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Development of a medical expert system to improve the quality of antenatal care in Tanzania

Kaaya, Elsie

NM-AIST

DEVELOPMENT OF A MEDICAL EXPERT SYSTEM TO IMPROVE THE QUALITY OFANTENATAL CARE IN TANZANIA

Elsie Somi Kaaya

A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master's in Information and Communication Science and Engineering of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Maternal mortality remains a global problem, with approximately 830 women dying every day as a result of childbirth and pregnancy complications. The maternal mortality ratio is as high as 524 deaths per 100 000 live births in Tanzania. The main causes of maternal mortality in developing countries are all linked to poor prenatal care, which is partially caused by treatment delays. Studies show that providing women with maternal health information can help achieve the goal of reducing global maternal mortality to less than 70 maternal deaths per 100 000 live births by 2030. Through Natural Language Processing (NLP), we leveraged the use of BERT question and answer model which is a pre-trained model that was fine-tuned to develop a model that can diagnose pregnancy complications, explain possible causes in simple language, and provide recommendations for care and treatment, for Malaria, Pregnancy hypertension (Pre-eclampsia), and miscarriage (Threatened abortion) which are the main preventable causes of maternal mortality in Tanzania. The expert system is embedded in a maternal smartphone app, *MamaApp,* that provides weekly information on fetal development, regular and concerning pregnancy symptoms, and self-care tips. The expert system model was able to diagnose the three conditions with confidence ranging from 79% to 100%. Validation of MamaApp in Arusha showed high acceptance from both the expectant mothers and doctors.

DECLARATION

I, Elsie Somi Kaaya do hereby declare to the senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being currently submitted for degree award in any other institution.

Elsie Somi Kaaya		21/09/2021
Candidate Name	**Signature**	**Date**

The above declaration is confirmed

Dr. Edith Luhanga		21st Sept 2021
Supervisor 1	**Signature**	**Date**

Prof. Jesuk Ko		21/09/2021
Supervisor 2	**Signature**	**Date**

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CERTIFICATION

The undersigned certify that, they have read and hereby recommend for acceptance by the Nelson Mandela African Institution of Science and technology a dissertation titled, "*Development of a medical expert system to improve the quality of antenatal care in Tanzania*" in partial fulfillment of the requirements for the Master of Science in Information and Communication Science and Engineering of the Nelson Mandela African Institution of Science and Technology.

Dr. Edith Luhanga		21st Sept 2021
Supervisor 1	**Signature**	**Date**

Prof. Jesuk Ko		21/09/2021
Supervisor 2	**Signature**	**Date**

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DEDICATION

To my loving father Somi Herman Kaaya and mother Felister Somi Kaaya

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LIST OF ABBREVIATIONS AND SYMBOLS

AE	Adverse Effects
ANN	Artificial Neural Networks
BERT	Bidirectional Encoder Representations from Transformers
BPMN	Business Process Modelling Notation
CDSS	Clinical Decision Support System
CLS	Class
CNN	Convolutional Neural Network
CPT	Current Procedural Terminology
CRIS	Clinical Record Interactive Search
DL-NLP	Deep Learning – Natural Language Processing
EMR	Electronic Medical Records
FANC	Focused Antenatal Care
FH	Family Health
GPU	Graphics Processing Unit
HIV	Human Immunodeficiency Virus
ICD	International Classification of Diseases
IR	Information Retrieval
ML	Machine Learning
MLM	Masked Language Model
NER	Name Entity Recognition
NLP	Natural Language Processing
OMG	Object Management Group
P1	Person One
P2	Person Two
P3	Person Three
P4	Person Four
QA	Question Answering
RCT	Randomized Controlled Trials
SDI	State Disability Insurance
SEP	Separating Sentences

SLaM	South London and Maudsley Trust
SLE	Systemic Lupus Erythematosus
SMS	Short Message Service
SQuAD	Stanford Question and Answering Dataset
SVM	Support Vector Machine
TCRA	Tanzania Communications Regulatory Authority
UML	Unified Modelling Language
USSD	Unstructured Supplementary Service Data
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the problem

Maternal mortality rates in the world are unacceptably high, with approximately 830 women dying each day from complications related to pregnancy or childbirth (Africa, 2019). The majority of these deaths take place in developing countries. In developing countries, the maternal mortality rate is 239 per 100 000 live births, compared to 12 per 100 000 live births in developed countries. More than half of maternal deaths in developing countries are in Sub-Saharan Africa, and nearly a third in South Asia (Africa, 2019). Goal 3 objective 1 of the Sustainable Development Goals is to reduce global mortality to less than 70 per 100 000 live births by 2030 (Africa, 2019).

A third to half of all maternal deaths are caused by hypertension (pre-eclampsia and eclampsia) and antepartum hemorrhage, which are caused by inadequate prenatal care (Africa, 2019). Antenatal care is a process that helps in identifying and managing the problems that are related to maternal mortality and morbidity through relevant physical examinations (Das, 2017). There are numerously acceptable, efficient, and effective interventions that have been developed to improve antenatal care. These include the World Health Organization's (WHO) Focused Antenatal Care (FANC) guidelines which help in guiding the obstetricians and Community health workers on the services that women should receive in each visit to reduce Maternal mortality. In rural areas, antenatal care fails to reach vulnerable women due to delay in seeking care and in delays in treatment, while in urban areas delays in arrival and delay in treatment are the main causes of poor antenatal care. In addition, hospitals in urban areas have higher caseloads, more health worker absences, more complex cases, and subpar diagnostics. According to the State Disability Insurance (SDI), the caseload in urban areas is one-third higher than in rural areas (Shabani *et al.,* 2018).

Pre-eclampsia/eclampsia and other diseases that can lead to maternal mortality such as malaria, and HIV have detectable preclinical phases (Nuamah *et al*., 2019). Pre-eclampsia/eclampsia should be screened at every antenatal care visit by checking the protein levels in the urine. Malaria is screened through a simple blood test in the first antenatal care visit, and it is repeated on subsequent visits if the woman is symptomatic. Screening for HIV is done on the first week of the antenatal visit, which is supposed to be before the sixteenth week of pregnancy (Kearns

et al., 2014).

There are several websites and mobile applications that have been developed to provide pregnant women with knowledge on proper antenatal care. Websites for pregnant women have information such as timing for antenatal clinic visits, what to expect during each clinic visit and during each phase of pregnancy, interactive 3-dimension (3D) visualizations that show fetal growth, and real-time access to answers from questions asked by pregnant mothers. Websites include WebMD and "What to expect when you're expecting", while applications include GiftedMom deployed in Cameroon and Jambo Mama and Wazazi nipendeni for Tanzania. Ideally, increased knowledge will help women to request necessary services during antenatal clinic visits and therefore ensure that they are provided with quality care. Improved knowledge can also support women with self-care i.e., the ability of individuals and communities to promote and maintain good health, and cope with illness and disability with or without the assistance of a healthcare provider. Self-care interventions have a unique potential for eliminating inefficiencies in health expenditure, enhancing the quality of health coverage, and giving even the most vulnerable people more agency and control in making health decisions (Course, 2019).

Studies have shown, however, that information on several pregnancy websites gives contradicting information to women (Johnsen *et al.*, 2018). In addition, websites often contain too much information, which makes it hard to retain, and often confuses women. A study by Johnsen *et al.* (2018) found that the use of commercial search engines for maternal health information seeking may be the cause of getting contradicting information, as the results returned are not always those from evidence-based sources. Developing countries account for nearly all maternal deaths worldwide, with the bulk of these deaths occurring in Sub-Saharan Africa, where the majority of women are unaware of obstetric danger signs. Early identification of the threat, as well as effective and timely referral to obstetric treatment, requires knowledge of the danger signs of obstetric complications (Woldeamanuel *et al*., 2019). A new approach to informing pregnant women on danger signs such as those related to pre-eclampsia is thus needed. Adopting a more client-centered approach might be an option (Williams *et al.*, 2013).

Expert systems have been shown to support pregnant women in identifying antenatal risks and gaining personalized knowledge on required obstetric care based on their health and gestational age, by giving immediate recommendations and the justification for the recommendation given input symptoms or questions. The recommendations are a combination of the pre-programmed

expertise of several domain experts, in this case, doctors, midwives, and other health workers. Examples of such systems include one developed for predicting early pregnancies with disorders (Maylawati *et al*., 2017), an expert system developed for the diagnosis of ectopic pregnancy (Kitporntheranunt and Wiriyasuttiwong, 2010), and an expert system for diagnosis and treatment of hypertension in pregnancy (Gudu *et al*., 2012). Evaluation results of these expert systems have shown great correspondence to clinical diagnosis, Therefore, unlike websites and traditional mobile applications, an expert system can ensure pregnant women are provided only with relevant knowledge promptly to manage potential risks. Most of the existing expert systems have been made for developing countries, which have differing antenatal clinic schedules, cultures, and burdens of disease than developing countries. It is therefore necessary to develop expert systems for developing countries that will suit the requirements of these countries.

This research aimed at developing a smartphone-based expert system for the prompt diagnosis of detectable, preclinical phases of the main causes of maternal mortality in Tanzania, and effective provision of general information on obstetric care and dangerous symptoms at different stages of pregnancy. A mobile expert system for maternal care in Tanzania is a feasible solution for addressing maternal deaths as the Tanzania Communications Regulatory Authority (TCRA) survey from 2020 shows there were 44.13 million mobile connections in Tanzania (corresponding to 75% of the total population) in January 2020, a rise of 709 thousand connections from January 2019, and there were 14.72 million internet (25% of the population) users.

1.2 Statement of the problem

Developing countries account for nearly all maternal deaths worldwide, with most of these deaths occurring in Sub-Saharan Africa. The majority of pregnancy complications are preventable or treatable; however, some complications can occur before pregnancy but escalate during pregnancy, particularly if not treated as part of the woman's treatment (Africa and Asia, 2019). Pregnant women who are unaware of the danger signs of obstetric problems will experience the consequences of a "first delay" in finding treatment during obstetric emergencies. It is important for a pregnant woman to be aware of and recognize danger signs during her pregnancy so that they can seek medical help as soon as possible (Tamang *et al*., 2021). Early identification of the problem, as well as effective and timely referral to obstetric treatment, requires knowledge of the danger signs of obstetric complications (Woldeamanuel

et al., 2019).

There are a large number of websites and mobile applications aimed at providing general maternity information and warnings for danger signs of pregnant women, but these are mostly developed in western countries. Hence, recommendations are mostly specific to western countries, leaving vulnerable women in developing countries with few relevant information resources. It is important for user-centered and context-relevant maternal information applications to be developed for these women, to support efforts against maternal mortality.

1.3 Rationale of the study

Ensuring that women have a firm knowledge of obstetric care can improve the health care services among pregnant women. Through the recommendations that are provided in the expert system, women can have control over the services that they receive in each visit which will ensure that proper screening is carried out and adequate services are offered. The explanations that are provided with the recommendations will enhance knowledge on obstetric care among women.

1.4 Research objectives

1.4.1 General objective

To develop a smartphone-based expert system for the early detection of observable, preclinical stages of the key causes of maternal mortality in Tanzania, as well as for the effective provision of general information on obstetric treatment and dangerous symptoms at various stages of pregnancy.

1.4.2 Specific objectives

(i) To identify information needs and application design requirements seeking of pregnant women in the Tanzanian context.

(ii) To develop an expert system for smartphone devices, which will diagnose the main causes of maternal mortality in Tanzania and provide pregnant women with general knowledge on pregnancy and antenatal care services.

(iii) To assess the accuracy of the expert system in diagnosing selected maternity complications in Tanzania.

(iv) To determine the relevance, usability, and acceptability of the expert system among pregnant women, midwives, gynecologists, and community health workers,

1.5 Research questions

(i) What are the maternal information needs among pregnant women in Tanzania, and what information-seeking behaviors do they use?

(ii) How should the smartphone application and expert system be designed to present timely and understandable information that can enhance conversation between healthcare workers and pregnant women?

(iii) How accurate can an expert system predict common maternal complications in Tanzania?

(iv) How relevant, usable and acceptable is the developed mobile-based expert system?

1.6 Significance of the study

Developing countries account for nearly all maternal deaths worldwide, with most of these deaths occurring in Sub-Saharan Africa, where the majority of women are unaware of obstetric danger signs. Early identification of the problem, as well as effective and timely referral to obstetric healthcare, requires knowledge of the danger signs of obstetric complications. When women are provided with this knowledge it will help to achieve the target of reducing global maternal mortality to less than 70 maternal deaths per 100 000 live births by 2030 (Woldeamanuel *et al*., 2019).

1.7 Delineation of the study

The development of the medical expert system is aimed at diagnosing the main causes of maternal mortality in Tanzania i.e., Pregnancy hypertension (pre-eclampsia), Infections (Malaria), and Miscarriage (Threatened abortion) among pregnant women. The system is designed to help women gain knowledge about complications during pregnancy, through the diagnosis of the symptoms and provide recommendations for the complications and tips for self-care during pregnancy.

CHAPTER TWO

LITERATURE REVIEW

2.1 Tanzanian health-related information-seeking habits

Studies on maternal health knowledge-seeking in Tanzania have largely focused on rural women. According to Mwangakala (2012), the majority of women prefer to receive knowledge about their maternal health from accredited healthcare providers. Due to these provider's restricted accessibility, many pregnant mothers sought information from traditional birth attendants and other women in the community. As a result, much of the information gathered was focused on personal experiences and opinions rather than expert expertise, making it difficult for the women to recognize danger signs. Kassim documented similar findings as well (Mohamed, 2017).

In addition, studies on health information-seeking behavior have shown a high dependence on oral sources of information, with qualified health professionals being preferred (Benard & Chipungahelo, 2017; Lwoga *et al*., 2017). However, Mwaisela and Mwantimwa (2018) discovered that health information preferences varied from person to person, depending on the reasons for seeking information, with oral sources being the most common among women seeking breastfeeding information. The perceived difficulty in obtaining information and expectations of accuracy are also barriers to online health information searching. Illiteracy, a lack of awareness that the Internet can beused as a source of information, and costs can all contribute to the low use of online resources in rural areas.

2.2 Mobile applications for antenatal care

In the African context, several applications have been established to aid in the healthy pregnancy and delivery of children. In South Africa, the MomConnect application has been one of the most effective (Barron *et al*., 2018). MomConnect, which was introduced in 2014, sends Short Message Service (SMS) messages to mothers and children about healthy habits. The messages are personalized to the gestational age of the woman. Women may also ask individual questions and provide input on the antenatal care they received via SMS. With over 500 questions asked daily, users register a high level of satisfaction. GiftedMom, a related app, sends women in Cameroon SMS and voice updates about upcoming antenatal appointments, as well as maternal health education (Temgoua *et al*., 2018). The application resulted in a 20%

increase in antenatal clinic attendance in 15 rural areas. Meanwhile, the Safe Delivery app Thomsen *et al*. (2019) in Ethiopia uses 5-7-minute animated videos to teach women how to handle the third stage of childbirth, with an emphasis on life saving techniques. Professionals in the healthcare field can watch the whole video or only the tactics they're interested in. Weekly SMS quizzes are also offered, along with links to video segments showcasing the results and lists of important medicines and equipment. The apps were generally well-received by health workers, with many continuing to use them to update their knowledge of life-saving techniques.

In Tanzania, Wazazi Nipendeni is an SMS service provided by the Airtel telecommunications company that aims to keep women informed and healthy during their pregnancy by providing information on diet, family planning, danger signs, and many other topics (Kaufman *et al*., 2017). Exposure to the app predicted whether women delivered in a health facility or were tested for HIV with their partner in unadjusted models. Several apps, ranging from SMS-based to smartphone-based,have also been introduced to assist women in learning about the stages of pregnancy and their symptoms. Other applications include:

(i) Jambo Mama: An interactive mobile application that links pregnant women to their healthcare providers and offers general health information. The woman's medical records will be sent to the hospital where she will give birth. Jambo mama frequently texts the mother with updates on her pregnancy and encourages her to respond to questions about how she is feeling and how her pregnancy is going.

(ii) Wired Mothers: A randomized controlled trial in Zanzibar used an SMS-based app with a voucher component to see whether a mobile app could increase antenatal care visits duringpregnancy.

The main downside of apps like Jambo Mama and Wazazi Nipendeni is that doctors must manually respond to messages, which is a time-consuming procedure for doctors and has resulted in late responses to pregnant women.

2.3 Mobile phone-based pregnancy support systems

A mobile phone-based approach is a customized approach that uses a mobile phone to inform women about pregnancy issues, track the child and mother’s progress, provide vital information, provide post-delivery care, and follow-up with medical check-ups. An appropriate

tool that is accessible at all times to help reduce pregnancy-related stress and anxiety, as well as its complications, is critical in the presence of strong cell phone technology and mobile network infrastructure. This platform will assist both the mother and her husband in understanding the changes that occur during pregnancy and the measures that must be taken (Hussain *et al*., 2020). This category includes expert systems, decision support systems, pregnancy-related websites, and mobile apps designed to run on mobile phones.

2.4 Expert and decision support systems for detection of early pregnancy complications

Maylawati *et al*. (2017) developed an expert system for predicting early pregnancy with disorders using an Artificial Neural Network. Several early pregnancy disorders were successfully diagnosed from input symptoms, including ectopic pregnancy, pre-eclampsia and eclampsia, Hyperemesis gravidarum, and hydatidiform mole. The study used Artificial neural networks (ANN) and the Backpropagation algorithm (Maylawati *et al*., 2017). In addition, a medical expert system for ectopic pregnancy diagnosis was developed by Kitporntheranunt and Wiriyasuttiwong (2010) with research revealing a 100% match with the clinical diagnosis in the testing community. Another maternal health expert system for hypertension diagnosis was established in Eldoret, Kenya (Gudu *et al*., 2012).

Umoh and Nyoho (2015) have used a fuzzy approach for pregnancy risk factor monitoring. Their study aimed to accurately diagnose and track pregnancy risk factors in women in the presence of a huge amount of data. The model aimed to provide a decision-making forum for doctors, obstetrical health practitioners, and pregnancy risk factor researchers. The research also aided health practitioners in obstetrical and gynecological clinics in educating women about the benefits of early clinic attendance as well as pregnancy risk factors.

Paydar *et al*. (2017) developed a clinical decision support system (CDSS) to predict the pregnancy outcomes of affected pregnant women with Systemic Lupus Erythematosus (SLE). The system did an excellent job of predicting the outcomes of contaminated women's pregnancies.

2.5 Natural Language Processing

In the 1950s, Natural Language Processing (NLP) emerged as a synthesis of artificial intelligence and linguistics. Text Information Retrieval (IR), which uses highly scalable

statistics-based techniques to index and scan large amounts of text efficiently, was originally distinguished from Natural Language Processing. Natural Language Processing and Information Retrieval, on the other hand, have converged more over time. The NLP already borrows from a variety of disciplines, necessitating a substantial increase in the mental knowledge base of today's NLP researchers and developers (Nadkarni *et al*., 2011).

2.5.1 Natural language processing in Africa

In South Africa, a project has been launched to create datasets for automatic speech recognition. De Vries' work encompasses a total of 800 hours of speech in eleven languages. This work has also included a better understanding of code switching (using various languages in the same conversation) for multilinguals, as well as the use of soap-opera data speech (Vukosi, 2020). Recent work out by Marivate concentrating on techniques to acquire and annotate Setswana and Sepedi data demonstrates how one may now study the usage of pre-trained models collected from a variety of sources) and then develop news categorization models (Marivate *et al*., 2020).

2.5.2 Natural language processing in medicine

Natural language processing has shown great promise in the field of medicine in the past years, it has been widely used in information extraction from clinical notes in electronic medical records (EMR). Shen *et al*. (2021) used natural language processing techniques to extract information from family history data to aid in the diagnosis and treatment decisions in clinical settings. The Family Health corpus with the help of Natural Language Processing methods was found to be a valuable source for researchers looking to develop FH analysis systems. As part of the research, participants from all over the world were encouraged to build Family Health extraction processes to better understand clinical narratives.

Lee *et al*. (2020) carried out a study to identify goals-of-care conversations through clinical reports from inpatient and outpatients with severe illnesses using Natural Language Processing and Machine Learning (ML) methods. Notes were gathered from a variety of sources: a) Abstracted notes from participants in two randomized controlled trials (RCTs) of palliative care treatments for documentation of goal-to-care discussions; b) Notes written by palliative care specialists who had designated each note as having or not having goals-to-care discussions for clinical service metrics, and c) Clinical notes from a random group of critically ill patients. A novel approach to defining goals to-care conversations was developed using NLP and ML

techniques. As a research result and efficiency measure, NLP and ML have shown promise in assessing goals-to-care discussions.

A study by Stewart and Velupillai (2021) showed that Natural Language processing has the potential to improve mental health research through the use of data from Electronic Medical Records (EMR). Important progress has been made in using Natural Language Processing (NLP) within the Clinical Record Interactive Search (CRIS) system to facilitate study at the South London and Maudsley Trust (Slam). The first phase of NLP on CRIS concentrated on capturing the most important research structures, which had previously been "invisible" within unstructured text, this Included interventions received (e.g., medications, psychotherapies), indications for interventions (e.g., symptom profiles), and wider factors predicting intervention response and longer-term outcome (e.g., substance use, physical health comorbidity, educational achievement, and occupation). Neural network-based NLP approaches inspired by machine translation methods to produce simulated clinical text data that can be used to test methods before deploying on real data. As a nascent discipline, applied clinical NLP holds a lot of promise.

Natural language processing has also been used in the detection and identification of morbidities in medicine (Borjali *et al*., 2021) used Deep Learning-Natural Language Processing approaches to detect adverse events from free-text medical narratives for detecting complete hip replacement dislocation written and signed by liable and accountable individuals. The study found that using the DL-NLP model in large-scale orthopedic registries yielded promising results. Other Epic-based EMRsystems may be able to use the NLP model to improve AE detection, and as a result, patient care quality and outcomes. Similarly, Dahl *et al*. (2021) carried out research to describe the development of a method that can be used to estimate the percentage of positive results in a series of radiology exams for a Norwegian hospital. The models performed nearly flawlessly in their given domain, as well as convincingly on reports involving a different patient group and modality. The models were found to be appropriate for classifying radiology reports for potential quality assurance purposes, with the fraction of exams with unusual findings for various patient subgroups being a key parameter.

In HIV patients, mental illness and substance addiction are widespread, and they often lead to poor health outcomes. Ridgway *et al*. (2021) carried out a study to Identify mental illness and substance use among people living with HIV by employing Natural Language Processing

(NLP) of unstructured text in clinical notes in the EMR. Patients in an urban HIV treatment clinic had high rates of mental illness and drug use, which were often not reported in formal EMR fields, according to NLP of clinical notes. This finding has far-reaching implications for HIV epidemiology and clinical care.

2.5.3 Natural language processing in pregnancy

Natural Language processing has been used for the detection and identification of various pregnancy issues to improve pregnancy outcomes among pregnant women. Zhong *et al*. (2018) conducted a study to compare Diagnostic codes and Clinical notes processed through Natural Language Processing to screen pregnant women for suicidal activity in electronic medical records. The use of natural language processing was shown to increase the sensitivity of screening suicidal behavior in EMRs significantly. However, among women who did not have diagnosis codes for suicidal activity but screened positive by NLP, the prevalence of reported suicidal behavior was found to be lower. For potential EMR-based phenotyping studies of suicidal behavior, NLP should be combined with diagnostic codes. Another study was carried out by Klein and Gonzalez-Hernandez (2020) to identify women reporting adverse pregnancy outcomes on Twitter using an annotated data set 6487 tweets that mention miscarriage, stillbirth, preterm birth or premature labor, low birth weight, neonatal intensive care, or fetal/infant loss, in general, were provided to advance the use of social media data as a supplementary resource for the epidemiology of adverse pregnancy outcomes. The study showed that “outcome” tweets can be used to learn more about patients’ views and perceptions of negative pregnancy outcomes, as well as guide researchers to the user’s full timeline of the tweet.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study purpose and design

A needs assessment survey and observation study were conducted in Arusha, Tanzania. The survey aimed to identify the main causes of maternal mortality in Tanzania and the knowledge-seeking behavior among Tanzanian pregnant women. A mobile expert system prototype was developed based on the identified requirements, and validated through a second survey and observation study, aimed at assessing the usability and acceptability of the pregnancy application.

3.2 Participants

A total of 192 participants (6 gynecologists, 4 Midwives, and 182 pregnant/recent mothers) took part in the initial survey study. Participants were selected randomly from three major hospitals in the city – Mt. Meru Referral Hospital, Arusha Lutheran Medical Centre, and AICC hospital. Ethical approval for the study was granted by Kibong'oto Infectious Diseases Hospital- Nelson Mandela African Institution of Science and Technology- Centre for Educational Development in Health, Arusha (KIDH-NM-AIST-CEDHA) Health Research Ethics Committee-KNCHREC. The study took place between February and June 2020. Only pregnant women and recent mothers (last pregnancy within 6 months) were included in the investigation.

Table 1: Demographic characteristics of the women

Demographic	No. of participants
Age	
18 - 23	27
24 - 29	94
30 - 35	61
Education	
Primary Education	47
Secondary Education	94
Higher Education	41

Before the study, all participants were informed on the purpose of the research, the scope of data to be collected, how their data would be used and their rights to decline participation or to withdraw at any point. Participants gave consent before the start of the study. They were also educated on how to answer the questionnaire.

Figure 1: Data collection at the Mt. Meru Hospital

3.3 Needs assessment survey design

The survey consisted of both questionnaires and interviews. The questionnaires were distributed to pregnant women and recent mothers, they consisted of 14 questions divided into 2 sections. The first section focused on collecting demographic details such as area of residence, age, education level, and the number of prior pregnancies. The second section assessed knowledge-seeking behaviors. The questions included were on whether they used their smartphones to search for information regarding symptoms that they experienced during pregnancy, the applications or websites they used, whether there was a correlation between the results from websites and what the doctors tell them, challenges they faced when using the applications and what additional knowledge and system features, they felt were needed to address the challenges faced. Participants provided both free responses and the most relevant options from multi-choice questions.

The interviews were conducted with gynecologists and midwives. They were structured and consisted of 13 questions. The questions were aimed at identifying common complications women experience during pregnancy, complications that were prevalent in Tanzania but less so elsewhere, the risk factors associated with the complications, how the complications can be prevented and managed, symptoms that should result in help-seeking behavior, and any first aid treatments that can be administered at home. The interviewer recorded the responses during the interview and reviewed them during the analysis stage.

The questionnaire was validated before the study by 32 women who were sent online questionnaires (Google Forms). Originally, the questionnaire contained 30 questions, but these were reduced to 14 after the validation study, as the omitted questions mainly provided repetitions of previous answers. Some questions were also rephrased to make them easier to understand and to prompt more verbose responses on the women's experiences.

3.4 Observation

Observations were conducted after the interviews. The pregnant/recent mothers were asked to show how they interacted with the applications or websites to search for information using their phones. They were asked to type in the questions they had on the applications and questioned them on the results obtained to gauge their understanding.

3.5 Data analysis

The collected data were pre-processed by analyzing consistencies in responses and filtering responses that did not match the questions. Responses from the questionnaires were fed into the Visual Paradigm data visualization tool, which is a UML CASE Tool supporting UML 2, SysML,and Business Process Modelling Notation (BPMN) from the Object Management Group (OMG).The responses to multiple-choice questions were presented using histograms to determine the distribution of responses. Pie charts were used to present the Qualitative responses where the proportion of responses was distributed based on the demographics of the participants.

3.6 Research framework

The research framework is a structure that explains how the research will be conducted from data collection to deployment of the system. Figure 1 shows the flow of our work. Upon completion, the trained model was tested to confirm if it made the right diagnosis. The end product of the research was a Mobile application that was developed based on the user requirements collected from pregnant women. The trained model was imported into the mobile application and the mobile application was then implemented.

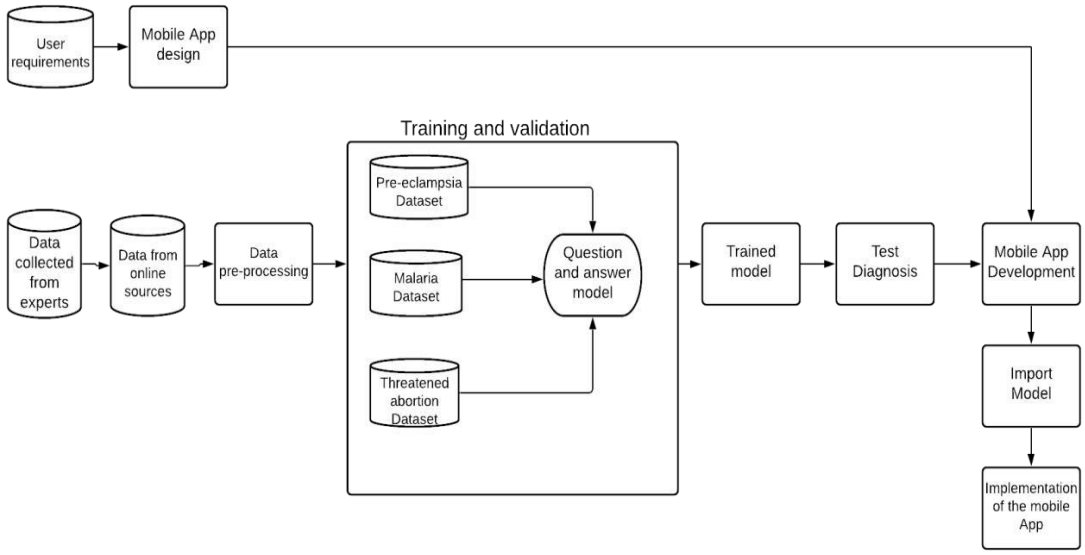

Figure 2: Research Framework

3.7 Data

The data collected was from multiple online sources which included data from published papers, web pages, and books relating to pregnancy and health. The collected information was accessed through a simple google search, published papers were accessed through google scholar and Pubmed. The collected data was from both developing and developed countries. The total number of documents collected was 1279, where 75 are books. Out of 75 books, 18 were malaria books, 9 were pre-eclampsia books, 6 were threatened abortion and 42 were books on general pregnancy topics, threatened abortion, malaria, and pre-eclampsia. The 1279 documents included 402 malaria documents, 382 pre-eclampsia documents, 316 threatened abortion, and 179 documents on general pregnancy symptoms. Each document consisted of symptoms, treatment, and recommendations, and for general pregnancy symptoms, self-care tips and home remedies were explained.

First data collected from experts on the complication's women in Tanzania face during pregnancy, and their recommendations are analyzed and compiled, the data from the experts is then used to collect online data on the prominent complication's women face during pregnancy in Tanzania i.e., Pre-eclampsia, Malarial Infections and Miscarriage (Threatened Abortion). Additionally, data on normal pregnancy symptoms such as Nausea and Vomiting, constipation, edema, back pain, bloating, fatigue, heartburn this data was collected so as women could gain knowledge on self-care when the symptoms arise since most of these symptoms have home remedies that can be administered at home. Online data collected was in the form of published papers, web page information, and books on the relevant complications. The collected data were then pre-processed to eliminate irrelevant data. Data preprocessing was performed manually. Datasets on Pre-eclampsia, Malaria, and miscarriage (Threatened abortion) are then trained on the Question-and-Answer model.

Table 2: Data collected from online sources

Condition	Documents	Books
Malaria	402	18
Pre-eclampsia	382	9
Threatened Abortion	316	6
General pregnancy symptoms	179	42

3.7.1 Data pre-processing

Data preprocessing is a crucial task in developing a Natural Language Processing Machine Learning model, and the results are determined by how well the data has been preprocessed. The text data was pre-processed so that the model could make intelligent diagnoses of Tanzania's three leading causes of maternal mortality. The text pre-processing phase was done in three stages: Data cleaning to filter irrelevant information, development of a corpus, developing a Gold Standard Corpora for each complication.

3.7.2 Data cleaning

Machine learning (ML) algorithms are only as good as the data they are trained on, so data cleaning has long been a key component of developing high-quality ML models (Li *et al*., 2020). In our study images, links, advertisements, and other irrelevant information that was found in the collected data were eliminated to improve the quality of data. After carrying out data cleaning the size of the dataset was 1.46 GB.

3.7.3 Development of a corpus

A corpus is a logically organized set of naturally occurring texts that are stored on a computer and, analyzed using special software. It is permissible since the texts chosen for inclusion are relevant to predetermined research goals (Evans, 2007). Three corpora, one for each trimester (First Trimester, Second Trimester, and Third Trimester), were chosen. In each corpus trimester-specific information on physical changes that occur to women during pregnancy, and complications during pregnancy were addressed with appropriate recommendations from doctors. It was advised by the experts that each complication and natural physical changes that take place in the woman during pregnancy to be grouped in trimesters in which they are most prominent, this makes it easier to diagnose. The tool used in developing the corpora is Sketch Engine. Since 2003, Lexical Computing Limited has provided a free online corpus manager and text analysis program called Sketch engine.

3.7.4 Development of a Gold Standard Corpora

When developing and evaluating Natural Language Processing (NLP) systems, the gold standard annotated corpora are essential tools (Deleger *et al*., 2014). A Gold Standard Corpus for Pre-eclampsia, Malaria and Threatened abortion were created using a free online text annotator tool called BRAT rapid annotation tool. Brat is a web-based text annotation software that allows you to add annotations to existing documents. After annotation of the text document through BRAT, atar.gz file was downloaded, the annotated document and text document was then extracted (.ann and .txt consecutively). The text document and annotated document are the ones to be uploaded into the model for training.

3.7.5 Design assumptions

(i) All women owned smartphones

(ii) All users understand English

(iii) The main users of the application are women

(iv) The users all have access to internet connection

In cases where women do not have smartphones and access to the internet USSD application will be developed. A Swahili component will be included to the application to cater to non-English speaking users. Additionally, further research will be carried out to identify system

requirements of male partners.

3.8 Question and answer model

In NLP, question answering (QA) is a well-studied problem. The QA has applications in a wide range of activities, including information retrieval and entity extraction, despite being one of the oldest research fields. Recently, QA has been applied to the development of dialog systems and chatbots that mimic human conversation. Most prior work in this field relied on a pipeline of traditional linguistically-based NLP techniques including parsing, part-of-speech marking, and co-reference resolution. These techniques are used by many cutting-edge QA systems, such as IBM Watson (Preena *et al*., 2019).

Question and answer models have been used in medicine to give information about different topics in health. Savery *et al*. (2020) developed a question-driven summarization tool for answers to consumer health questions, this was aimed to help non-medical experts to understand health information. The study reproduced quality, detailed summaries of the answers to consumer's questions. Research carried out by Abacha and Zweigenbaum (2015) used a combination of NLP techniques and semantic web technologies to develop a medical question and answering system. In the study, real questions and answers were extracted from MEDLINE articles. The study showed promising results in providing accurate responses to medical questions, unlike those provided in search engines. During the COVID-19 outbreak, Lu *et al*. (2021) sought to reveal opinions for COVID-19 questions using a context retriever, an opinion aggregator, and a question and answering model. They found that opinion generation led to more interpretable, robust, and comprehensive question-specific literature reviews.

3.9 Bidirectional Encoder Representations from Transformers (BERT)

The Bidirectional Encoder Representations from Transformers (BERT) is designed to pre-train deep bidirectional representations from the unlabeled text by conditioning on both left and right context in all layers, unlike recent language representation models. As a result, the pre-trained Bidirectional Encoder Representations from Transformers model can be fine-tuned with only one additional output layer to produce state-of-the-art models for a variety of tasks, such as Question Answering and language inference, without requiring significant task-specific design changes.

3.9.1 Input representation

Token embeddings, segment embeddings and position embeddings are the three embeddings used in BERT input representation. In BERT, the tokens CLS and SEP are used. The CLS is used to denote the beginning of a sequence, while SEP is used to separate segments (or sentences). Bidirectional Encoder Representations from Transformers inputs are:

(i) Token embeddings: These are general word embeddings; they use vectors to represent token (word).

(ii) Segment embeddings: These are also known as sentence embeddings. When two sentence are entered, corresponding sentence embeddings are allocated to specific words. One segment embedding will be used if the input is a single sentence. The location would be accumulated in the case of two sentences.

(iii) Position Embeddings: This refers to a token sequence of input.

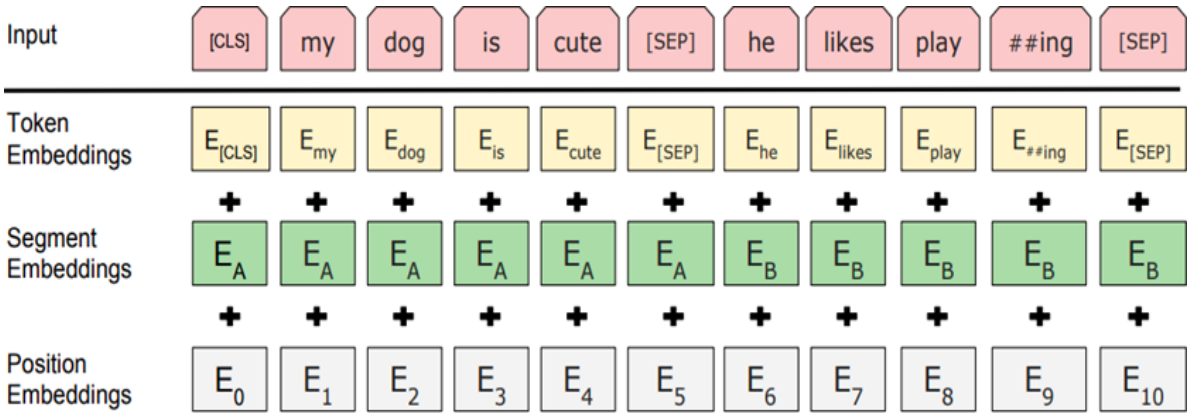

Figure 3: BERT input representation by Devlin *et al*. (2018)

3.9.2 Training tasks

In this section, the Bidirectional Encoder Representations from Transformers (BERT) training will be discussed. Training BERT involves two tasks, the first task is the masked language model, and the second task is to predict the next sentence.

(i) Masked language model

The first step in the pre-training process is to use a masked language model (Masked LM). Bidirectional Encoder Representations from Transformers uses bidirectional as a pre-training

goal rather than the conventional directional model. If a bidirectional model is trained using a conventional method, each word would be able to see "itself" indirectly. As a result, BERT employs the Masked Language Model (MLM) strategy. BERT predicts masked tokens rather than the entire input by masking certain tokens at random and using others to predict those masked tokens to learn the representations. In contrast to other methods. In the experiments, 15% of the tokens are chosen at random to be replaced. There are a few drawbacks to this. First, in the fine-tuning stage and actual prediction, the MASK token, which will be replaced by this token, will never be seen. As a result, the chosen token for masking will not always be masked, but: **A**: 80% of the time, it will be replaced by a (MASK) token, **B**: It will be replaced 10% of the time by another real token, **C**: It will be kept in its original form 10% of the time.

For example, in scenario A, if the original sentence is "I am learning NLP", and NLP is the chosen token for masking, the token will be displayed 80% of the time as "I am learning NLP" (MASK).In scenario B, the token will be replaced 10% of the time by another token, such as "I am practicing OpenCV". And the rest of the time it will be displayed as the original "I am learning NLP" as it is explained in scenario C. Random replacement (Scenario B) can ruin the meaning of the sentence. But it only masks 15% of the token out of the entire dataset and 10% of this 15%, hence it is not believed to harm the model. Another downside is that a longer time is taken for training if only 15% of the token is masked (Predicted).

(ii) Next Sentence Prediction

Predicting the next sentence is the second pre-training activity. Since it cannot predict the relationship between sentences, this method requires changes to the first task. It aims to determine whether or not the second sentence comes next. Example, Input 1: I'm studying French at the moment. Input 2: Nouns are a part of the French language. The predicted result will be either "isNextSentence" or "notNextSentence", with data chosen at random.

3.9.3 Model training

Bidirectional Encoder Representations from Transformers (BERT) receives two-phase training. The model is trained using a generic dataset in the first phase, and then fine-tuned using a domain-specific dataset in the second phase. Pre-training phase. During the pre-training phase, BooksCorpus (800 M) and English Wikipedia (2500 M) words are used to retrieve the sentences (Xu *et al*., 2020). Masked LM: There will be 512 tokens per sequence (2 concatenated sentences) and 256 sequences per batch. To train a model, approximately 40

epochs are set. The configure is:

(i) With a learning rate of 1e-4, 1 = 0.9, and 2 = 0.999, Adam

(ii) 0.01 weight decay in L2

(iii) All layers are dropped out.

(iv) For activation, we'll use Gelu.

For the "next sentence prediction" pre-training exercise, two sentences are chosen. Another sentence is randomly selected and labeled as "notNextSentence" 50% of the time, whereas the other sentence is the real next sentence 50% of the time.

3.9.4 Fine-tuning phase

Just a few model hyper parameters, such as batch size, learning rate, and the number of training epochs, are modified in the pre-training phase; the majority of model hyper parameters remain unchanged. The following value ranges performed well through tasks during the experiments:

- Size of the batch: 16, 32
- 5e-5, 3e-5, 2e-5 are the rates of learning.
- Number of epochs: 3, 4

The fine-tuning technique varies and is dependent on downstream tasks.

3.9.5 Bidirectional Encoder Representations from Transformers working mechanism

Transformer, an attention mechanism that learns contextual relationships between words (or sub-words) in a text, is used by BERT. The transformer comprises two main mechanisms in its basic form: an encoder that reads the text input and a decoder that generates a task prediction. Only the encoder mechanism is required because BERT aims to generate a language model.

The Transformer encoder reads the entire series of words at once, unlike directional models that read the text input sequentially (from left to right or right to left). As a result, it is classified as bidirectional, but it is more appropriate to describe it as non-directional. This feature allows the model to deduce the meaning of a term from its surroundings (left and right of the word).

3.9.6 How to use BERT (Fine-tuning)

It's pretty simple to use BERT for a particular mission. Bidirectional Encoder Representations from Transformers adds a small layer to the core model which can be used for a wide range of language tasks. Tasks carried out by BERT are:

(i) Sentiment analysis and other classification tasks are performed in the same way as Next Sentence classification by layering a classification layer on top of the Transformer output for the [CLS] token.

(ii) Question Answering tasks (such as SQuAD v1.1) require the software to obtain a question about a text sequence and mark the answer in the sequence. A Q&A model can be trained using BERT by learning two extra vectors that mark the start and end of the answer.

(iii) The software in Named Entity Recognition (NER) is given a text sequence and is asked to identify the various types of entities (Person, Organization, Date, etc.) that appear in it. By feeding the output vector of each token into a classification layer that predicts the NER label, a NER model can be trained using BERT.

Note that most hyper-parameters in fine-tuning training are the same as in BERT training.

3.9.7 Bidirectional Encoder Representations from Transformers Question Answering system

Bidirectional Encoder Representations from Transformers treats the question and passage as a single packed sequence for the Question Answering task. The input embeddings are made up of the token and section embeddings added together. Before entering the model, the input is processed as follows:

(i) Token embeddings: At the start of the question, a [CLS] token is added to the input word tokens, and a [SEP] token is inserted at the end of both the question and the paragraph.

(ii) Segment embeddings: Each token has a marker that indicates whether it is Sentence A or Sentence B. The model can differentiate between sentences as a result of this.

A start vector and an end vector is introduced to fine-tune BERT for a Question-Answering scheme. A dot product between the final embedding of the word and the start vector, followed by a softmax over all the words, is used to measure the likelihood of each word being the start word. The probability value of the term with the highest probability value is taken into account.

3.10 Experiment setup

The experiment was carried out in a laptop pre-installed with Windows 10 Pro, version 20H2, equipped with Intel (R) Core (TM) i7-8565U CPU @ 1.80GHz 1.99 GHz Processor, 16 GB RAM. The programming language used was Python. Ktrain was used for implementing the pre-trained BERT model. Kaggle was the platform prepared for training the model. Kaggle helps data scientists build models with data. The data can be uploaded by the user or data published by other users.

The data collected was divided into Trimesters. This was done to group pregnancy complications, and natural physical changes in the order of their time of occurrence, this is because diagnosis is easier when experts know how far the pregnancy is, most complications and symptoms are time-specific. The data had information about natural physical changes that occur in women, their cause and recommendations (home remedies) and complications common in each trimester, their symptoms, cause, and recommendations from experts. Three Gold Standard Corpora was developed for the main causes of maternal mortality in Tanzania, the selected complications were: pregnancy hypertension (Pre-eclampsia), Malarial Infections, and Miscarriage (Threatened Abortions) each Gold Standard Corpus showed entities and relationships between the entities.

3.11 Model training

Natural language processing (NLP) has become very popular over the years in the fields of study and research. The basics of Natural language processing are widely known and easy to grasp. However, deep learning becomes essential for NLP tasks when the text data becomes large and unstructured. Deep learning is an artificial intelligence subset of machine learning that uses networks to learn unsupervised from unstructured or unlabeled data. Deep learning requires massive amounts of data to train models, finding data of such magnitude is often difficult and also preparation of the data sets is too costly. Additionally, it is costly to run advanced deep learning algorithms on GPUs. As a result, researchers began using pre-trained state-of-the-art deep learning models via a technique known as Transfer learning. Transfer

learning requires fewer resources than training a deep learning model from the ground up, and it can deliver good results with limited amounts of training data.

In this study, a BERT pre-trained model was used. The model was implemented by Ktrain. Ktrain has a handy feature that allows you to translate text data into features for the model being worked on. The library performs the preprocessing steps, which are not done manually. Ktrain is a lightweight wrapper for the TensorFlow Keras (and other libraries) deep learning library that makes it easier to build, train, and deploy neural networks and other machine learning models. Ktrain is a deep learning and AI framework extension inspired by ML framework extensions such as fastai and ludwig. Its goal is to make deep learning and AI more available and easier to implement for both beginners and established practitioners. Through the process of fine-tuning, the pre-trained model was converted for Question Answering tasks. Fine-tuning, in general, means making small adjustments to a process to achieve the desired output or performance. In deep learning, fine-tuning entails programming another related deep learning method with weights from a previous deep learning algorithm. Each neuron in one layer is connected to every neuron in the next layer in the neural network using weights. Since it already incorporates vital knowledge from a pre-existing deep learning algorithm, the fine-tuning process greatly reduces the time taken to program and process a new deep learning algorithm.

The model training process was carried out on Kaggle, the data used was trimester-specific, according to complications and natural pregnancy symptoms that occur in each trimester. The complications trained were: Pregnancy hypertension (Pre-eclampsia), Malarial Infections, and Miscarriage (Threatened Abortions). Natural pregnancy symptoms in which the model was trained are Back pain, bloating, Braxton hicks contractions, constipation, dizziness, edema, fatigue, headache, heartburn, hemorrhoids, morning sickness, nasal congestion, stretchmarks, swollen gums, varicose veins.

3.12 System validation

In this section, a detailed description of the system validation is provided. This was carried out to observe if the system requirements were met and the acceptability of the system in urban Tanzania. Description of the validation area, participants, survey design, observation, and results.

3.12.1 Validation area

The validation of the system was carried out in Arusha, Tanzania. Arusha was selected for system validation to gauge whether the developed system met the requirements of the pregnant women and experts. Where system requirements were initially collected. In this study, 5 gynecologists, and 30 pregnant women were interviewed. The validation was done in three hospitals in the city - Mt. Meru Referral Hospital, Arusha Lutheran Medical Centre, and AICC Hospital.

3.12.2 Participants

A total of 35 participants took part in validating the system. Where 5 (14.3%) were gynecologists and 30 (85.7%) were pregnant women. Participants were selected randomly from three hospitals in the city - Mt. Meru Referral Hospital, Arusha Lutheran Medical Center, and AICC Hospital. The validation of the system took place for four weeks.

Table 3: Demographic characteristics of women

Demographic	No. of participants
Age	
18-23	6
24-29	18
30-35	6
Education	
Primary Education	10
Secondary Education	11
Higher Education	9

3.12.3 Survey design

Five gynecologists and 30 pregnant women were interviewed for the study. Expert interviews were conducted with different questions compared to those conducted with pregnant women. The expert's interviews were six questions long, while the pregnant women's interviews were eight questions long. The experts were asked questions on the overall performance of the system, whether they thought the application would prompt women to seek care early in pregnancy if they would recommend the system to expecting mothers in Tanzania, and their opinion on the ideal confidence of the model's diagnosis. The expecting mothers were asked if they would trust the system to make a diagnosis for them, whether the system would prompt

them to seek care early if they thought the language used in the application was complex, whether it was easier for them to access information in this system compared to other systems If the application was ideal for pregnant women in Tanzania, and their overall experience in the developed application versus existing applications. The pregnant women were asked to give consent before beginning the validation study.

3.12.4 Observation

The participants were asked to interact with the system to observe how they navigate through the application and to examine if the system provides them with the information they need. After the observation, the participants were interviewed by the researcher to understand if the requirements of pregnant women were met and additional features that they needed in the application.

3.12.5 Data analysis

The data collected from the interviews were analyzed manually by the researcher by observing correspondence of the responses to the questions asked. Irrelevant responses were eliminated. The Visual Paradigm data visualization tool, which is a UML CASE Tool from the Object Management Community (OMG) that supports UML 2, SysML, and Business Process Modelling Notation (BPMN), was used for data analysis. Responses were presented in histograms and pie charts for a better understanding of the distribution of responses.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Smartphone ownership and usage for information searching

The majority of women owned smartphones of the 182 women who were interviewed, 114 62.6%) owned a smartphone while 68 (37.4%) did not own a smartphone. However, only 99 (86.8%) of smartphone owners used their devices to access information regarding pregnancy. The rest were either uninterested or unaware of pregnancy apps and websites and relied mostly on doctors, midwives, and friends.

The information that was most searched for regarding pregnancy was on nutrition, specifically on the types of foods to eat for a healthy pregnancy, and on self-care during pregnancy. Table 4 presents the frequently searched information by pregnant women and the proportion of women who searched for that information.

Table 4: Frequently searched information by pregnant women

Type of Information	No of women in percentage (%)
Nutrition	99.5
Fetal development	34.6
How to prepare for labor	52.7
Physical changes	61.5
Breastfeeding and baby food	40.7
Exercise during pregnancy	53.3
Substances to be avoided during pregnancy	48.9
How to sleep when you are pregnant	29.7
Psychology in pregnancy	14.8
Self-care during pregnancy	64.3
The do's and don'ts during specific periods	35.2
Pregnancy countdown	24.2

The main source of pregnancy information on smartphones was mobile applications 99 (86.8%), with the BabyCentre app being the most popular (used by 95 women i.e. 95.96% of the women) and YouTube being the second most popular (used by 61 women. i.e. 61.6% of the women). The Bump, Pregnancy +, WebMD, what to expect, Medscape, NetMum, YouTube, Instagram, Pinterest, The Blueberry, Flo, Pregnancy Tracker and Pregnancy Calendars were also used. The reason given for the preference for mobile applications was that mobile phones are readily available and the information is presented in a more user-friendly

way than when viewed on the original website.

"It is easy to access information through my phone compared to a computer; I walk with my phone everywhere otherwise I have to get a computer from the internet café"

The apps also provided additional features such as weekly notifications on changes to expect, the countdown to pregnancy, pregnancy week by week, etc. Notifications in particular were deemed very useful.

"*Mobile applications alert you at the beginning of every week on the countdown to your due date, It reminds you of what you need to do and normal physical changes during pregnancy. It helps me updated"*

Regarding user experiences with BabyCentre, participants remarked on the easy-to-understand language and wide range of information on safe and unsafe practices as helpful and engaging.

"*Baby center gives tells me how far I am in my pregnancy in weeks, how many days I have left until I give birth, and how big my baby is, this helps in understanding my pregnancy"* -P1.

"*The application provides information on what exercises are safe to do, foods that are good to eat, the amount of sleep I need to get. This helped me in coping with pregnancy*" -P2

However, one participant who was a first-time mother complained about the community clubs:

"*I don't like talking to other women online, they make me anxious. I would rather read the information provided in the applications and listen to the experts*"

The reason for YouTube's popularity was the perceived ease of understanding information due to the use of videos and animations.

"*It doesn't take me a long time to understand information from YouTube, it is easier for me to understand because they explain things in simple words and pictures compared to other sources*"

Overall, most of the women 72 (72.7%) were observed to use a combination of sources (websites and applications) to search for information, with only 27 (27.3%) using a single source. Websites and applications with more visual presentations were preferred to wordy ones, as the women felt wordy applications could be confusing and less engaging (easy to lose interest in).

4.2 Other sources of information on pregnancy, childbirth and childcare

Other sources of pregnancy information that were reported were medical doctors (obstetricians and gynecologists), midwives, friends, and sometimes books to search for information. Preference on where to get the information varied among women who did not own smartphones, 68 (100%) women preferred doctors, 52 (76.5%) preferred midwives, 27 (39.7%) preferred friends, and 7 (10.3%) preferred books.

"I prefer asking doctors about pregnancy because they can explain well, and I trust them more" -P1

"I like talking to the midwives, they are mostly mothers also so they understand my situation more" -P2

"I am more open talking to my friends, they explain their experiences to me at home. I don't have to go to the hospital a lot" - P3

"When I read books, I gain a lot of knowledge. In case I don't understand something, I ask the doctor or midwife in the next meeting" -P4

4.3 Correlation of information between doctors and the applications

When asked whether the applications matched what the doctors told them, 91 (91.9%) of women said that they found correspondence between what the doctor said and what was written in the applications, while 8 (8.08%) of women said that the information provided was sometimes different.

Education level may have influenced whether the women felt there were differences in the provided information, with the more educated women being more likely to report observing a difference. This could be due to their higher information and technology literacy, which resulted in their searching for information from more online sources, using more search terms, and overallreading more articles, even those with more complicated language. The main perception was that applications provided more information than doctors.

"*The applications provide more information than the doctors, sometimes the doctors don't tell you enough about your pregnancy so through the applications I get to learn more"* -P1

P1 was concerned with Toxoplasmosis, which is a parasitic infection caused by Toxoplasma gondii, one of the most common parasites on the planet. Eating undercooked contaminated foods, coming into contact with infected cat feces, or passing the virus from mother to child during pregnancy are the most common ways to become infected. Toxoplasmosis infection can cause flu-like symptoms in some individuals, but the majority of those infected never show any signs or symptoms. Toxoplasmosis can cause severe problems in babies born to infected mothers and people with compromised immune systems. According to the interviews with doctors, the condition is more common among women in western countries than it is in Tanzania. Women rarely get Toxoplasmosis in Tanzania because few people live with pets in the house, which reduces the likelihood of getting infected. As a result, this condition is rarely talked about with patients.

4.4 Challenges faced during information search

Only a minority of the women 20 (20.2%) reported facing challenges in retrieving the information they sought online. The main challenge reported was finding an explanation for the symptoms they faced using search engines. However, observation showed that far more women were not able to find the right keywords to use on search engines. One participant, for example, was asked to search for symptoms that she was experiencing. The participant was able to describe in Swahili that she felt dizzy, bloated, and had a headache. However, she was only able to describe one symptom, "headache". She also failed to include pregnancy in her search terms. Consequently, the results she obtained were too vague. More than half of the women 66 (66.6%) of the women also complained that the search results were too wordy for them to understand.

"It is sometimes not easy to understand results from google because they provide too much information which ends up confusing me, so I lose interest in the middle"-P1

"It is easier to receive information from YouTube because they keep the flow of information interesting; they include a lot of pictures that help me understand better"- P2

4.5 Recommendations on improving apps and websites for maternal information

The main recommendation given 144 (86.8%) was to include health professionals in the development of the system to improve trust in the systems.

"I will have more confidence in the systems if health professionals will work with system developers in developing the systems, it will show in the results we receive" -P1

"I do not want to be confused with the information I receive from the systems, if health professionals will be involved then there will be less confusion" -P2

Another popular recommendation was to have the system information matching the Tanzanian context 122 (73.6%):

"Sometimes the advice I receive from the system does not match what is in the environment, it is frustrating" -P1

"The size of the fetus is compared to things that I have never seen before, I think those things are found in western countries, not here" -P2

4.6 Training confidence and results

4.6.1 Malarial infection

Table 5 illustrates the results from six iterations of training the malaria dataset. Based on the training results, more text data on Malaria was added to improve the results of the model, in cases where the confidence of the diagnosis did not improve the gold standard corpus was refined before beginning another iteration to improve the understanding of the model.

Table 5: Training results for the Malaria infection dataset

Condition	Iteration Number	Confidence (%)
Malaria Infection	1	23
	2	29
	3	33
	4	58
	5	70
	6	100

In the first iteration, the confidence of the model was 23% after the input symptoms were fever, headache, muscle pain, diarrhea, and fatigue. The diagnosis result was "*and fatigue are malaria symptoms"*. There were two main issues noted in the diagnosis: 1. The model quoted a sentence from a document; despite the model being trained to give a specific answer indicating the condition 2. The confidence of the model's result was low indicating that the model needed training on more data. This indicated the need to refine the gold standard corpus.

```
answers = qa.ask('fever, headache,muscle pain,diarrhea,fatigue')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	and fatigue are malaria symptoms	annotation 101 fever, chills, headache, nausea and vomiting, muscle pain and fatigue are malaria symptoms .	0.232952	malaria-annotated-doc/1993.txt
1	headache nausea vomiting	common symptoms of malaria include : shaking chills that can range from moderate to severe high fever profuse sweating headache nausea vomiting abdominal pain diarrhea anemia muscle pain convulsions coma bloody stools	0.232952	maternal-health/second_trimester.txt
2	headache nausea vomiting	common symptoms of malaria include : shaking chills that can range from moderate to severe high fever profuse sweating headache nausea vomiting abdominal pain diarrhea anemia muscle pain convulsions coma bloody stools	0.232952	maternal-health/third_trimester_1 (1).txt

Figure 4: Diagnosis results from the first iteration of training on the malaria dataset

The model's diagnosis had a confidence level of 29% in the second iteration. Fever, headache, muscle discomfort, nausea and vomiting, abdominal pain, and fatigue were the symptoms input. The symptoms were identified as those of malaria by the model. The diagnosis confidence, however, remained poor. More data was added into the model before performing the third iteration.

In the third iteration, the confidence of the model's diagnosis rose to 33%. The symptom input was fever, headache, muscle pain, nausea and vomiting, abdominal pain, chills, diarrhea, and fatigue. The low confidence of the diagnosis results was evidence that more data on malaria should be added.

After adding more data, symptoms were input to test how well the model could diagnose malaria. The input symptoms were fever, chills, nausea and vomiting, fatigue, and muscle pain. The confidence of the diagnosis rose to 58%. Despite the diagnosis being right its confidence was still low. More data was added before beginning the fifth iteration.

In the fifth and sixth iteration, there was a significant rise in the model's confidence. Malaria symptoms were identified to relate to conditions such as UTI, anemia, and gestational diabetes, for example, symptoms such as fever, nausea and vomiting, chills, and headache are common in UTI, anemia, and gestational diabetes and are also found in Malaria. The model trained on datasets of numerous conditions that are common in pregnancy which are found in the documents collected from online sources. During training the model also trained on these documents, when symptoms were input the model was able to diagnose the condition but not with 100% confidence as seen in iterations 1 to 5, this is because a person with those symptoms could have UTI, anemia, or gestational diabetes. It is worth noting that, unlike doctors, models have no access to laboratory tests where they can confirm the diagnosis.

Doctors would listen and observe symptoms that the patient presents, they would have a list of possible conditions/diseases that the patient might have,and finally, request laboratory results to confirm their hypothesis. When most common malaria symptoms were searched from the text data, Fever, headache, diarrhea, and fatigue were the most prominent. These symptoms were input to get a diagnosis, the model diagnosed malaria with 100% confidence. This might not be the symptoms that every malaria patient presents since every patient presents different symptoms, but this is evidence that with proper training NLP models are capable of medical diagnosis.

Figure 5: Diagnosis of the six iterations of training

4.6.2 Pre-eclampsia dataset

Pre-eclampsia is a common pregnancy complication that occurs after 20 weeks of pregnancy. Table 6 illustrates 8 iterations of training that were carried out in the model.

Table 6: Training results for the pre-eclampsia dataset

Condition	Iteration Number	Confidence (%)
Pre-eclampsia	1	36
	2	41
	3	60
	4	62
	5	65
	6	66
	7	69
	8	79

In the first iteration of training, the confidence of the model's diagnosis was 36%. Severe headache,blurred vision, difficulty urinating, swollen feet, hands, and face were the input symptoms. To improve the confidence of the system in diagnosing pre-eclampsia data on pre-eclampsia was added, and refined the gold standard corpus to improve the model's training.

In the second iteration of training, the confidence of the system rose to 41% that is a 5% increment, in this iteration, the input symptoms were Severe headache, blurred vision, heartburn, difficulty urinating, and pain below the ribs. The rise of the model's confidence indicated that with more data and refining of the gold standard corpus, the model was able to produce results with higher confidence. The gold standard corpus was refined before the third iteration because the model was seen to quote a sentence in one of the documents instead of providing the diagnosed conditionitself, the diagnosis displayed was

"Pre-eclampsia symptoms are: Change in vision, including temporary loss of vision or vision sensitivity, upper abdominal pain under the ribs"

Although the model was able to make the right diagnosis, its confidence was low, and it provided a quoted result instead of the diagnosed condition itself. In the third fourth and fifth iteration the confidence of the model increased to 60%, 62%, and 65% respectively, this was after increasing data on the pre-eclampsia dataset and refining the gold standard corpus.

After the fifth iteration, more training data was added to the model and refined the gold standard corpus. In Iteration six the confidence of the model's diagnosis increased to 66%, when a severe headache, vision problems, swollen feet, hands, and face were the input symptoms. The gold standard corpus was refined and input severe headache, vision problems, swollen feet, hands, and face, nausea and vomiting, little urine, and pain below the ribs as symptoms, the model diagnosed pre-eclampsia with a confidence of 69%.

```
answers = qa.ask('severe headache, vision problems,swollen feet, hands and face, little urine, pain below the ribs')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	are pre eclampsia symptoms	annotation 105 blurred vision, vomiting, nausea, swollen feet, face, and hands, pain below the ribs, heartburn, severe headache, peeing less are pre eclampsia symptoms severe headache, heartburn, pain below the ribs, swollen feet, hand and face, difficulty urinating, nausea, vomiting, rapid heartbeat	0.793783	preeclampsia-annotation-3/1956.txt
1	nausea or vomiting	phase 8 pre eclampsia symptoms are : severe headache, vision problems, such as blurring vision or flashing before the eyes, severe pain just below the ribs, nausea or vomiting , heartburn that does not go away with antacids, rapidly increasing swelling of the face, hands or feet (for example if your watch or rings suddenly do not fit.), feeling very unwell	0.090919	preeclampsia-ann-5/121212.txt
2	ribs vomiting	similarly, you should consult a health professional if your headache is accompanied by any of the following symptoms : problems with vision such as blurring or seeing flashing lights pain below your ribs vomiting sudden swelling of the face, hands, feet, or ankles	0.084420	maternal-health/second_trimester_2.txt

Figure 6: Diagnosis of the eighth iteration of training the pre-eclampsia dataset

After eliminating nausea and vomiting as seen from iteration five to eight, the confidence of the system increased from 65% to 79%. This shows that once symptoms similar to other conditions/diseases are input, the confidence of the system drops despite making the correct diagnosis. This is because our training data has information about other diseases and

complications during pregnancy with nausea and vomiting as a symptom. Pre-eclampsia is specific to its symptoms and time of occurrence. Blurred vision, Severe headache that doesn't do away with painkillers, swollen feet, hands, and face, pain on the right side of the abdomen (below the ribs), passing little urine after 20 weeks of pregnancy is most likely pre-eclampsia, this makes it easier to diagnose pre-eclampsia unlike Malaria, that can occur what any stage of pregnancy.

4.6.3 Miscarriage (Threatened abortion)

Miscarriage (Threatened abortion) occurs before 20 weeks gestation when a patient presents with vaginal bleeding. Table 7 illustrates 3 iterations of training that were carried out in the model.

Table 7: Training results for the miscarriage (Threatened abortion) dataset

Condition	Iteration Number	Confidence (%)
Miscarriage	1	36
	2	57
	3	86

In the first iteration of training Vaginal bleeding, clotted discharge from the vagina, back pain, and, abdominal pain were the input symptoms, the confidence of the diagnosis was 36%. Due to its low confidence, more data on miscarriage (threatened abortion) was added.

In the second iteration of training, the confidence of the model's diagnosis was 57%. The input symptoms were vaginal bleeding, abdominal cramps, back pain, and discharge of tissue from the vagina. More data on miscarriage (threatened abortion) was added, and made improvements to the gold standard corpus due to its low confidence.

In the third iteration of training, vaginal bleeding at 20 weeks, clotted discharge from the vagina, back pain, and abdominal pain was input. When specific time of the occurrence of vaginal bleeding i.e., 20 weeks was input the confidence of the model's diagnosis rose to 86%. Note that the model can make the right diagnosis with high confidence when the symptoms input is specific to time. This shows that conditions that have a specific time of occurrence can be diagnosed best when the time of occurrence is input, this allows the model to rule out other conditions and make the right diagnosis.

```
answers = qa.ask('vaginal bleeding at 20 weeks,clotted discharge from the vagina, back pain, abdominal pain ')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	113 symptoms of threatened abortion	annotation 113 symptoms of threatened abortion are : heavy spotting, vaginal bleeding, discharge of tissue or fluid from vagina, severe abdominal pain or cramping, back pain	0.865110	threatened-abortion-ann/1155.txt
1	without abdominal cramps	symptoms possible symptoms of miscarriage may include : low back pain or abdominal pain that is dull, sharp, or cramping tissue or clot like material that passes from the vagina vaginal bleeding, with or without abdominal cramps	0.027613	maternal-health/first_trimester (2).txt

Figure 7: Diagnosis of the third iteration of training of the miscarriage (Threatened Abortion) dataset

4.7 Results from system validation

After training the system, the system was validated by pregnant women and gynecologists to gauge its acceptance.

4.8 System scalability

The general performance of the system was good. Multiple pregnant women were able to use the system at the same time with ease.

4.9 Validation from pregnant women

4.9.1 Overall performance of the system

When asked to rate the system's performance, 24 (80 %) said it was outstanding, 4 (13.3%) said it was good, and 2 (6.7 %) said it was good. When asked to give reasons for their responses, expecting mothers who rated the applications outstanding said:

"I can easily select the symptoms that I am feeling easily and it gives me the diagnosis with the experts' recommendations. I highly recommend this application for my fellow pregnant women" -P1

"I can see that the recommended foods to eat are the ones found in our local markets, and they are affordable. Now I can easily guide myself in my food choice" -P2

Pregnant women who rated the application as very good:

"There are more complications than the ones in the system, please do not neglect them. I would like to see more of them otherwise I like the application" - P1

"I cannot see any information for men. How will they know what to do? It would be nice to use

the application with my husband; I know he will like it as well" -P2

The reasons for pregnant women who rated the application as good was:

"It looks very good; from the description of the application, it seems to be very useful. But I don't speak a lot of English, how will I benefit from it?" -P1

"It would be nice to have videos in the application that explain these conditions" -P2

4.9.2 Expecting mothers trust in the system

All 30 women said that they trust the system, mainly because the experts were involved in the development of the system.

"I like that our experts are also part of the application. When it is ready the experts should also recommend the system to pregnant women, this will increase more trust" -P1

"Pre-eclampsia is indeed affecting a lot of pregnant women these days, I am happy that the doctors included it. This will help a lot of pregnant women, I trust it" -P2

"I trust the system because it has involved the doctors, and also because it was developed by a woman" -P3

4.9.3 Influence of the system on pregnant women

One hundred percent of the pregnant women said that the application would encourage them to seek care early. This is mainly contributed by the recommendations that are provided by the experts, and the justification for such recommendations.

"The system explains the condition and tells you what should be done. It's not easy to ignore it. I will seek immediate care" -P1

"The system makes me feel like I am talking to a doctor. I will seek immediate care for the sake of my health and my baby's" -P2

"When you have a clue of what might be happening, it is hard to ignore it especially because they are our doctor's recommendations. I will seek care to make sure I am not at risk" -P3

"If I understood English well enough, I believe the application would help me in seeking care

early" -P4

4.9.4 Comparison between the developed application and the existing applications

When asked if the language used in the application was easy for them to understand compared tothe one used in other applications, of the expecting mothers 28 (93.3%) said that the developed application used simple terms.

"The language used is easy to understand. I believe most women will benefit from the information; no complex terms have been used. This is better than western applications" -P1

"The information is simple and well summarized, it's easier for me to understand" -P2

However, 2 (6.7%) said that they could not understand English properly hence the application was difficult for them to understand.

"I will benefit from the application if it will be in Swahili, I don't understand English properly" -P1

"Please consider the application in Swahili language, most of us know basic English terms" -P2

The women were asked if it was easier for them to access information in the developed application compared to existing applications. Of the respondents 28 (93.3%) said that it was easier for them to access information in the developed application.

"The application is very straight forward. It's easy to get the information I need directly; I don't have to search so much" -P1

"All the symptoms are in the application; I just need to select the ones that I am experiencing. That is very easy for me" -P2

However, 2 (6.7%) of the women who were not English speakers insisted that it would be easy for them if it was in Swahili.

When asked to rate the information in the developed application versus that in existing applications 4 (14.3%) of the women said that the information in the developed application was excellent.

"The application is truly made for women in Tanzania, I can relate to the majority of things" -P1

"I like those common conditions that affect pregnant women in Tanzania have been addressed" -P2

"Self-care recommendations are easy to follow, this will help a lot of pregnant women in Tanzania" -P3

Majority of pregnant women, that is 21 (75%) rated the application as very good.

"There is room for improvement, consider adding information in Swahili" -P1

"Men should also be included in the application, information such as the best way to support your wife during pregnancy is important. Men here need that" -P2

However, 3 (10.7%) of the expecting mothers rated the application as good.

"We need an application every woman can understand, an application for pregnant women in Tanzania should be in Swahili"

4.9.5 Relevance of the application to pregnant women in Tanzania

Majority of expectant mothers 28 (93.3%) found that the application was relevant to the Tanzanian context. With the emphasis that inclusion of men in the applications and the use of Swahili language will highly encourage more pregnant women to use the application. Pregnant women 2 (6.7%) felt that the application would be suitable for them if it was in Swahili.

"I would like to see the application in Swahili, It will represent us better" -P1

"I would like to use the application with my husband, I want him to learn to a point that he can understand pregnancy" -P2

4.10 Validation results from experts

4.10.1 Overall impression of the system

When the experts were asked to rate the overall performance of the system 1 (20%) said it was excellent, 2 (40%) said it was very good, and 2 (40%) said it was good. The experts were

required to give reasons following their responses.

"I have seen the impact of these applications on pregnant women in western countries, I believe that an application made for women in Tanzania will improve pregnancy outcomes for a lot of women"

The two experts who rated the system as very good explained that lack of other complications that affect women during pregnancy and sufficient information for women on how to use the application was lacking in the system.

"Malaria, Pre-eclampsia, and miscarriage (Threatened abortion) are just the tip of the iceberg, there are so many other complications that haven't been explored" -P1

"There is a need to educate the woman on how to use the system, how to input symptoms, and how they can get results. Only then can the application truly benefit all of us." -P2

Two experts rated the system as good. Their reason being more emphasis should be kept on the pregnancy complications, to prompt the woman to seek care early and the woman needs to be thoroughly educated on how to use the application.

"There should be an alarm to tell the woman to seek immediate help as soon as she is diagnosed with any of the complications. The application needs to ensure that pregnant women won't ignore symptoms"-P1

"The application has the potential to encourage more women to seek care. If they are taught how to use it and what needs to be done after the diagnosis then it will help us all" - P2

4.10.2 Influence of the system on pregnant women

The experts were asked if the system has the potential to help women in easy recognition of pregnancy complications and whether it would enhance immediate health-seeking behavior. All 5 experts said that the application has the potential to help women in easily recognizing pregnancy complications. All experts said that the application has the potential to enhance immediate care-seeking behavior when the expecting mothers are properly trained on how to use the application.

"If education is provided to mothers on the use of the application and when they need to seek medical care, it will enhance immediate seeking of care" -P1

"The application has great potential to increase safe pregnancies. If the pregnant women understand how it works and is willing to use it then it will benefit them" -P2

"With the right education, the application will help the pregnant woman recognize pregnancy complications and encourage her to seek immediate care" -P3

4.10.3 Overall acceptance of the system

All five experts showed great acceptance of the system. Furthermore, the experts were positive in recommending the application to Tanzanian pregnant women.

"I would recommend the application to pregnant women especially because it reflects our situation in Tanzania. However, I also encourage more involvement of experts in Tanzania" -P1

"The application is good for expecting mothers, the unique aspect of the application is that it not only diagnoses, it goes further to recommend what needs to be done" -P2

"The self-care recommendations will help women; they are not so different from what I tell my patients, I encourage the use of the application."-P3

4.10.4 Ideal confidence of the system

Experts proposed that the system's ideal confidence level be between 75% and 90%. One expert indicated that the system's ideal confidence should be at least 75%, while another suggested that it should be around 80%. Two experts suggested that 85% would be the ideal confidence, while one expert suggested that 90% would be the ideal confidence.

"A good baseline for me is 75%. As seen in the malaria diagnosis there are specificsymptoms and associated symptoms, patients present different symptoms making it hard to tell for sure what they are suffering from" -P1

"The right confidence is 85%, in my opinion, If it can go higher then it will mean that the system is well equipped to make the right diagnosis" -P2

"If we allow the confidence of the system to be too low then we will be leaving room for false diagnosis, 8% is a good start" -P3

"If the system will be able to diagnose those results starting from 90% then it will mean that

there is more certainty in the application" -P4

4.10.5 Recommendations from the experts

Four experts (80%) recommended training to be done with the women to teach them how to use the application before deploying it in the society, 3 (60%) recommended involving more doctors in the application, All five (100%) doctors recommended adding more complications in the application to ensure that the woman can receive an early diagnosis which will prompt early seeking of care.

"To make the application successful, pregnant women should be educated on how to use the application. Only then will the application have a great impact" - P1

"We have doctors with different experiences, involving a variety of doctors will ensure that context-specific problems and solutions are addressed" -P2

"There are many conditions that haven't been covered in the system, there is a need to research other conditions and include them in the application" -P3

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, the knowledge-seeking behavior of pregnant women in Tanzania was identified. Women were identified to seek information from doctors, midwives, friends, and online sources. However, with the increase of smartphone users and Internet penetration over the past few years, expectant mothers have been using mobile applications and websites on pregnancy as a source of information. According to the study, women in Tanzania were found to trust the mobile applications and pregnancy websites that involved experts.

Through interviews conducted with domain experts Malaria, Pre-eclampsia, and Miscarriage (threatened abortion) were identified as the main causes of maternal mortality in Tanzania. With the use of a pretrained BERT model, a Natural Language Processing model was trained on Malaria, Pre-eclampsia, and Miscarriage (threatened abortion) dataset. The model was able to diagnose the conditions with confidence ranging from 79% to 100%, indicating that pregnancy complications can be diagnosed through expert systems. Additionally, recommendations on the pregnancy complications diagnosed and self-care tips have provided women with information to help them in becoming more proactive in seeking care early. And decreasing the severity of natural pregnancy symptoms respectively.

Pregnant women have shown great interest in learning about pregnancy complications and self-care tips. Overall, the pregnancy application gained great acceptance from both pregnant women and gynecologists. Medical experts showed great interest in the developed pregnancy application, they encouraged the use of the pregnancy application suggesting that pregnant would benefit greatly from it. However, the use of the English language and lack of information on encouraging male involvement during pregnancy was highly requested by the pregnant women, while more involvement of more medical experts, the addition of more pregnancy complications, and intensive training for pregnant women was recommended by the doctors.

As previous studies suggest, there is a need to provide pregnant women with knowledge on obstetric complications. Client-centered approach have shown promising results as shown in the research conducted. Both expecting mothers and the experts have shown great interest in the developed system. More research should be done to cater to the needs of women without

smartphones, and inclusion of the male partners.

The results obtained show the proposed model achieved the best accuracy. The experimental findings indicate that our method works well on the diagnosis of pregnancy complications and can be used for robust diagnostics.

Despite the good performance of the model, there is a need for more data on pregnancy complications and home remedies for natural pregnancy conditions. The study focused on three pregnancy complications in Tanzania that were recommended by experts; Malaria, Pre-eclampsia, and Miscarriage (Threatened abortion). Other causes of maternal mortality such as Hemorrhage, Obstructed labor have not been included in the research. Additionally, women in rural areas were not included in the research. This is due to limited time and resources to carry out the research.

5.2 Recommendations

Knowledge requirements of male partners should be researched, to encourage the participation of men during pregnancy. With stakeholder's inclusion more participants can be involved in to improve the quality of data. Additionally, further research on the knowledge-seeking behavior of pregnant women in rural Tanzania should be carried out to enable researchers to devise new methods to educate women on pregnancy complications. Also, other causes of maternal mortality should be investigated and included to improve diagnosis of pregnancy complications.

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APPENDICES

Appendix 1: Research ethical clearance certificate

Kibong'oto Infectious Diseases Hospital- Nelson Mandela African Institution of Science and Technology- Centre for Educational Development in Health, Arusha (KIDH-NM-AIST-CEDHA) -KNCHREC

RESEARCH ETHICAL CLEARANCE CERTIFICATE

Research Proposal No: KNCHREC 0038/RW/2/21 **24th FEB 2021**

Study Title: DEVELOPMENT OF A MEDICAL EXPERT SYSTEM FOR QUALITY ANTENATAL CARE IN DEVELOPING COUNTRIES

Study Area: ARUSHA, MWANZA AND TANGA REGION

PI Name: ELSIE SOMI KAAYA

Co-Investigator:

Institutions: NM-AIST -School of Computational and Communication Science And Engineering (CoCSE)

The Proposal has been approved by KNCHREC on 24th Feb.2021

1. Subject to this approval you will be required to submit your progress report to the KNCHREC, National Institute for Medical Research, and Ministry of Health Community Development Gender Elderly and Children
2. Publication of your findings is subject to presentation to the KNCREC and NIMR Approval.
3. Copies of final publication should be made available to KNCHREC, National Institute of Research and Ministry of Health Community Development Gender Elderly and Children

Duration of Study Renewal: Subject to Renewal within ONE YEAR
Span From: 24th Feb. 2021 to 3rd Feb. 2022.

Simon Njeya

.....
Mr. Simon Njeya
Secretary
KNCHREC

.....
Prof. Raymond Mosha
Chairperson
KNCHREC

Appendix 2: Interview questions

1. What are the most common complications that women face during pregnancy which are associated with maternal deaths? E.g. Pre-eclampsia and Eclampsia, Hemorrhage, Ectopic pregnancy, Infections, Abortions.

2. What are the causes of these complications? (Elaborate individual complications)
    - Pre-eclampsia and Eclampsia
    - Hemorrhage
    - Ectopic Pregnancy
    - Infections (Three common Infections)
    - Abortions

3. Can these complications be detected early before their occurrence?

4. How can a pregnant woman detect the occurrence of these complications? /Symptoms.
    - Pre-eclampsia and Eclampsia
    - Hemorrhage
    - Ectopic Pregnancy
    - Infections (Elaboration on three common Infections)
    - Abortion (Spontaneous and Induced)

5. What recommendation do you give to women who have been diagnosed with such complications?
    - Pre-eclampsia and Eclampsia
    - Hemorrhage
    - Ectopic Pregnancy
    - Infections

6. How can we justify these recommendations to women so as they may gain sufficient knowledge on pregnancy related complications? (Explain for each complication)

7. Are there other symptoms that women might experience that can be administered at home? (Discomfort)

System specific i.e.

- Respiratory
- Cardiovascular
- Gastrointestinal Tract (GIT)
- Skin
- Central Nervous system
- Musculoskeletal System
- Genital Tract

8. What are those symptoms?

9. What causes these symptoms?

10. Can these symptoms be prevented?

11. What recommendation will you give a woman experiencing such symptoms? (Elaborate Individually)

12. How can we justify these recommendations to the pregnant women?

13. How can we enhance better communication between the pregnant women and medical personnel?

Appendix 3: Questionnaire questions

1. Do you own a smart phone?

   (Je simu yako ni smart phone?)
   - Yes (Ndio)
   - No (Hapana)

2. Do you use your phone to search for information regarding symptoms that you encounter in your pregnancy?
   (Hua unatumia simu yako kutafuta habari kuhusu dalili unazozipata kipindi cha ujauzito?)
   - Yes (Ndio)
   - No (Hapana)

3. Is there a specific application(s) or website(s) that you use?
   (Je, kuna programu au Tovuti maalumu unayotumia?)
   - Yes (Ndio)
   - No (Hapana)

4. If the answer is YES, please list the application(s) or website(s) that you use.
   (Kama jibu lako ni NDIO, tafadhali orodhesha majina ya Programu au Tovuti hizo)

5. Does the information you get in the application or websites match what the doctors tell you?
   (Je, taarifa unazozipata kupitia program na tovuti hizi huendana na taarifa anazokupa daktari?)
   - Yes (Ndio)
   - No (Hapana)

6. What challenges do you face from other applications/ websites?

   (Ni changamoto gani unazopata katika tovuti hizo?)

7. What can the system do to address these challenges?
   (Je mfumo huu uweke kitu gani ili uweze kukabili changamoto unazozipata katika tovuti hizo?)

8. What other features should the system have to make it a more convenient platform for pregnant women?

   (Ni vipengele gani ungependekeza kwenye mfumo ilikufanya uwe rahisi kwa matumizi?)

9. What language do you prefer in the system? Swahili/English or both?
   (Ungependekeza lugha gani itumike katika mfumo huu kiingereza,kiswahili au zote mbili?)

Short exercise/ Zoezi fupi

10. Examine how the women use the Applications/Websites.
    (Uchunguzi wa jinsi wajawazito hutumia mifumo mbali mbali)

Appendix 4: English consent form

The Nelson Mandela
African Institution of Science
and Technology

CONSENT FORM TO PARTICIPATE IN RESEARCH

Read: Hi, My name is_____ from_____.

You are invited to participate in this research under the title "Development of an expert system for quality antenatal care in Tanzania". It is important to know the aim of the research before deciding whether to participate or not. Your participation in this research is of free will and we do not anticipate that it will affect you in any way. You can stop at any time when not comfortable. However, there will be no payment of any sort for your participation. You can ask questions for clarification if you do not understand something and you can also request a copy of this form.

The aim of this research is to use artificial Intelligence to help pregnant women gain knowledge on the danger symptoms during pregnancy and the services they need to receive during visits to the doctor so as they may become more proactive in receiving treatments. If you agree to answer this questionnaire, please put your signature in this form to confirm that you have agreed the terms and you will give full cooperation and correct answers.

We believe that this research will enable us to get more information about pregnancy related complications and the best ways to educate women so as to promote better pregnancy outcomes to women in Tanzania.

WHO TO CONTACT?

If any concern arises from this research you can communicate with the researcher Ms Elsie Somi Kaaya
+255 759 240 600

WOULD YOU LIKE TO PARTICIPATE? YES……./**NO**……..(if the answer is YES then you can proceed)

CERTIFICATE OF CONSENT

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I consent voluntarily to participate in this study.
Name _____

Signature (Fingure print)_____Date_____

Appendix 5: Swahili consent form

The Nelson Mandela African Institution of Science and Technology

FOMU RIDHAA YA USHIRIKI

***SOMA*:** Habari Jina langu ni_____na ninatoka_____.
Umealikwa kushiriki katika utafiti wa "Utengenezaji wa mfumo wa kiinteligensia wa kitaalamu utakao saidia kuboresha huduma za afya za mama mjamzito Tanzania" unahitaji kufahamu maudhui ya utafiti kabla ya kufanya maamuzi ya kushiriki au kutoshiriki. Ushiriki wako katika utafiti huu ni wa hiari. Uamuzi wako hautakudhuru kwa namna yoyote. Unaweza kusitisha ushiriki wako muda wowote bila kushurutishwa. Aidha, hakuna malipo yoyote utakayopata kwa kushiriki kwako.Unaweza kuuliza maswali ikiwa hujaelewa jambo, au unataka maelezo zaidi na unaweza kupata nakala ya hii fomu.

Maudhui ya utafiti huu ni kujua jinsi gani ujuzi wa bandia una weza kutumika kumuelimisha mama juu ya dalili hatarishi wakati wa ujauzito na pia kuboresha huduma za afya za mama mjamzito Tanzania. Ukikubali kushiriki katika utafiti huu, tutakuomba uweke sahihi yako katika fomu hii kuthibitisha kuwa umeridhia kujibu dodoso na utatoa ushirikiano wako kikamilifu na kwa usahihi.

Tunaamini kuwa utafiti huu utasaidia kupata taarifa zaidi kuhusu dalili hatarishi mama mjamzito anzopatana, njia bora za kumuelimisha mama ili aweze kushiriki kikamilifu katika huduma anazopata hospital na pia kuboresha matokeo ya ujauzito Tanzania.

NITAFANYAJE IKIWA NITAHITAJI TAARIFA ZAIDI?
Ikiwa una jambo lolote kuhusu utafiti huu unaweza kuwsiliana na mtafiti Bi Elsie Somi Kaaya +255 759240600

JE UTAPENDA KUSHIRIKI? Ndio……./Hapana ….(ikiwa jibu ni ndio endelea na makubliano)

MAKUBALIANO YA USHIRIKI
Nimesoma/nimesomewa na nimeelewa maudhui ya utafiti huu. Nimeuliza maswali na nimeridhika na majibu. Ninaridhia kushiriki na nitajibu maswali katika dodoso husika.

Jina _____

Sahihi yako ama alama (alama ya dole gumba)_____Tarehe_____

Appendix 6: Introductory letter from NM-AIST

THE NELSON MANDELA
AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY
(NM-AIST)
School of Computational and Communication Science and Engineering

Direct Line: +255 272970001
Fax: +255 272970016
E-mail: dean-coese@nm-aist.ac.tz

Tengeru
P.O. Box 447
Arusha, TANZANIA
Website: www.nm-aist.ac.tz

OUR Ref.No. NM-AIST/M.032/T.18

Date: 20th February, 2020

To Whom It May Concern

Dear Sir/Madam,

RE: INTRODUCTION TO Ms. ELSIE SOMI KAAYA

Kindly refer to the above heading.

I wish to introduce Ms. Elsie Somi Kaaya with Registration No. NM-AIST/M.032/T.18, a Masters student at Nelson Mandela African Institution of Science and Technology in the School of Computational and Communication Science and Engineering.

As part of the requirement for Master's degree, Ms. Elsie is undertaking a research entitled ***"Development an Expert System for Quality Antenatal Care in Tanzania".***

In order to accomplish her research objectives, she would like to collect some information from your office/institution. The information to be collected will be used for research purposes only and will help the student to design a system that will help to come up with a quality antenatal care solution.

It is my sincere hope that you will assist the student in accomplishing her study.

Looking forward to your cooperation.

Sincerely,

Shubi Kaijage *PhD*
Ag. Dean, School of CoCSE

cc: Dr. Edith Luhanga (Supervisor)

Appendix 7: Permit letter from Mt. Meru Hospital

THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF HEALTH, COMMUNITY DEVELOPMENT, GENDER, ELDERLY AND CHILDREN

Telegrams: "REGCOM"
Telephone: 250-335751 -2
Fax: 2544904
Website: www.arusha.go.tz
E-mail: mt.merurrh@afya.go.tz
In reply please quote:

RMO/ARS/F-1/15C/25

REGIONAL REFERRAL HOSPITAL,
P.O. Box 3092,
ARUSHA

17th June, 2020.

ELSIE SOMI KAAYA,

ARUSHA.

RE: RESEARCH PERMIT

Refer to the subject matter above, as well as your research Assistance request dated 13th March, 2020.

Our office is permitting you to stay in this Hospital for two months commencing from 22nd June, 2020 to 22nd August, 2020 up to purposely for collecting data concerning your research study on issues related to *Development of an expert system for quality antenatal case in Tanzania*. If you will need more time, you will request for extension of permit.

Counting your good cooperation .

A. A. Kimathi

For: MEDICAL OFFICER IN CHARGE

ARUSHA

Copy to:

Obstetric and Gynecology Coordinator

MEDICAL OFFICER INCHARGE
P.O. BOX 3092
ARUSHA
ARUSHA REGIONAL REFFERAL HOSPITAL

Appendix 8: Model's Performance

```
answers = qa.ask('fever, headache,muscle pain, Nausea and vomitting, abdominal pain, fatigue')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	are malaria symptoms	annotation 101 fever, chills, headache, nausea and vomiting, muscle pain and fatigue are malaria symptoms .	0.298171	malaria-annotated-doc/1993.txt
1	s mild headache	mild weakness or dizziness fatigue chill s mild headache joint / muscle pain cough anorexia nausea / vomiting sleep disorder loss of appetite difficulty sleeping sleepiness cough nausea abdominal pain weakness (mild or severe)	0.276103	maternal-health-trimester-1/first_trimester (2).txt
2	s mild headache	mild weakness or dizziness fatigue chill s mild headache joint / muscle pain cough anorexia nausea / vomiting sleep disorder loss of appetite difficulty sleeping sleepiness cough nausea abdominal pain weakness (mild or severe)	0.193241	maternal-health/first_trimester (2).txt
3	: fever chills headache nausea and vomiting muscle pain and fatigue	symptoms a malaria infection is generally characterized by the following signs and symptoms : fever chills headache nausea and vomiting muscle pain and fatigue other signs and symptoms may include : sweating chest or abdominal pain cough some people who have malaria experience cycles of malaria " attacks.	0.116243	maternal-health/third_trimester_1 (1).txt

Diagnosis of the third iteration of training on the malaria dataset

```
answers = qa.ask('fever, headache,muscle pain, Nausea and vomitting, abdominal pain, chills, diarrhea, fatigue')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	are malaria symptoms	annotation 101 fever, chills, headache, nausea and vomiting, muscle pain and fatigue are malaria symptoms .	0.332400	malaria-annotated-doc/1993.txt
1	sweating headache nausea vomiting	common symptoms of malaria include : shaking chills that can range from moderate to severe high fever profuse sweating headache nausea vomiting abdominal pain diarrhea anemia muscle pain convulsions coma bloody stools	0.223774	maternal-health/second_trimester.txt
2	sweating headache nausea vomiting	common symptoms of malaria include : shaking chills that can range from moderate to severe high fever profuse sweating headache nausea vomiting abdominal pain diarrhea anemia muscle pain convulsions coma bloody stools	0.205290	maternal-health/third_trimester_1 (1).txt
3	: fever chills headache nausea and vomiting muscle pain and fatigue	symptoms a malaria infection is generally characterized by the following signs and symptoms : fever chills headache nausea and vomiting muscle pain and fatigue other signs and symptoms may include : sweating chest or abdominal pain cough some people who have malaria experience cycles of malaria " attacks.	0.119268	maternal-health/third_trimester_1 (1).txt
4	: fever chills headache nausea and vomiting muscle pain and fatigue	symptoms a malaria infection is generally characterized by the following signs and symptoms : fever chills headache nausea and vomiting muscle pain and fatigue other signs and symptoms may include : sweating chest or abdominal pain cough https : / / www.	0.119268	maternal-health/second_trimester.txt

Diagnosis of the third iteration of training on the Malaria Dataset

```
answers = qa.ask('Fever, Chills, Nausea and vomiting, fatigue, muscle pain')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence
0	are malaria symptoms	annotation 101 fever, chills, headache, nausea and vomiting, muscle pain and fatigue are malaria symptoms .	0.584629
1	s mild headache	mild weakness or dizziness fatigue chill s mild headache joint / muscle pain cough anorexia nausea / vomiting sleep disorder loss of appetite difficulty sleeping sleepiness cough nausea abdominal pain weakness (mild or severe)	0.141899
2	s mild headache	mild weakness or dizziness fatigue chill s mild headache joint / muscle pain cough anorexia nausea / vomiting sleep disorder loss of appetite difficulty sleeping sleepiness cough nausea abdominal pain weakness (mild or severe)	0.141899
3	: fever chills headache nausea and vomiting muscle pain and fatigue	symptoms a malaria infection is generally characterized by the following signs and symptoms : fever chills headache nausea and vomiting muscle pain and fatigue other signs and symptoms may include : sweating chest or abdominal pain cough some people who have malaria experience cycles of malaria " attacks.	0.077183
4	symptoms a malaria infection is generally characterized by the following signs and symptoms : fever chills headache nausea and vomiting muscle pain and fatigue	symptoms a malaria infection is generally characterized by the following signs and symptoms : fever chills headache nausea and vomiting muscle pain and fatigue other signs and symptoms may include : sweating chest or abdominal pain cough https : / / www.	0.054389

Diagnosis of the fourth iteration of training on the Malaria dataset

```
answers = qa.ask('fever, headache,nausea and vomitting,muscle pain, fatigue')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	are malaria symptoms	annotation 101 fever, chills, headache, nausea and vomiting, muscle pain and fatigue are malaria symptoms .	0.703549	malaria-annotated-doc/1993.txt
1	: fever chills headache nausea and vomiting muscle pain and fatigue	symptoms a malaria infection is generally characterized by the following signs and symptoms : fever chills headache nausea and vomiting muscle pain and fatigue other signs and symptoms may include : sweating chest or abdominal pain cough some people who have malaria experience cycles of malaria " attacks.	0.158788	maternal-health/third_trimester_1 (1).txt
2	: fever chills headache nausea and vomiting muscle pain and fatigue	symptoms a malaria infection is generally characterized by the following signs and symptoms : fever chills headache nausea and vomiting muscle pain and fatigue other signs and symptoms may include : sweating chest or abdominal pain cough https : / / www.	0.137663	maternal-health/second_trimester.txt

Diagnosis of the fifth iteration of training on the Malaria dataset Pre-eclampsia dataset

```
answers = qa.ask('severe headache,blurred vision,difficulty urinating, swollen feet, hand and face')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	are pre eclampsia symptoms	annotation 104 severe headache, heartburn, pain below the ribs, swollen feet, hand and face, difficulty urinating, nausea, vomiting, rapid heartbeat are pre eclampsia symptoms	0.362674	preeclampsia-annotation-2/1954.txt

Diagnosis results of the first iteration of training the pre-eclampsia dataset

[9]:
```
answers = qa.ask('severe headache,blurred vision,heartburn,difficulty urinating, pain below ribs')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	pre eclampsia symptoms are : change in vision, including temporary loss of vision, blurred vision, or vision sensitivity, upper abdominal pain under the ribs	pre eclampsia symptoms are : change in vision, including temporary loss of vision, blurred vision, or vision sensitivity, upper abdominal pain under the ribs on the right side, nausea or vomiting, decreased urine output, shortness of breath.	0.417850	preeclampsia-ann-5/121212.txt
1	are pre eclampsia symptoms	annotation 105 blurred vision, vomiting, nausea, swollen feet, face, and hands, pain below the ribs, heartburn, severe headache, peeing less are pre eclampsia symptoms severe headache, heartburn, pain below the ribs, swollen feet, hand and face, difficulty urinating, nausea, vomiting, rapid heartbeat	0.258219	preeclampsia-annotation-3/1956.txt

Diagnosis results from the second iteration of training on the pre-eclampsia dataset

```
answers = qa.ask('severe headache,vision changes,difficulty urinating, swollen feet and face')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	rapidly increasing swelling of the face, hands or feet	phase 8 pre eclampsia symptoms are : severe headache, vision problems, such as blurring vision or flashing before the eyes, severe pain just below the ribs, nausea or vomiting, heartburn that does not go away with antacids, rapidly increasing swelling of the face, hands or feet (for example if your watch or rings suddenly do not fit.), feeling very unwell	0.607327	preeclampsia-ann-5/121212.txt
1	of pre eclampsia include severe headache, vision problems such as blurring or flashing lights, and pain under the ribs	other symptoms of pre eclampsia include severe headache, vision problems such as blurring or flashing lights, and pain under the ribs .	0.158176	maternal-health/second_trimester_2.txt
2	away problems with your vision, such as blurring or flashing lights	you should call your midwife or hospital maternity unit immediately if you have : a sudden increase in swelling in your face, hands or feet a very bad headache or a dull headache that wo not go away problems with your vision, such as blurring or flashing lights severe pain just below your ribs feeling sick or vomiting feeling unwell.	0.072750	maternal-health/second_trimester.txt

Diagnosis results of the third iteration of training on the pre-eclampsia dataset

```
answers = qa.ask('severe headache,vision changes,difficulty urinating, swollen feet and face')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	are pre eclampsia symptoms	annotation 103 blurred vision, vomiting, nausea, swollen feet, face, and hands, pain below the ribs, heartburn, severe headache, peeing less are pre eclampsia symptoms	0.628272	preeclampsia-annotated-1/1955.txt

Diagnosis results of the fourth iteration of training on the pre-eclampsia dataset

```
answers = qa.ask('severe headache,vision problems,swollen feet, hands,and face')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	are pre eclampsia symptoms	annotation 105 blurred vision, vomiting, nausea, swollen feet, face, and hands, pain below the ribs, heartburn, severe headache, peeing less are pre eclampsia symptoms severe headache, heartburn, pain below the ribs, swollen feet, hand and face, difficulty urinating, nausea, vomiting, rapid heartbeat	0.662793	preeclampsia-annotation-3/1956.txt

Diagnosis results of the fifth iteration of training on the pre-eclampsia dataset

```
answers = qa.ask('severe headache,vision problems,swollen feet, hands,and face, nausea and vomitting, little urine, pain below the ribs')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	are pre eclampsia symptoms	annotation 105 blurred vision, vomiting, nausea, swollen feet, face, and hands, pain below the ribs, heartburn, severe headache, peeing less are pre eclampsia symptoms severe headache, heartburn, pain below the ribs, swollen feet, hand and face, difficulty urinating, nausea, vomiting, rapid heartbeat	0.694629	preeclampsia-annotation-3/1956.txt

Diagnosis results of the sixth iteration of training on the pre-eclampsia dataset (Threatened Abortion)

[9]:
```
answers = qa.ask('vaginal bleeding,clotted discharge from the vagina, back pain, abdominal pain')
qa.display_answers(answers[:10])
```

	Candidate Answer	Context	Confidence	Document Reference
0	113 symptoms of threatened abortion	annotation 113 symptoms of threatened abortion are : heavy spotting, vaginal bleeding, discharge of tissue or fluid from vagina, severe abdominal pain or cramping, back pain	0.369216	threatened-abortion-ann/1155.txt

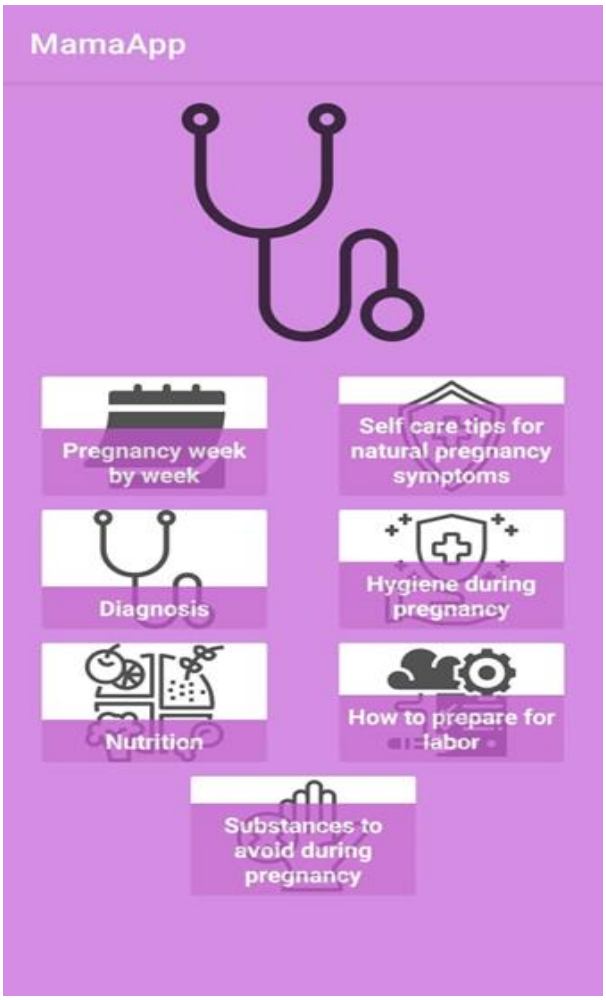
Diagnosis results of the first iteration of training on the Miscarriage (Threatened Abortion) dataset

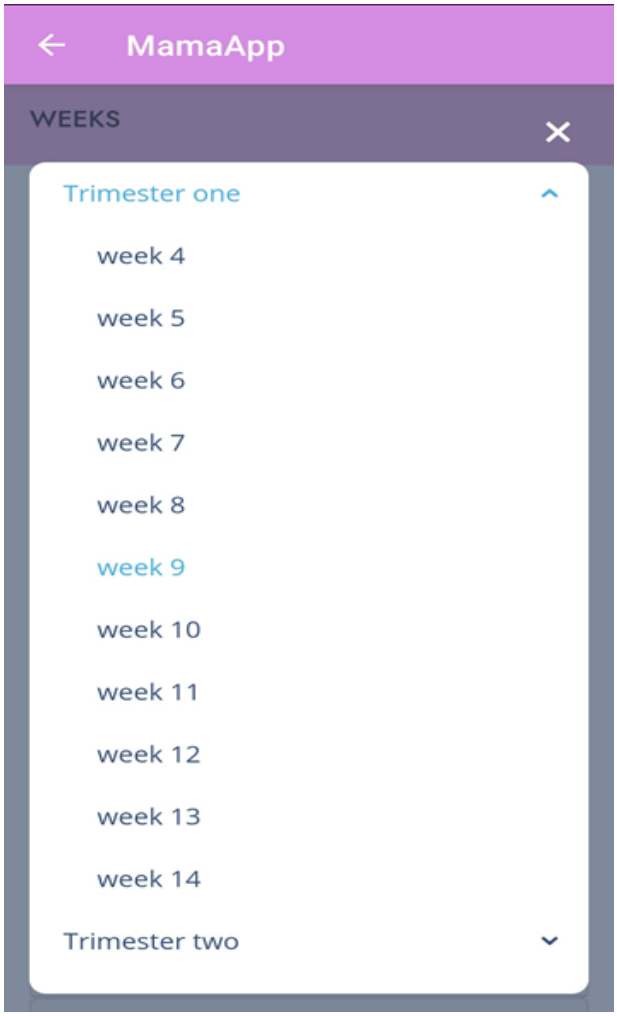
```
answers = qa.ask('vaginal bleeding,abdominal cramps,back pain,discharge of tissue from the vagina')
qa.display_answers(answers[:10])
```

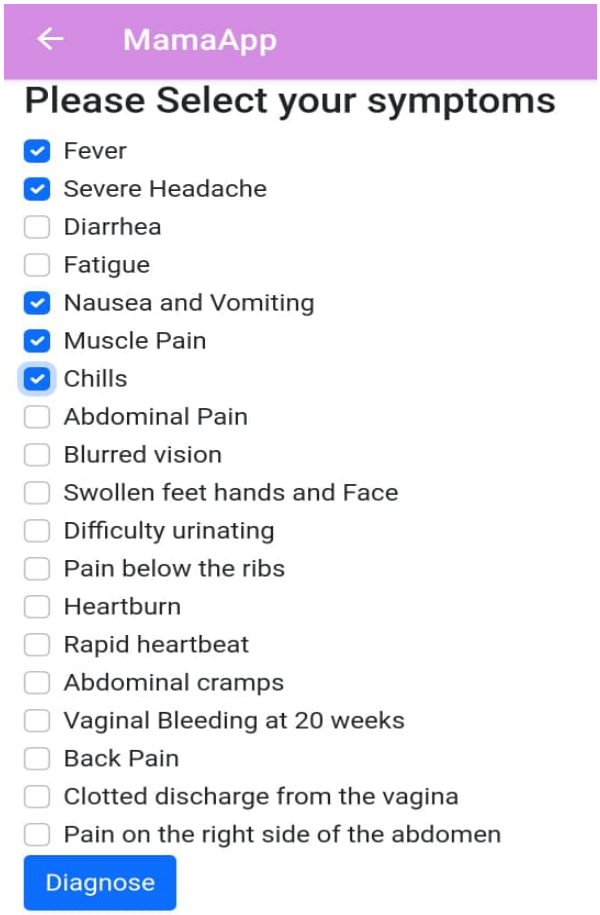
	Candidate Answer	Context	Confidence	Document Reference
0	of threatened abortion	symptoms of threatened abortion are : passing tissue with clot like material from the vagina, abdominal pain, vaginal bleeding.	0.575511	threatened-abortion-annotation-2/993.txt

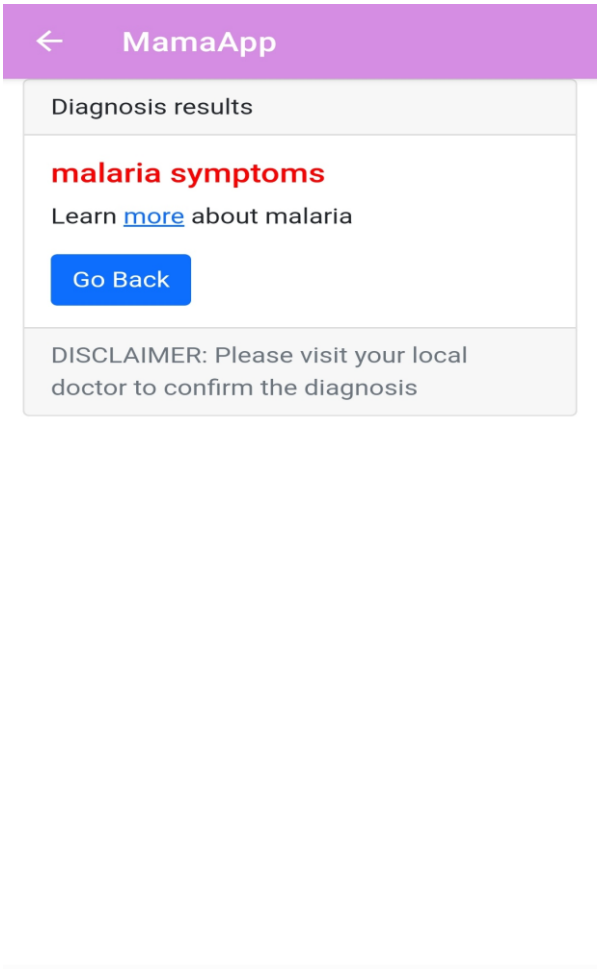
Diagnosis results of the second iteration of training on the Miscarriage (Threatened Abortion) dataset

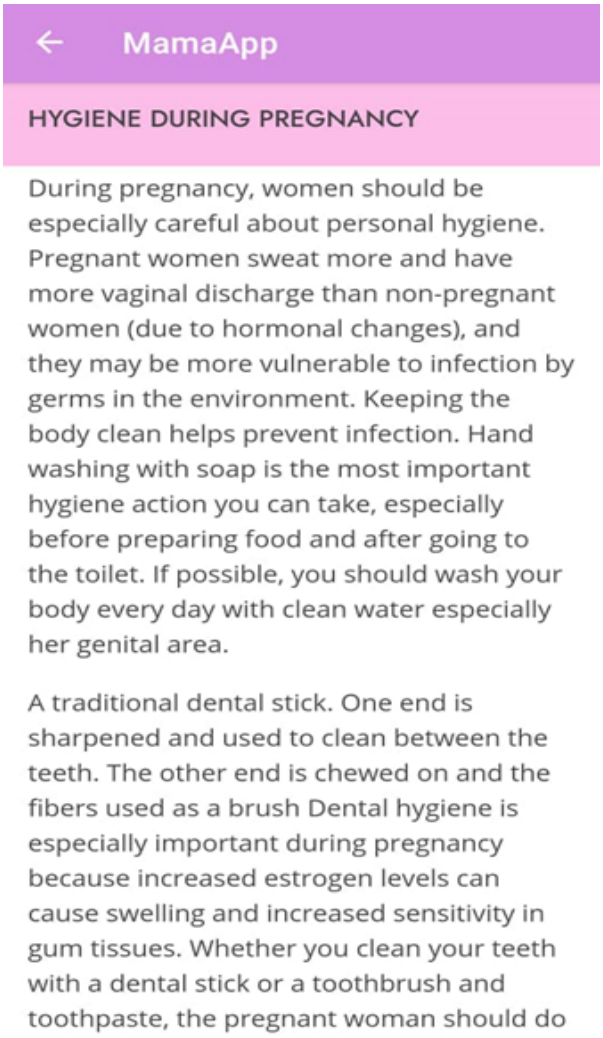
Appendix 9: Mobile Application Screenshots

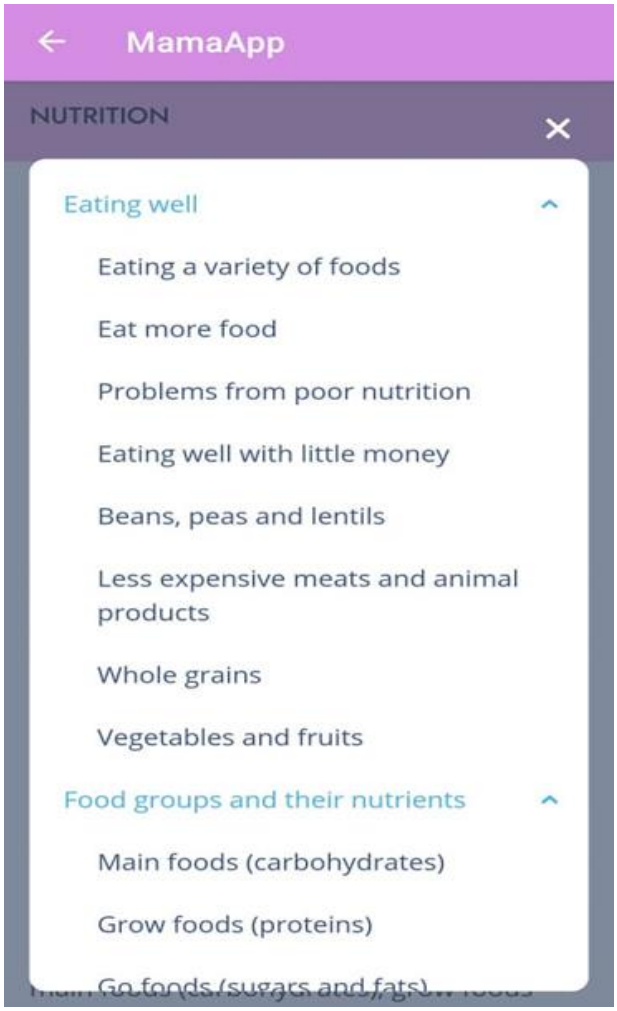


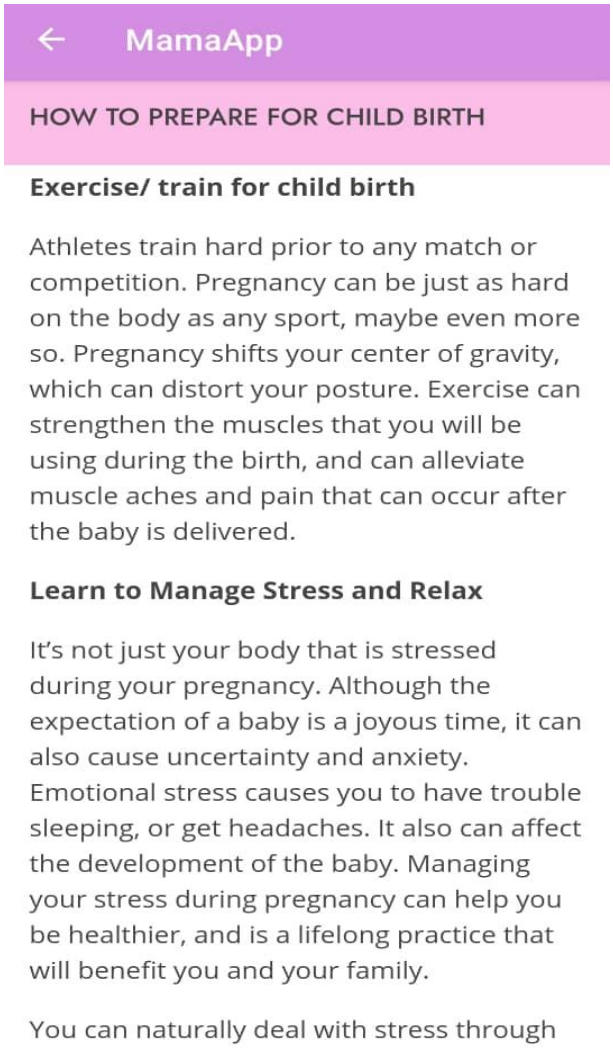

MamaApp
WEEKS
Trimester one
week 4
week 5
week 6
week 7
week 8
week 9
week 10
week 11
week 12
week 13
week 14
Trimester two

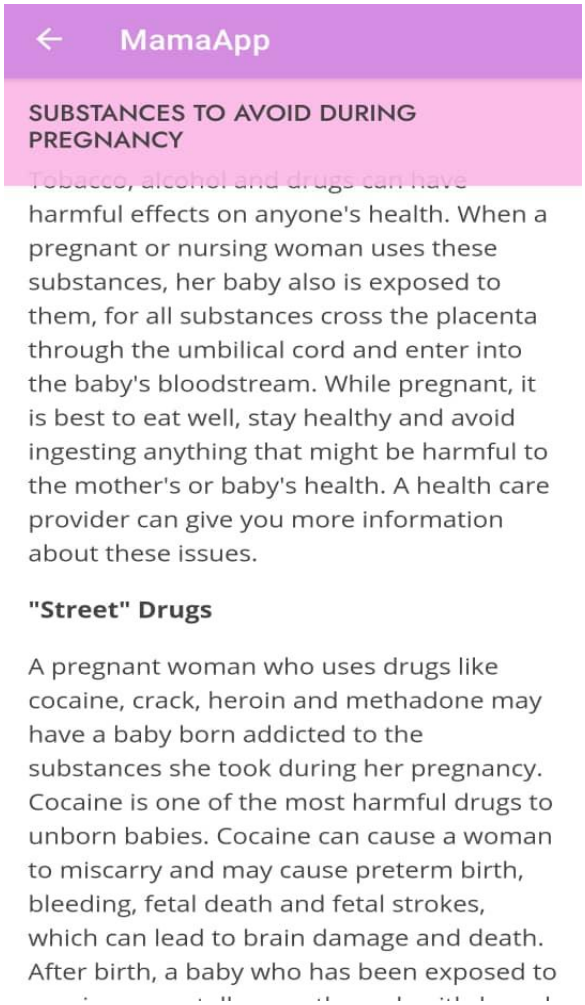

MamaApp
Please Select your symptoms
Fever
Severe Headache
Diarrhea
Fatigue
Nausea and Vomiting
Muscle Pain
Chills
Abdominal Pain
Blurred vision
Swollen feet hands and Face
Difficulty urinating
Pain below the ribs
Heartburn
Rapid heartbeat
Abdominal cramps
Vaginal Bleeding at 20 weeks
Back Pain
Clotted discharge from the vagina
Pain on the right side of the abdomen
Diagnose


MamaApp
Diagnosis results
malaria symptoms
Learn more about malaria
Go Back
DISCLAIMER: Please visit your local doctor to confirm the diagnosis


MamaApp
HYGIENE DURING PREGNANCY
During pregnancy, women should be especially careful about personal hygiene. Pregnant women sweat more and have more vaginal discharge than non-pregnant women (due to hormonal changes), and they may be more vulnerable to infection by germs in the environment. Keeping the body clean helps prevent infection. Hand washing with soap is the most important hygiene action you can take, especially before preparing food and after going to the toilet. If possible, you should wash your body every day with clean water especially her genital area.
A traditional dental stick. One end is sharpened and used to clean between the teeth. The other end is chewed on and the fibers used as a brush Dental hygiene is especially important during pregnancy because increased estrogen levels can cause swelling and increased sensitivity in gum tissues. Whether you clean your teeth with a dental stick or a toothbrush and toothpaste, the pregnant woman should do


MamaApp
NUTRITION
Eating well
Eating a variety of foods
Eat more food
Problems from poor nutrition
Eating well with little money
Beans, peas and lentils
Less expensive meats and animal products
Whole grains
Vegetables and fruits
Food groups and their nutrients
Main foods (carbohydrates)
Grow foods (proteins)


MamaApp
HOW TO PREPARE FOR CHILD BIRTH
Exercise/ train for child birth
Athletes train hard prior to any match or competition. Pregnancy can be just as hard on the body as any sport, maybe even more so. Pregnancy shifts your center of gravity, which can distort your posture. Exercise can strengthen the muscles that you will be using during the birth, and can alleviate muscle aches and pain that can occur after the baby is delivered.
Learn to Manage Stress and Relax
It's not just your body that is stressed during your pregnancy. Although the expectation of a baby is a joyous time, it can also cause uncertainty and anxiety. Emotional stress causes you to have trouble sleeping, or get headaches. It also can affect the development of the baby. Managing your stress during pregnancy can help you be healthier, and is a lifelong practice that will benefit you and your family.
You can naturally deal with stress through


MamaApp
SUBSTANCES TO AVOID DURING PREGNANCY
Tobacco, alcohol and drugs can have harmful effects on anyone's health. When a pregnant or nursing woman uses these substances, her baby also is exposed to them, for all substances cross the placenta through the umbilical cord and enter into the baby's bloodstream. While pregnant, it is best to eat well, stay healthy and avoid ingesting anything that might be harmful to the mother's or baby's health. A health care provider can give you more information about these issues.
"Street" Drugs
A pregnant woman who uses drugs like cocaine, crack, heroin and methadone may have a baby born addicted to the substances she took during her pregnancy. Cocaine is one of the most harmful drugs to unborn babies. Cocaine can cause a woman to miscarry and may cause preterm birth, bleeding, fetal death and fetal strokes, which can lead to brain damage and death. After birth, a baby who has been exposed to

RESEARCH OUTPUTS

Manuscript Accepted

Kaaya, E., Ko, J., & Luhanga, E. (2021). Maternal knowledge seeking behavior among pregnant women in Tanzania. *Women's Health, 17, 1-7.*

Poster Presentation

Development of a Medical Expert System for Quality Antenatal Care in Tanzania.

Manuscript Accepted

Original Research Article

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SAGE

Maternal knowledge-seeking behavior among pregnant women in Tanzania[AQ: 2]

Elsie Somi Kaaya[1], Jesuk Ko[2] and Edith Luhanga[1][GQ: 1]

Abstract

Background: Maternal mortality continues to be a global challenge with about 830 women dying of childbirth and pregnancy complications every day. Tanzania has a maternal mortality rate of 524 deaths per 100,000 live births.

Objective: Knowing symptoms associated with antenatal risks among pregnant women may result in seeking care earlier or self-advocating for more immediate treatment in health facilities. This article sought to identify knowledge-seeking behaviors of pregnant women in Northern Tanzania, to determine the challenges met and how these should be addressed to enhance knowledge on pregnancy risks and when to seek care.

Methods: Interview questions and questionnaires were the main data collection tools. Six gynecologists and four midwives were interviewed, while 168 pregnant women and 14 recent mothers participated in the questionnaires.

Results: With the rise in mobile technology and Internet penetration in Tanzania, more women are seeking information through online sources. However, for women to trust these sources, medical experts have to be involved in developing the systems.

Conclusion: Through expert systems, diagnosis of pregnancy complications and recommendations from experts can be made available to pregnant women in Tanzania.[AQ: 4] In addition, self-care education during pregnancy will save women money and reduce hospital loads in Tanzania.

Keywords

antenatal care, expert systems, knowledge-seeking behavior, maternal mortality, pregnancy, self-care

Date received: 19 May 2021; revised: 21 July 2021; accepted: 22 July 2021

Introduction

Antenatal care is a well-proven method that uses relevant physical tests to detect issues linked to maternal morbidity and mortality.[1] Every day, nearly 830 women die as a result of complications during pregnancy or childbirth.[2] Developing countries account for almost all of these deaths, with maternal mortality rates of 239 per 100,000 live births compared to 12 per 100,000 in developed countries. One-third of maternal deaths are caused by hypertension (pre-eclampsia and eclampsia), whereas half are caused by antepartum hemorrhage, both of which are linked to poor prenatal care.[3] Late seeking of care has also been identified to be a crucial factor in maternal deaths.[4]

The maternal mortality rate in Tanzania is about 524 per 100,000 live births. According to a study conducted in Dodoma,[5] three-phase delays in seeking healthcare among pregnant women were identified as the main contributing factors to the deaths. The first-phase delay occurs when a family takes a long time to determine whether or not to seek help. This may be due to a lack of awareness of the warning signs, a lack of funds to bring the expecting mother to a medical center, or the expecting mother's

[1]School of Computational and Communication Science and Engineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania
[2]Department of Industrial Engineering, Universidad Mayor de San Andrés (UMSA), La Paz, Bolivia

Corresponding author:
Elsie Somi Kaaya, School of Computational and Communication Science and Engineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania.
Email: elsiek@nm-aist.ac.tz[AQ: 3]

[AQ: 1]

inability to determine where she wants to give birth. The second-phase of the delay occurs on the way to the medical center, this can be attributed to the unavailability of transport to a health facility or bad roads. The third-phase delay occurs when a woman is unable to receive immediate and satisfactory treatment at a health facility, which may be due to staff shortages or inadequate expertise, as well as a lack of medications, medical supplies, or equipment. The third-phase delay also includes a delayed referral from one health facility to another. The Tanzania National Road Map Strategic Plan[6] reduces maternal, newborn, and infant morbidity and mortality by identifying two classes of critical challenges. These are as follows:

1. Health system factors: limited human resource, scarcity of quality health services, poor implementation of pro-poor policies, low implementation of modern family planning services, lack of equipment and supplies, substandard health infrastructure, defective referral systems, shortage of skilled healthcare providers, inadequate health management at all levels, and poor coordination between public and private facilities.
2. Non-health system factors: some social-cultural beliefs and practices, poor involvement and participation in planning, implementation, monitoring, and evaluation of health services in the communities, poor health-seeking behavior, weak educational sector, and gender inequality.

Tanzania, through the Ministry of Health, Community Development, Gender, Elderly, and Children (MoHCDGEC), has made numerous efforts to reduce maternal mortality rates. Programs such as the Primary Health Sector Development Program (PHSDP) aim to reduce maternal mortality through increased birth coverage aided by skilled birth attendants through increasing the accessibility of human and material resources. The National Road Map Strategic Plan in Tanzania is designed to enhance reproductive, maternal, infant, child, and adolescent health. The initiative includes One Plan II and Health Sector Strategic Plan (HSSP).[7] Strategies such as notifying maternal deaths in less than 48 h and responding to them within 7 days are being introduced in the Dodoma region, which is home to the country's capital. Action plans for perceived gaps are formulated during these meetings.[8]

Studies have shown increased maternity knowledge can help women to understand the role of clinicians better and proper pregnancy self-care. Research by Chesser et al.[9] found that providing expectant mothers with knowledge on prenatal education improved the number of attendees in group prenatal education classes and was connected to positive knowledge and health outcomes. In addition, Fondjo et al.[10] and McCaw-Binns et al.[11] presented that the distribution of cards with figures depicting the symptoms of pre-eclampsia resulted in decreased adverse events among the patients, and awareness of pre-eclampsia and its related causes among pregnant women contributed to its prevention, control, and management.

As of 2020, an estimated 4.54 billion people were using the Internet, reflecting a 7% increase compared to 2019.[12] Engaging with pregnancy applications seems to have become a routine part of the maternity experience for many expectant mothers. Globally, the most common mobile application in medicine appears to be pregnancy apps, which attests to their ever-increasing popularity.[13] In addition, the majority of smartphone owners in the world are women, with implications that pregnancy itself is an incentive to buy a smartphone.[13] Pregnancy-specific websites include "What to expect when you're expecting" (WTE), BabyCentre, and the Bump. Sections on pregnancy and baby guides are found on medical websites such as WebMD, Mayo Clinic, and the UK's National Health Service (NHS). Mobile applications include those developed to accompany websites, for example, the BabyCentre app and the pregnancy tracker app from WTE while others such as *GiftedMom* deployed in Cameroon, *Jambo Mama*, and *Wazazi nipendeni* for Tanzania do not have corresponding websites. The content featured ranges from information on upcoming doctor's visits, interactive three-dimensional (3D) visualizations, and descriptions of fetal growth and risks at different stages of pregnancy. The information is usually presented on a week-to-week basis, with a tool to calculate gestational age (number of weeks of pregnancy). Pregnancy and baby editorial articles and real-time answers to questions asked by mothers during pregnancy are included.

However, information on pregnancy websites can give contradicting information to women.[14] This may be due to the information being for differing contexts. For example, schedules for medical visits, prevalent conditions will differ from country to country, and this may be reflected in the different websites. The language used also caters to the literacy level of the specific countries. For women in countries such as Tanzania, the language used and the lack of conditions such as malaria in pregnancy, a serious and often occurring condition, may make the information difficult to understand or may lead to confusion or distrust in the information given, respectively. Moreover, the information given can sometimes be too much, making it confusing and hard to retain for many women.[14]

To ensure online and mobile information sources provide the necessary knowledge to women that can allow them to improve care-seeking behavior, a more client-centered approach must be used for differing contexts.[14]

This study intended to investigate the knowledge levels and knowledge-seeking behavior of pregnant women in the Tanzanian context. We interviewed 182 women, which included those attending antenatal clinics and new mothers, as well as 6 gynecologists and 4 midwives. Interviews

with the pregnant women focused on where, when, and how they seek information on pregnancy, their trust in the information received, how relevant they find the information gained, and what information and features they wish were included in pregnancy apps. The interviews with the gynecologists and midwives focused on the most common pregnancy complications in Tanzania, their causes, symptoms, and recommendations for dealing with them. The scope was limited to women in urban areas, as they are more likely to seek information and statistics show a growth of maternal mortality rates in urban areas.[4]

This article is organized as follows. Section "Related work" addresses several related research works concerning maternal health information and practical applications. Section "Methods" introduces the overall approach to solve the issues of pregnant women in Tanzania. Section "Results" describes the study results based on key research findings, and section "Discussion" provides a discussion including recommendations. Section "Conclusion" concludes this research work.

Related work

Information-seeking practices of women in Africa

According to Ukonu and Ajaebili,[15] women in Nsukka, Southeast Nigeria, used multiple sources of information with family and friends being the most common source. [AQ: 5] They suggested that high reliance on friends and family as a source of information might have been influenced by low literacy level and income level among the respondents. They found that despite the rise of social media and Internet usage, mass media was declining as a primary source of health information which could have been influenced by low literacy and income among the women. Okafor and Goon[16] found that a majority of women in South Africa (70.2%) got information about physical exercise during pregnancy through social media, television, and radio, while 49.1% used books, newspapers, and magazines as a source of information. The study showed that lack of physical activity information from midwives in charge of their antenatal care clinic influenced high reliance on friends, family, magazines, and most importantly the Internet as a source of information.

Health information-seeking behavior in Tanzania

In Tanzania, studies on maternal health knowledge-seeking have primarily centered on rural women. A study by Mwangakala[17] found that the majority of women chose to get information about their maternal health from qualified healthcare providers. However, the limited accessibility of these providers led many expecting mothers to seek information from traditional birth attendants and other women in society. Much of the information gained therefore was based on personal experiences and opinions rather than expert knowledge, which prevented the women from taking danger signs seriously. Similar findings were also reported by Kassim and Katunzi-Mollel.[18]

Studies on health information-seeking behavior have also shown large reliance on oral sources of information, with the preference being from skilled health providers.[19,20] However, Mwaisela and Mwantimwa[21] found that preferences for the source of health information varied from person to person, depending on the reasons for seeking information, although oral sources were also the most frequently used sources among women seeking breastfeeding information. Barriers to online health information seeking include the perceived difficulty in accessing information and perceptions of quality. In rural areas, illiteracy, lack of knowledge that the Internet can be a source for information, and costs may be reasons for the low usage of online sources.

Mobile applications for antenatal care

Numerous applications have been developed to support safe pregnancy and child delivery in the African context. One of the most successful applications is the MomConnect application in South Africa.[22] MomConnect, launched in 2014, sends Short Message Service (SMS) on behaviors that improve maternal and child health outcomes. The messages are tailored based on a woman's gestational age. In addition to SMS, women can also ask individual questions and provide feedback on antenatal care received. Users report very high satisfaction, with over 500 questions being asked daily. A similar application, GiftedMom, provides SMS-based and voice-based reminders on upcoming antenatal appointments as well as maternal health education to women in Cameroon.[23] In 15 rural areas, the application resulted in a 20% rise in antenatal clinic attendance. Meanwhile in Ethiopia, the Safe Delivery app[24] uses 5–7 min animated videos to provide instruction on the management of the third step of labor, with a focus on lifesaving techniques. Health workers can choose to view the entire video or view-specific techniques in the video. Weekly SMS quizzes with links to the video segments which showcase the results and lists of essential medicines and equipment are also provided. Health worker's experience with the app was overall positive, with many opting to use it to refresh knowledge on lifesaving techniques.

In Tanzania, maternal health applications include *Wazazi Nipendeni*—an SMS service by the Airtel telecommunications company, that aims to keep women aware and safe at all stages of their pregnancy by providing information on diet, family planning, danger signs, and a variety of other main topics.[25] In unadjusted models, exposure to the app predicted whether women delivered in a health facility

or screened for HIV with their partner. Several applications, from SMS-based ones to smartphone ones, have also been launched to help women in gaining knowledge of pregnancy progression and symptoms. Other applications include as follows:

1. Jambo Mama: an interactive mobile application that provides general health information regarding expecting women and connects them to their health workers. Medical records are sent to the hospital where the woman will give birth. Jambo mama also sends text updates about the mother's pregnancy and encourages her to answer questions about how she is feeling and how her pregnancy is progressing.
2. Wired Mothers: an SMS-based application with a voucher component that was used in a randomized controlled trial in Zanzibar to see whether a mobile app could improve antenatal care visits during pregnancy.

A major drawback to applications such as Jambo Mama and Wazazi Nipendeni is the need for doctors to manually reply to received messages, which is a tedious process for doctors that resulted in late responses to pregnant women.

Mobile phone–based pregnancy support systems

A mobile phone–based approach is a personalized approach that helps to educate women on issues related to pregnancy, monitoring of the child and mother's progress, critical updates, post-delivery support, and follow-up with medical check-ups through mobile phone. In the presence of good mobile phone technologies and mobile network infrastructure, a suitable platform that is available at all times to help in reducing pregnancy-related stress and anxiety and its complications is vital. This platform will not only help the mother but also her spouse to be aware of changes that occur during pregnancy and the necessary precautions that need to be taken.[26] Expert systems, decision support systems, pregnancy-related websites, and mobile applications designed to run on mobile phones all fall in this category.

Expert and decision support systems for detection of early pregnancy complications

An expert system for Predicting Early Pregnancy with Disorders using Artificial Neural Networks (ANNs) was developed by Maylawati et al.[27] Several early pregnancy disorders such as ectopic pregnancy, pre-eclampsia and eclampsia, hyperemesis gravidarum, and hydatidiform mole were successfully detected from input symptoms. The study used ANNs and backpropagation algorithm.[27] Kitporntheranunt and Wiriyasuttiwong[28] also developed a medical expert system for ectopic pregnancy diagnosis, with testing showing a 100% correspondence to the clinical diagnosis in the testing group. Another maternal health expert system was developed in Eldoret, Kenya, for hypertension diagnosis.[29]

A fuzzy approach has also been used by Umoh and Nyoho[30] for pregnancy risk factor monitoring. Their research aimed at diagnosing and monitoring pregnancy risk factors in women with accuracy in the presence of a huge amount of data. The model was aimed to provide a decision support platform to physicians, health practitioners in obstetrical, and also pregnancy risk factor researchers. The study also assisted health practitioners in obstetrical and gynecology clinics in providing education to women about the advantages of early clinic attendance and the risk factors related to pregnancy.

Paydar et al.[31] developed a clinical decision support system (CDSS) to predict the pregnancy outcomes of pregnant women affected with Systemic Lupus Erythematosus (SLE). The system performed well in predicting pregnancy outcomes of the infected women.

Methods

The principal investigator conducted a survey and observation study in Arusha, Tanzania, from February to August 2020. The study design used was a mixed-method explanatory sequential design where 182 (94.8%) of the participants were pregnant women and mothers, while 10 (5.2%) were gynecologists and midwives. Arusha city in Tanzania was selected because it is an urbanized city, and recent studies have suggested that the maternal mortality rate in Tanzania has risen over recent years and is now increasingly urban. These results have raised concerns from the Government of Tanzania and stakeholders about the reasons for such inconsistencies.[4]

Participants

A total of 192 participants (6 gynecologists, 4 midwives, 168 pregnant women, and 14 recent mothers) took part in the study. Participants were selected randomly from three major hospitals in the city—Mt. Meru Referral Hospital, Arusha Lutheran Medical Centre, and AICC hospital. One hundred eighty-two women participated in the study, where 32 women were sent online questionnaires for validation purposes and 50 women were selected from each of the three hospitals. Time and resource constraints influenced the selected sample size. The inclusion criteria were women who were pregnant at the time of the study, recent mothers who had given birth within 6 months of the study's commencement, and medical personnel who were either gynecologists or midwives.[AQ: 6] The research was strictly limited to the researcher and the participants.

Table 1. Demographic characteristics of the women who participated in the data collection process.

Demographic	Category	Number of participants
Age	18–23	27
	24–29	94
	30–35	61
Education	Primary education	47
	Secondary education	94
	Higher education	41
Number of prior pregnancies	0–3	163
	4–7	19

Ethical approval for the study was granted by Kibong'oto Infectious Diseases Hospital—The Nelson Mandela African Institution of Science and Technology—Centre for Educational Development in Health, Arusha (KIDH-NM-AIST-CEDHA)—KNCHREC under research proposal number KNCHREC 0038/RW/2/21.[AQ: 7] The study took place between February and August 2020. Table 1 shows the demographics of the women who took part in the data collection.

Before the study, ethical clearance/permission for this stage was obtained from the hospitals. All participants were informed on the purpose of the research, the scope of data to be collected, how their data would be used, and their right to decline participation or to withdraw at any point. Participants gave written consent before the start of the study.

Survey design

The survey consisted of both questionnaires and interviews. The questionnaires were distributed to the pregnant women and recent mothers; they consisted of 15 questions divided into 2 sections. The first section focused on collecting demographic details such as area of residence, age, education level, and the number of prior pregnancies. The second section assessed knowledge-seeking behaviors. The questions included were on: whether they used their smartphones to search for information regarding symptoms that they experienced during pregnancy, the applications or websites they used, whether there was a correlation between the results from websites and what the doctors tell them, challenges they face when using the applications, and what additional knowledge and system features, they felt were needed to address the challenges faced. Participants provided both free responses and the most relevant options from multi-choice questions. During the interviews, field notes were recorded and reviewed at the end of the survey.

The interviews were conducted with gynecologists and midwives. They were structured and consisted of 13 questions. The questions were aimed at identifying common complications women experience during pregnancy, complications that were prevalent in Tanzania but less so elsewhere, the risk factors associated with the complications, how the complications can be prevented and managed, symptoms that should result in help-seeking behavior, and any first aid treatments that can be administered at home. The interviewer recorded the responses during the interview and reviewed them during the analysis stage.

The questionnaire was validated before the study by 32 women who were sent online questionnaires (Google Forms). Originally, the questionnaire contained 30 questions, but these were reduced to 15 after the validation study, as the omitted questions mainly provided repetitions of previous answers. Some questions were also rephrased to make them easier to understand and to prompt more verbose responses on the women's experiences. In the online questionnaire, a description of the study was provided followed by a consent form that was filled before participating in the questionnaire. Personal details such as the city of residence, age, and level of education were included. The validation results showed that the questionnaires provided to the women produced better results when they were provided with multiple choices and checkboxes. Questions such as "Do/Did you search for Nutrition, safe exercises during pregnancy, and self-care during pregnancy? Is there any additional information you search for?" Provided limiting responses with little insight, and the likelihood of the women forgetting some information was great, but when women were given a variety of information to select from, we found that they selected more information they sought during pregnancy. In addition, questions that required long answers were skipped more with the women this was an indicator to structure questions with answers they could select from to maintain the women's engagement during the study. Moreover, the women were hesitant to respond to questionnaires that had too many questions, we eliminated the repetitious questions to encourage more women into participating in the questionnaire while maintaining the intent of the questionnaire.

Observation

Observations were conducted after the interviews. We asked the pregnant women and recent mothers to show us how they interacted with the applications or websites to search for information using their phones. We asked them to type in the questions they had on the applications and questioned them on the results obtained to gauge their understanding.

Data analysis

The collected data were pre-processed by the principal investigator by analyzing consistencies in responses and filtering responses that did not match the questions.

Table 2. The types of information pregnant women searched for based on the most popular information sought to the least popular information sought.

Type of information	Number of women (%)
Nutrition	99.5
Self-care during pregnancy	64.3
Physical changes	61.5
Exercise during pregnancy	53.3
How to prepare for labor	52.7
Substances to be avoided during pregnancy	48.9
Breastfeeding and baby food	40.7
The dos and don'ts during specific periods	35.2
Fetal development	34.6
How to sleep when you are pregnant	29.7
Pregnancy count down	24.2
Psychology in pregnancy	14.8

Responses from the questionnaires were fed into the Visual Paradigm data visualization tool, which is a UML CASE Tool supporting UML 2, SysML, and Business Process Modeling Notation (BPMN) from the Object Management Group (OMG). The responses to multiple-choice questions were presented using histograms to determine the distribution of responses. Pie charts were used to present the qualitative responses where the proportion of responses were distributed based on the demographics of the participants.

Results

Smartphone ownership and usage for information searching

The majority of women owned smartphones. Of the 182 women who were interviewed, 114 (62.6%) owned a smartphone while 68 (37.4%) did not own a smartphone. However, only 99 (86.8%) smartphone owners used their devices to access information regarding pregnancy. The rest were either uninterested or unaware of pregnancy apps and websites and relied mostly on doctors, midwives, and friends.

The information that was most commonly searched for regarding pregnancy was on nutrition, specifically on the types of foods to eat for a healthy pregnancy, and on self-care during pregnancy. Table 2 presents the types of information searched for based on their popularity.

The main source of pregnancy information on smartphones was mobile applications, where all 99 women used mobile applications with the BabyCentre app being the most popular used by 95 women (95.96%) and YouTube being the second most popular used by 61 women (61.6%). The Bump, Pregnancy+, WebMD, What to expect, Mediscape, NetMum, YouTube, Instagram, Pinterest, The Blueberry, Flo, Pregnancy Tracker, and Pregnancy calendar were also used.[AQ: 8] The reason given for the preference for mobile applications was mobile phones are readily available and the information is presented in a more user-friendly way than when viewed on the website:

> It is easy to access information through my phone compared to a computer, I walk with my phone everywhere and the mobile applications are more user-friendly there. For me to use the websites I need to get a computer from the internet café or ask a friend because the website is more user-friendly on a computer

The apps also provided additional features such as weekly notifications on changes to expect, the countdown to delivery, and pregnancy week by week. Notifications in particular were deemed very useful:

> Mobile applications alert you at the beginning of every week on the countdown to your due date, it reminds you of what you need to do and normal physical changes during pregnancy. This keeps me at peace because I know what's going on.

Regarding user experiences with BabyCentre, participants remarked on the easy-to-understand language and wide range of information on safe and unsafe practices as helpful and engaging:

> Baby center gives me information such as how far I am in my pregnancy in weeks and also tells me how many days I have left until I give birth, it also tells the growth progression of my baby, this helps in understanding my pregnancy. (P1)

> The application provides information on what exercises are safe to do, foods that are good to eat and the ones to avoid, the amount of sleep I need to get. This helped me in coping with pregnancy. (P2)

However, one participant who was a first-time mother complained about the community clubs:

> I don't like talking to other women online, they make me anxious. I would rather read the information provided in the applications and listen to the experts.

The reason for YouTube's popularity was the perceived ease of understanding information due to the use of videos and animations:

> It doesn't take me a long time to understand information from YouTube, it is easier for me to understand because they explain things in simple words, pictures, and videos compared to other sources.

Overall, we observed that most of the women 72 (72.7%) used a combination of sources (websites and applications) to search for information, with only 27 (27.3%) using a single source. Websites and applications

with more visual presentations were preferred to wordy ones, as the women felt wordy applications could be confusing and less engaging (easy to lose interest in).

Other sources of information on pregnancy, childbirth, and childcare

Other sources of pregnancy information that were reported were medical doctors (obstetricians and gynecologists), midwives, friends, and sometimes books to search for information. Preference on where to get the information varied among women who did not own smartphones. Sixty-eight (100%) women preferred doctors, 52 (76.5%) preferred midwives, 27 (39.7%) preferred friends, and 7 (10.3%) preferred books:

> I prefer asking doctors about pregnancy because they can explain well, and I trust them more. (P1)

> I like talking to the midwives, they are mostly mothers so they understand my situation better. (P2)

> I am more open talking to my friends, they explain their experiences to me at home. I don't have to go to the hospital a lot. (P3)

> When I read books, I gain a lot of knowledge. In case I don't understand something, I ask the doctor or midwife in the next meeting. (P4)

Correlation of information between doctors and the applications

When asked whether the applications matched what the doctors told them, 91 (91.9%) of women said that they found correspondence between what the doctor said and what was written in the applications, while 8 (8.08%) women said that the information provided was sometimes different.

Education level may have influenced whether the women felt there were differences in the provided information, with the more educated women being more likely to report observing a difference. This could be due to their higher information and technology literacy, which resulted in their searching for information from more online sources, using more search terms, and overall reading more articles, even those with more complicated language. The main perception was that applications provided more information than doctors:

> The applications provide more information than the doctors, sometimes the doctors don't tell you enough about your pregnancy so through the applications I get to learn more. (P1)

P1 was concerned with toxoplasmosis, which is a parasitic infection caused by the *Toxoplasma gondii* parasite, one of the most common parasites on the planet. Eating undercooked tainted meat, coming into contact with infected cat feces, or mother-to-child transmission during pregnancy are the most common ways to become infected. Toxoplasmosis infection can cause flu-like symptoms, However, the majority of those who are affected never show any signs or symptoms. According to the interviews with doctors, the condition is more common among women in Western countries than it is in Tanzania. Women rarely get toxoplasmosis in Tanzania because few people live with pets in the house, which reduces the likelihood of getting infected. As a result, this condition is rarely talked about with patients.

Recommendations on improving apps and websites for maternal information

The main recommendation given by 144 (79.1%) women was to include health professionals in the development of the system to improve trust in the systems:

> I will have more confidence in the systems if health professionals will work with system developers in developing the systems, it will build more trust in the results we receive. (P1)

> I do not want to be confused with the information I receive from the systems, if health professionals will be involved then there will be less confusion. (P2)

> When I am sure that health professionals are involved in these applications, I will be motivated to buy a smartphone and use the applications. (P3)

Another popular recommendation was to have the system information matching the Tanzanian context 122 (67%):

> Sometimes the advice I receive from the system do not match what is in the environment, it is frustrating. (P1)

> The size of the fetus is compared to things that I have never seen before, I think those things are found in western countries, not here. (P2)

> These systems are developed for western people. Their methods are not like ours they are more advanced; I would prefer something that is designed for us which I can understand. Then I will use the applications. (P3)

> I don't understand English very well, If there are applications in Swahili then I will start using them. (P4)

Challenges faced during information search

Only a minority of the women 20 (20.2%) reported facing challenges in retrieving the information they sought online.

The main challenge reported was finding an explanation for the symptoms they faced using search engines. However, observation showed that far more women were not able to find the right keywords to use on search engines. One participant, for example, was asked to search for symptoms that she was experiencing. The participant was able to describe in Swahili that she felt dizzy, bloated, and had a headache. However, she was only able to describe one symptom, "headache." She also failed to include pregnancy in her search terms. Consequently, the results she obtained were too vague.

More than half of the women 66 (66.7%) complained that the search results were too wordy for them to understand:

> It is sometimes not easy to understand results from google because they provide too much information which ends up confusing me, so I lose interest in the middle. (P1)

> It is easier to receive information from YouTube because they keep the flow of information interesting, they include a lot of pictures that help me understand better. (P2)

The influence of prior pregnancies on the knowledge-seeking behavior

The number of prior pregnancies was seen to have influenced the knowledge-seeking behavior of the women, with first-time pregnancies prompting more curiosity than women who have had more than one pregnancy:

> I understand pregnancy because this is my second child. Every pregnancy is different, my first pregnancy was smooth but this time my first trimester was hard. I still seeking information from the experts and the internet but not as much as I did in my first pregnancy. (P1)

> This is my first child; I search for information anytime I experience a new symptom or whenever I want to learn about my progress and the baby. It is better to be prepared, it eliminates fear. (P2)

> I still seek for health information when I am pregnant regardless of being a mother of two. It was more frequent in my first pregnancy but I have learned through experience how pregnancy works so it is not very frequent now. (P3)

> I read about pregnancy a lot; it is difficult for me to be pregnant for the first time. Everything is new so I have a lot to learn. (P4)

Discussion

According to this study, Women in urban Tanzania were seen to lack knowledge about pregnancy complications which is contrary to popular belief. The majority identified vaginal bleeding and abdominal pain as symptoms of pregnancy complications. However, symptoms such as swollen face, hands, and feet, blurred vision, severe headache, and difficulty urinating at 20 weeks of pregnancy which are often overlooked indicate a serious complication called pre-eclampsia which is one of the leading causes of maternal mortality in Tanzania. Due to poor knowledge on obstetric dangers, many women seek care when their condition has worsened, leaving experts with little to do, but if they had known about these conditions and their symptoms, countless lives would have been saved.[32]

With the increase in smartphone usage, women have been seen to use their mobile phones to access information on pregnancy.[13] However, in this study, the majority of the women struggled to get the information they searched for on the Internet, this was primarily due to poor input of symptoms which often led to vague results. In addition, when the results provided lengthy responses, the women would often lose interest in reading the information. They preferred short answers to questions and the use of audio, videos, and pictures as a method of information delivery.

The research conducted shows that to enhance knowledge that women have on the risks during pregnancy and the services that they are to receive, the information provided to them must be represented in a short simple format. The user interface should be simplified using common icons, easy words, and provide more descriptions to make it a suitable platform for them to learn. Also, with the help of videos, pregnant women will be able to understand the information provided easily.

Moreover, the majority of the women requested health specialist's recommendations on pregnancy complications, safe practices during pregnancy such as nutrition, exercise during pregnancy, substances, and behavior to avoid during pregnancy, preparation for labor, and breastfeeding and baby food to be included in the system to enhance trust in the applications and diverse knowledge in regard to pregnancy. In addition, the women shared that information on fetal development and physical changes related to pregnancy will help them in understanding their pregnancy progression.

The challenge faced by some women in the study is their inability to search for the information they need. When developing a suitable platform for pregnant women in Tanzania, there is a dire need to present symptoms in a way that can easily be understood by the woman so as to provide the most relevant results.

Women in urban Tanzania were the focus of the study. However, pregnant women in rural Tanzania should have their knowledge-seeking behavior studied so that researchers may develop solutions that are customized to their needs. Another limitation of the study was a restriction of time and resources; more research should be done in different parts of Tanzania and with a large sample size to compare the requirements of pregnant women in order to develop an acceptable solution for each pregnant woman.

Conclusion

With maternal mortality still being high in developing countries, women need to know pregnancy complications. In this study, women have shown great interest in learning about complications that are accompanied by pregnancy, and self-care recommendations during pregnancy provided that there are reliable platforms endorsed by health specialists. The participation of experts when developing these platforms is vital because it ensures the women are being provided with reliable information. In this study, we were able to collect requirements for pregnancy applications from women in the Tanzanian context. Based on the data collected, we found that expert systems are ideal for providing women with the necessary knowledge.

With proper training of the machine learning models, expert systems can enhance knowledge in pregnant women which will aid in the reduction of the maternal mortality rate in Tanzania. Moreover, providing women with self-care tips will not only improve the quality of pregnancy but also will save women time and money.

In the future, we aim to develop an expert system that will diagnose pregnancy complications, provide knowledge on the causes of the complications, and recommendations from experts. In addition, the expert system will provide self-care information for natural pregnancy conditions.

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Author contributions

The study consists of three contributors E.S.K. the student (female), E.L. the internal supervisor (female), and J.K. the external supervisor (male). The study was conceived by E.S.K. and E.L. E.S.K. designed the study, carried out data collection and analysis, and was responsible for the preparation of the manuscript. E.L. and J.K. were in charge of a thorough revision of the paper. The final manuscript was read and approved by all of the authors.

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Guarantor

E.S.K. is the guarantor of this study.

ORCID iDs[GQ: 3]

Elsie Somi Kaaya https://orcid.org/0000-0002-2420-6316
Jesuk Ko https://orcid.org/0000-0002-0577-8589

Supplemental material[AQ: 9]

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Poster Presentation

DEVELOPMENT OF A MEDICAL EXPERT SYSTEM FOR QUALITY ANTENATAL CARE IN TANZANIA

1. Elsie Somi Kaaya, (Student), 2. Professor Jesuk Ko, 3. Dr. Edith Luhanga (Supervisors)
Email: elsiek@nm-aist.ac.tz, jesukko361@gmail.com, and edith.luhanga@nm-aist.ac.tz

ABSTRACT

Maternal mortality remains a global problem, with approximately 830 women dying every day as a result of childbirth and pregnancy complications. The maternal mortality ratio is as high as 524 deaths per 100,000 live births in Tanzania.

Studies show that providing women with maternal health information can help achieve the goal of reducing global maternal mortality to less than 70 maternal deaths per 100,000 live births by 2030. Expert systems have shown promising results providing medical diagnostics, including for pregnancy complications.

The developed system *MamaApp* is capable of diagnosing pregnancy complications with confidence ranging from 79% to 100%.

OBJECTIVES

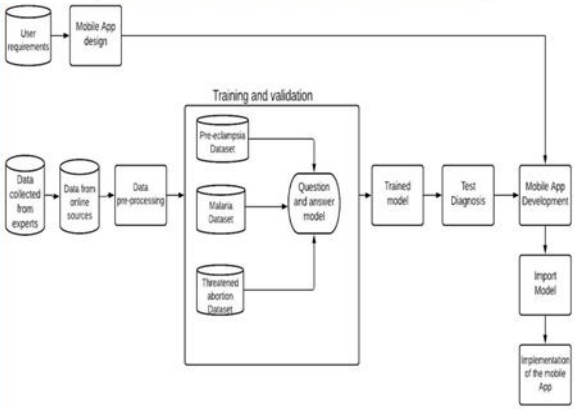
THE MAIN OBJECTIVE :

To develop a smartphone-based expert system for the early detection of the key causes of maternal mortality in Tanzania, as well as for the effective provision of general information on obstetric treatment and dangerous symptoms at various stages of pregnancy.

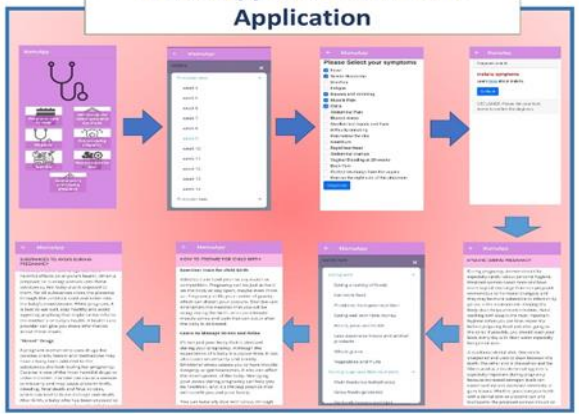
SPECIFIC OBJECTIVE:

- ❑ To identify system requirements and knowledge seeking behavior of pregnant women in Tanzania.
- ❑ To develop an expert system for smartphone devices, which will diagnose the main causes of maternal mortality in Tanzania and provide pregnant women with general knowledge on pregnancy and antenatal care services.
- ❑ To assess the accuracy of the expert system
- ❑ To Validate the developed system with pregnant women and Medical experts.

CONCEPTUAL FRAMEWORK



MamaApp Android Mobile Application



RELATED WORK

Studies on maternal health knowledge-seeking in Tanzania have largely focused on rural women. According to Mwangakala's findings (Mwangakala, 2012), the majority of women prefer to receive knowledge about their maternal health from accredited healthcare providers.

In Tanzania, Wazazi Nipendeni is an SMS service provided by the Airtel telecommunications company that aims to keep women informed and healthy during their pregnancy by providing information on diet, family planning, danger signs, and many other topics (Kaufman et al., 2017). Jambo Mama an interactive mobile application that links pregnant women to their health care providers and offers general health information. The woman's medical records will be sent to the hospital where she will give birth, and Wired Mothers, a randomized controlled trial in Zanzibar used an SMS-based app with a voucher component to see whether a mobile app could increase antenatal care visits during pregnancy.

Maylawati (Maylawati et al., 2017) developed an expert system for predicting early pregnancy with disorders using an Artificial Neural Network. In addition, a medical expert system for ectopic pregnancy diagnosis was developed by (Kitporntheranunt & Wiriyasuttiwong, 2010) with research revealing a 100 percent match with the clinical diagnosis in the testing community. Another maternal health expert system for hypertension diagnosis was established in Eldoret, Kenya.(Gudu et al., 2012).