term use. Step 6 focusses on programme evaluation including both an effect and process evaluation. All six steps consist of distinct tasks that need to be completed before

proceeding to the next step. At the same time, Intervention Mapping allows for an iterative work process going forwards and backwards through steps and tasks. A flowchart of the different steps is shown in Figure 2.



Step 1: Logic Model of the Problem	• Establish and work with a planning group • Conduct a needs assessment to create a logic model of the problem • Describe the context for the intervention including the population, setting, and community • State program goals
Step 2 Program Outcomes and Objectives – Logic Model of Change	• State expected outcomes for behavior and environment • Specify performance objectives for behavioral and environmental outcomes • Select determinants for behavioral and environmental outcomes • Construct matrices of change objectives • Create a logic model of change
Step 3 Program Design	• Generate program themes, components, scope, and sequence • Choose theory- and evidence-based change methods • Select or design practical applications to deliver change methods
Step 4 Program Production	• Refine program structure and organization • Prepare plans for program materials • Draft messages, materials, and protocols • Pretest, refine, and produce materials
Step 5 Program Implementation Plan	• Identify potential program users (implementers, adopters, and maintainers) • State outcomes and performance objectives for program use • Construct matrices of change objectives for program use • Design implementation interventions Implementation
Step 6 Evaluation Plan	• Write effect and process evaluation questions • Develop indicators and measures for assessment • Specify the evaluation design • Complete the evaluation plan

Figure 2: The six steps of Intervention Mapping (Bartholomew Eldredge et al., 2016)

To assess the soundness of the development process of the NAA, we make use of the planning evaluation tool developed by Godin and colleagues (2007), which is based on the six steps of Intervention Mapping (Bartholomew Eldredge et al., 2016; Godin et al., 2007). The planning tool was developed to assist professionals in performing a rigorous evaluation of an intervention and consists of 40 criteria that make up 19 tasks (see Table 1) that can be scored. The application of this tool to the intervention development process provides insight into the steps and tasks that were undertaken and completed during the development and implementation of the NAA. To score the criteria of step 1 and step 2 in the planning tool, models and matrices were retrospectively created. This gave insight into

the extent to which choices made by the project team were in line with models that would have been created based on the available empirical literature, theory and collected data. The logic model of the problem was retrospectively created mainly based on the results of the needs assessment while the logic model of the problem was retrospectively created based on stakeholder meeting reports. Previous research has been published documenting a similar method of retrospectively evaluating an intervention (De Lijster et al., 2019; Godin et al., 2007; Schaafsma et al., 2013).

The NAA project team

In 2012, the African Women Foundation created a partnership with Crop Marketing Bureau (CROMABU), a Tanzanian organisation aimed at empowering small-scale farmers by using Information and Communication Technologies (ICT) in Magu district, Tanzania and commenced conducting research related to maternal health. In 2013, the Woman Centered Care Project was initiated. The project team of the Woman Centered Care Project consisted of one Tanzanian head of staff, one Dutch programme manager, one Dutch research officer, one Dutch liaison programme officer, and three Tanzanian research assistants. The research activities of the project were conducted in close collaboration with four universities (three in the Netherlands and one in Tanzania). The programme manager worked closely together with the board of the African Woman Foundation in the Netherlands, which had an advisory, fund-raising, partnership, and decision-making role. The programme manager also worked on the development and maintenance of the NAA in collaboration with ICT Healthcare Technology Solutions (formerly Buro Medische Automatisering B.V.), a Dutch private company specialised in digital solutions in the domain of obstetrics (Healthcare Technology Solutions, 2020).

Desk research

To assess processes and milestones in the development and implementation of the NAA, desk research was conducted using digital project archives, project documents, and content from the NAA itself. Data sources consisted of minutes of meetings, for which a template was made available at the time (i.e., minutes of 67 bi-weekly project team meetings from November 2013 until August 2016, minutes of meetings with stakeholders, including three meetings with the district reproductive and child health coordinator, minutes of 13 meetings with healthcare workers at their health facility, and minutes of 59 meetings with district officials held twice a year per subdivision of the district); reports on project activities that were approved by the board of the African Woman Foundation (i.e., workshop and training sessions offered by the project team to healthcare workers, monthly financial reports of the project, annual and quarterly project reports); field notes (i.e., supervision visits undertaken by the project team to all participating healthcare facilities, logs of the technical support provided by the research assistants of the project team to healthcare workers working with the NAA); personal timesheets of members of the project team kept for verification of

working hours; and e-mail conversation between board members, the project team, and the ICT specialists. One researcher conducted the search among the data sources and carried out the document synthesis, which was verified by a second researcher. Project-team discussions were held to discuss comprehensiveness of data, access to archives, and making sense of the data.

Data Analysis

Data obtained through the desk research were used to assess the development and implementation process of the NAA by scoring the criteria specified in the planning tool. Firstly, the two researchers worked independently from each other to score each of the 40 criteria of the planning tool (+ fully accomplished; +/- partially accomplished; - not accomplished). Secondly, the two researchers jointly evaluated whether or not a task was accomplished. Tasks were considered accomplished if at least one criterion was coded as "fully accomplished" (Godin et al., 2007). Thirdly, the two researchers jointly evaluated whether each of the Intervention Mapping steps was completed. Steps were considered completed when at least half of the tasks within that step were scored as accomplished (Godin et al., 2007).

For example, step 3 of the Intervention Mapping approach consists of two tasks, reflected in four criteria of the planning tool (numbered 21 – 24). If, for example, criterion 21 was scored as "not accomplished" and criterion 22 as "partly accomplished", task 10 was considered to be not accomplished overall. However, if criterion 24 was scored as "accomplished" and criterion 23 as "not accomplished", task 11 was considered accomplished. Consequently, since half of the tasks in step 3 were accomplished, the step was considered completed (see Table 1).

Semi-structured interviews

To complement the results of the analysis, semi-structured interviews were held with two developers of the NAA selected to gain insight into the development process from distinct perspectives. The team of the Woman Centered Care Project consisted of six people. Of these, only two could be contacted, as others had moved on: a Tanzanian project research assistant based in Tanzania and a Dutch programme researcher based in Magu district, Tanzania at the time of NAA development. Both these participants were involved from the beginning to the end of the development of the NAA, and had the possibility to influence the decision making process regarding the development of the NAA. It proved not possible to include software developers involved in the development of the NAA, as both had moved on. Participants were approached individually by e-mail with a request for participation and both agreed. During the semi-structured interviews, participants were encouraged to share their critique on the completed planning tool, to verify the results and check for any inconsistencies. Prior to the interview, the completed planning tool was sent to the participants so that they could prepare in advance. Interviews were conducted by phone and lasted for ~40 minutes.

Interviews were audio-recorded with verbal informed consent of the participants. During the interview, the intervention planning tool was discussed until consensus was reached by the interviewee and the interviewer about the appropriate coding.

Practical execution of the six steps of Intervention Mapping

Data obtained through the desk research and semi-structured interviews that did not correspond to criteria of the planning tool were included as additional information to assess the practical execution of the development and implementation of the NAA. Although the analysis of the practical execution of the six steps of Intervention Mapping is not officially part of the planning tool, we believe that the examples on the practical execution of the six steps might help to inform future programme planners. Intervention Mapping was retrospectively used to structure the data and assess what steps of Intervention Mapping were executed. Specifically, required models and matrices were retrospectively created based on the data. At the time of the development of the NAA, Intervention Mapping was not applied, therefore this part of the data created a comprehensive overview of all activities conducted during the process of development and implementation of the NAA.

Results

A description of the completed planning tool combined with the analysis of the practical execution of the six steps of Intervention Mapping is presented below to evaluate the development and implementation of the NAA. Results will be described following the six steps of Intervention Mapping.

Step 1: Logic model of the problem

Research regarding the needs assessment was performed in 2015 and 2016 by the programme researcher in collaboration with the four universities and the local government in Magu district. As described in the introduction, the result of the needs assessment, combined with literature on maternal health issues in rural Tanzania, provided a clear description of the problem the community was facing as well as of the target population of the intervention. Several focus group discussions, workshops, and technical meetings were conducted to discuss the findings of the needs assessments. Larger groups were brought together when the focus was more on brainstorming or dissemination of key messages to a larger audience. Smaller group sessions facilitated the targeted exchange of ideas and the discussion of politically sensitive issues that may not be appropriate to address in a larger group setting. A logic model of the problem was created retrospectively, framed around the problem of high maternal mortality in Magu district, which was chosen as the health problem (Figure 3). The needs assessment highlighted that pregnant women did not receive ANC of sufficient quality, due to several behavioural and environmental factors. The behaviours of the healthcare

workers became the main point of focus to reduce the high number of maternal death in the district, as visualised in Figure 3 in bold font. This focus was aligned with the a priori idea of the board of the African Woman Foundation in the Netherlands to develop a digital health tool for healthcare workers. The needs assessment showed that the highest burden of maternal health issues was in rural parts of the district. In rural areas, dispensaries are the main access point for reproductive health services, including antenatal care. It was specified that all healthcare workers in dispensaries were the target population for the intervention.

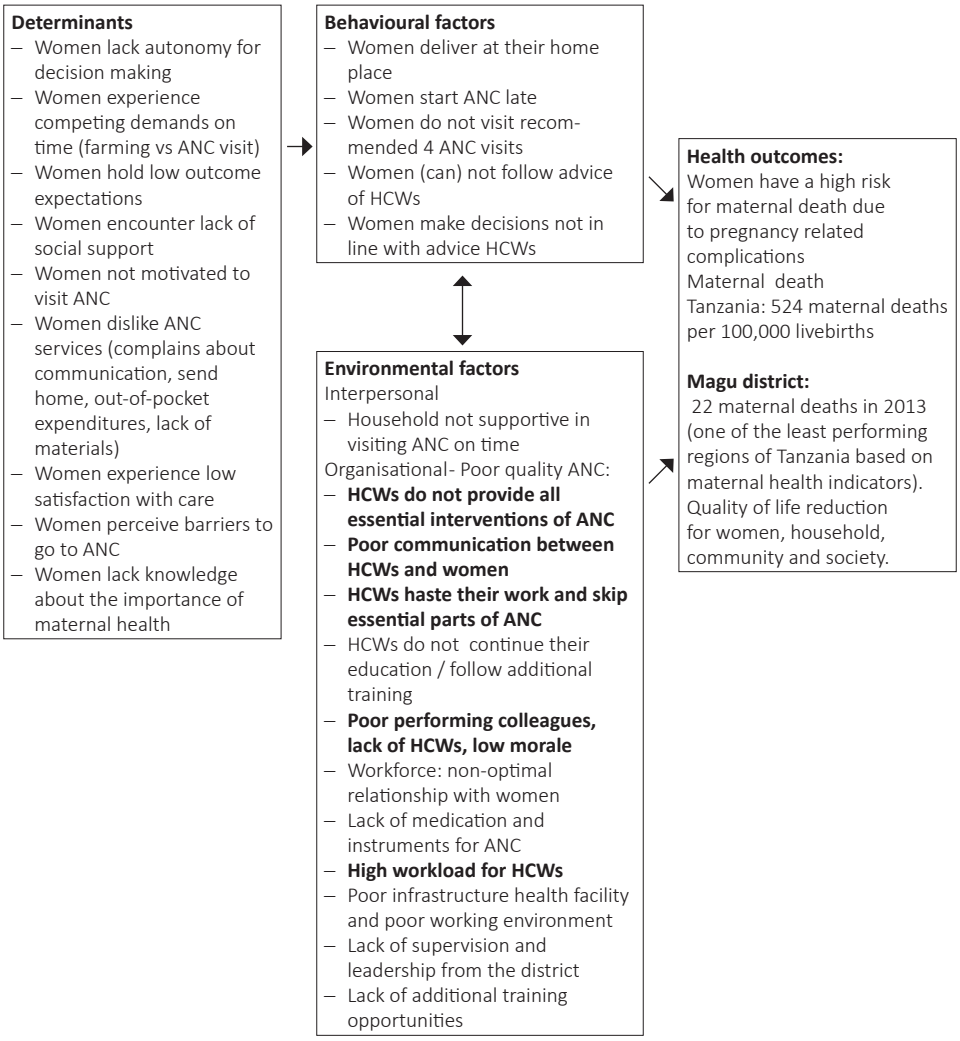


Figure 3: Retrospective logic model of the problem

At the start of the Woman Centered Care Project, a memorandum of understanding was signed by the local government, collaborating universities, and the African Woman Foundation to agree on a set of activities and division of responsibilities. From the start, it was a clear aim to share costs and responsibilities between the project team and the local government, to facilitate local ownership and sustainability. In practice, this meant that renovations of the healthcare facilities required to provide antenatal care were the responsibility of the local government, while costs related to the NAA intervention were covered by the Woman Centered Care Project. On some occasions, there were discussions about tasks and responsibilities that reflected expectations of the local government that the Dutch project team would have the financial means to solve issues of health service infrastructure, for example to repair or replace a broken solar system. In the planning tool, step 1 consists of 4 tasks which were all scored as accomplished. As a result step 1 was considered completed (see Table 1).

Step 2: Logic model of change

The main objective of the project was to increase the quality of ANC by improving healthcare worker performance in rural dispensaries. The desired behavioural outcomes of the project were that healthcare workers would provide all essential ANC interventions and assure appropriate communication with pregnant women. The NAA would assist healthcare workers in conducting the ANC consultation in line with step-by-step guidance on effective ANC. Data of the desk research showed that the focus of the project team was hence on educating healthcare workers in appropriately providing ANC with the use of the NAA and assess change in healthcare workers' behaviour (and patient satisfaction) related to the implementation of the NAA. The retrospectively created logic model of change is visualised in Figure 4, and the related behaviour change diagram, including performance and change objectives, is shown in Figure 5. At the time of development of the NAA, these objectives were not specifically identified, and determinants for behaviour change were not explicitly taken into account. The objectives shown in Figure 5 were retrospectively created, based on data obtained from the desk research. As can be seen, at the level of behavioural determinants (change objectives) the project intended to increase the skills of healthcare workers regarding providing ANC with use of the NAA, increase their own outcome expectation that using the NAA will improve the quality of ANC, and influence attitudes and self-efficacy of healthcare workers toward the NAA positively.

The NAA was developed without making use of a theoretical framework for intervention development and therefore no behaviour change theories were specified to guide the design of the intervention to promote behaviour change among healthcare workers. The content of the NAA was based on national and international evidence-based guidelines that were verified by experts in practice, such as the local reproductive and child health coordinator and several local healthcare workers. These guidelines were also used to develop a scoring sheet for the evaluation of the performance of the healthcare workers.

As can be seen in Table 1, no logic model for the development of the NAA was specified and no behaviour change theories were applied. Therefore only one of the five tasks was accomplished and step 2 of Intervention Mapping was therefore considered incomplete.

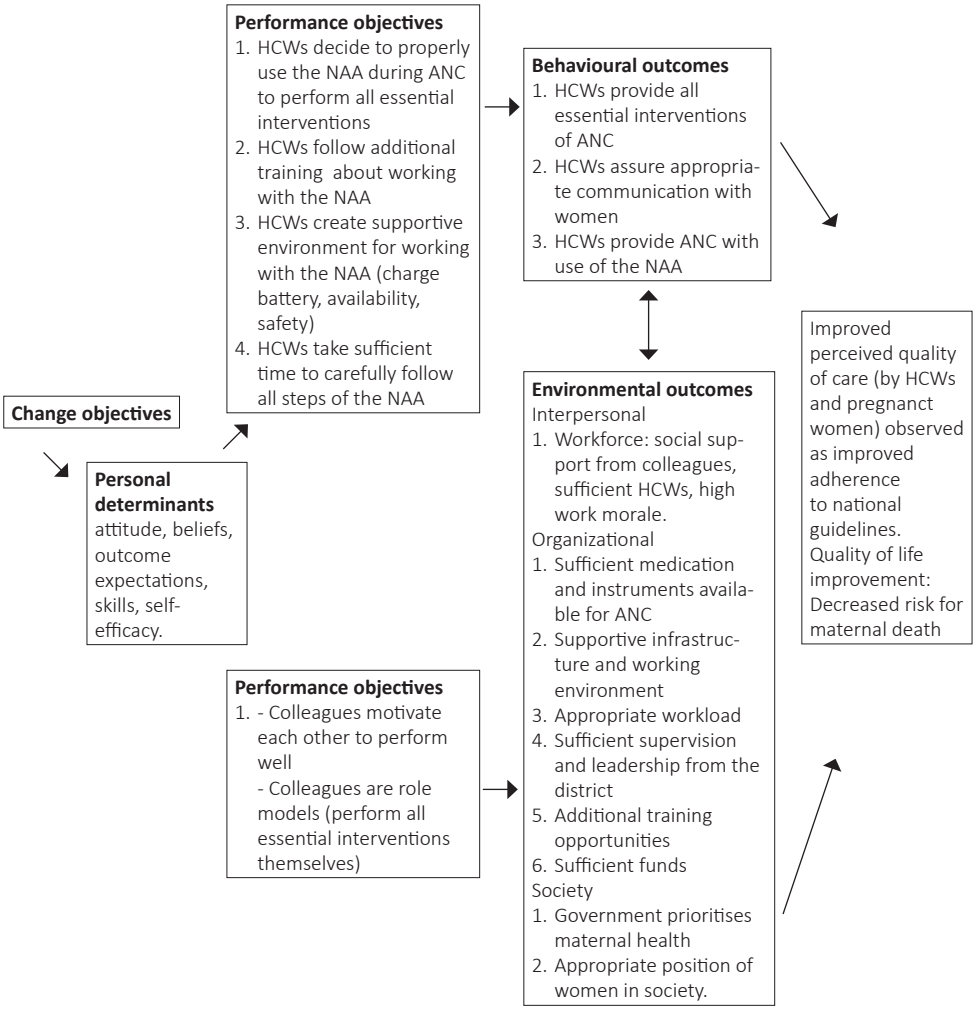


Figure 4: Retrospective logic model of change

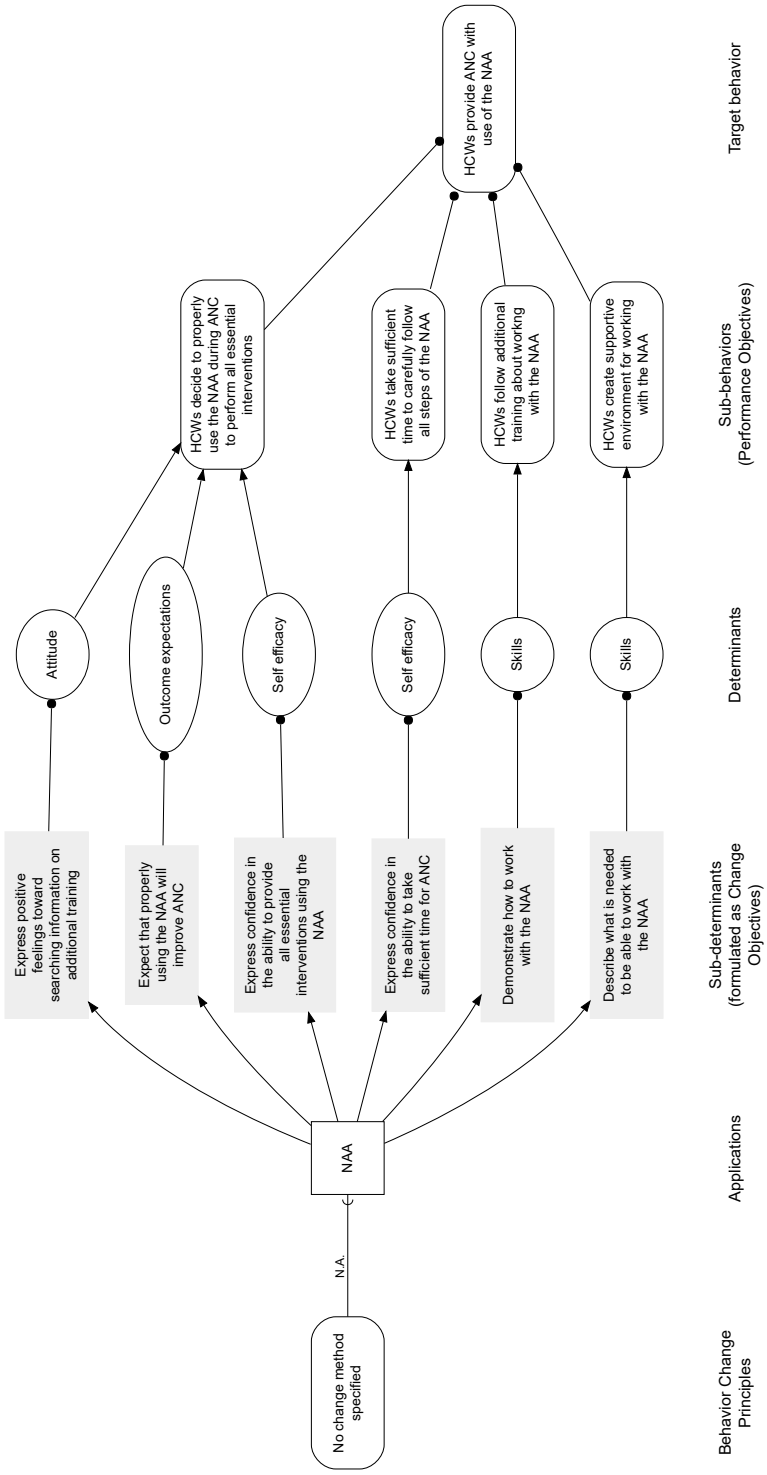


Figure 5: Behaviour change diagram

Step 3: Programme design

The choice for the NAA as the best possible intervention to improve healthcare worker performance during ANC was based on reading empirical and theoretical literature on e-health interventions and maternal health in general. Although this choice was made by the board of the African Woman Foundation in the Netherlands and could not be influenced by local stakeholders, the NAA programme itself - from initial draft until the final product – was developed in collaboration with all project team members, the local reproductive and child health coordinator, local healthcare workers, pregnant women receiving service at the participating sites, and the local government. All project team members were extensively involved and enthusiastic about the development of the NAA and contributed experiential knowledge to design and implement the intervention and fit appropriately in the local context. The NAA was presented and discussed extensively with all relevant stakeholders in the district to ensure cultural appropriateness of the NAA and obtain approval for its implementation. Two criteria of step 3 of Intervention Mapping focus on community engagement, and were scored as (partly) accomplished; therefore only one task of step 3 was considered accomplished. Consequently, since half of the steps were considered accomplished, step 3 of Intervention Mapping was considered completed (see Table 1).

Step 4: Programme production

The choice for a tablet as the device to run the NAA application was made by the board of the African Woman Foundation in the Netherlands. This choice was made based on the practical features of a tablet: a portable device with a relatively large screen which makes it easy to make and send pictures and that does not require abundant pre-existing knowledge on mobile technology. A pre-pilot study was conducted in a different district, where healthcare workers trialled a test version of the NAA during ANC with the goal to assess user-friendliness, willingness to work with the NAA, and search for errors. The results of the pre-pilot study were used to further develop the NAA. The content of the NAA was translated from English to Kiswahili and vice versa during several rounds of forward and backward translation and verified for accuracy by local healthcare workers and an external Kiswahili language teacher. At several points in time, stakeholders were invited via official letters and had the opportunity to share their ideas on the NAA and make suggestions as to any modifications to the implementation process of the NAA, including the training activities. The final look, content, sequence, and structure of the NAA were created in close collaboration with local healthcare workers, pregnant women, the local reproductive and child health coordinator, the ICT specialists, and the local government, through several smaller or larger group meetings. The final version of the NAA was adjusted to the ANC work practice to minimize its effect on the existing workflow and make it an easy-to-use tool. To contribute to workplace adaptation, each healthcare facility received two tablets to enable running two separate ANC visits by two different healthcare workers at the same time.

In light of problems with the electricity and internet network in the district, all participating healthcare facilities were audited for the availability and stability of electricity and mobile network connections. It was ensured that at the start of the implementation of the NAA, all participating healthcare facilities were connected to the national electricity grid or had a good working solar power system. However, on some occasions, unforeseen challenges arose. Due to heavy rains, some healthcare facilities experienced more frequent and longer power interruptions than expected, and the relatively long time to fully charge the tablet in healthcare facilities using solar power was not anticipated. This resulted in occurrences of non-charged tablets and on some occasions, women did not receive ANC because healthcare workers did not want to proceed without the NAA. In addition, mobile network issues caused challenges as well since the files that needed to be sent to the NAA server were larger than expected. As a result, many electronic files of pregnant women that were not properly saved got lost and the pertinent information could not be re-entered during the specific ANC revisit. (In Tanzania, pregnant women are responsible for keeping their paper-based antenatal care card, which is used for documentation and contains the information relevant to their pregnancy. The implementation of the NAA did not influence this common practice to prevent losing medical files). Furthermore, one healthcare facility was not accessible during the rainy season due to bad road conditions. Step 4 of Intervention Mapping was considered completed, as all three tasks of this step were fully accomplished (see Table 1).

Step 5: Programme implementation

An implementation plan that systematically described the content and sequence of activities, was developed by the programme researcher in collaboration with the research team. The emphasis of the project on appropriate community involvement was reflected in ongoing activities that started already during the development phase. While the ownership of the NAA and responsibility for the implementation of the NAA remained with the project team of the Woman Centered Care Project, healthcare workers and other stakeholders were consulted frequently.

The implementation plan consisted of several implementation strategies. Firstly, the project team provided training for healthcare workers about the essentials of ANC about six months before the introduction of the NAA in practice. During these training sessions, the initial concept of the NAA was also shared and input was asked regarding its development and implementation. Secondly, the reproductive and child health coordinators of each participating healthcare facility were invited for a workshop to view the test version of the NAA and share their ideas on improving the content. Thirdly, all healthcare workers providing ANC at participating facilities were invited for a two-day NAA training to develop their skills needed to work with the NAA during ANC. Fourthly, participating healthcare facilities were visited by members of the project team to provide three days of on-the-job training. This on-the-job training was provided to continue guiding healthcare workers who needed extra support to incorporate the use of the NAA in ANC practice. Furthermore, a user manual was

provided with the tablet, a technical support team was available for those healthcare workers who needed some extra support to work with the NAA or experienced technical difficulties, and all participating healthcare facilities were visited or called twice a month to ask if they experienced any difficulties.

Related to the implementation of the NAA in practice, some unforeseen challenges arose that needed to be solved. For example, three healthcare workers were not able to attend the two-day NAA training and were therefore trained individually at their healthcare facility. Also, of the in total fifteen tablets five broke down, of which three could not be replaced and some remaining "bugs" in the application were discovered. Healthcare workers did not always express their true opinions or would not call the technical support team when problems occurred. There was no script available in the implementation plan to guide responses to unexpected changes making it difficult to solve problems and ensure sustained use of the programme. Both criteria related to step 5 of Intervention Mapping planning tool were accomplished, and step 5 was considered completed (see Table 1).

Step 6: Programme evaluation

A robust evaluation plan was designed prior to implementation, by the project team and academic partners in both the Netherlands and Tanzania. Pertinent data were collected before, during, and after the implementation of the NAA. Both qualitative and quantitative data were collected to enhance triangulation of findings, and perspectives of different stakeholders were planned into the evaluation. Other sources of data (e.g. field notes) were also taken at every meeting in the project, to contribute more context to the interview, focus group, and survey data.

There were several components of the evaluation plan. Firstly, healthcare workers were asked to fill in a questionnaire before and after working with the NAA, containing questions about their experiences working with the NAA, the perceived impact of the NAA on the quality of ANC, and their willingness to incorporate the NAA in their ANC workflow. Secondly, quantitative clinical observations of ANC consultations were undertaken before and after the implementation of the NAA to observe differences in ANC processes. Thirdly, in-depth interviews were held with healthcare workers and pregnant women about their experiences with the NAA. Fourthly, an overall evaluation of the Woman Centered Care Project was undertaken to assess progress in contributing to reductions in maternal and neonatal health in the district (Solnes Miltenburg et al., 2019). Results of the evaluation will be presented in future work (in preparation). The memorandum of understanding signed at the beginning of the project did not have a sustainability plan to continue the work of the NAA after the end of the project. This resulted in a termination of working with the NAA during ANC in the participating healthcare facilities as the local government did not have the resources and did not prioritise taking over activities or processes related to the NAA. The three tasks of step 6 related to preparing and conducting the evaluation were fully accomplished and the

task related to communicating the results to partners was partly accomplished (see Table 1). Consequently, step 6 of Intervention Mapping was considered completed.

Table 1: Planning evaluation tool (Godin et al., 2007)

Criteria	Intervention Mapping task	Accomplishment	Step completed yes/no
Step 1 logic model of the problem			Yes
	Task 1 Identify the problem		
1	consult literature	**+**	
2	validate with local supporters	**+**	
	Task 2 Identify the target population		
3	socio-demographic profile	**+**	
4	socio-cultural context	**+**	
	Task 3 Identify determinants		
5	consult literature	**+/-**	
6	gather information on the population	**+/-**	
	Task 4 Analyse the environment		
7	identify places, methods and times to contact the participants	**+**	
8	identify hindering and facilitating factors	**+**	
9	identify partners and their respective roles	**+**	
Step 2 logic model of change			**No**
	Task 5 Specify the population		
10	consider the particularities	**+**	
	Task 6 Overall objective		
11	word precisely the selected change	**+/-**	
	Task 7 Performance objectives		
12	specify what should be obtained	**-**	
13	develop objectives based on theory, empirical data or deep	**-**	
14	understanding validate with partners	**-**	
	Task 8 Choice of determinants		
15	choose with respect to their connection with the target behaviour	**-**	
16	choose with respect to their potential success	**-**	
17	validate with partners	**-**	
	Task 9 Change objectives		
18	related to performance objectives and determinants	**-**	
19	based on theoretical notions	**-**	
20	validate with partners	**+/-**	
Step 3 programme design (match determinants and methods and support with theory on paramaters of use)			**Yes**
	Task 10 Choose the models		
21	support with tested theoretical methods	**-**	
22	consider population characteristics (determinants)	**+/-**	
	Task 11 Translate into strategies		
23	support with theory	**-**	
24	validate with partners	**+**	
Step 4 programme production			**Yes**
	Task 12 Organisational structure		
25	consider limitations of the milieu	**+/-**	
26	carry out with partners	**+**	
27	train and support workers	**+**	

Table 1 continued.

Criteria	Intervention Mapping task	Accomplishment	Step completed yes/no
	Task 13 Sequence and content of activities		
28	activities related to objectives	+	
29	realistic calendar	+	
30	validate with partners	+	
	Task 14 Production of material		
31	involvement of partners	+	
32	begin scheduled activities	+	
33	accessible and properly communicated	+	
34	adapt the material	+	
Step 5 programme implementation			**Yes**
	Task 15 Support of decision-makers and community		
35	active partners	+/-	
36	identify the person in charge	+	
Step 6 evaluation plan			**Yes**
	Task 16 Evaluation plan		
37	plan before implementation	+	
	Task 17 Process		
38	document information about the population and the intervention	+	
	Task 18 Impact		
39	measure the degree to which objectives are archived	+	
	Task 19 Communication		
40	discuss findings with partners	+/-	

Discussion

This study applied the planning tool of Godin and colleagues (2007) combined with broader knowledge on Intervention Mapping and semi-structured interviews to evaluate the development and implementation of the NAA, and electronic clinical decision and support system for ANC in Magu district, Tanzania. We found that 22 of the 40 tasks and five of the six steps of Intervention Mapping were completed. Specifically, tasks related to community engagement, adjustment to local context, implementation in the practical context in collaboration with local partners, and rigorous evaluation were scored as accomplished. However, tasks related to identifying theory-based behaviour change methods were scored as not accomplished.

The results of the current study indicate that the primary focus during intervention development and implementation of the NAA was on collaboration with local partners and the adjustment of the intervention to the local circumstances of the target population. The development process lacked focus on the theoretical aspects of behaviour change and intervention development, and how the NAA would contribute to behaviour change among healthcare workers. These results are in line with several other studies on the implementation of digital health interventions in low- and middle-income countries (Crehan et al., 2019; Edgcombe et al., 2016; Yau et al., 2019). These studies emphasise the importance of stakeholder

involvement and feedback sessions with the target population and do not mention the need for applying evidence-based theories while developing a digital intervention (Crehan et al., 2019; Edgcombe et al., 2016; Yau et al., 2019). It has been found that interventions often fail to incorporate theories and evidence in the choices they make for developing their intervention (Godin et al., 2007; Hansen et al., 2017), indicating a gap between science and practice (Hansen et al., 2017). Prior studies suggest (Hansen et al., 2017; Mkumbo et al., 2009; O'Cathain et al., 2019) that the use of theory, and Intervention Mapping specifically, is considered to be too time-consuming, expensive, and therefore not feasible to use in all circumstances (Hansen et al., 2017; Mkumbo et al., 2009; O'Cathain et al., 2019). In the context of a non-profit organisation or private company, it might not be common practice to include academic components and apply a theoretical approach. In addition, pre-existing knowledge on behaviour change theories is required to successfully identify relevant behaviour change methods and apply them correctly. That is something practitioners are often not trained in (Hansen et al., 2017). Intervention Mapping acknowledges the necessity of working with a planning group that should always include a behaviour change specialist (Bartholomew Eldredge et al., 2016). Also, evidence and published literature on the specific case one is developing an intervention for might be lacking in low- and middle-income countries which makes it challenging to follow all steps of Intervention Mapping (Mkumbo et al., 2009; Ruiter & Crutzen, 2020).

Although the project team did not use theoretical frameworks such as Intervention Mapping as a guide during the development and implementation of the NAA, it managed to take into account the importance of cultural acceptability and tailoring of interventions to local circumstances. During the development and implementation of the NAA, community engagement was seen as the key ingredient of success which is recognised in theoretical frameworks like Intervention Mapping (Fernandez et al., 2019) and supported by several studies (Aarø et al., 2014; Leshabari et al., 2006; Mkumbo et al., 2009). Intervention Mapping highlights that an intervention is most likely to fail when it is not culturally appropriate (Bartholomew Eldredge et al., 2016). As can be seen in the current study, even though no theories on behaviour change or intervention development have been used, five out of six steps of Intervention Mapping have been carried out. Therefore, Intervention Mapping could still be a useful framework to systematically develop and plan interventions in situations in which less behavioural expertise might be available. Especially since Intervention Mapping explains that behaviour change theories apply even outside the context the theory was tested in (Bartholomew Eldredge et al., 2016).

The results of the current study also indicate that the initial idea of an electronic clinical decision and support system as the solution for the high maternal death rates in Magu district came from the board of the African Woman Foundation in the Netherlands. Therefore, the question could be raised about how well community involvement has been achieved.

During the process of development and implementation, many stakeholder meetings were held to ensure as much involvement and input as possible, however the type of intervention that was going to be developed was already determined and any new intervention idea or need emerging from the local stakeholders would not be possible to take into account. However, this was not the case since healthcare workers and other stakeholders expressed their enthusiasm and willingness to work with the NAA from the beginning and showed their dedication during the implementation to make the NAA successful. Related to this it is important to mention that different interests were awakened since the opportunity to receive free electronic devices was at play which might have influenced the behaviour and willingness to participate in the project (Wells et al., 2010). Therefore, it remains unclear whether the NAA was truly culturally appropriate and the best possible solution to solve the problem of maternal death in the district.

Data shows that the NAA intervention lacked a clear programme objective and desired outcomes. These limitations might influence the effectiveness, sustainability, and usefulness of the NAA even more than the lack of reference to behaviour change theories. Essential for developing interventions to improve quality of care, is engaging the broader health system and making stakeholders accountable (Nambiar et al., 2017). Stating clear programme goals and sharing expectations about the desired change is part of this. Although involvement with all stakeholders was abundant and the approval of the District Medical Officer was acknowledged as essential to conduct all activities, the project team of the Woman Centered Care Project was responsible for the development and implementation of the NAA. Looking back, it is essential for the sustainability of the project to share ownership and responsibilities with stakeholders and to create clear goals and desired change objectives. In this light, we recommend that the existing government technological infrastructure should also have been taken into account during the development process to make the NAA a better fit within the existing (digital) healthcare structures.

Although a pre-pilot was conducted in another district unforeseen challenges arose in Magu district. These could have been partly avoided in four ways. First, the pre-pilot could have been conducted with the final version of the NAA instead of the test version. Second, the stakeholder meetings could have focused more on the practical use of the NAA in the healthcare facility and its environment. Third, the choice for the type of device to run the NAA application could have been a choice made by the end-users and not by the Board. And last, a script with potential problems could have been developed before the implementation to anticipate and prepare for potential challenges.

Strengths and limitations

The strength of the current study is the practical and accessible description of the evaluation and lessons learned from the development and implementation process of an electronic

clinical decision and support system in a low- and middle-income country, which to the best of our knowledge, has not been described before. A limitation of the study is the fact that researchers involved in the evaluation were also involved in the implementation. Although this allows for a clear understanding of all the documents and processes, it carries a risk of bias in the interpretation of data. Results were verified by two initial developers of the NAA. The reason only two interviews were conducted was based on the dissolution of the Woman Centered Care Project, and our inability to contact additional relevant key informants who were part of the project and the development of the NAA. Despite the facts that only two semi-structured interviews were conducted, we believe that the results present a realistic representation of the development and implementation process. Also, as this was a retrospective evaluation, there is a potential risk of recall bias. To reduce this bias, project archives were consulted to check for inconsistencies and search for written proof to base the results on. This project did not have the aim to do a quality assessment of the documents included in the project but used the documents to gain insight into de decision-making process and the involvement of the various stakeholders. Furthermore, locally specified goals and objectives were not taken into account as much as they could be included, which could have impacted ownership of the NAA. In addition, we found that it is crucial to identify the intended behavioural outcome of the intervention as well as the behavioural determinants before intervention development, and rely on theory and empirical research in doing so. Also, more explicit attention could have been given to both adopter and innovation characteristics to promote NAA's implementation and use (see for example (Thomas et al., 2020). Despite these limitations, we believe that this study contributes to providing valuable insights for future digital health tool developers in low- and middle-income countries.

Conclusion

In sum, this retrospective evaluation of the development and implementation process of the NAA revealed that 5 out of 6 steps of Intervention Mapping were successfully completed. Specifically, the tasks related to community engagement, adjustment to local context, implementation in the practical context in collaboration with local partners, and rigorous evaluation were satisfactorily accomplished. Based on the lessons learned during the process of developing and implementing the NAA we recommend future programme developers to (1) engage the community and listen to their insights, (2), focus on clear programme goals and the desired change, (3), consult or involve a behaviour change specialist, and (4), anticipate potential problems in unexpected circumstances. As such, the current description of the development and implementation of an electronic clinical decision and support system, including lessons learned, is unique and contributes to building necessary knowledge to successfully develop and implement digital health tools in low- and middle-income countries.

CHAPTER 5

An electronic clinical decision and support system designed to improve the quality of antenatal care in rural Tanzania: Impact of the *Nurse Assistant App*

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Abstract

High quality antenatal care is an essential strategy to reduce maternal mortality in sub-Saharan African countries. Unfortunately healthcare workers' adherence to antenatal care guidelines in Tanzania is low and one innovative solution to promote adherence to these guidelines is the implementation of an electronic clinical decision and support system (eCDSS). However, it remains unclear to what extent an eCDSS could improve the quality of antenatal care service provision. Therefore, we conducted two studies focussed on the impact of an eCDSS on workflow and quality of care in rural Tanzania. This study was conducted at control and intervention facilities measured before and after implementation and aimed to assess to what extent an eCDSS contributes to delivery of essential antenatal care services. Antenatal care observations (n = 557) were performed and completeness scores calculated based on World Health Organization checklists and the focussed antenatal care guideline of Tanzania (Study 1). Additionally, to explore perceptions and experiences of healthcare workers that used the eCDSS, healthcare workers providing antenatal care in the intervention facilities (n = 67) filled out questionnaires in February 2016 (baseline, n = 39) and August 2016 (post-test, n = 28), and 17 of them were selected for in-depth interviews (Study 2). For Study 1, the results from independent-samples t-tests showed that, contrary to our expectations, intervention health facilities did not score a higher completeness score for delivery of antenatal care services compared to control health facilities ($t(205) = .58$, $p = .566$, M = 22.92 and M = 21.97). In both control and intervention facilities the overall completeness score did not exceed 25%, indicating that the completeness score was not improved due to the eCDSS. The results of Study 2 indicated that although healthcare workers were overall positive about using the eCDSS, the results of Study 1 could partly be explained by the perceptions of healthcare workers that the eCDSS increased their workload, and that the infrastructural circumstances – e.g. lack of electricity or internet connection – made working with the eCDSS challenging. Overall we conclude that the eCDSS was not successful in improving the delivery of essential antenatal care services. For an eCDSS to improve the quality of antenatal care and healthcare workers' adherence to antenatal care guidelines, infrastructural barriers should first be removed and the availability of staff prioritised.

Introduction

The availability of high-quality antenatal care (ANC) is a key strategy in combatting high maternal mortality rates in sub-Saharan Africa. In Tanzania, the maternal mortality ratio is estimated to be 524 per 100 000 live births (World Health Organization et al., 2019). The most prevalent causes of maternal death in Tanzania include haemorrhage and hypertensive disorder which are preventable and can be detected during ANC (Afnan-Holmes et al., 2015). It has been shown that the effectiveness of ANC in Tanzania is highly influenced by the performance of healthcare workers providing ANC, which may be improved through the use of guidelines (Nyamtema et al., 2012). In 2001, the World Health Organization released guidelines for ANC (World Health Organization et al., 2006) which were adopted by many sub-Saharan African countries, including Tanzania. In 2016, new guidelines were issued (Lattof et al., 2020). In the World Health Organization ANC guidelines of 2001, a minimum of four ANC consultations that include individual counselling, physical assessment, and preventive interventions is recommended (Callaghan-Koru et al., 2016; Kearns et al., 2014). For each ANC consultation, guidelines are available that explain all essential interventions for the specific gestational period in order to assure timely identification of complications. Unfortunately, research on maternal health in Tanzania has demonstrated a general low adherence to ANC guidelines (Solnes Miltenburg et al., 2017a; Nyamtema et al., 2012; Pembe et al., 2010; Sarker et al., 2010) resulting in less effective ANC services, which in turn negatively impact the health of pregnant women (Solnes Miltenburg et al., 2017a; Nyamtema et al., 2012; Pembe et al., 2010; Sarker et al., 2010).

Research in recent years has focused on reasons for low adherence to ANC guidelines by healthcare workers in sub-Saharan Africa, and demonstrated that the absence of clear paper-based ANC guidelines in health facilities as well as lack of awareness about these guidelines among healthcare workers are important contributors to the low adherence (Biza et al., 2015; Conrad et al., 2012; Van Pelt et al., 2020). Moreover, studies of the quality of ANC in Tanzania showed that healthcare workers experience a lack of supportive supervision (Mubyazi et al., 2012; Van Pelt et al., 2020), and feel that they had not received enough education to provide all essential interventions (Nyamtema et al., 2012; Van Pelt et al., 2020). Furthermore, the ANC guidelines are often in English and are lengthy, making them difficult to understand and use for healthcare workers in Tanzania, where the primary language is Kiswahili and where time is limited due to high caseloads.

In Tanzania, the government has implemented several strategies to increase uptake of ANC guidelines, including better training opportunities and supervision, rotation of healthcare workers to increase exposure to new work standards, and health facility upgrades (MoH, 2016; Mrisho et al., 2009). Unfortunately, this has not resulted in better performance in the delivery of essential ANC interventions by healthcare workers. Innovative tools are

likely needed that can address healthcare workers' experienced needs regarding knowledge, skills and supportive supervision (Van Pelt et al., 2020), as well as promote adherence to ANC guidelines to improve service provision of ANC. One innovative solution might be the implementation of an electronic clinical decision and support system (eCDSS) in health facilities. Several studies have demonstrated the positive effects of working with an eCDSS in low- and middle-income countries (Abejirinde et al., 2018; Adepoju et al., 2017; Agarwal et al., 2015; Horner et al., 2013; Oluoch et al., 2012). It has been shown that an eCDSS can improve healthcare workers' performance and adherence to guidelines. For example, a study conducted in Tanzania that digitalised the guideline for childhood illnesses found more adherence to the electronic version of the Integrated Management of Childhood Illness protocol and high uptake by healthcare workers (DeRenzi et al., 2008; Mitchell et al., 2012).

Only a few prior studies have assessed the impact of working with an eCDSS on ANC service provision (Adepoju et al., 2017; Agarwal et al., 2015; Horner et al., 2013; Oluoch et al., 2012). These studies focussed on perceptions of healthcare workers and pregnant women, reporting positive views on the use of an eCDSS during ANC consultations, and a belief that an eCDSS could improve the quality of ANC. Respondents mentioned that they believed an eCDSS would especially improve record-keeping, performance of healthcare workers, and communication between healthcare workers and pregnant women (Van Pelt et al., 2020; Van Pelt et al., 2021). However, a program implementing an eCDSS in three sub-Saharan African countries found no significant improvement in the overall quality of the delivery of ANC (Mensah et al., 2015; Saronga et al., 2017). Evaluating the impact of an eCDSS on daily work practices and quality of care is essential when considering sustained use of a digital health tool among healthcare workers. To further contribute to the evidence base about the use of an eCDSS during ANC in low-resource settings, we present findings from two studies specifically focussed on assessing the impact of an eCDSS on workflow and quality of care in rural Tanzania. Study 1 details an evaluation of the impact of an eCDSS on the delivery of ANC service provision in control and intervention facilities, and aims to assess to what extent an eCDSS aids in comprehensive delivery of ANC care. Study 2 aims to understand and contextualise findings from the evaluation, by exploring the perceptions and experiences of using the eCDSS and its implementation, through questionnaires and in-depth interviews with healthcare workers from the intervention facilities.

The current research: Design & context

The studies reported here were part of a larger project, the *Woman Centered Care Project*, which aimed to improve maternal and neonatal health in Magu district, Tanzania (Solnes Miltenburg et al., 2017a; Solnes Miltenburg et al., 2019). Magu district is part of the Lake Zone in Tanzania, which nationwide has one of the highest maternal mortality rates (Shoo et al., 2017) and lowest coverage of quality ANC (MoH et al., 2016). In rural areas of the district, reproductive health services are provided at one of the 26 dispensaries (hereafter:

health facility) that serve as first-level primary healthcare and are the main access point for reproductive health services, including ANC. The Woman Centered Care Project was active in thirteen health facilities that were selected using purposive sampling based on different geographic factors, such as proximity to the district hospital and the proportion of remote villages in the catchment area of the health facility, to represent the district as adequately as possible. In all health facilities, ANC is provided by healthcare workers of different education levels ranging from the lowest level medical attendant to the highest level clinical officer. At the time of the current research, approximately 60 healthcare workers provided ANC in these health facilities, on average 4.6 healthcare workers per health facility.

One of the activities of the Woman Centered Care Project was the pilot study to develop and implement an eCDSS, the *Nurse Assistant App* (NAA), which has described in detail elsewhere (Van Pelt et al., 2021). In short, the NAA is a tablet-based application, written in Kiswahili, to facilitate and increase the performance of healthcare workers providing ANC in health facilities. The NAA offers step-by-step guidance through all essential interventions of each ANC consultation as well as "alarm bells" with follow-up actions and tailored advice when abnormalities are detected.

STUDY 1

In Study 1, ANC observations were performed at control and intervention facilities to evaluate the impact of an eCDSS on the delivery of ANC service provision. We hypothesized that compared to control health facilities, the use of an eCDSS would increase the number of essential interventions that should be provided during ANC consultations with pregnant women in Magu district.

Methods

Study design and sampling

This quantitative study evaluated the impact of working with the NAA on healthcare workers' performance in delivering ANC using ANC observations collected before (baseline) and after (post-test) implementing the NAA at control and intervention health facilities. Prior to development and implementation of the NAA, a comprehensive health facility audit was conducted in all thirteen health facilities (Solnes Miltenburg et al., 2017a) complemented with tests of the availability and stability of electricity. Seven health facilities were connected to the national electricity grid or had a good working solar power system, and six health facilities did not have a power source. Based on these results, health facilities with a power source were purposively selected as intervention sites and the other health facilities as

control sites. Intervention and control health facilities were as similar as possible, taking into account the total number of ANC visits, total number of healthcare workers providing ANC and their education level, availability of supplies, and demographical characteristics of the patient population (Solnes Miltenburg et al., 2017a).

Healthcare workers in the intervention facilities were invited to a two-day training on using the NAA. During this training, it is inevitable that some information regarding ANC is provided as well. Therefore, all healthcare workers, regardless of the study group, received one day of training on focussed ANC. Both trainings were held after the baseline data was collected. Each health facility in the intervention group was provided with two tablets for a pilot period of six months from February 2016 until August 2016. Using the NAA was voluntary and used in parallel with the standard paper registers.

Data collection

ANC observations were performed to assess the comprehensiveness of essential ANC services at baseline (from half August until half September 2015) and post-test (from half June until half August 2016) at all thirteen health facilities. For both baseline and post-test, each health facility was visited unannounced three times by a research assistant, which resulted in 557 observed ANC consultations divided over thirteen health facilities with an average of 43 observations (range 14 – 64) per health facility.

Trained research assistants fluent in KiSwahili observed the ANC consultations from start to finish, both during the individual consultation and the group education sessions, using an adaptation of the Maternal and Newborn Quality of Care Survey ANC observation checklist developed by the Maternal and Child Health Integrated Program and USAID (United States Agency for International Development, 2014). The ANC observation checklist was used as a reference guide for essential ANC services and consisted of questions categorised into facility characteristics, basic ANC consultation information, registration, gynaecological history, clinical investigation, laboratory investigation, drug administration, education and counselling, actions on abnormal findings, and final remarks (see Appendix A of this chapter). Healthcare workers were not informed about the content of the ANC observation checklist and emphasis was placed on the anonymous character of the observations. Research assistants were introduced by the healthcare worker to the pregnant women and intervened as little as possible by sitting quietly on a chair to record what topics were covered. Scores were entered using the Magpi mobile data collection platform for mobile phones, allowing for digital data entry and reducing entry errors.

Primary outcome measure

The primary outcome for the ANC observations was the completeness score expressed as a percentage of the total amount of items observed per ANC consultation. Completeness

scores were measured by the summation of scores observed per ANC observation divided by all checklist items. The maximum completeness score per ANC observations was 100% (94 items) which was identified using recommendations of the World Health Organization on ANC for a positive pregnancy experience (World Health Organization, 2016) and the focused antenatal care guideline of Tanzania (von Both et al., 2006) to select essential ANC services. This resulted in 94 items of the ANC observation checklist divided into seven categories: Registration; Gynaecological history; Current pregnancy; Investigation; Laboratory; Medication; and Education and communication (see Appendix B of this chapter). Items on the ANC observation checklist that did not meet the criteria of essential ANC service, were excluded from data analysis and consisted of items that measured time spend per ANC consultation, identification, follow-up actions for high-risk pregnancies, and open questions.

Data analysis

Data analysis for the ANC observations was performed using SPSS (IBM SPSS Statistics 27). Descriptive statistics were analysed and an independent-samples t-test was conducted that examined mean differences in completeness scores between control and intervention health facilities before and after implementation of the NAA. Additional independent-samples t-tests were conducted to assess the difference per category of the ANC observation checklist. Initially, we aimed to perform comprehensive analyses of variance (ANOVA) to compare control and intervention health facilities at post-test while controlling for baseline measures. Unfortunately, the assumptions for this analysis were violated since the observations performed at baseline and post-test were not dependant and the independent variable 'PrePost' could not be seen as a within-subject factor. Observations collected at baseline (n = 334) could not be linked to observations performed at post-test (n = 204) because different healthcare workers were observed and the amount of observations per health facility differed. As a result, we did not have one between-subject factor and one within-subject factor to test for an interaction on the dependent variable (completeness score) and it appeared to be impossible to transform the data and meet the assumptions. Furthermore, analyses were performed that looked at possible covariates (i.e. the differences between first visits and re-visits and at the age of the healthcare worker) but there were not significant covariates. As a result, we decided to perform separate independent-samples t-tests for the control and intervention facilities respectively.

Ethical considerations

Ethical approval for this study was obtained from the National Institute of Medical Research of Tanzania (MR/53/100/103-244-245-349-399) and Maastricht University in the Netherlands (OZL_188_10_02_2018_S72). A research permit was granted by the Tanzanian Commission for Science and Technology (No.2015-227-NA-2013-32). The district authority permitted to conduct the study in Magu district. Informed consent was obtained from pregnant women of whom the individual ANC consultation was observed. In case the participant was not able to

read, the consent form was read out loud by the research assistant.

Results & Discussion

ANC observations were performed on three separate days per health facility. It sometimes appeared that this was a quiet day at the health facility and only a few ANC consultations could be observed for that specific day. As a result, a total of 557 ANC consultations were observed, of which 239 were performed at control health facilities and 299 at intervention health facilities and 334 during baseline and 204 during post-test. For 31% of these consultations (n = 168), it was the pregnant women's first ANC visit, and for 68% (n = 380), a return visit. Table 1 provides an overview of the difference in the total completeness scores specified per category. As can be seen in Table 1, in all thirteen health facilities the completeness scores are low and only small differences are visible per category and per health facility. This means that, irrespective of the intervention, only a small percentage of all essential ANC services were provided. The most provided services were related to the registration of the women, physical examination (investigation), and medication provision.

Before implementation of the NAA (baseline), results from the independent-samples t-test showed that mean completeness score in the control health facilities (M = 19.88, SD = 7.13) was lower than in the intervention health facilities (M = 24.76, SD = 7.88) with a statistically significant difference (mean difference -4.88 (95% CI, -6.53 to -3.24), $t(333) = -5.84$, $p = .000$ and a large-to-medium effect size (cohen's $d = -.65$). After implementation of the NAA (post-test), results from the independent-samples t-test showed that the mean completeness score was comparable between the control health facilities (M = 22.92, SD = 10.16) and the intervention health facilities (M = 21.97, SD = 13.13), a mean difference of 0.95 (95% CI, 1.65 to 2.30), $t(205) = .58$, $p = .566$ (see Table 1).

Further analyses were performed that observed differences over time, and showed that the completeness score for intervention health facilities was statistically significantly higher at baseline (M = 24.76, SD = 7.88) than at post-test (M = 21.97, SD = 13.13) with a mean difference of 2.79 (95% CI, .42 to 5.17), $t(300) = 2.31$, $p = .000$ and a small effect size (Cohen's $d = .27$). For control health facilities, analysis indicated that the completeness score for control health facilities was significantly lower at baseline (M = 19.88, SD = 7.13) than at post-test (M = 22.92, SD = 10.16) with a mean difference of -3.04 (95% CI, -5.24 to -.84), $t(238) = -2.73$, $p = .001$ and a small-to-medium effect size (Cohen's $d = -.36$). Additional analyses performed on the seven separate categories of essential ANC can be found in Table 1.

Results of Study 1 could not confirm the hypothesis that the use of an eCDSS would increase the number of essential ANC interventions. In fact, an opposite result was found that showed a decrease in completeness score (pre- and post-implementation of the NAA) in health facilities that performed ANC with use of the NAA. Moreover, the results showed that in both control and intervention facilities, the performance of healthcare workers providing ANC is poor as the overall completeness score does not exceed 25%, meaning that only 25% of all essential ANC services are provided to pregnant women coming for ANC. To gain more insight into the reasons for the poor uptake of the NAA among healthcare workers using the NAA, in Study 2, in-depth interviews were conducted and questionnaire were administered to further explore healthcare workers' experiences of working with the NAA.

Table 1: Overview completeness scores per category

Essential ANC category	**Baseline**			**Post-test**		
	Control health facility Mean (Std. deviation)	**Intervention health facility Mean (Std. deviation)**	**t-value**	**Control health facility Mean (Std. deviation)**	**Intervention health facility Mean (Std. deviation)**	**t-value**
Total completeness score	19.88 (7.13)	24.76 (7.88)	-5.837***	22.92 (10.16)	21.97 (13.13)	0.575
Registration	34.83 (37.29)	40.19 (32.49)	-1.410	45.38 (47.63)	29.95 (45.45)	2.428 **
Gynaecological history	6.43 (9.31)	9.48 (13.37)	-2.470*	11.14 (11.96)	10.75 (16.62)	0.190
Current pregnancy	8.01 (7.86)	12.53 (7.71)	-5.281***	10.65 (8.51)	13.82 (14.83)	-1.913*
Investigation	35.32 (9.74)	42.30 (11.53)	-6.034***	35.14 (9.40)	36.10 (9.22)	-0.747
Laboratory	10.96 (13.48)	12.18 (13.07)	-.838	28.10 (27.55)	20.91 (24.57)	2.030*
Medication	36.64 (20.48)	45.73 (18.71)	-4.251***	29.00 (19.18)	33.33 (21.24)	-1.565
Education and Communication	22.42 (12.23)	26.74 (13.44)	-3.043**	24.18 (15.38)	20.29 (16.77)	1.770*

Statistical significance of *<.05, **<.01, ***<.001

STUDY 2

The aim of this second study is to explore the perceptions and experiences of healthcare workers with using the NAA and its implementation. Self-report questionnaires were

administered to gain insight into the intention of working with the NAA and experience with working with the NAA during service provision. In-depth interviews were conducted to gain a deep understanding of working with the NAA during ANC provision and listen to suggestions to improve the NAA.

Methods

Study design & sampling

A mixed-methods study was undertaken, consisting of questionnaires (n = 67) and in-depth interviews (n = 17), to explore the perceptions and experiences of healthcare workers providing ANC with the use of the NAA. Healthcare workers at all seven intervention health facilities were invited to fill in the questionnaire. For the in-depth interviews, healthcare workers were purposeful selected, based on their availability for the interview. The majority of the sample of healthcare workers selected for the interviews also participated for the questionnaire.

A: Self-report surveys; materials, procedure and data analysis

Self-report paper-and-pencil questionnaires were administered to all healthcare workers of the intervention facilities, to gain insight into their perceptions about and experiences with using the NAA. Healthcare workers providing ANC in the intervention facilities (n = 67) filled out questionnaires in February 2016 (baseline, n = 39) and August 2016 (post-test, n = 28). In total, 27 healthcare workers participated at both baseline and post-test. The questionnaires were completed by the healthcare workers at the health facility, during one of the monthly project visits by the research team, or at the project office when a healthcare worker was present for another occasion.

The questionnaire was use to gain more insight into the intention of working with the NAA and experiences with working with the NAA during service provision. Questions were related to the usefulness of the NAA, the reactions of others on the use of the NAA, and the practical implications of working with the NAA. Questions could be answered on a five point scale and healthcare workers were instructed to circle only one of the five answer options. Example questions include: *I want to use the NAA during ANC provision; Using the NAA is bad /good; Using the NAA increases workload*. (See Appendix C of this chapter for the questionnaire). Questionnaires were analysed using descriptive statistics for questions on the assessment among healthcare workers about using the NAA and the context of the NAA. Extreme skewness of the data prevented performing comparable statistical analysis between groups. Therefore, questionnaire responses were made dichotomous by merging “strongly agree” and “somewhat agree” as *agree* and “strongly disagree” and “somewhat disagree” as *disagree*. Since there were only a few respondents that scored “neither disagree nor agree” it was decided to see those as a missing value.

B: In-depth interviews; materials, procedure and data analysis

Interviews with 17 healthcare workers were conducted between March and April 2016, one month after the implementation of the NAA. Interviews took place in a private area in or surrounding the health facility, in Kiswahili or English, depending on the participant's preference. After the respondents were informed about the purpose and content of the interviews and the voluntary nature of their participation, they provided informed consent and gave permission to audio-record the interviews. A member of the research team (a foreign assistant working on the project in Tanzania) was assisted by a local research assistant who was present and available for English translations in case the interview was conducted in Kiswahili.

An interview guide was developed and discussed within the local research team (see Appendix D of this chapter). Questions concerned healthcare workers' experiences and attitudes towards working with the NAA during ANC provision. Moreover, healthcare workers were asked for suggestions to improve the NAA, specifically in light of any practical challenges they might have experienced. In addition, they were asked to describe the reaction of pregnant women towards the use of the NAA during the ANC consultation. No new information emerged after 17 interviews and the research team decided that data saturation was reached.

All interviews were transcribed verbatim and data analysis was performed employing a directed content analysis approach (Hsieh & Shannon, 2005). Codes were deductively derived, based on the interview guide, and newly emerging themes were coded as well and added to the initial codes. First, interviews were read and re-read to get familiarized with the data. After this, an initial codebook was created based on the concepts/questions of the interview guide. Relevant parts of the transcripts were then coded and grouped into this initial codebook, as well as the new emergent codes were formed during initial reading. With these codes and categories, comprehensive coding took place of all transcripts. For example, part of the transcript that said something about the guidance from the NAA, were coded into the category 'NAA guidance', which belongs to the theme 'usefulness'. After this, codes were merged or re-labelled when necessary which resulted in the final codebook and in two main themes, described below.

Ethical considerations

Ethical approval for this study was the same as for Study 1. Informed consent was obtained from all healthcare workers participating in the study.

Results & Discussion

Self-report questionnaire

Table 2 shows the perceptions and experiences with using the NAA at baseline and post-test assessment. At baseline, all (100%) healthcare workers were intending to use the NAA during

Table 2: Perceptions and experiences of healthcare workers using the NAA

Questions	Pre-measure		Post-measure	
	Agree	Disagree	Agree	Disagree
Usefulness of the NAA				
I want to use the NAA during ANC provision	100%	0%	96.4%	1.5%
Using the NAA during ANC is bad good	100%	0%	100%	0%
Using the NAA during ANC provision increases the quality of ANC	100%	0%	100%	0%
Using the NAA during ANC provision improves record keeping	100%	0%	100%	0%
Guidance of the NAA				
Using the NAA helps me recognise danger signs and risk factors	100%	0%	100%	0%
Using the NAA makes provision of ANC easier*	N/A	N/A	82.9%	7.1%
Using the NAA ensures that you do everything you need to for ANC	100%	0%	100%	0%
Practical implications of the NAA				
Using the NAA during ANC is time consuming	36.1%	63.9%	66.7%	33.3%
Using the NAA during ANC increases workload	55.6%	44.4%	55.6%	44.4%
Using the NAA during ANC endangers the privacy of ANC clients	82.9%	17.1%	75.0%	25.0%
The clients like me to use the NAA during ANC	100%	0%	88.9%	11.1%
Skills				
It was easy to become skilful at using the NAA	97.4%	2.6%	100%	0%
I decide myself whether or not I want to use the NAA during ANC	84.2%	15.8%	39.3%	60.7%
Infrastructure				
There is often no electricity available in the facility	78.4%	21.6%	53.8%	46.2%
There is often no internet connection in the facility	70.3%	29.7%	57.1%	42.9%
The NAA often stops working*	N/A	N/A	50%	50%
The speed of the NAA made it difficult to use the NAA during ANC*	N/A	N/A	35.7%	57.1%
Reason for not using the NAA: Battery of tablets were empty*	N/A	N/A	32.1%	64.3%
Reasons for not using the NAA: Too many clients/too busy*	N/A	N/A	25.0%	71.4%
Work pleasure				
I enjoy using the NAA during ANC*	N/A	N/A	96.4%	3.6%
I would prefer to use the ANC card (instead of the NAA)*	N/A	N/A	35.7%	64.3%
I am completely satisfied with the NAA*	N/A	N/A	96.4%	3.6%
I would prefer to use the NAA (instead of the ANC card)*	N/A	N/A	71.4%	28.6%

* questions were only administered at post-test

ANC service provision and thought the use of the NAA would benefit the quality of care and their performance. After six months of working with the NAA (post-test), this intention remained high at 96.4%. However, at post-test, 66.7% of healthcare workers indicated that working with the NAA was time consuming (compared to 36.1% at baseline), 35.7% expressed that they preferred working with the paper-based ANC cards, and approximately half of the healthcare workers expressed that they experienced logistical barriers in working with the NAA (no electricity, internet connection, or malfunctioning of the NAA). Moreover, only 39.3% of the healthcare workers at post-test indicated that they would be able to decide themselves whether or not to use the NAA, compared to 84.2% at baseline.

In-depth interviews

The sample of n=17 healthcare workers selected for the in-depth interviews consisted of 12 females (70.6 %) and 5 males (29.4 %). Most of the healthcare workers were nurses (64.7 %); others were medical attendants (17.6 %) or (assistant) clinical officers (17.7 %). The healthcare workers had a mean age of 27.9 years (*SD* = 6.53; ranging 23 - 50), and they had a mean of 4.03 years of experience (*SD* = 5.88; range 1 - 22). About half of the healthcare workers (52.9 %) had privately used a tablet or smartphone before using the NAA (52.9 %) or owned a tablet or smartphone (47.1 %).

Theme 1: Experiences with and attitudes towards working with the NAA

All healthcare workers expressed a positive attitude towards working with the NAA during ANC provision. The most important aspect mentioned was the simplification of their work, mainly by the automatic detection of danger signs, i.e. the 'alarm bells' with advice on follow-up actions, and the reminder to perform all essential interventions, so they would not forget anything in the care process. About a quarter of them specifically mentioned that they appreciated that the guidance was in their own language Kiswahili.

> *"First it is simplifying work, and it makes it possible to ask all the questions that are needed to be asked the mother* (sic)*, then at the same time I'm not speaking something from my mind, it's just through the alarms. I can just read and you know what to tell the mama, or some advice to mama* (sic) *rather than just thinking maybe you have to do this, this, and this."* (Medical Attendant, Male, Age: 23)

About two-thirds of the healthcare workers explained that the NAA was very useful for recordkeeping. Other positive aspects mentioned were the ease of the automatically generated 'expected due date', the summary including gynecological history, and the return date for the next visit. Two healthcare workers expressed that they gained new knowledge by working with the NAA and two others expressed that the NAA assisted them in the conversation with the pregnant women by phrasing the right questions so that women are encouraged to open

up. The majority of the healthcare workers also acknowledged the importance of the NAA for maternal health outcomes.

> *"Before using the NAA, we examined the mama, just examine, without knowing the many problems they were facing. But now, we examine them, we know when they have a problem, we rate them well until they deliver* […] *to help pregnant women and to reduce maternal health* (death)." (Nurse, Female, Age: 23)

Some negative experiences were also mentioned. For example, all the respondents expressed that working with the NAA required a lot of time, especially because of the many questions that need to be asked and filled in. Most minimized this barrier by explaining that they did not feel bad about it, because the NAA was important.

> *"It's true that the NAA takes a long time but those questions inside are more important so I cannot care about the time it takes because the questions are very important."* (Nurse, Female, Age: 25)

However, some healthcare workers were less pleased with the extra time needed to work with the NAA.

> *"So the NAA affect negative way for ANC* (sic) *because it consumes a lot of time, and also it needs more healthcare workers because you need to ask the mama and the same times you need to fill in the cards* […] *and the books* (government registration books). *But in general NAA it has positive, more positive effects to the pregnant mama rather than negative effects* (sic)." (Nurse, Male, Age: 32)

Healthcare workers also described that some pregnant women did not want their data to be stored in the device or for their picture to be taken (a small icon with the women's picture was stored on the device to be associated with her healthcare record). However, after an explanation, all agreed to receive services from the healthcare worker using the NAA. Healthcare workers felt confident that all community members will be positive about the NAA after experiencing care delivery with it or receiving information about it.

> *"The majority understands it, and they like it. But few don't understand* (sic), […] *whenever we want to start the process; we always educate them that we're using this app, this NAA, and the importance of it."* (Nurse, Female, Age: 26)

Further, half of the healthcare workers expressed that they felt that their advice was taken more seriously by their clients now that they were working with the NAA.

> *"It brings a positive effect to the pregnant mama* […]*and this alarm will refer the pregnant mama to go to Magu hospital, so the mama believes that by looking because she sees the red alarms, so the mama knows that this decision is come directly from the NAA and thinks maybe that's why I should go there. For now, they see that there is this danger sign prompt direct so the mama decides to go to Magu* (hospital) *for further investigation* (sic)*."* (Medical Attendant, Male, Age: 23)

Healthcare workers expressed that the NAA was easy to use. Those who were not familiar with an electronic device sometimes faced more difficulties in the beginning, but reported that the training was helpful and that practice in using the NAA made it easier.

> *"It was not difficult because we were sent there to get the training and each and everything was explained in a good way, so there weren't any difficulties."* (Clinical Officer, Female, Age: 48)

Theme 2: Challenges/barriers in using the NAA and suggestions for improvement

Almost all healthcare workers mentioned that a primary barrier were unreliable electrical power supply and internet connection, making the NAA not able to use at times. Healthcare workers mentioned that the battery of the tablet does not last long enough to serve all pregnant women in a given clinic day. They also mentioned that the tablet takes a long time to charge. Tablets were often charged inside the healthcare workers' house next to the health facility due to safety issues or because the health facility has only a few or no sockets available to charge the tablet. An empty tablet therefore means that service provision with the NAA could not continue.

> *"*[…] *maybe sometimes you can find no electricity, and you have a patient and you are putting the records and its halfway then the tablets went off* (sic)*."* (ClinicalOfficer, Female, Age: 26)

One healthcare worker explained that the unreliable electrical power supply caused them to travel to town to charge the tablet in shop.

> *"Because here when we do not have power, you need to go to Kisesa* (village) *to charge it* (in one of the shops that have power, leave it there to charge)*."* (Medical Attendant, Female, Age: 34)

With regard to the unreliable internet connection, some healthcare workers mentioned that the tablet fails to send patient files to the server which sometimes resulted in losing files. And several healthcare workers explained that the reaction time of the NAA is slow, resulting in waiting time to process input during busy clinic times. A few healthcare workers specified they sometimes faced angry clients because of the extra waiting time.

> *"The NAA is very good but it takes a long period. Since in the morning* (sic), *pregnant women were here, and they are still here. We are still using* (sic) *so it's very slow and it needs patience and it needs time. That causes some of the husbands, when they escort their wives, to get furious and leave."* (Clinical Officer, Male, Age: 50)

Despite the mentioned challenges, the majority of the healthcare workers had difficulties with formulating improvements for the NAA. Some healthcare workers experienced difficulty distinguishing a first ANC visit from a re-visit in the NAA and would like to see some changes in the layout to make this clear. Furthermore, about one-third of the healthcare workers suggested expanding the NAA to different aspects of care, such as children under 5 care, or linkage with the national system. Other than this, no more improvements were suggested.

Results of Study 2 demonstrate that the included healthcare workers were positive about working with the NAA. Despite the extra time it takes to fill in the NAA, healthcare workers experienced improvements for ANC service provision. However, when challenges about working with the NAA were discussed, healthcare workers mentioned that service provision with the NAA was sometimes not possible due to infrastructural barriers.

General Discussion

This paper presents findings from two studies focussed on the impact of an eCDSS on workflow and quality of care in rural Tanzania. Study 1 presents results of an evaluation on the impact of an eCDSS on the comprehensive delivery of ANC services, by performing ANC observations in control and intervention facilities. Study 2 was conducted to understand and contextualise the findings of Study 1, by exploring the perceptions and experiences of healthcare workers in the intervention facilities on working with the eCDSS using self-report questionnaires and in-depth interviews.

Contrary to our expectations, the results of Study 1 indicate that health facilities where the NAA was used during ANC service provision obtained a *lower* completeness score for delivery of ANC services compared to control health facilities. This result does not confirm the hypothesis that the use of an eCDSS would increase the number of essential ANC

interventions. However, this unexpected result is consistent with previous studies conducted on the effects of an eCDSS in Ghana and South Africa, which demonstrated that although the performance of healthcare workers improved somewhat, no significant improvement in the overall quality score of ANC was found after implementation of the eCDSS (Horner et al., 2013; Mensah et al., 2015; Saronga et al., 2017). Our results may indicate that at intervention facilities where the NAA was used, essential components of ANC service delivery were skipped more than in control facilities. However, we must note that both completeness scores were very low: 22.92% in the control facilities versus 21.97% in intervention facilities, shedding doubt on the ecological significance of these findings.

A possible explanation for the low completeness scores at both control and intervention facilities might be the lack of equipment and materials to perform all essential interventions (Solnes Miltenburg et al., 2017a; Nyamtema et al., 2012; Van Pelt et al., 2020). Previous research has demonstrated that in Mwanza region, compared to the rest of the country, the health facilities are the least well equipped with (basic) instruments needed for antenatal care (29). In addition, a possible explanation for the unexpected decrease in ANC service delivery at health facilities using the NAA might be the extra burden for healthcare workers using the NAA. Results from the questionnaires and in-depth interviews in Study 2 show that healthcare workers expressed that the NAA increased their workload, and took more time than using the paper-based ANC card. These findings are consistent with previous research on the use of an eCDSS in sub-Saharan Africa where concerns about the extra time was mentioned as an explanation for the broad variety in uptake of the eCDSS between different health facilities (Abejirinde et al., 2019; Adepoju et al., 2017; Zakane et al., 2017). Given the fact that healthcare workers are already faced with a high workload due to the critical shortage of staff (MoHSW et al., 2013; Nyamtema et al., 2012), healthcare workers might have been too occupied with filling in the NAA completely. Moreover, the current research was conducted about 3 months after the implementation of the NAA, whereas an evaluation study conducted in Ghana and Tanzania focussed on the influence of an eCDSS on ANC workflow, found that over a period of 17 months the time needed for ANC using the eCDSS did not increase (Mensah et al., 2015). This suggests that a longer 'training' period could give healthcare workers more time to adjust to the new situation of providing ANC with the eCDSS.

Another possible explanation for the unexpected result that the NAA did not improve ANC service delivery might be related to the poor infrastructure at many health facilities. Consistent with previous studies, healthcare workers expressed several infrastructural challenges while working with the NAA such as losing patient files, and the slow reaction time of the NAA due to the unstable electrical power and internet connection (Benski et al., 2017; Oluoch et al., 2012; White et al., 2016; Zakane et al., 2017). The practical situation of busy clinic days combined with these challenges might have made working with the NAA difficult and sometimes not possible, which might also have influenced healthcare workers' willingness

to work with the NAA (Abejirinde et al., 2019; Zakane et al., 2017). Given our finding that all healthcare workers acknowledged the utility of the content and the practical guidance of the NAA on the quality of ANC, it is of crucial importance for future intervention developers to be sensitive to the context where the device will be implemented (Abejirinde et al., 2019). This could avoid the critical challenged as expressed by the healthcare workers working with the NAA.

Furthermore, the NAA was used in parallel with the standard paper registers due to the fact that healthcare workers in Tanzania are required to fill in the paper-based registry books and that the coordination with other health facilities is also paper-based. Having to use the NAA thus created double administrative tasks for them. Results from the questionnaire show that more than one third of the participating healthcare workers indicated they preferred working with the paper-based registration card instead of the NAA. Previous research conducted in Burkina Faso on the use of an eCDSS for maternal healthcare found that this double documentation increased the workload, and healthcare workers preferred working with the paper-based version of the partograph because it fit better with their workflow (Zakane et al., 2017). This finding thus highlights the importance of integrating an eCDSS in the existing local registration structure.

Overall, healthcare workers had a positive attitude towards the content of the NAA and expressed that the guidance of the NAA was helpful for their performance and the overall quality of ANC. Results from the questionnaires show that this initial enthusiasm and intention to work with the NAA decreased after they worked with the NAA for six months. As demonstrated in previous research conducted in low- and middle- income countries, the novelty of a new and innovative intervention such as the NAA could have induced this initial enthusiasm of the healthcare workers (Agarwal et al., 2015). Several studies conducted in sub-Saharan African countries implementing an eCDSS also found that initial enthusiasm to use the eCDSS slowly decreased over time (Abejirinde et al., 2018; Adepoju et al., 2017).

Strengths and limitations

The current research had some limitations that need to be considered. Due to practical considerations, the selection of control and intervention health facilities was based on the availability of electrical power and mobile network connection which might have influenced our results. However, since results show lower scores in intervention facilities we believe that the results present a realistic view of the differences in service provision between control and intervention facilities. Regarding the statistical analysis performed, we were not able to assess the interaction effect between the two variables time (pre and post measure) and group (control and intervention health facility). Due to practical choices made during data collection, the assumption for an analysis of variance to work with at least one within-subject factor was violated and therefore we chose to perform an independent-sample-t-test.

Last, self-report questionnaires were used to gain insight into perspectives and experiences of healthcare workers using the NAA which carries the risk of social desirability bias. Participants could have reported in a certain way because they might have had the feeling that their answers could have impacted their job or the provision of tablets. Nevertheless, the strength of this study it that is draws upon multiple data sources that are complementary and give meaning to individual results. Therefore, we believe that this study provides valuable inside into the effects of using an eCDSS on ANC service provision as well as perceptions and experience of healthcare workers using an eCDSS.

Conclusion

The current findings suggest that implementing an eCDSS is not the first step to take in improving the adherence to ANC guidelines by healthcare workers in low- and middle-income countries. Although our results show that healthcare workers believed that the guidance of the NAA during service provision would benefit the quality of ANC, the results of the evaluation showed that the quality of care decreased in health facilities were the NAA was used during ANC. Based on the current findings, we believe that the focus for improving healthcare worker adherence to guidelines should be on solving the challenges related to the working conditions of healthcare workers. Poor working conditions might induce feelings of frustration and demotivation and influence quality of care (Mubyazi et al., 2012). Therefore, the infrastructure of the health facilities should be sufficient to be able to perform all ANC essential services and there should be enough staff available to be able to dedicate sufficient time for ANC. We believe that when these issues are solved, an eCDSS can be an useful tool to increase knowledge levels of healthcare workers and promote adherence to ANC guidelines.

Appendix A – ANC observation checklist

1. Part 1 Basic info
2. Date of observation
3. Name of data collector
4. Name of facility
5. Healthcare worker ID
6. Woman ID, in order to link the data in MagPi with the copied ANC card.
7. Before observing the consultation, make sure to obtain permission from both the service provider and the client. Also make sure that the provider knows that you are not there to evaluate him or her and that you are not an "expert" to be consulted during the visit.
8. Start time of ANC visit, when does the woman enter the room. Use English time for example 1030

9. Part 2 Basic consultation info
10. ANC visit number
11. ANC card available or received during visit
12. Accompanying person during visit

13. Part 3 Registration
14. The following items are asked or mentioned
- Clients name
- Clients age
- Clients work
- Clients place of residence
- Husband's name
- Husband's age
- Husband's work
- None of above items were mentioned

15. Part 4 History
16. Is the woman pregnant for the first time?
17. Are the following items mentioned by the woman or the health provider?
- Total number of pregnancies
- Total number of prior deliveries
- Number of living children
- Prior abortions
- Prior neonatal death
- Prior still birth
- None of the items above were mentioned

18. Comment Box Obstetric history. In case anything was unclear regarding Obstetric History, please write that in this box.
19. Did the healthcare worker ask about or did the client mention any of the following facts?
- Date of last delivery
- Mode of previous deliveries
- Multiple pregnancies (twins or more)
- Prior Stillbirth [Baby born dead does not breathe or cry]
- Prior neonatal death [Baby born alive, died after birth]
- Heavy bleeding during or after previous delivery
- Placenta problems
- Previous pre-term birth
- Prolonged or obstructed labour (Did labour take too long, the baby too big or passage to small?)
- Anaemia during pregnancy lack of blood
- High blood pressure/convulsions
- No facts related to history discussed

20. Past medical/surgery history, does the HCW ask about or does the woman mention any of the following items on medical history?
- Operation
- Medication
- Tuberculosis
- Heart disease
- Diabetes
- No facts related to medical/surgery history discussed

21. HIV/PMTCT discussed
- Asked HIV status
- Asked about if on medication
- Asked about CD4 count
- Asked about CTC clinic
- Asked about adherence of drugs
- Nutrition advice baby
- No facts related to HIV/PMTCT discussed

22. Date of 1st day last menstrual period (LNMP). Enter "99" if not mentioned.
23. Present pregnancy, which of the following items are mentioned by the HCW.
- Calculates trough pregnancy circle
- Calculates by formula
- Mentions EDD
- Mentions Gestational Age
- None

24. Complaints or current complaints during this pregnancy. Did the health provider mention one of the following items?
- Fever
- Vaginal bleeding
- Headache or blurred vision
- Swollen face or hands
- Convulsions or loss of consciousness
- Severe difficulty breathing

- Persistent couch for two weeks or longer
- Severe abdominal pain
- Foul smelling discharge
- Frequent or painful urination
- (Decrease or stop of) foetal movements (if > 20 weeks)
- Any (other) problems
- No questions about current complaints asked

25.Did the nurse ask: “do you have any complaints”?

26. Part 5 Observation and clinical investigation

27. Record if the provider carried out the following steps and/or examinations
- Temperature
- Pulse
- Blood Pressure
- Weight
- Height
- None of the above

28. Clinical examination, record whether the provider carried out the following steps and/or examinations
- Pallor (checked the eyes/hands/tongue)
- Oedema
- Breasts
- Lungs and Heart
- Not performed

29. Obstetric complications. Record whether the provider carried out the following steps and/or examinations
- Fundal height with tape measure
- Fundal height with hands
- Foetal presentation and engagement
- Foetal heart sound
- Not performed

30. Vaginal examination performed

31. Part 6 Laboratory investigation

32. Laboratory investigation. Document if the health worker performs the following tests
- Haemoglobin
- Grouping and rhesus factor
- RPR (syphilis)
- Malaria
- Urine
- Voluntary counselling and testing for HIV/PMTCT
- No tests performed

33. Laboratory referral. Document if the health worker refers the woman for one of the following tests
- Haemoglobin
- Grouping and rhesus factor
- RPR (syphilis)
- Malaria
- Urine
- Voluntary counselling and testing for HIV/PMTCT
- Not referred

34. Part 7 Drug administration and immunisation

35. Document if the health provider gave the following treatments or advised to get them from pharmacy (or checked if already received in case of TT)
- Iron
- Folic Acid
- Anti-malaria (SP)
- Tetanus toxoid
- Mebendazol
- No treatment provided or referred to other place
- Not specified medication provided or prescribed

36. Did the health provider give information about purpose/side effects/use of which medication
- Iron
- Folic Acid
- Anti-malaria (SP)
- Tetanus toxoid
- Mebendazol
- Other
- No information provided

37. Part 8 Education and counselling

38. The following education was given in group
- Process of pregnancy and its complications
- Diet and nutrition
- Rest and exercise in pregnancy
- Personal Hygiene
- Danger signs in pregnancy
- Use of drugs in pregnancy
- Effects of STI/HIV/AIDS
- Care of breasts and breast feeding
- Symptoms and signs of labour
- Plans for delivery
- Plans for post-partum care
- Family planning
- Harmful habits (smoking, drug abuse, alcoholism)
- Schedule of return visit
- No education was given
- Don’t know

39. The following education was given individual
- Process of pregnancy and its complications
- Diet and nutrition
- Rest and exercise in pregnancy
- Personal Hygiene

- Danger signs in pregnancy
- Use of drugs in pregnancy
- Effects of STI/HIV/AIDS
- Care of breasts and breast feeding
- Symptoms and signs of labour
- Plans for delivery
- Plans for post-partum care
- Family planning
- Harmful habits (smoking, drug abuse, alcoholism)
- Schedule of return visit
- No education was given

40. If danger signs were discussed, are the following items discussed?
- Vaginal bleeding
- Convulsions
- Severe headache with blurred vision
- Fever and too weak to get out of bed
- Severe abdominal pain
- Fast and difficult breathing
- Swelling of fingers, face or legs

41. If plans for delivery were discussed, are the following items discussed?
- Asked where she will deliver
- Emergency preparedness
- Advised to use skilled worker during delivery
- Transportation
- Financial arrangements
- Purchase relevant items

42. Part 9 Actions taken on abnormal or high risk findings

43. High risk identified? Does the health provider identify this women as high risk. Which of the following items are mentioned?
- No high risk mentioned
- Age < 20
- First pregnancy on age > 35
- > 5 times pregnant
- Last birth > 10 years ago
- Previous stillbirth/neonatal death
- Previous C/S or Vacuum delivery
- Previous bleeding
- Previous > 2 times abortion
- Previous pre-term delivery
- Current high BP (>140/90mmHg)
- Current Low Hb or clinically anaemia
- Current GA >40w
- Current No FHR
- Current mal presentation at > 36weeks
- Current Danger sings present
- Current Twin pregnancy
- Current sign of polyhydramnios and oligohydramnios
- Current infection (Syphilis, UTI, other)
- Abnormal urine test
- Other diseases (HT/Diabetes/TBC/HIV/Epilepsy/mental illness)
- Previous placenta problems
- Height < 150
- Pelvic abnormalities
- Limb oedema

44. Actions taken on abnormal findings
- Referral for ANC Advised to go for ANC at a higher centre
- Referral for delivery Advised to give birth at health centre or hospital level
- Treatment provided
- Additional investigation done or recommended
- No actions taken

45. If revisit, did the health provider the client mention anything related to the previous visit? Please answer, Yes or No and please explain.

46. Part 10 End of visit

47. Did the HCW ask whether the patient had any questions?

48. End time of ANC visit, when does the woman leave the room. Use English time for example 1030

49. Did the health worker write on the ANC card?

50. Did the health worker write in the government registration books?

51. Any remarks about this observation?

Appendix B – 94 essential ANC items

	Registration
1	1. Clients name
2	2. Clients age
3	3. Clients work
4	4. Client place of residence
5	5. Husband's name (document if no husband)
6	6. Husband's age
7	7. Husband's work
	Gynaecological history
8	1. Primi gravida
9	2. Total number of pregnancies
10	3. Total number of prior deliveries
11	4. Number of living children
12	5. Prior abortions
13	6. Prior neonatal death
14	7. Prior still birth
15	8. Date of last delivery
16	9. Mode of previous deliveries (normal or assisted delivery, vacuum, caesarean section)
17	10. Multiple pregnancies (twins or more)
18	11. Previous delivery Stillbirth
19	12. Previous delivery neonatal death
20	13. Heavy bleeding during or after previous deliver
21	14. Placenta problems (stuck
22	15. Previous pre-term birth
23	16. Prolonged or obstructed labour
24	17. Anaemia during pregnancy lack of blood
25	18. High blood pressure/convulsions
26	19. Operation
27	20. Medication
28	21. Tuberculosis
29	22. Heart disease
30	23. Diabetes
	Current pregnancy
31	1. Calculates trough pregnancy circle
32	2. Calculates by formula
33	3. Mentions EDD
34	4. Gestational Age
35	5. Fever
36	6. Vaginal bleeding
37	7. Headache or blurred vision
38	8. Swollen face or hands
39	9. Convulsions or loss of consciousness
40	10. Severe difficulty breathing
41	11. Persistent couch for two weeks or longer
42	12. Severe abdominal pain
43	13. Foul smelling discharge
44	14. Frequent or painful urination
45	15. Decrease or stop of foetal movements
46	16. Other
47	17. Did HCWs ask: Do you have any complaints
	Laboratory
48	1. Haemoglobin tested or referral
49	2. Grouping and rhesus factor tested or referral
50	3. Syphilis tested or referral
51	4. Malaria tested or referral
52	5. Urine tested or referral
53	6. HIV/PMTCT tested or referral
	Investigation
54	1. Temperature
55	2. Pulse
56	3. Blood Pressure
57	4. Weight
58	5. Height
59	6. Pallor
60	7. Oedema
61	8. Breasts
62	9. Lungs and Heart
63	10. Fundal height with tape measure
64	11. Fundal height with hands
65	12. Foetal presentation and engagement
66	13. Foetal heart sound
67	14. Vaginal examination
	Medication
68	1. Iron
69	2. Folic Acid
70	3. Anti-malaria (SP)
71	4. Tetanus toxoid
72	5. Mebendazol
73	6. Other
74	7. Education Iron
75	8. Education Folic Acid
76	9. Education Anti-malaria (SP)
77	10. Education Tetanus toxoid
78	11. Education Mebendazol
79	12. Education Other
	Education and communication
80	1. Process of pregnancy and its complications
81	2. Diet and nutrition
82	3. Rest and exercise in pregnancy
83	4. Personal Hygiene
84	5. Danger signs in pregnancy
85	6. Use of drugs in pregnancy
86	7. Effects of STI HIV AIDS
87	8. Care of breasts and breastfeeding
88	9. Symptoms and signs of labour
89	10. Plans for delivery
90	11. Plans for postpartum care
91	12. Family planning
92	13. Harmful habits smoking drug abuse alcoholism
93	14. Schedule of return visit
94	15. Did the healthcare worker ask any questions

Appendix C – Questionnaire

Please fill out the following questions. Please do not skip any questions.
If there are multiple options **please circle the answer** that fits best with your situation or feeling.
Try to be as complete as possible when answering the open questions.

1. Name

2. In the last 2 months, how many days have you worked with the NAA (approximately)

3. In the last 2 months, How often did you use the NAA during first ANC visits?	Every ANC visit	Most of the ANC visits	About half the ANC visits	Less than half the ANC visits	None of the ANC visits
4. What was the reason for not using the NAA during a first ANC visit? Select from the 12 options (multiple answers possible)	NAA was not working	Tablet was not working	Not enough tablets	Battery of tablets were empty	Client did not give consent
	NAA takes too much time	Too many clients/ too busy	I could not login	I did not feel experienced enough	I prefer using the ANC card only
	NAA is too difficult	I used NAA for every first visit			
5. In the last 2 months, how often did you use the NAA during re-visits?	Every re-visit	Most of the re-visits	About half the re-visits	Less than half the re-visits	None of the re-visits
6. What was the reason for not using the NAA during a follow-up ANC visit? Select from the 15 options (multiple answers possible)	NAA was not working	Tablet was not working	Not enough tablets	Battery of tablets were empty	Client did not give consent
	NAA takes too much time	Too many clients/ too busy	I could not log in	I did not feel experienced enough	I prefer using the ANC card only
	NAA is too difficult	First visit was not entered in NAA	I did not know how to enter a follow-up visit	Could not find client in NAA	I used NAA for every re-visit

7. Any other reasons for not using the NAA during a (first or follow-up) ANC visit? State them here

8. How often do you look at the summary of previous visits	Every follow-up visit	Most of the follow-up visits	About half of the follow-up visits	Less than half of the follow-up visits	None of the follow-up visits	Don't know
9. How often do you follow the advice that the NAA gives?	Always	Most of the time	About half of the time	Less than half of the time		Never
10. What are reasons for not following the advice that the NAA gives (multiple answers possible)	Advice does not match guidelines	Client will or cannot follow the advice	Do not have the resources	I don't understand the advice		I follow every advice that the NAA gives
11. What other reasons are there for not following the advice of the NAA?						
	To what extent do you agree with the following statements?					
12. I always follow the advice that the NAA gives	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree	
13. I want to use the NAA during ANC provision	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree	
14. I plan to use the NAA during ANC provision	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree	
15. Using the NAA during ANC is	Very harmful	Somewhat harmful	Neither harmful nor beneficial	Somewhat beneficial	Very beneficial	
16. Using the NAA during ANC is	Very unpleasant	Somewhat unpleasant	Neither unpleasant nor pleasant	Somewhat pleasant	Very pleasant	
17. Using the NAA during ANC is	Very undesirable	Somewhat undesirable	Neither undesirable nor desirable	Somewhat desirable	Very desirable	
18. Using the NAA during ANC is	Very bad	Somewhat bad	Neither bad nor good	Somewhat good	Very good	
19. I enjoy using the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree	

20. I would prefer to use the ANC card (instead of the NAA)	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
21. I am completely satisfied with the NAA	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
22. I would prefer to use the NAA (instead of the ANC card)	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
23. Using the NAA makes provision of ANC easier	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
24. Using the NAA during ANC provision increases the quality of ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
25. Using the NAA during ANC provision improves record keeping	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
26. Using the NAA during ANC helps me recognise danger signs and risk factors	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
Please fill out the following questions. Please do not skip any questions. If there are multiple options **please circle the answer** that fits best with your situation or feeling. Try to be as complete as possible when answering the open questions.					
27. Using the NAA helps me in decision-making	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
28. Using the NAA during ANC ensures that you do everything you need to do during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
29. Using the NAA makes report writing more efficient	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
30. Using the NAA during ANC is time consuming	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree

31. Using the NAA during ANC increases workload	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
32. Using the NAA during ANC endangers the privacy of ANC clients	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
33. Using the NAA during ANC makes me look smarter in front of patients	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
34. Using the NAA during ANC is efficient	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
35. Using the NAA helps me in providing education to the pregnant women	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
36. Using the NAA during ANC increases the satisfaction of clients	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
37. What do you believe are <u>other</u> advantages of using the NAA during ANC?					
38. What do you believe are <u>other</u> disadvantages of using the NAA during ANC?					

To what extent do you agree with the following statements?

39. It is expected of me to use the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
40. I feel support from others to use the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
41. The ANC clients like me to use the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
42. My colleagues are using the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree

Please fill out the following questions. Please do not skip any questions.
If there are multiple options **please circle the answer** that fits best with your situation or feeling.
Try to be as complete as possible when answering the open questions.

43. It was easy to become skilful at using the NAA	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
44. Using the NAA during ANC is easy for me	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
45. I decide myself whether or not I want to use the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
46. I feel confident using the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
47. It is easy for me to correct a mistake in the NAA	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
48. Sending the data of the NAA is easy for me	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
49. Finding patients in the NAA is easy for me	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
50. I received enough training on using the NAA	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
51. The NAA often stops working	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
52. The support I received from the WCCP team was enough	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
53. The speed of the NAA made it difficult to use the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree

54. There is often no electricity available in the facility	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
55. There is often no internet connection in the facility	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
56. The internet connection in my facility made it difficult to use the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
57. The status of electricity in my facility made it difficult to use the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
58. The high workload made it difficult to use the NAA during ANC	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
59. Even when there are many clients for ANC, I am using the NAA.	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
60. Even when there is no internet connection in the facility, I am using the NAA during ANC.	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
61. Even when there is no electricity available in the facility, I am using the NAA during ANC.	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
62. Do you have any other remarks about the NAA you would like to share with us? State them here:					

Appendix D – Interview guide

Introduction	Interviewer introduces self, the research, privacy, independence from the project Participant fills in informed consent

Themes	**Questions**
Antenatal Care	- Why do you provide ANC? ➢ What do/don't you like about it? - Why is it important for pregnant women to attend ANC? - What do you think of the ANC provided by you and your facility? ➢ What do/don't you like about it? ➢ What could be improved?
The NAA Implementation	- How often do you use the NAA? Why? ➢ Are there parts you did not use? Why? - When and how do you use the NAA? ➢ How does the NAA influence the workflow
The NAA Attitude	- What do you think of the NAA? ➢ What do/don't you like about it? ➢ How useful do you think it is? ➢ What is the effect of the NAA on ANC? ➢ Did your opinion change? - What do you think about the advice the NAA provides? ➢ Do you always follow the advice? ➢ Did you knew all information or is it new? - What are the biggest differences between normal ANC and ANC with NAA? - If you had to choose, what kind of NAA do you prefer and why? - Do you know why the NAA is implemented? Why? ➢ if not, can you think of it yourself?
The NAA Norms	- How do you think the pregnant woman like being treated with the NAA? - What do your colleagues think of the NAA? ➢ Do they use it? Do they like it? - What do you think people in Magu district think of the NAA? ➢ How accepted do you think it is to use the NAA? ➢ What do your patients/people from the village think about it?
The NAA Adoption	- What are your reasons for using the NAA? - What did you expect of the NAA? - Has the NAA met your expectations?
The NAA Self-efficacy	- Do you think it is easy to use? ➢ How could we make it easier to use? - What challenges do you face when using the NAA? ➢ How can we minimize those challenges? - How difficult is it to learn to work with the NAA? ➢ How could we make it easier to learn how to work with the NAA? ➢ Lay-out/structure?
The NAA Suggestions for improvement	- If you could change anything about the NAA, what would it be? - Is there something you would add? ➢ For example, to delivery care, or the tablet. - What else should be done to make the NAA more effective?
End Questions	- What do you think about working with a tablet? ➢ Do you use it for other things? - What if we would stop with the NAA, would that change the ANC? ➢ How and/or why would it change? - Do you think other facilities should use the NAA as well? Why (not)? - Do you have any other important remarks or questions?

CHAPTER 6

General discussion

This dissertation aimed to increase knowledge on the practical situation of antenatal care in Magu district, Tanzania and to explore whether an electronic decision aid would be useful to improve the quality of antenatal care delivery in low-resource settings. The reported empirical studies describe the situation before, during, and after the implementation of the Nurse Assistant App, a tablet-based electronic decision aid to be used by healthcare workers during antenatal care. Specifically, healthcare workers and pregnant women were asked about their experiences with antenatal care and their opinion on the possibility to use an electronic decision aid during service provision, the development and implementation process of the Nurse Assistant App was systematically evaluated, the usefulness of the Nurse Assistant App on the workflow and delivery of antenatal care services was assessed, and perceptions and experiences of healthcare workers using the Nurse Assistant App were explored.

Summary of main findings

Chapter 2 presents findings of the needs assessment undertaken with sixteen healthcare workers providing antenatal care in Magu district, with the aim to identify the determinants that influence their work performance, and to explore their perceptions on improving the quality of antenatal care including the usefulness of an electronic decision aid. Results show that healthcare workers acknowledged the importance of antenatal care for the wellbeing of pregnant women and their unborn child. While healthcare workers rated their own performance highly, they were more critical in their perceptions of the work of colleagues, noting that sometimes important antenatal care interventions were not provided to pregnant women. Healthcare workers expressed concerns and frustrations about their working conditions, such as the lack of equipment, high workload, and shortage of staff. Moreover, several healthcare workers attributed differences in provider performance to the unequal level of education, resulting in a lack of experience, skills, and knowledge. In addition, most healthcare workers felt that they had not received enough education to provide good quality antenatal care and requested additional training. With respect to the feasibility and utility of having an electronic decision aid, healthcare workers were positive towards using one in practice, expecting the aid to improve record-keeping and the overall quality of care.

The study in *Chapter 3* focused on the second part of the needs assessment. The study was undertaken with nineteen pregnant women receiving antenatal care in Magu district to gain insight into pregnant women's perceptions and experiences with antenatal care and understand to what extent digital health tools are perceived as beneficial for quality improvement of antenatal care. Results showed that pregnant women were grateful for the received antenatal care services and acknowledged its importance during pregnancy; however, certain medication and test shortages meant that women sometimes missed important interventions/ procedures or had to come back to the clinic again when the item became available. Furthermore, one-third of the participants felt that healthcare workers could perform better and questioned healthcare workers' willingness to perform or explain certain procedures. For

example, almost all pregnant women knew stories of healthcare workers becoming angry when women do not adhere to their rules. The participating pregnant women expressed a need for improved antenatal care delivery, particularly the availability of diagnostic tests, and strategies to improve performance and strengthen motivation of healthcare workers. Regarding the use of an electronic decision aid during antenatal care, women were positive towards the use of an electronic decision aid, noting that it could improve the quality of antenatal care due to improved record-keeping, improved performance of healthcare workers, and improved communication between healthcare workers and pregnant women.

Chapter 4 builds upon the findings of Chapter 2 and 3 to describe the development process and implementation of the Nurse Assistant App. The Nurse Assistant App was developed by the members of the Woman Centered Care Project based on their practical experiences and knowledge. At the time of its development in 2014, the process of developing and implementing digital health tools in low- and middle-income countries was not yet routinely described or evaluated. This study aimed to assess how the Nurse Assistant App was developed, and whether theoretical frameworks and concepts were employed to inform the development of the intervention. This retrospective assessment, using Intervention mapping showed that tasks related to community engagement, adjustment to local context, implementation in the practical context in collaboration with local partners, and rigorous evaluation were accomplished. However, tasks related to identifying theory-based behaviour change methods were not accomplished. The chapter gives several examples and explains why it is important to engage the community and listen to their insights, formulate clear programme goals, and specify the desired change, and anticipate potential problems. This chapter was written to inform future programme planners in low- and middle-income countries on important considerations and pitfalls to avoid when developing an electronic decision aid. Furthermore, the chapter shows that the six steps of Intervention Mapping can be a useful framework to apply when systematically evaluating the development and implementation process of a digital health tool.

Chapter 5 presents findings of two studies to explore the impact of an electronic decision aid on workflow and quality of care in rural Tanzania. The first study led to an unexpected finding, where health facilities delivering antenatal care using the Nurse Assistant App did not provide more essential antenatal care interventions compared to control facilities, contrary to what was expected. In fact, the results showed a decrease in number of essential antenatal care services (pre-and post-measure) when working with the Nurse Assistant App. Moreover, in both control and intervention facilities, the performance of healthcare workers providing antenatal care was poor as the overall completeness score (the amount of items observed during antenatal care) did not exceed 25%, meaning that only about a quarter of all essential antenatal care services was provided to pregnant women coming for antenatal care. The second study in this chapter aimed to provide more insight into the reasons for the

poor uptake of the Nurse Assistant App among healthcare workers. Results indicated that although healthcare workers were positive overall about using the Nurse Assistant App in practice, they felt it increased their workload and infrastructure challenges, such as the lack of electricity or internet connection – made working with the App challenging.

Implications and recommendations

Stakeholders' perceptions

This dissertation shows that the quality of antenatal care is perceived differently by healthcare workers and pregnant women. In Chapter 2 we discussed the contradiction between the positive attitude of healthcare workers towards performing antenatal care and their actual behaviour during antenatal care provision. Healthcare workers felt capable of providing good quality antenatal care and rated their services as being of high quality. At the same time, however, they acknowledged that sometimes important antenatal care interventions were not provided to pregnant women. Findings from chapter 2 show that healthcare workers experience a high burden of workload and feel they do not have enough time to perform all antenatal care interventions. Prior research demonstrated that, among other factors, lack of time, financial incentives and resources influences healthcare workers' adherence to guidelines (Almazrou et al., 2020; Correa et al., 2020). Healthcare workers also explained that this occurs due to lack of supplies and lack of skilled healthcare workers, which is consistent with previous studies conducted in Tanzania (Conrad et al., 2012; Solnes Miltenburg et al., 2017a; Nyamtema et al., 2012; Sarker et al., 2010). Interestingly, pregnant women interviewed in Chapter 3 expressed their concerns about the quality of care, which were not only related to the availability of supplies, like healthcare workers stated, but also to healthcare workers' motivation to perform their jobs. Indeed, previous studies have shown that there is a relationship between healthcare workers' motivation to perform their job and quality of care (Gross et al., 2011; Mosadeghrad, 2014; Mrisho et al., 2009). Several pregnant women in this study described that healthcare workers reacted emotionally towards patients, did not consistently provide high-quality care and did not give sufficient and relevant information to the pregnant women. These findings are in line with prior research conducted in rural areas of Tanzania (Mahiti et al., 2015; Mrisho et al., 2009; Tancred et al., 2016).

It might be that the poor health facility infrastructure influences motivation to deliver care among healthcare workers as demonstrated in previous studies in rural sub-Saharan Africa (Gross et al., 2011; Mosadeghrad, 2014; Mrisho et al., 2009). Being faced on a daily basis with challenges such as missing equipment and supplies, a high workload, the lack of reliable water and electricity, poor housing conditions, can lead to a decrease in motivation and morale (Gross et al., 2011; Mosadeghrad, 2014; Mrisho et al., 2009; Penfold et al., 2013), as experienced by some of the pregnant women (see Chapter 3). In addition, Chapter 2 found that healthcare workers did not feel empowered to change the situation demonstrated by the

facts that they waited for governmental funds to solve the problems. It is important to listen to the voices of healthcare workers expressing the challenges they face that prevent them from providing high-quality antenatal care. Previous research has demonstrated that the lack of control and lack of supportive management reduce work motivation or performance of healthcare workers (Manzi et al., 2004; Mosadeghrad, 2014; Tibandebage et al., 2016). Therefore, the infrastructure in and around the health facilities should be sufficient and motivating for healthcare workers to perform well. For example, electricity, water, supplies, medication, and other equipment to perform all procedures should be available at all times. Furthermore, supportive management as well as possibilities for participation to solve the current challenges are needed. In addition, it necessary to increase the workforce of trained healthcare workers: This would alleviate the issue of high workload and limited time to perform all procedures needed for high-quality antenatal care.

This dissertation also presents the views of healthcare workers and pregnant women regarding the use of an electronic decision aid during antenatal care. In the last decade, researchers have emphasised the importance of e-health as tools to improve maternal healthcare in sub-Saharan Africa (Blaya et al., 2010; Temmerman et al., 2015; World Health Organization, 2011). This dissertation informs the debate regarding the importance – and/or necessity – of technological progress in relation to quality of care and health in general. The studies in Chapters 2 and 3 of this dissertation found positive views among healthcare workers and pregnant women regarding the use of an electronic decision aid during antenatal care. Both expressed that an electronic decision aid could improve the quality of antenatal care due to improved record-keeping, improved performance of healthcare workers, and improved communication between healthcare workers and pregnant women. However, the most mentioned barrier among healthcare workers and pregnant women in these studies was the lack of electricity, which hinders the feasibility of using such an aid. In the process evaluation, part of Chapter 5, we indeed found that the infrastructural circumstances including lack of electricity or internet connection, made working with the electronic decision aid challenging. Infrastructural challenges are a common issue in low- and middle-income countries in relation to the use of e-health and previous studies have explored the effect of these on the uptake of e-health innovations (Benski et al., 2017; Oluoch et al., 2012; White et al., 2016; Zakane et al., 2017). One of the lessons learned in the current project (see also Chapter 4) is that e-health innovations in healthcare are more likely to be successful under certain conditions (Abejirinde et al., 2019). Therefore, future intervention developers should take the practical use in the health facility and its environment into account when developing an electronic decision aid. Without consistent electricity and internet connection, sufficient charging possibilities and a safe place to store the device, any tool is likely to fail if attention and funding is not dedicated to ensure these infrastructure and logistical considerations, which projects often do not sufficiently embed into project plans and budgets (Abejirinde et al., 2019; Hackett et al., 2019). Furthermore, to create local ownership, researchers are

recommended to engage the community and listen to their insights and to locally formulated goals (Edgcombe et al., 2016; Mooij et al., 2020). Healthcare workers complained about the extra workload due to double administrative tasks (see also Chapter 5). This was because paper-based registers were supposed to be filled in after the Nurse Assistant App was completed to fulfil the duty to report cases and findings to the district officials. This could have been avoided if the Nurse Assistant App had been better incorporated within the existing government administration and referral structure. For example, by creating the possibility to digitally send the reports of the Nurse Assistant App to the district administration system. We acknowledge the difficulty of this as it would have required substantial on-the-ground work with ministry and health officials to modify processes related to record keeping that have been in place for years.

Potential proximal explanations for non-effectiveness

This dissertation demonstrates that the implementation of the Nurse Assistant App, as a possible solution to improve the quality of antenatal care in Magu district, did not have the desired result. A possible explanation for this result might be related to the fact that the project team did not sufficiently take into account that working with the Nurse Assistant App would involve considerable behaviour change of healthcare workers. Chapter 2 describes that healthcare workers requested better training opportunities, improved supply chain, and supportive supervision but they did not feel capable of solving the challenges they faced themselves and reported waiting for governmental funds to resolve the problem, which is consistent with previous research in Tanzania (Bremnes et al., 2018; Mkoka et al., 2015).

Chapter 2 also indicated that having a positive attitude and the right knowledge on providing high-quality antenatal care, may not be sufficient to enable behaviour change. The Nurse Assistant App was developed to guide healthcare workers during antenatal care provision to ensure that all essential antenatal care services were provided. As demonstrated in Chapter 4, the project team underestimated the extent of the changes in process and behaviour that would be needed to have the Nurse Assistant App serve as a tool embedded in daily practice in the health facility. Working with the Nurse Assistant App requires developing digital skills and a change in sequence of tasks. Healthcare workers might not have been willing or capable to change their behaviour. Indeed, our results indicate that there could have been low readiness to behaviour change among healthcare workers since they believed that they did not have the power to change the circumstances and were not the ones in charge of deciding whether the app would be sustainably implemented or not (see also Chapter 5). As described in Chapter 4, the project team had regular meetings with district health officials to discuss the implementation of the Nurse Assistant App. However, the changes in the practical work situation resulting from the implementation of the Nurse Assistant App impacted the working behaviour of the healthcare workers providing antenatal care.

Furthermore, the healthcare workers reported that the decision to use or not use the Nurse Assistant App was out of their control. Motivational interviewing could have been a useful method to explore healthcare workers' readiness to change as well as resolve the possible reluctance towards behaviour change (Miller & Rollnick, 2002). Motivational interviewing focusses on participants' readiness to change (Rubak et al., 2005). Therefore this would have made it a useful technique in the context of Magu district to make healthcare workers aware of the usefulness of their behaviour change on the quality of antenatal care. In addition, if more attention had been paid to the behaviour change of healthcare workers during service delivery and expected increase in workload, the implementation plan could have been adjusted to that. For example, one suggestion could be to give healthcare workers more time to get used to the new working conditions.

Moreover, improving the quality of antenatal care might not only be achieved through intervening at the healthcare worker level – intervening at the macro level (e.g. health services and policy level) might also be needed. The results of Chapter 2 gave insight into the perceptions of healthcare workers on the quality of antenatal care and showed that healthcare workers mainly attributed the difference in quality of provided antenatal care to external factors, such as the lack of electricity, equipment, and medication. This result was confirmed by previous studies conducted in Tanzania (Bremnes et al., 2018; Manongi et al., 2006; Mkoka et al., 2015; Mubyazi et al., 2012). As reported in Chapter 4, the Nurse Assistant App was developed to create a step-by-step guide for healthcare workers to systematically guide antenatal care consultations based on international recommendations and guidelines. It might be that the challenging working conditions as described by the healthcare workers (see chapter 2) require efforts from the national Tanzanian government because such infrastructural improvements are outside of healthcare workers' control. That the efforts of the Woman Centered Care Project in Magu to solve infrastructural challenges in collaboration with the local government did not bring the desired improvements might be in part due to the fact that most of the decision-making in that regard takes place at the national level, which was beyond the reach of the project. The vast majority of research conducted on improving maternal health agrees that the focus should be on the quality, coverage, and completeness of health services (Koblinsky et al., 2016; Temmerman et al., 2015) and therefore not on individual healthcare worker performance. At the same time, the call for strengthening healthcare workers' performance and their adherence to evidence-based guidelines is widely recognised (Koblinsky et al., 2016; Miller et al., 2016). The project in Magu district aimed to improve the performance of healthcare workers by providing training and giving practical guidance of the Nurse Assistant App during the provision of antenatal care.

Potential distal explanations for non-effectiveness

The result that the health facilities which used the Nurse Assistant App did not increase the number of essential antenatal care interventions relates to the role of foreign aid. The debate

on the effectiveness and appropriateness of external aid has often taken place in the context of economic development for low- and middle-income countries. On the one hand, the scholars grouped around the World Bank, most prominently Jeffrey Sachs, have argued in favour of the primacy of foreign aid in improving local living conditions in low-and middle-income countries (Sachs, 2012, 2014). They are of the position that low-income countries themselves are not able to reach universal health coverage without the help of donor money and that those countries first need a healthy population in order to reach economic growth (Sachs, 2012). On the other hand, those statements have been criticised by other scholars, especially William Easterly, who has argued that foreign aid was unlikely to succeed in the absence of detailed consideration of local and cultural circumstances (Easterly, 2003, 2006). Regarding maternal health, there is only limited research linking foreign aid and maternal mortality reduction (Banchani & Swiss, 2019). A recent study conducted by the United Nations showed that aid specifically targeting reproductive health services is associated with a reduction of maternal mortality, in contrast to overall aid which does not appear to reduce maternal mortality (Banchani & Swiss, 2019).

This dissertation contributes to this literature by discussing whether the Nurse Assistant App was truly tailored to local and cultural circumstances. This dissertation does not provide an answer to the question of whether there was a true demand for an electronic decision aid among healthcare workers – rather, to attain improved healthcare worker performance, the conditions of a supportive environment must be met first. Chapter 4 demonstrated that the project team emphasised the importance of collaborating with local stakeholders and end-users during the process of development and implementation of the Nurse Assistant App to ensure cultural and practical appropriateness. However, the initial idea of using an electronic decision aid came from clinicians based in high-income countries. A comprehensive needs assessment to see if the Nurse Assistant App would be the most valuable way to invest the project budget into was never performed. A recent study conducted in Uganda has shown that projects aiming to improve maternal health using digital health tools often lack such a needs assessment (Kiberu et al., 2017). Perhaps, in Magu district, an electronic decision aid was not what the local population truly needed, and this result thus lends credit to the critique of foreign aid, since locally specified goals and objectives were not considered as much as they could have been.

Another consideratio related to the effectiveness and appropriateness of foreign aid might be the tension regarding the outsiders' view. The Woman Centered Care Project commenced conducting research related to maternal health in Magu district in 2012 after the African Women Foundation created a partnership with Crop Marketing Bureau (CROMABU). This collaboration was established based on mutual respect, joint input, and with the best intentions. However, it cannot be denied that part of the project team, as well as the initiators, were outsiders to the district, which inevitably created a certain power imbalance (England,

1994; Hanson, 2017; Wiederhold, 2015). We believe that the project team was aware of these possible tensions and reflected on this regularly with the whole team. However, reflexivity does not prevent the outsiders' role from shaping the research process and outcomes (Aronowitz et al., 2015; England, 1994). This outsiders' view also creates a possibility to introduce new topics and possibilities (Wiederhold, 2015) as well as implement new techniques and create the possibility to get involved in research (Mooij et al., 2020).

Strengths, limitations, and directions for future research

There are several strengths and limitations to note in this dissertation. One strength of this dissertation is that it offers a thorough overview of the situation regarding the provision of antenatal care in Magu district and analyses processes and efforts taken to improve the quality of care by implementing the Nurse Assistant App. This dissertation is one of the first to present a practical and accessible evaluation and lessons learned from the development and implementation process of an electronic decision aid in low-resource settings. Furthermore, this dissertation presents the perspectives of a broad range of stakeholders (healthcare workers, pregnant women, district officials) regarding antenatal care in general and the use of an electronic decision aid. This dissertation may therefore help to inform future programme planners in low- and middle-income countries on important considerations and pitfalls to avoid when developing a digital health intervention. Another strength is the use of mixed methods to obtain a comprehensive understanding of the experience of using and actual implementation of the Nurse Assistant App by healthcare workers. This thorough overview may help in prioritising strategies to improve the quality of antenatal care in rural settings.

There are several limitations to the studies in this dissertation that need to be taken into consideration. The evaluation of the impact of the Nurse Assistant App on workflow and quality of care was based on data from observations performed at control and intervention facilities at two points in time (baseline and post-test), without follow-up time points over a longer duration of time after implementation of the Nurse Assistant App. This prevents the possibility of linking the use of the Nurse Assistant App to maternal health outcomes; therefore, an evidence gap remains regarding the effects of digital health tools on maternal health outcomes. Furthermore, the selection of control and intervention facilities was based on the infrastructural circumstances in the health facility to ensure that the Nurse Assistant App could be adopted in practice. Not all health facilities included in the study had access to electrical power and mobile network connection and the selection of intervention facilities was therefore dependent on this. This influences the interpretation of the causality between the dependent variable 'completeness score' and the two independent variables 'time' (pre and post measure) and 'group' (control and intervention health facility). However, since the results were complemented with in-depth interviews and a self-report questionnaire, we believe it presents a useful view of the differences in service provision between control and intervention facilities.

The studies in Chapters 2 and 5 present the positive attitudes and willingness of healthcare workers towards the possibility of using the Nurse Assistant App during service provision. However, as Chapter 5 details, the healthcare workers also reported that this initial enthusiasm decreased after working with the Nurse Assistant App for more than three months. A possible explanation for a decrease in the initial enthusiasm could be found in the factors described in the sections above. However, it might also be that healthcare workers initially responded in a socially desirable fashion in the interviews and self-reports before working with the Nurse Assistant App as they wanted to show their willingness and positivity to the new system. Healthcare workers might have felt a certain (albeit implicit) pressure to show their gratitude towards the outsiders who were willing to spend their time and money to solve an urgent issue in the district.

Another limitation of this dissertation is that the data of the four studies were collected in rural Tanzania based on a relatively small sample. Therefore, generalisation to all of Tanzania or low-income countries must be made with caution due to the narrow geographical scope. However, possible explanations for the negative effect of the Nurse Assistant App on completeness of service provision can mainly be attributed to factors related to experiences and infrastructure. It is likely that this will be comparable in other low-resource settings. Furthermore, similar results have been found in other rural areas in low-resource settings. For the study in Chapter 3, only women who had attended antenatal care at the health facility were sampled. This excludes the valuable perception of women who do not seek antenatal care, which carries a risk of bias. Pregnant women included in this study already see the value of antenatal care and therefore may be more positive about the importance of antenatal care and the possibilities for an electronic decision aid. Nevertheless, the sample represents a well-experienced group of pregnant women with a broad variety in the number of antenatal care consultations attended.

A final limitation of this dissertation is that the studies were part of a larger project - the Woman Centered Care Project - that made donations of equipment and materials to the included health facilities as well as funded the development and implementation of the Nurse Assistant App. As mentioned earlier, this might have increased the possibility for answers that were given in a socially desirable fashion. Furthermore, it might have been that the possibility to receive free tablets and get access to a modern way of working might have influenced healthcare workers' willingness to accept the Nurse Assistant App and influence baseline results.

Conclusion

Electronic decision aids can be a promising tool to improving the quality of antenatal care in low- and middle-income countries. This dissertation contributes to the knowledge on the usefulness of electronic decision aids and describes conditions under which electronic

decision aids can reach their full potential. The initial perspectives of healthcare workers and pregnant women on the use of an electronic decision aid during antenatal care service provision were positive. Both healthcare workers and pregnant women expected the aid to improve record-keeping and the overall quality of care but both groups also raised their concerns about the availability of electricity and internet connection. This dissertation also found a decrease in completeness score (pre-and post-implementation) in health facilities that performed antenatal care with use of the Nurse Assistant App. Healthcare workers using the Nurse Assistant App experienced an increase in workload due to the extra time needed to complete the antenatal care consultation and the extra administrative burden. For electronic decision aids to contribute to improvements in antenatal care, it is essential that the working conditions of healthcare workers are sufficient to perform their work. Furthermore, the development and implementation process of an electronic decision aid should be primarily performed by local stakeholders in close collaboration with the end-users.

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Summary

Tanzania is one of the countries with the highest maternal mortality ratio worldwide. One crucial strategy for reducing maternal mortality is availability and accessibility of high-quality antenatal care. Unfortunately, the quality of antenatal care in Tanzania is low and one of the reasons for this low quality is the shortage of qualified healthcare workers. Electronic decision aids have shown promise in enabling better quality care in low- and middle-income countries by improving healthcare workers' performance and adherence to guidelines. To contribute to this evidence base, the Nurse Assistant App, an electronic decision aid, was developed for use in antenatal care settings

The Nurse Assistant App is a tablet-based application, written in Kiswahili, which offers step-by-step guidance for healthcare workers providing antenatal care in rural health facilities in Tanzania. The Nurse Assistant App consists of a comprehensive questionnaire to be filled in by healthcare workers during antenatal care provision based on results obtained through observations and/or responses of the pregnant woman. After completing all steps, it generates a clinical summary and provides advice on treatment, referral, and follow-up.

This dissertation aims to assess whether an electronic decision aid could improve the process and delivery of antenatal care in rural Tanzania. Therefore, this dissertation investigated: 1) the perceptions of healthcare workers and pregnant women on the quality of antenatal care and the potential utility of an electronic decision aid during antenatal care service delivery; 2) the development and implementation process of a specific type of electronic decision aid, the Nurse Assistant App; and 3) the impact of the Nurse Assistant App on workflow and service delivery in antenatal care.

In the study described in Chapter 2, we explored the factors that are associated with the performance of healthcare workers in providing antenatal care and we asked what is needed to improve quality of care. Results showed that healthcare workers enjoy their work and view their work as important for the health of pregnant women. We also found that healthcare workers experience social pressure from their colleagues, pregnant women, and other people in the community to perform well. At the same time, they noted differences in the quality of care provided by their colleagues and differences in the level of motivation between them. All healthcare workers participating in this study expressed challenges related to poor working conditions, such as the lack of equipment, high workload, and shortage of staff. They articulated the need for equipment and materials, more training opportunities, and better supervision to be able to perform their jobs better. In this study, we also investigated healthcare worker views on the utility of working with an electronic decision aid and found that healthcare workers had a positive attitude toward the use of such an aid in their work. Healthcare workers expected that an electronic decision aid would improve record-keeping and the overall quality of antenatal care.

The views of pregnant women on the quality of antenatal care received were explored in Chapter 3. In this study, we asked pregnant women coming for antenatal care about their experiences with the care they received and their perceptions on the quality of that care. We also asked them about the possibility to receive care with the use of an electronic decision aid. This study showed that pregnant women are motivated to seek antenatal care and are grateful for the services received. At the same time, they expressed that diagnostic tests, medications, and other materials are often out of stock. They also expressed their concerns about the availability of staff since they experienced long waiting times or observed the high workload and poor working conditions among healthcare workers. Pregnant women also explained that the interaction with healthcare workers is not always optimal, expressing that healthcare workers were sometimes unwilling or unmotivated to provide all interventions or explain procedures, and sometimes reacted angrily when clients did not follow orders and recommendations. The participating pregnant women expressed positive attitudes towards the potential use of an electronic decision aid during care provision, and they indicated that the aid could help in storing files and improving communication with healthcare workers.

In the study reported in Chapter 4, we used Intervention Mapping to systematically evaluate the development and implementation process of the Nurse Assistant App. Intervention Mapping is a six-step protocol for theory- and evidence-based intervention development. We used this protocol retrospectively to evaluate the comprehensiveness of the development and implementation of the Nurse Assistant App and found that five of the six steps of Intervention Mapping were achieved during the intervention development process. Specifically, the App was developed in close collaboration with the community, adjusted to the practical context, and systematically implemented and evaluated. However, it was not based on insights from theories of behavioural determinants nor on behaviour change theories and related methods of change. This study also provides recommendations on considerations when developing an electronic decision aid in low-resource settings, such as the importance of community engagement, the involvement of a behaviour change specialist, programme flexibility, and clear programme goals.

Chapter 5 presents two studies providing a mixed-method evaluation of the impact of the Nurse Assistant App on the quality of antenatal care. We investigated whether the Nurse Assistant App contributes to the amount of essential antenatal care services provided. Essential antenatal care services include routine screening for complications, such as high blood pressure or sexually transmitted infections, and the provision of prophylaxis for infectious diseases. We also investigated how healthcare workers experience working with the Nurse Assistant App. Results showed that health facilities where the Nurse Assistant App was used during antenatal care had a *lower* completeness score for delivery of essential antenatal care services compared to health facilities where the App was not implemented. Results also showed that in both control and intervention health facilities no more than 25%

of all essential antenatal care services were provided, meaning that pregnant women receive less than 25% of all services they should have received during antenatal care. Furthermore, healthcare workers were overall positive about using the Nurse Assistant App but they also explained that it increased their workload. Furthermore, the lack of a stable electricity and internet connection made working with the Nurse Assistant App logistically challenging.

The studies in this dissertation show that improving the quality of antenatal care with the use of an electronic decision aid is generally accepted among healthcare workers and pregnant women in Magu district, Tanzania. This dissertation also illustrates that poor working conditions, such as lack of electricity and internet connection, high workload and shortage of healthcare workers make working with an electronic decision aid challenging. Our results are consistent with other studies conducted on the use of electronic decision aids in low- and middle-income countries that confirm the importance of developing a system that is well suited to the environment in which it will be implemented. Therefore, we recommend that an electronic decision aid should not be a stand-alone intervention. We conclude that there are certain conditions under which electronic decision aids deploy their full potential in enabling better care processes and outcomes, as well as support quality improvement of healthcare. These conditions include working conditions for healthcare workers that are sufficient to perform their work, and a development and implementation process of an electronic decision aid that is primarily performed by local stakeholders in close collaboration with the end-users. Future research should focus on the evaluation of the development and implementation process of an electronic decision aid conducted by end-users in collaboration with a behaviour change specialist. Research is also needed on the effects of an electronic decision aid on maternal health outcomes to reduce the high maternal mortality ratio.

Samenvatting

Tanzania behoort tot de landen met een zeer hoog moedersterftecijfer. Goede en toegankelijke prenatale zorg is essentieel voor het terugdringen van moedersterfte. De kwaliteit van prenatale zorg in Tanzania is laag en een belangrijke reden hiervoor is het tekort aan gekwalificeerd zorgpersoneel. Om daaraan iets te doen zijn digitale innovaties veelbelovend omdat die het zorgpersoneel kunnen ondersteunen bij het nemen van beslissingen tijdens het verlenen van zorg en zij zich beter aan de richtlijnen houden. In dit proefschrift hebben we de ontwikkeling en het gebruik van de Nurse Assistant App onderzocht.

De Nurse Assistant App is een applicatie die gebruikt wordt op een tablet en stap-voor-stap begeleiding biedt aan zorgverleners tijdens het verlenen van prenatale zorg in gezondheidsposten in rurale gebieden in Tanzania. De applicatie bestaat uit een uitgebreide vragenlijst, geschreven in Kiswahili, die door zorgverleners tijdens een prenataal zorg consult wordt ingevuld op basis van informatie verkregen door klinisch onderzoek en/of antwoorden van de zwangere vrouw. Na het doorlopen van alle vragen genereert de applicatie een klinische samenvatting en volgt er advies voor de verdere behandeling, inclusief een eventuele aanbeveling voor doorverwijzing naar een gespecialiseerd gezondheidscentrum.

Het doel van het onderzoek in dit proefschrift is om na te gaan of bovenstaande digitale ondersteuning de kwaliteit van de prenatale zorg in gezondheidsposten in rurale gebieden in Tanzania kan verbeteren. Daartoe hebben we specifiek onderzoek gedaan naar: 1) de opvattingen van zorgverleners en zwangere vrouwen over de kwaliteit van de prenatale zorg en hun mogelijke interesse in het gebruik van digitale ondersteuning tijdens de prenatale zorg; 2) het proces van ontwikkeling en implementatie van de Nurse Assistant App; en 3) de impact van de Nurse Assistant App op de manier van werken en kwaliteit van prenatale zorg. In het onderzoek beschreven in hoofdstuk 2 onderzochten we de factoren die van invloed kunnen zijn op de kwaliteit van prenatale zorg door zorgmedewerkers en vroegen we wat volgens hen nodig is om de kwaliteit van prenatale zorg te verbeteren. Uit de resultaten bleek dat prenatale zorgverleners hun werk met plezier doen en hun werk belangrijk vinden voor de gezondheid van zwangere vrouwen. We vonden ook dat zorgverleners sociale druk ervaren van hun collega's, zwangere vrouwen en de lokale overheid om goed te presteren. Tegelijkertijd constateerden zij ook verschillen in de kwaliteit van de prenatale zorg en de motivatie van collega zorgverleners. Bovendien noemden alle zorgverleners de slechte werkomstandigheden zoals het gebrek aan materialen, de hoge werkdruk en het tekort aan zorgpersoneel als factoren die bijdragen aan verminderde kwaliteit van zorg. Alle deelnemers vroegen om meer apparatuur en materialen, opleidingsmogelijkheden en beter toezicht als factoren die de werksituatie kunnen verbeteren. In deze studie onderzochten we ook de interesse van prenatale zorgverleners in werken met digitale ondersteuning. We vonden dat zij positief stonden tegenover digitale ondersteuning tijdens hun werk omdat deze digitale ondersteuning het opslaan van dossiers kan vergemakkelijken en gedacht werd dat digitale ondersteuning de kwaliteit van de prenatale zorg in het algemeen kan verbeteren.

De mening van zwangere vrouwen over de kwaliteit van de ontvangen prenatale zorg is onderzocht in de studie beschreven in hoofdstuk 3. We vroegen zwangere vrouwen naar hun ervaringen met de prenatale zorg die ze hadden ontvangen en de kwaliteit daarvan. We vroegen hen ook naar hun interesse om prenatale zorg te ontvangen van een zorgverlener die gebruikt maakt van digitale ondersteuning. Uit dit onderzoek bleek dat zwangere vrouwen gemotiveerd zijn om naar de gezondheidspost te komen voor prenatale zorg en dankbaar zijn voor de ontvangen diensten. Tegelijkertijd gaven zij aan dat diagnostische tests, geneesmiddelen en andere materialen vaak niet voorradig zijn. De zwangere vrouwen uitten ook hun bezorgdheid over de beschikbaarheid van de zorgverleners, aangezien ze te maken hadden met lange wachttijden. Ook benoemden ze de hoge werkdruk en slechte arbeidsomstandigheden zoals het gebrek aan materialen en de hoge werkdruk voor het zorgpersoneel als knelpunten. Verder gaven zij ook aan dat de interactie met de zorgverleners niet altijd optimaal is. Sommigen van hen merkte op dat zorgverleners soms niet bereid of gemotiveerd waren om goede zorg te verlenen of procedures uit te leggen en soms boos worden als cliënten zich niet aan hun regels houden. De deelnemende zwangere vrouwen waren positief over het mogelijke gebruik van digitale ondersteuning tijdens prenatale zorg. Zij gaven aan dat deze ondersteuning zou kunnen helpen bij het opslaan van dossiers en het verbeteren van de interactie met zorgverleners.

In het onderzoek dat in hoofdstuk 4 wordt beschreven, hebben we Intervention Mapping gebruikt om het proces van de ontwikkeling en implementatie van de Nurse Assistant App te evalueren. Intervention Mapping is een zes-stappenplan voor het ontwikkelen van interventies aan de hand van theorie en inzichten uit wetenschappelijk onderzoek. We vonden dat vijf van de zes stappen van Intervention Mapping zijn uitgevoerd tijdens het ontwikkelings- en implementatieproces van de Nurse Assistant App. Uit de evaluatie bleek meer specifiek dat de Nurse Assistant App was ontwikkeld op basis van samenwerking met lokale actoren waardoor die was aangepast aan de lokale situatie en dat de App systematisch was geïmplementeerd en geëvalueerd. Bij de ontwikkeling van de Nurse Assistant App is echter geen gebruik gemaakt van theorieën over gedragsdeterminanten. De studie biedt concrete aanbevelingen om bij de ontwikkeling van digitale ondersteuningssystemen voor landen met weinig middelen rekening te houden. In het bijzonder worden genoemd: het belang van samenwerking, zorgdragen voor betrokkenheid van lokale actoren, flexibiliteit in de ontwikkeling en uitvoering, het formuleren van duidelijke programmadoelen en de betrokkenheid van gedragsverandering experts tijdens het proces van ontwikkeling en implementatie.

Hoofdstuk 5 omvat twee onderzoeken naar de impact van de Nurse Assistant App op de kwaliteit van de prenatale zorg. We onderzochten of de Nurse Assistant App bijdraagt aan de hoeveelheid essentiële componenten van zorg die uitgevoerd zijn tijdens de prenatale zorg. Onder essentiële componenten vallen het meten van vitale lichaamsfuncties, zoals bloeddruk,

prenatale screening op infectieziekten en preventieve medicatie. We onderzochten ook hoe zorgverleners het werken met de Nurse Assistant App ervoeren. De resultaten toonden aan, tegen de verwachting in, dat gezondheidsposten waar de Nurse Assistant App werd gebruikt *minder* essentiële interventies tijdens de prenatale zorg verleenden dan gezondheidsposten waar de App niet werd gebruikt. De resultaten toonden ook aan dat in zowel controle als interventie gezondheidsposten niet meer dan 25% van alle essentiële prenatale zorg componenten werden uitgevoerd. Dit betekent dat zwangere vrouwen minder dan 25% van de prenatale zorg ontvangen die ze zouden moeten. De zorgverleners waren over het algemeen positief over het gebruik van de Nurse Assistant App, maar ze ervoeren ook dat de Nurse Assistant App hun werkdruk verhoogde. Ook maakten het gebrek aan elektriciteit en internetverbinding het werken met de Nurse Assistant App lastig.

De studies in dit proefschrift laten zien dat het verbeteren van de kwaliteit van prenatale zorg met behulp van digitale ondersteuning breed geaccepteerd is onder zorgverleners en zwangere vrouwen in Magu district, Tanzania. Echter, de slechte werkomstandigheden zoals het gebrek aan elektriciteit en internetverbinding, de hoge werkdruk en het tekort aan zorgpersoneel maken werken met digitale ondersteuning lastig. Onze resultaten worden bevestigd door ander onderzoek naar het gebruik van digitale ondersteuning in landen met weinig middelen en tonen het belang aan van het ontwikkelen van een systeem dat goed past bij de omgeving waarin het gebruikt gaat worden. Daaruit kan worden afgeleid dat een systeem voor digitale ondersteuning geen op zichzelf staande interventie zou moeten zijn.
Geconcludeerd wordt dat er bepaalde voorwaarden zijn aan het succesvol gebruik van digitale ondersteuning om deze volledig tot haar recht te laten komen en betere zorgprocessen en -uitkomsten mogelijk te maken in de prenatale zorg. Deze voorwaarden omvatten in de eerste plaats ondersteunende arbeidsomstandigheden voor zorgverleners zodat zij hun werk in een prettige en stimulerende omgeving kunnen uitvoeren. Daarnaast is het van belang dat de ontwikkeling en implementatie van een systeem voor digitale ondersteuning wordt uitgevoerd en gedragen door lokale actoren om nog meer rekening te houden met lokale doelstellingen. Toekomstig onderzoek kan zich richten op het evalueren van een ontwikkelings- en implementatieproces van een systeem voor digitale ondersteuning uitgevoerd door eindgebruikers van het systeem in samenwerking met een gedragsconsulent. Er is ook onderzoek nodig naar het effect van digitale ondersteuning op de gezondheidsuitkomsten voor zwangere vrouwen om de vraag te kunnen beantwoorden of digitale ondersteuning kan bijdragen aan het terugdringen van moedersterfte.

Impact

Worldwide, pregnant women are at risk of pregnancy-related health complications. This risk is substantially higher for women living in low- and middle-income as opposed to high-income countries and where there is limited access to high-quality maternal health services such as antenatal care. The main aim of this dissertation was to investigate whether an electronic decision aid would be useful to support improvements in the quality of antenatal care in a low-income country.

The studies in this dissertation describe the situation regarding the provision of antenatal care in Magu district, Tanzania, and provide several suggestions for improvement from a broad variety of perspectives. Both healthcare workers and pregnant women expressed the need for improved infrastructure to ensure the availability of medication, equipment, and diagnostics. High quality antenatal care is difficult to ensure without basic health facility infrastructure in place including basic stock and availability of equipment required in antenatal care. We found in our research that participating health facilities could only deliver 25% of essential services for pregnant women. Not receiving essential antenatal care interventions can not only negatively impact health outcomes of pregnant women and their unborn child but also influences a women's decision to seek care and the motivation of healthcare workers in delivering care. Moreover, innovations such as an electronic decision aid are likely to fail without a supportive environment for adoption and implementation. These results show that there is a need for decision-makers at the regional (district) and national level to focus on upgrading basic health facility infrastructure as a foundation for better healthcare, including antenatal care. This should be enabled before introduction or investing in new innovations that the healthcare facility climate may not yet be ready for or benefit optimally from.

The results of this dissertation might also be relevant for programme developers in Tanzania or other low- and middle-income countries considering developing and implementing an electronic decision aid in healthcare settings. Available evidence focuses on the outcomes of digital health interventions and much less on process optimization in the development or implementation phase. This dissertation is one of the first to present a practical and accessible evaluation and lessons learned from the *development and implementation process* of an electronic decision aid in low-resource settings. This pragmatic evaluation presents examples and lessons learned during this process and shares important considerations and pitfalls to avoid when developing and implementing an electronic decision aid.

In our research we reported that health facilities where the electronic decision aid was used during antenatal care obtained a *lower* completeness score for delivery of essential antenatal care services compared to control facilities. Reasons for this decrease in antenatal care service delivery at health facilities using the electronic decision aid might be the extra burden this tool places on healthcare workers. Indeed, in the qualitative part of this mixed-methods research project, healthcare workers expressed that the electronic decision aid increased

their workload and took more time than using the paper-based registration system. These results might help programme developers in taking an informed decision to focus on the development of an electronic decision aid or focus on other interventions first optimize the conditions for a future health intervention, including the training of staff. Furthermore, for programme developers considering developing and implementing an electronic decision aid, these findings draw attention to the need to comprehensively map local contextual factors that are likely to influence implementation, and design clear implementation protocols for an intervention, which are agreed upon and co-developed with local implementers to ensure alignment with local realities.

Finally, this dissertation is of direct relevance for international organisations aiming to improve healthcare in low- and middle-income countries through the development of an electronic decision aid. Through the case of the implementation of an electronic decision aid to promote antenatal care in Magu district, Tanzania, the conditions are described under which a programme is likely to fail or succeed. The primary goal of any electronic decision aid in healthcare settings is to enable better health outcomes or healthcare improvements. To reach this, it is important that the local healthcare system and contextual factors are understood and reflected in the development, implementation, and designs of the electronic decision aid. Historically, many international organisations have focused on developing interventions or electronic decision aids which are well intentioned but did not sufficiently account for local health system or infrastructure challenges and realities. This might create a mismatch between envisaged outcomes of an intervention and actual possibilities given local realities and factors. This dissertation highlights the importance of formative work in intimately understanding the local context and infrastructure as these factors can significantly impact the uptake of an intervention and its possibility for being embedded in clinical practice over time.

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Curriculum vitae

Sandra van Pelt was born in Hellevoetsluis in the Netherlands on 19 february 1987. After she graduated at S.G. Spieringshoek in 2005, she attended the University of Applied Sciences in Utrecht to become a Registered Nurse in 2009. During this Bachelor she participated in the Minor International Health Studies where she found the inspiration to continue her studies. In 2013, she graduated for the Master in International Public Health at the VU University in Amsterdam. Soon after her graduation, she left to Tanzania, for three years, where she worked for a maternal health project from the African Woman Foundation in Magu district. Working for this project resulted in the opportunity to start a PhD-traject with the data collected and activities performed within this maternal health project. Her PhD research focussed on the possibility to improve the process and delivery of antenatal care in rural Tanzania by using an electronic decision aid. During all her studies and her PhD, Sandra worked as a dedicated nurse, first in a hospital and later in a homecare organisation. Currently she is living in Zurich, Switzerland with her boyfriend, where she hopes to translate health science into daily health practise.

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Van Pelt, S., Massar, K., Shields-Zeeman, L., De Wit, J.B.F., Van Der Eem, L., Lughata, A.S., Ruiter R.A.C. (2021). The development of an electronic clinical decision and support system to improve the quality of antenatal care in rural Tanzania: lessons learned using Intervention Mapping. *Frontiers in Public Health*. *9*(645521).

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Other publications

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