FETAL HEART BEAT RATE MONITORING SUPPORT DEVICE FOR PREGNANT WOMEN DIAGNOSED WITH MILD PRE-ECLAMPSIA/HYPERTENSION IN TANZANIA

Christina Wilfred Mariki

A Project Report Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Embedded and Mobile Systems of the Nelson Mandela African Institution of Science and Technology

Arusha, Tanzania

July, 2022

ABSTRACT

The standard care for pregnant women in Tanzania is done in health facilities. The fetal heart rate monitoring among other things is done during scheduled antenatal clinic visits. High number of still birth caused by timely and inaccurate fetal heart rate monitoring is one of the major concerns in the management of those diagnosed with mild pre-eclampsia throughout their pregnancy. Pregnant women in the low income countries ,at gestational age of 28+ weeks are at high risk and require to perform fetal heart rate monitoring frequently. Therefore, the automated tool for self-monitoring of fetal heart rate remotely is of high need to save both the life of the mother and the unborn child. A mixed method was used to identify and gather requirements for fetal heart beat rate monitoring tool. Agile methodology was used to design the prototype of the fetal heart beat rate monitoring device. This study observed that, 54% of the pregnant women conducted their own fetal heart rate monitoring through charting fetal kicks manually. In addition, the fetal heart beat rate monitoring device has been developed to sense and record in real-time the fetal heart beats and pregnant women's heartbeat. Apart from that the belt has also succeeded to record the temperature, location using GPS of the pregnant woman. Using GSM module and the Blynk Application the captured information is sent to the patient and health facility for monitoring purposes. In implementation of this study, it avails raise of awareness on the importance of continuously monitoring the fetal heart beat rate for pregnant women with hypertensive condition during pregnancy in communication with the health facility- medical personnel.

DECLARATION

I, Christina Wilfred Mariki, To the Senate of Nelson Mandela Africa Institution of Science and Technology, I am certifying that this dissertation is my own original work, and that no other institution has or is presently reviewing it.

Christina Wilfred Mariki		18/07/2022
Candidate Name	**Signature**	**Date**

The above declaration is confirmed

Prof. Kisangiri Michael		19-07-2022
Supervisor Name (1)	**Signature**	**Date**

Dr. Judith Leo		19th July, 2022.
Supervisor Name (2)	**Signature**	**Date**

COPYRIGHT

This project report contains intellectual property content that is protected by the Berne Convention, the Copyright Act of 1999, and other international and state laws governing intellectual property. It may not be reproduced in whole or in part, except for brief excerpts in fair dealing, for researcher private study, critical scholarly review, or discourse with appropriate acknowledgement, without the written permission of the Deputy Vice Chancellor for Academic, Research, and Innovation, on behalf of both the author and the Nelson Mandela African Institution of Science and Technology.

CERTIFICATION

The undersigned certifies that I have read and recommends for acceptance by the Nelson Mandela African Institution of Science and Technology a dissertation titled "Fetal Heart Beat Rate Monitoring Support Device for Pregnant Women Diagnosed with Mild Pre eclampsia/ Hypertension in Tanzania," submitted in partial fulfillment of the requirements for the award of the Master of Embedded and Mobile Systems degree at the Nelson Mandela African Institution of Science and Technology.

Prof. Kisangiri Michael		19-07-2022
Supervisor Name (1)	**Signature**	**Date**
Dr. Judith Leo	Leo	19th July 2022.
Supervisor Name (2)	**Signature**	**Date**

ACKNOWLEDGEMENT

In the first place, I express my gratitude to the Almighty God for his blessings, grace, and direction during my time as a master's student. Second, I would like to convey my heartfelt appreciation to my supervisors, Prof. Kisangiri Michael and Dr. Judith Leo, who have been by my side during the whole process of performing this study. They have been instrumental in my success. I express my gratitude to them for their direction, constructive criticism, and overall support during the project. They have always made themselves accessible for frequent meetings and conversations, which have really aided me in completing this project successfully.

An extra special thanks to the CENIT@EA project scholarship for granting me full scholarship to pursue my master's degree at the Nelson Mandela – African Institute of Science and Technology-Master of science in Embeded and Mobile Systems.

In particular, I would like to express my gratitude to the KCRI- Kilimanjaro Clinical Research Institute for granting me permission to conduct my internship and project study. I am also grateful to Mr. Kennedy Ngowi and Dr. Eusebio Maro for their tireless efforts in proofreading my work and assisting me throughout this project. In addition, I would like to express my gratitude to my EMoS cohort 2 classmates and instructors for their tremendous support during my studies.

My parents Mr. and Mrs. Wilfred Mariki, my three sisters Martina W Mariki, Anna W Mariki, and Neema W Mariki all deserve a special word of appreciation for their prayers and encouragement during my academic career. There would have been no way to achieve this feat without them.

Thank you.

DEDICATION

This project is dedicated to the Almighty God, who began a good work and will continue to complete it until the day of the LORD, as well as to my beloved parents, Mr. and Mrs. Wilfred Mariki, whose good hard work and prayers have resulted in this achievement, which is the result of their endless efforts and prayers towards my academic career growth, which you have abundantly loved.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

COVID-19	Corona Virus Disease 2019
CPR	Cardiopulmonary Resuscitation
CSS	Cascading Style Sheets
CTG	Cardiotocography
FHR	Fetal Heart Rate
FHRM	Fetal Heart Rate Monitoring
FHRV	Fetal Heart Rate Variability
GA	Gestational Age
GPS	The Global Positioning System
GSM	Global System for Mobile Communication
HLH	Haydom Lutheran Hospital
HTML	Hyper Text Markup Language
IDE	Integrated Development Environment
ISSHP	The International Society of the Study of Hypertension in Pregnancy
KCMC	Kilimanjaro Christian Medical Center
KCRI	Kilimanjaro Clinical Research Institute
LED	Light Emitting Diode
LIC	Low Income Country
MYSQL	Structured Query Language
NICE	Neonatal and Intrauterine Deaths according to Ethology
OLED	Organic Light Emitting Diode
PCB	Printed Circuit Board
PE/E	Preeclampsia / Eclampsia
RDBMS	Relational Database Management System
RTC	Real Time Clock

CHAPTER ONE

INTRODUCTION

1.1 Background of the problem

Prenatal mortality and morbidity are connected to maternal mortality and morbidity, and this has a direct influence on neonatal deaths, stillbirths, and fetal intrauterine death. Maternal near-miss, also known as the extreme end of maternal morbidity, has emerged as an important statistic for judging the quality of healthcare services and initiatives in recent years. There have been facility-based maternal morbidity and near-miss events since the standardization of maternal morbidity and near-miss concepts. Hypertensive state in pregnancy is one of the primary causes of maternal morbidity in primigravida and multigravida or multipara women who have a history of hypertensive issue from previous pregnancies (Hirose *et al.*, 2019)

High blood pressure is known scientifically as hypertension, which indicates that blood exerts force when it travels through the walls of blood vessels. This can cause health problems, and in the worst-case scenario, death. Pre-eclampsia, moderate pre-eclampsia, and severe eclampsia are all examples of maternal hypertensive disorder, which includes pre-eclampsia, mild pre-eclampsia, and severe eclampsia. These disorders are produced by a variety of factors in the human body, including sedentary lifestyles, inappropriate diets, such as excessive fat consumption, and stress as a result of continual strain in completing one's obligations and goals. As a result, a pregnant woman with any hypertension disease may result in maternal mortality, neonatal death, stillbirth, and intrauterine fetal death if correct medical treatment is not provided (Kidanto *et al.*, 2009).

Pre-eclampsia is a pregnancy-related disorder that affects 3–5% of expectant mothers. When a pregnant woman has high blood pressure and proteinuria, it is often identified. Pre-eclampsia is a prominent cause of maternal, fetal, and neonatal mortality, especially in low- and middle-income countries. In 2014, the International Society for the Study of Hypertension in Pregnancy (ISSHP) changed the pre-eclampsia diagnostic criteria. According to the International Society of Pregnancy, pre-eclampsia is defined by de novo hypertension after 20 weeks of pregnancy, proteinuria (>300 mg/day), and other maternal organ dysfunction, such as renal insufficiency, liver involvement, neurological or haematological complications, uteroplacental dysfunction, or fetal growth restriction. Other causes of proteinuria (>300 mg/day) include renal insufficiency, liver involvement, neurological or haematological issues,

uteroplacental dysfunction, or fetal development restriction. Proteinuria is no longer required in the new categorization; hence protein uric pre-eclampsia and non-protein uric pre-eclampsia are now two separate diseases (Fu *et al.*, 2019).

Pregnant women in developed countries can contact a gynecologist, whereas in developing or low-income countries, especially government hospitals, it is difficult for women to get service from medical personnel or specialists because most of them are overworked and work in shifts, resulting in most women receiving medical attention from nurse attendants who are not well-versed in pre-eclampsia management. In comparison to what is happening in industrialized nations, experts and other medical staff are less inclined to handle random calls from all women who may have any issues surrounding their pregnancy owing to their hypertension condition. Private health facilities, on the other hand, are in a different predicament since the majority of individuals in low-income nations cannot afford to pay for their services (Lai *et al.*, 2016).

In this study, an Internet of Things which is a cheap technical solution is described, proposed, and supplied for the vulnerable issue of maternal and neonatal health in Tanzania for pregnant women diagnosed with moderate pre-eclampsia. This solution focuses on providing an enhanced and user-friendly technique for measuring and recording the unborn baby's Fetal Heart Rate, the mother's temperature in relation to the ongoing COVID-19 epidemic, and a GPS position for the device since the pregnant lady will use it from her home.

1.2 Statement of the problem

Due to the fact that only women with Servia pre-eclampsia are hospitalized to be intensively watched by medical staff, the current standard of treatment in Tanzanian health facilities for pregnant women diagnosed with mild pre-eclampsia lacks continuous monitoring of fetal heartbeats and fetal movements. This increases the risk of stillbirth for women diagnosed with moderate pre-eclampsia who monitor themselves at home, leading the frequency of stillbirths after 28 weeks gestation age (GA) to climb. Because only women with Servia pre-eclampsia are hospitalized and closely monitored by medical personnel, the current standard of care for expecting mothers in Tanzania is offered during prenatal checkups, which are scheduled once a month during the perinatal period. Women with pre-eclampsia who monitor their unborn child at home are more likely to have a stillbirth as a result of this.

In Tanzania's health facilities, both inpatient and outpatient therapy comparing the proportion of women diagnosed with moderate pre-eclampsia to those diagnosed with severe pre-

eclampsia both groups of women get anti-hypertensive pharmacological therapies, and blood pressure monitoring in relation to antenatal clinic visit schedules. During prenatal checkups, the unborn child is cared for by utilizing a fetoscope to monitor fetal heart rate and movement. When women are at home, according to health personnel's instructions, fetal heart rate (FHR) is monitored by whether the unborn child is kicking; however, this is done manually by the mother listening to their unborn child's kicks and charting on a piece of paper from home, and the record trail is verbally reported to medical personnel during their antenatal visits in most cases. Because there is no accurate way to monitor the fetal heart rate, which is a cause of most intrauterine fetal deaths and stillbirths, this has been a severe risk for women with hypertension (Tlaye *et al*., 2020).

Childbirth is considered as a normal physiological operation; but, in low-income countries (LIC) (Massawe *et al*., 2018). A woman's hypertension puts her and her unborn child at greater risk of death, increasing the danger to both. More than 99 percent of all baby deaths occur in low-income countries (LIC), with a scarcity of competent staff, required equipment, and resources, including pharmaceuticals, being key contributing causes. The Fetal heart rate monitoring device, which is currently in use is the fetoscope, which does not provide readings of the pulse rate and is commonly used, and the doppler machine, which is expensive and rarely available to the majority of Tanzanian health facilities, but these devices are also only available in health facilities and not in the homes of pregnant women. Due to a lack of FHR monitoring at home, this increases the chance of stillbirth.

To increase the safety of the unborn kid, the fetal heart rate monitoring process must be improved remotely. The remote fetal heart rate monitoring technology must be improved in order to increase the safety of the unborn kid.

1.3 Rationale of the study

The development of fetal heart beat rate monitoring support device aims to provide a safe pregnancy journey and the unborn child’s safety with respect to the pregnant woman’s health conditions during the time of pregnancy. This device will help provide awareness on the necessity of continuous monitoring of fetal heart rate and movements in the low-income countries and avoidance of avoidable still births and neonatal deaths with the help of health workers who will be able to manage medical conditions with respect to their patients’ vitals history from the fetal heart rate support system of the developed device. The realization of the

fetal heart rate device is also aimed at utilizing technology of embedded systems to improve efficiency of sensing body vitals, increase comfortability and safety for pregnant women with hypertensive conditions during their pregnancies which is common for majority of women during their first pregnancies.

1.4 General objectives

1.4.1 Main objectives

To design and develop a fetal heart beat rate monitoring support device for pregnant women diagnosed with mild pre-eclampsia/hypertension in Tanzania.

1.4.2 Specific objectives

(i) To review and identify requirements for developing fetal heart beat rate monitoring support device for pregnant women diagnosed with mild pre-eclampsia/hypertension in Tanzania

(ii) Design and development of the fetal heart beat rate monitoring support device.

(iii) To test and verify the fetal heart beat rate monitoring support device system performance.

1.5 Research questions

(i) What are the current methods utilized in low- and middle-income countries' health facilities to monitor fetal heart rate for pregnant women with maternal problems such as hypertension disorders while they are at home?

(ii) What is missing or lacking in the currently used devices (fetoscope) and methods to monitor the fetal heart rate for pregnant women in Tanzania?

(iii) Is the current method affordable and user-friendly for pregnant women to use from home for monitoring their unborn child's pulse rate? And where can improvement be made on the currently existing methods of monitoring fetal heart rate?

1.6 Significance of the study

The consistency and successful accomplishment of implementation and adaptation of the results from this research are likely to contribute to the following.

(i) This study will reduce the number and eventually avoid stillbirths, neonatal deaths and intrauterine fetal death caused by pregnant woman's hypertensive condition during 28+ weeks of gestation age during pregnancy and before delivery.

(ii) Avoid stillbirths, neonatal deaths, and intrauterine fetal death caused by lack of their fetal heart rate monitoring as pregnant women are in their area of residence and away from health facilities.

(iii) This study provides improvement and advancement with the working procedures for medical personnel by remotely monitoring the unborn child's wellbeing to excel the maternity department in Tanzania health facilities

(iv) In the implementation of this study, it avails raise of awareness to the community and women in Tanzania on the importance of continuously monitoring the fetal heart rate for pregnant women who have been diagnosed with mild pre-eclampsia

1.7 Delineation of the study

This research focuses heavily on the requirements of pregnant women diagnosed with mild Pre-eclampsia in low- and middle-income countries which is a serious health problem. To improve their unborn child's wellbeing and ensure safety during delivery, pregnant women physically seek medical personnel's care in health facilities because, in the event of an anonymous situation at home involving the unborn child, pregnant women physically seek medical personnel's care in health facilities. Because of the current COVID-19 epidemic, pregnant women are one of the specific populations who must take all necessary precautions to avoid infection.

Background information was presented in this chapter, along with the issue description and the key goals and objectives for developing a fetal heart beat rate monitoring device for pregnant women diagnosed with mild pre-eclampsia and temperature monitoring in connection to an on-going COVID-19 pandemic. As detailed in this chapter, the study's primary focus and its

predicted significance are highlighted. In the previous chapter, a comprehensive literature review was conducted for this project.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter goes into detail on the review of historical and current strategies for outpatient and inpatient care of fetal heart r

ate monitoring for pregnant women in Tanzania who have been diagnosed with moderate pre-eclampsia. This chapter's principal objective is to raise knowledge of the current methodologies and technologies used and their availability and robustness. At this stage of the research, some of the needs have been collected so that a foundation of knowledge may be built on strengths and limitations in order to repair them while building the system.

2.2 Maternal and neonatal mortalities review

According to the World Health Organization, there were around 2 million stillbirths worldwide in 2019. If adequate treatment had been available, many of these may have been avoided. There were 13.9 stillbirths per 1000 total births in the previous year, according to the most recent available data. A stillborn kid is born every 16 seconds or one in every 72 live births. Although stillbirths are often underreported, they are not unheard of. As a consequence, it's possible that this figure is inflated (Massawe *et al.*, 2018).

If you're experiencing mild pre-eclampsia before 37 weeks, you may benefit from prenatal or outpatient therapy, which has been shown to extend your pregnancy by a median of more than 11 days, depending on when you begin treatment. There were 1659 stillborn children born to KCMC Hospital moms throughout the course of the study's five-year span, including 1472 who had a stillbirth at 28 weeks or later and 187 who experienced a repeat stillbirth (Chuwa *et al.*, 2017).

2.3 Cardiotocography

According to the research Fetal movements as a predictor of health, cardiotocography (CTG) and Fetal heart rate variability (FHRV) are modern technologies used to monitor Fetal heart rate but are only available in health facilities. Data from 3816 Tanzanian women and 8305 Ugandan women were collected for the study. When compared to postpartum poor outcomes,

In Uganda and Tanzania, women who had an intrapartum near-miss had a 3.73-fold and a 4.55-fold increased risk of stillbirth, respectively (Lai *et al*., 2016).

The majority of women who had a near-miss were already suffering from organ dysfunction before they arrived, or they acquired it shortly after they arrived. Caesarean sections in Tanzania and Uganda had a 42 % and a 59 % decreased risk of stillbirth after intrapartum non-near-miss adverse events, respectively, but preterm births had a greater risk.

In this research, the perinatal outcome of preeclamptic women was divided into two categories: alive and deceased. There were three sets of independent variables: the patient's age and place of residence; the patient's gestational age (at admission and delivery); the patient's prenatal follow-up (for the current pregnancy); and the patient's current medical history (comorbidities) (Massawe *et al*., 2018).

Aside from perinatal factors like intrapartum fetal heartbeat, APGAR score, and birth weight, treatment options include antihypertensive drugs, ant convulsion medications, as well as the mode of delivery. There are also perinatal factors such as intrapartum fetal heartbeats, APGAR scores, and birth weights. There are also peripartum factors such as intrapartum Fetal heartbeats, APGAR scores, and birth weights.

The Fig. 1 displays the rate of neonatal difference of 88.9% and 74.1% for mild preeclampsia and severe preeclampsia respectively, the neonatal deaths caused by severe condition is low compared to the mild condition of preeclampsia.

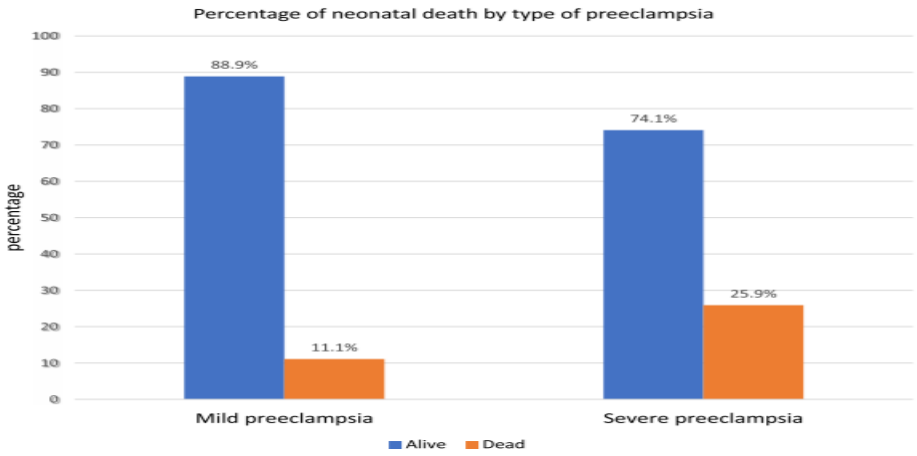


Figure 1: Percentage of neonatal death by type of preeclampsia

The current study investigated at the viewpoints and experiences of competent delivery attendants who utilized an electronic FHRM monitor called the Fetal stethoscope. The research participants thought a fetal stethoscope was a useful tool for increasing FHRM. The use of the Fetal stethoscope was hampered due to a lack of understanding about how to correctly use the equipment. The use of a fetal stethoscope appears to be impacted by the conditions in which it was used (Mdoe *et al*., 2018).

2.4 Fetoscope device used for fetal heart rate measuring

The fetoscope (Fig. 2) is widely used in all health facilities in Tanzania, both rural and urban, because it has made it easier for health facility workers to detect fetal heart rate in pregnant women; however, it is not exactly accurate because it cannot provide readings other than the health worker's approximation (Plotkin *et al*., 2020).

Figure 2: Fetoscope

A fetoscope has been used to monitor the fetal heart rate for all women, with and without pregnancy difficulties, which is unjust and puts women with pregnancy issues, such as high blood pressure and low blood pressure, at danger of stillbirth (Kamala *et al*., 2018).

2.5 Fetal heart rate monitoring

The image in Fig. 3 shows how a health facility worker uses a fetoscope to detect the fetal heart rate from a pregnant woman's tummy. There is no reading per hour or minute for the fetal pulse rate here. In most circumstances, it is to check that the baby is alive, however it does not offer information if the baby's pulse rate is lower than prior visits or if the unborn infant requires rapid medical assistance, such as early delivery (Plotkin *et al.*, 2020).

Figure 3: A midwife erforming fetal heart rate monitoring using a fetoscope (Kidanto *et al.*, 2012)

In recent years, when the fetal doppler equipment was suggested in multiple studies and with reference from industrialized nations, certain private hospitals, as well as religious referral institutions and at least one big government hospital in a few locations, have begun to use it (Kidanto *et al.*, 2012).

In Tanzania, studies have found that intermittent FHR auscultations with fetoscopes are not carried out in accordance with guidelines, which may result in avoidable neonatal deaths and sickness. Based on these insights, a new low-cost free-play Doppler was created to fulfill the demands of rural communities, there have been trials of our free-play Doppler fetoscope in Uganda and Tanzania, where we have a small rural hospital. Even while the free play Doppler arm of the Ugandan study detected more FHR abnormalities, this did not translate into improved perinatal outcomes. While aberrant FHR detection was comparable between the Pinard fetoscope and the free play Doppler, midwives often broke the randomization process by utilizing the Pinard fetoscope instead of the Free play Doppler in this research. For the last

five years, a Safer Births effort has been in place that aims to improve FHR monitoring and neonatal CPR (Kidanto *et al*., 2009). Because they have been witnessing all births since 2009 and documenting the most often used device for each woman, the research assistants in this experiment have found that the Pinard fetoscope was preferred by the majority of midwives regardless of the randomization arm.

From March 2013 to August 2015, a randomized control trial compared the Pinard fetoscope with the Free-Play Doppler for intermittent FHR monitoring. Hospital (HLH), a rural referral hospital in northern Tanzania, was the site of the data collection. More than 2 million people are served by the wider reference area, which includes the hospital's population of around 500,000 people and the surrounding area. Obstetricians do surgical deliveries, whereas midwives handle the more routine ones (Mdoe *et al*., 2018).

The accompanying midwife often uses a Pinard fetoscope to monitor FHR. The wind-up hand-held Free-Play Doppler was used in this experiment. Every six months, all midwives and physicians were retrained on how to use the Doppler and were given information about aberrant FHR patterns and the obstetric treatment that goes along with them. It was permitted for use by midwives (Hlongwane *et al*., 2021).

In 2015, there were an estimated 1.3 million stillbirths in the womb, which is a global concern. The bulk of them were found in settings with minimal resources and no access to intrapartum fetal cardiac monitoring devices. There was a correlation between the frequency of abnormal Fetal heart rate (FHR) detection and poor neonatal outcomes in this research (Lai *et al*., 2016).

2.6 Electronic Doppler machine for fetal heart rate measuring

Studies conducted in Tanzania have shown irregularities in the use of fetoscopes for intermittent FHR auscultation, which may lead to the death or sickness of unborn children. In response to these findings, a new Free play Doppler was designed specifically for rural areas. In our remote Tanzanian hospital, a Pinard fetoscope was randomly compared to this Doppler (Kamala *et al*., 2018).

They also demonstrated a strong sense of teamwork and camaraderie among themselves in order to avoid being held accountable for poor Fetal outcomes and the repercussions that accompany them. We suggest that a lack of resources to offer appropriate labor care, along

with a fear of being blamed for and dealing with a bad Fetal outcome, would lead to high levels of stress, adversely compromising patient care.

According to a comprehensive assessment, burnout is fairly widespread among healthcare workers in nations with a low and moderate income. Participants in the study reported feeling more at ease while using a Fetal stethoscope since they knew the alarm would alert the delivery attendants if there was Fetal distress, as well as an overall sense that the instrument made their work easier.

Intermittent Doppler monitoring was shown to have a greater chance of detecting abnormal FHR than the Pinard method. Subgroup analysis showed that neonates with abnormal FHR delivered vaginally in the Doppler group had better perinatal outcomes than those delivered by Pinard. The time elapsed between when an abnormal FHR was discovered and when the baby was born was lengthy in both groups. Previous study from Kampala and Harare has shown that the Doppler detects more FHR problems than the Pinard Fetal stethoscope, which is consistent with our results. Although the Doppler technique boosted the detection of FHR problems, the perinatal outcome remained unchanged in the Kampala trial, which is consistent to our overall result. One theory is that the absence of prompt steps to deliver the newborn is due to several contextual limits in low-resource conditions. In addition, the high patient-to-worker ratio in the labor and delivery department and the fact that many patients are waiting for an emergency caesarean section at the same time are among these limitations (Kidanto *et al.*, 2009).

It was conducted from March 2013 to August 2015 using randomization to compare intermittent FHR monitoring with the Pinard fetoscope and the Free-Play Doppler. The data was gathered at the Haydom Lutheran Hospital (HLH), a rural referral hospital in northern Tanzania. The hospital serves a population of around 500 000 people and provides comprehensive emergency obstetric care and basic baby care to a nearly 2-million-person region. Physicians on call 24 hours a day, seven days a week are more likely to do surgical births than midwives. A Pinard fetoscope is traditionally used by the visiting midwife to check for fetal heart rate variability (FHRV). This project introduced the wind-up hand-held Free-Play Doppler. As a part of their first training, all midwives and physicians were also given information regarding abnormal FHR patterns and associated obstetrical therapy. Even though the delivery wasn't part of the study, midwives were permitted to utilize Doppler if it was available.

Severe pre-eclampsia (PE/E) has been linked to considerable mother and infant morbidity and mortality in Tanzania in 2016, according to research conducted in Dar es Salaam. Pre-eclampsia may be prevented if it is diagnosed and treated early enough. Preventing morbidity and mortality from PE/E requires the administration of anticonvulsants and antihypertensives immediately (as part of emergency obstetric and neonatal care). Analysis of Dar-es-Salaam health facilities' competence to handle PE/E is the goal of this research.

Public health clinics in Dar es Salaam that offer reproductive and child health care undertook descriptive cross-sectional study. Among the medical facilities were four hospitals, three health clinics, and 23 dispensaries. The availability of equipment, supplies, and drugs was checked using a checklist, and healthcare workers were interviewed using a standardized questionnaire to gauge their knowledge of PE/E risks, symptoms, and treatment options. Percentages are used to express the results.

However, only 39% of pharmacies had access to standard protocols for treating patients with PE/E. Even though all facilities had functional blood pressure monitors and stethoscopes, only one hospital (25 percent) and nine dispensaries (39 percent) had urine test strips for detecting protein in the urine. All medical facilities offered anticonvulsant medicines. Magnesium sulphate, the first-line prescribed anticonvulsant, was only available in a fifth of the pharmacies. One-quarter of the dispensaries sold antihypertensive nifedipine, whereas hospitals and health centers had 75% and 100% availability of methyldopa, respectively. Hydralazine, an antihypertensive drug, was available in 50% of hospitals, 33% of health centers, and 8% of dispensaries. It was found in just one hospital and one health facility.

All the risk factors, symptoms, and drugs used to treat hypertension and convulsions in PE/E were well-understood by healthcare providers. In terms of understanding risk factors, symptoms, and medications, doctors had a leg up over their counterparts in the nursing and clinical fields. Patients with PE/E were prescribed magnesium sulphate as a treatment for convulsions by the vast majority of healthcare professionals (Mol *et al.*, 2016).

There is inadequate screening and treatment of PE/E because of a lack of equipment, supplies, and drugs. Pre-eclampsia is well-understood by medical professionals, who are familiar with risk factors, symptoms, and medicines. For the treatment of women with PE/E, this needs a greater supply of equipment, supplies, and drugs. Women with PE/E need ongoing education for healthcare providers in order to ensure appropriate treatment (Tlaye *et al*., 2020).

Data from past studies show specialists preferring the fetoscope over the Doppler. It is essential that assessments be performed correctly, findings are correctly interpreted, and the interpretation prompts appropriate and timely responses for FHR monitoring to be successful. The midwives' appraisal of the FHR monitoring device is critical to correct FHR monitoring, interpretation, and action. Providers should feel secure in their ability to discuss and make judgements about the data since these specialists selected a device that consistently generates consistent results. An examination of eclampsia patients' hospital treatment in a low-income country revealed significant shortcomings that must be addressed if the health of the mother and fetus is to be improved. Most of these improvements may be made without spending any more money. In this urban tertiary facility, this was the first time that eclampsia patients' care had been analyzed for areas of weakness. We were tasked with comparing current practices to the defined standard at this point in the audit cycle. The audit's next step is to assess how well the intervention has worked.

There were 389 cases of eclampsia among the 7667 newborns studied over the time of the study. The typical case of eclampsia was that of a young primiparous mother. Eclampsia was found in 184 (47%) of the 389 cases, whereas intrapartum was seen in 159 (41%) and postpartum in 46 (12%). 73 percent of antepartum eclampsia cases were preterm, but 61 percent of intrapartum and 71 percent of postpartum eclampsia cases were at term. There had been an average of two seizures (ranging from one to 12) before to admission. It was estimated that 5.1 percent of all hospitalized moms had eclampsia (Tlaye *et al*., 2020).

Between July 2000 and October 2010, the Kilimanjaro Christian Medical Centre (KCMC) in northern Tanzania recorded a total of 58 stillbirths and early infant deaths with a birth weight more than 500 grams in its Medical Birth Register and newborn register. Classification of Neonatal and Intrauterine Deaths according to Ethology (NICE).

Perinatal mortality was 57.7% per 1000 births (1958 out of 33 929), with 1219 stillbirths (35.9%) and 739 early neonatal deaths (21.8%). Unexplained asphyxia (n=425, 12.5/1000), obstetric problems (n=303, 8.9/1000), maternal illness (n=287, 8.5/1000), unexplained antepartum stillbirths after 37 weeks of gestation (n=219, 6.5/1000) were the leading causes of perinatal mortality and unexplained antepartum stillbirths before 37 weeks of gestation (n=184, 5.4/1000).

Obstructed/prolonged labor was the most prevalent obstetric issue (251/303, or 82.8%). There were 253 cases of pre-eclampsia and 287 cases of eclampsia, which accounted for 88% of all maternal illnesses. When women hospitalized to the KCMC for delivery for medical reasons were eliminated, perinatal mortality dropped to 45.6/1000. (19.1 percent of all births and 36.0 per cent of all deaths). Pregnancy-related deaths fell from 8.9 per 1000 live births to 2.1 per 1000 live births, with maternal conditions falling from 8.5 per 1000 to 5.5% per thousand live births.

Women with mild preeclampsia and medical staff will benefit from the proposed solution because it will make the entire process of tracking the movement of their fetuses more efficient and accurate because the tracking will be done automatically to prevent inaccurate information about the fetus' health. However, more sophisticated monitoring of fetal heart rate and movement is long overdue in order to protect the health of both the unborn child and the pregnant woman with hypertension (Mol *et al*., 2016).

Figure 4 shows an image of a doppler machine currently used in modern health facilities in Tanzania and it can display values and record trail or link of the device the hospital systems to keep track of the reading on visits biases.

Figure 4: Doppler Machine

A modest number of people were interviewed for a research. However, few professionals work at the national policymaking level on intrapartum care supply as given by the Government of Tanzania's health-care system. Furthermore, there was a high level of agreement/saturation in the responses, leading to the conclusion that the number of respondents was sufficient to achieve saturation.

This analysis of the usage of Doppler for FHR monitoring does not include a discussion of the optimum forms of Doppler for Tanzania's needs. It was accepted that there are several types of Doppler equipment, and more research would be required to determine which technologies are most suited for use in Tanzanian health care settings. Although this study focused on environmental factors related to the expansion of Doppler for FHR monitoring in Tanzania, community, facility, and individual-level factors are also significant. More research is required in these areas (Kamala *et al.*, 2020).

2.7 Fetoscope vs. Doppler Groups: Infants' outcomes

Figure 5 shows while using the Pinard fetoscope and the Free-Play Doppler, this study found no significant differences in the identification of FHR abnormalities and 24-hour neonatal outcomes.

Outcomes	Fetoscope *n* = 1375	Doppler *n* = 1309	Effect measure[a]	*p*-value
FHR abnormalities	49 (3.5)	66 (5.0)	1.42 (0.98, 2.03)	0.064
Abnormal FHR	42 (3.1)	56 (4.2)	1.38 (0.93, 2.04)	0.109
Not measured FHR	7 (0.5)	10 (0.7)	1.5 (0.57, 3.93)	0.40
Time interval admission to first abnormal FHR assessment (minutes)	520 ± 386	429 ± 321	90.2 (−63.9, 244.3)	0.248
Time interval abnormal FHR to birth (minutes)	90.8 ± 122	95.1 ± 132	−4.34 (−58.2, 49.5)	0.873
Time interval last recorded FHR to birth (minutes)	79.1 ± 185	79.5 ± 188	−0.43 (−14.6, 13.8)	0.952
Cesarean Section	286 (20.8)	273 (20.9)	1.00 (0.87, 1.16)	0.972
Bag mask ventilation	82 (6.0)	80 (6.1)	1.03 (0.76, 1.38)	0.872
Apgar Score < 7				
1 Minute	46 (3.3)	43 (3.3)	0.98 (0.65, 1.48)	0.921
5 Minutes	11 (0.8)	10 (0.8)	0.95 (0.40, 2.24)	0.914
Adverse perinatal outcome	35 (2.5)	32 (2.4)	0.96 (0.59, 1.54)	0.867
Fresh stillbirths	4 (0.3)	3 (0.2)	0.78 (0.17, 3.51)	0.527
Early neonatal deaths	5 (0.4)	9 (0.7)	1.89 (0.63, 5.63)	0.244
Admitted neonatal area	26 (1.9)	20 (1.5)	0.81 (0.45, 1.44)	0.475

Figure 5: Outcomes of the Infants in the Fetoscope versus the Doppler Groups (Kamala *et al.*, 2020)

Many other notable discoveries on intermittent FHR monitoring as well as substantial issues with performing a randomized trial in this distant setting have been identified, however.

Figure 6 show the clear image of a doppler machine with the gel tube to be used by medical personnel while probing on a pregnant woman's stomach to obtain reading of the fetal heart rate, If the health center is out of gel, the procedure cannot be performed.

Figure 6: A doppler machine with a gel

To diagnose abnormal FHR, Doppler was roughly 1.4 times more accurate than the fetoscope. Although this was little, it was a type 2 error. In addition, our study found a lower incidence of abnormal FHR detection in both arms compared to previous studies of similar designs. Premature births were decreased by 32 percent when compared to the Pinard fetoscope, a conventional Doppler equipment.

To the fullest extent possible, this chapter examined the statistics on maternal and neonatal mortality, as well as the techniques and technology now being used to monitor the fetal heart rate and to treat hypertensive patients both in the hospital and in the outpatient setting. There are restrictions and challenges. Fetal heart rate support device will be built using various hardware and software technologies in the next chapter.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

Requirement identification and analysis are carefully specified as well as the materials utilized in the design, development, implementation of, and testing of the Fetal heart rate support belt for women diagnosed with mild pre-eclampsia in Tanzania, which include hardware components and software. In order to address the research challenges highlighted in the introduction chapter, this is done in the order that examines the existing techniques in Tanzania for fetal heart rate monitoring. In-depth explanations are provided on everything from why the technology was suited for this system to how it was carried out in order to achieve the desired goals of a well-functioning fetal heart rate system

3.2 Study area and scope of the research project

These research activities took place in the Kilimanjaro Clinical Research Institute in Tanzania's Kilimanjaro area, with the primary goal of acquiring knowledge, prerequisites, and guidelines for conducting a clinical trial. Kilimanjaro Clinical Research Institute is situated in Tanzania's northeastern region.

3.3 Development approach

The fetal heart rate monitoring belt support system was created utilizing a mix of prototype and agile methodologies, iteratively and incrementally, with a major emphasis on process adoption, user safety, and timeliness, and built on a foundation of the conventional system development lifecycle. This approach to project development enables gradual and progressive system development, as well as user interaction throughout the process, resulting in a stronger ability to meet user needs.

The Agile system development life cycle was selected because it is self-contained; each phase should be self-evaluable. As a consequence, it should be as independent as possible from external factors. Negotiable, a compelling tale should be debated and co-created by the developer and the customer. The customer must feel the story is worthwhile. As a consequence, if the developers run into difficulties, they must explain them to the client in an understandable

and straightforward way. To produce a preliminary estimate, the project needs enough information to determine what the stages require.

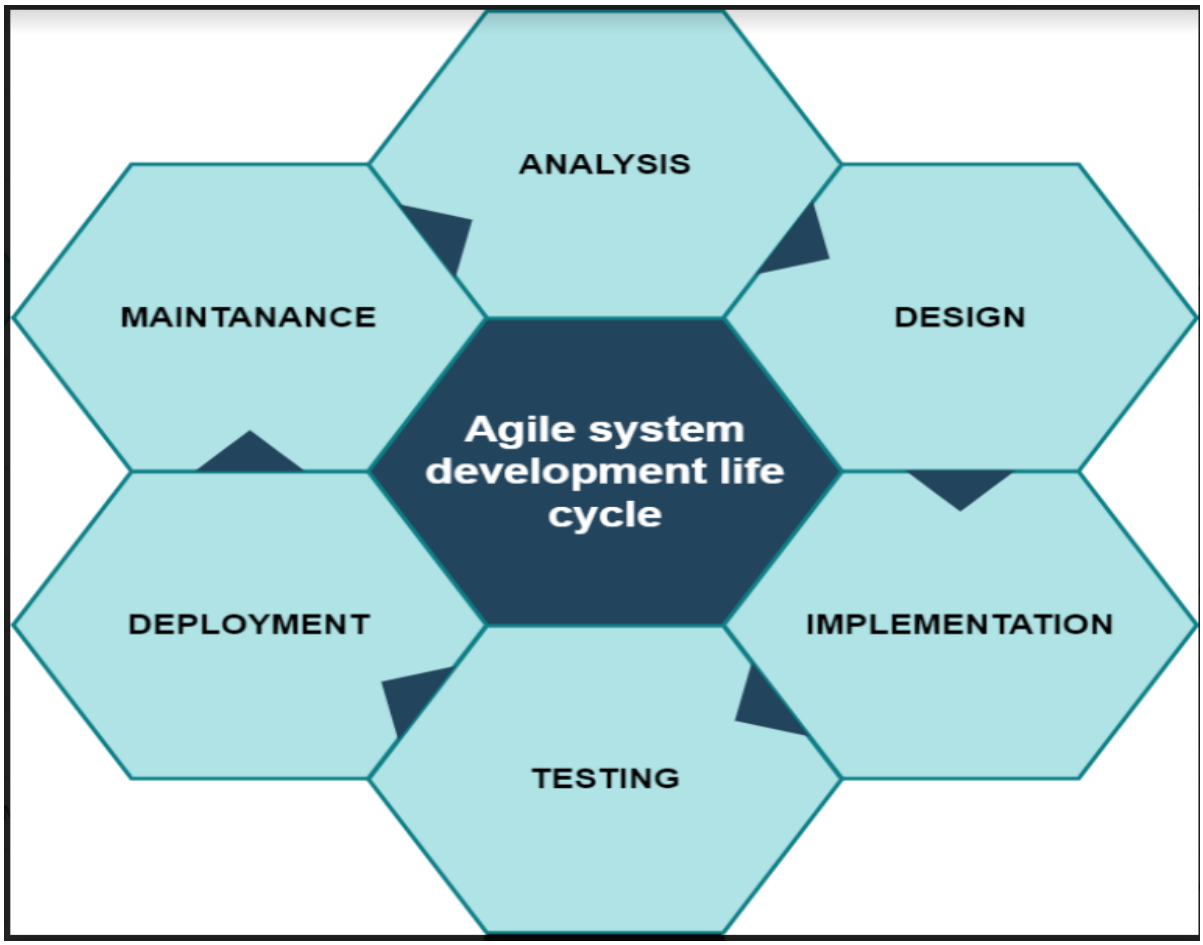


Figure 7: Agile system development life cycle

3.3.1 An illustration of the Agile system development life cycle

These estimates should provide the end user an idea of what to anticipate. If the tale is lengthy, the engineers may choose to divide it in order to get a more precise estimate. Smaller phases are simpler to forecast, and as previously said, if a plot becomes too vast, it may be separated. Understanding what to test in a system displays an in-depth understanding of the project. Additionally, it proves that it adds true value to the end user.

3.3.2 Data collection methods

The data for this research project were gathered through a review of previously published literature on Fetal Heart Rate Monitoring in Developing Countries, observation of standard operating procedures in an antenatal clinic at Kilimanjaro Christian Medical Center in

collaboration with the Kilimanjaro Clinical Research Institute, where I was enrolled and conducting my internship, and a survey questionnaire for pregnant women regarding their perceptions of antenatal care.

The previously mentioned mixed method yielded data that was both qualitative and quantitative in nature. We developed questionnaires and interview questions, and answers were compiled on a form response sheet to analyze quantitative characteristics. The data collection methodologies recommended for this research study are summarized below.

(i) Document review

A document evaluation was conducted by reading a large number of diverse publications and existing documentations pertaining to Fetal Herat rate monitoring in underdeveloped countries, notably Tanzania. This was done to obtain a better knowledge of the present methods for fetal heart rate monitoring, their benefits and limits, and to see where there is space for development. The primary technique was to collect concreate information in order to construct a fetal heart rate monitoring support system that would benefit and protect pregnant women with moderate pre-eclampsia.

(ii) Observation

During my internship at the Kilimanjaro Clinical Research Institute, I was assigned to visit pregnant women's Prenatal clinics to observe their standard operating procedure for antenatal planned appointments. The primary goal was to study and comprehend their inpatient therapy of pregnant women with moderate pre-eclampsia. The study was carried out at the infertility clinic, the antenatal clinic, and the postnatal clinic. All of this was done on different days of the week in order to provide women with safe and high-quality health clinic services.

(iii) Survey questionnaires

A google form questionnaire was constructed and utilized to collect answers from different ethnic groups of a hundred women in Tanzania in order to better understand women's perceptions about prenatal health. This was an alternative to a paper-based questionnaire in order to save money and avoid violating the COVID-19 safety standards. The questionnaire was divided into three pieces. The first segment was intended for all women. It included three questions that were used to divide the ladies into two groups based on their responses. The

second portion was for women who have children or who have been pregnant in the past. There were fourteen questions in this section. The third division was for women who had never been pregnant and did not have children. This portion included six questions designed to elicit information about these women's knowledge of pregnancy safety and complications. This amounts to a total of twenty-three questions. In general, all women were asked about their feelings concerning the fetal heart rate monitoring support belt.

(iv) Interviews

Interviews were done to learn about medical personnel's perspectives on designing a fetal heart rate monitoring support belt for pregnant women with moderate pre-eclampsia. The interview questions were developed, and 10 doctors were questioned. A total of fifteen questions were written, and all of the interviews were conducted over the phone. Medical professionals' views were both critical and very encouraging in the development of the fetal heart rate monitoring support belt, which was designed to reduce the risk of stillbirth in pregnant women with mild pre-eclampsia.

(v) Desktop research and benchmarking

This entailed examining and re-analyzing historical and present data regarding the existing methods for fetal heart rate monitoring in all low- and middle-income countries' health facilities. Identifying the limits and downsides of existing techniques, as well as attempts to produce a better approach and inventive solution to the existing restrictions. The statistics on infant mortality and maternal mortality due to high blood pressure in pregnancy were reviewed in order to understand and maintain track of it.

3.4 Requirement analysis

3.4.1 Functional requirements

The functional requirements are the functions that the system or device must be able to accomplish in the absence of physical restrictions. It specifies the proposed system's input and output behavior. They are also known as the qualities that the final product of the intended work must have and explain the system's non-behavioral features.

Table 1: Functional requirements

Functional requirements	Description
The system and the device shall measure and monitor body temperature, GPS location, Fetal heart beats, mother's pulse rate and oxygen saturation level	The data collected, which are body temperature, GPS location, Fetal heartbeats, mother's pulse rate and oxygen saturation level and shared to the system, will be accessed by medical personnel in real-time.
The device shall send data to the Blynk application	For the woman to read in real-time the data from the device collected by the sensors with which it is embedded, the Blynk app will be a part of the actuation.
The device's screen display data	The screen shall display data harvested by the sensors in real-time as the pregnant woman has worn the device.
The device shall send information timely via text message to the pregnant mother	The device shall send information timely via text message to the pregnant mother, and that will save as a trail after she has received a serval number of texts with respect to the number of times, she has worn the device.
Add medical personnel, and they add patients	Add medical personnel, and they add patients who are pregnant women with the devices they have been assigned.

3.4.2 Non-functional requirements

Non-functional system requirements establish the limitations that a developer and engineer must adhere to during the design, development, method for measuring fetal heart rate. A thorough explanation of how the fetal heart rate monitor works in conjunction with the newly developed technology is provided here

Table 2: Non-functional requirements

Non-Functional Requirement	Description
Security	The system and the users shall use authentication that is a username and highly protected passwords before access is granted.
Robustness	The system and the device shall be able to recover from any form of failure in case of any inconveniences with the software or the hardware part.
Usability	The system and the device are all easy to use for both pregnant women and medical personnel.
Availability	The device will be available in health facilities, and it will prescribe to pregnant women with respect to the doctor's review of their progress.
Performance	The system and the device shall process the required data from the sensors and communicate and share information to be passed accordingly.

3.4.3 Design cycle

The design cycle in this project research included four dynamic system development process lifecycles: system requirements analysis, functional model iterations, design and build, and implementation. The dynamic system development approach is a quick application development method for dynamic systems, notably information systems, that is intended to reduce excessive project development and implementation costs, poor quality, and delays. The emphasis on collaboration between medical experts, pregnant women, and administrators led to the decision to employ the dynamic system development technique in this project research. The whole system and gadget will be built to meet the functional and testing requirements.

3.4.4 System modeling

The management of the system and the sensors modeling were used to describe the functions of the process while decreasing the complexity of the descriptions in the creation of the fetal heart rate support belt for pregnant women diagnosed with moderate pre-eclampsia. Each process involved in system development was examined in terms of how it operates, interacts with other processes, and produces the desired outcome. The following are the systems modeling approaches employed in this study.

(i) Circuit diagram

A circuit diagram is a graphical depiction of an electrical circuit. The electronic circuit depicts how various electronic components are electrically linked. In this project, research was used in the design and development of the data acquisition unit, also known as the sensing unit, which has several sensors each collecting a different type of data and also includes a microcontroller, sensors, actuators, and other transducers with different electrical characteristics. The circuit diagram was created using proteus IDE software, which is easily accessible and user-friendly, and it is mostly and widely used for the creation of electronic circuit diagrams. It is open-source software that is available both online and offline, and it greatly supports engineering process design activities.

(ii) Flow chart diagram

When it comes to visualizing algorithms, a flow chart is a plain and easy way to show how algorithms work. It uses shapes and arrows to show how activities flow step by step toward the desired outcome. These diagrams were used to develop decision algorithms that were used not only to read and transport sensor data over the network, but also to analyze the sensor information to check whether it complies with the specified standards values.

(iii) Use case diagram

The use case diagram depicts how the system actor interacts with the system and the device in order to meet the functional requirements. As a means of illustrating an actor's relationship to his or her environment, it is used in the creation of computer animations. When it comes to this project research, the benefits of adopting the use case diagram as a design technique have been highlighted, including the fact that it assures accurate and explicit capture of system functional requirements while also being very simple to build and comprehend for system users. When it comes to complex applications and systems, it is used for real-time management.

(iv) Data flow diagram

Using a data flow diagram, you may show how a system's logic is supposed to work in practice. Using this diagram, you can see how data travels from one location to another and finally ends up in a storage device. Diagramming the system's interrelationships between devices and the

system, as well as establishing a clear channel for data to travel are main goals of data flow diagrams.

(v) Context diagram

There is just one process in the system context diagram, often referred to as a data flow diagram level zero, which depicts the whole system and establishes its context and constraints. It shows how the system communicates with external entities. For the most part, context diagrams are part of requirements documents. All project participants must read it, thus it should be written in plain language so that they can understand the components. External components and events should be considered when developing a complete set of system needs and constraints, and this is where the system context diagram comes in.

3.5 System development tools and technologies

3.5.1 Software environment and libraries

There are a number of software tools and environment used to developing the fetal heart rate support system explained in detailed towards developing system to interact with the device.

(i) Hypertext Markup Language (HTML)

Hypertext Markup Language is a very basic language composed of components that may be applied to text to give it varied meanings in a document structure, divide a document into logical sections, and embed information such as photos and videos into a website. The HTML was utilized in the design and development of this project, together with CSS and Python, to construct a web gateway for medical staff to assign devices and receive data from devices.

(ii) Cascading Style Sheet (CSS)

Cascading style sheet is a style sheet language used to describe the display of a document authored in a markup language such as Hypertext Markup Language. Cascading style sheet, like Hypertext Markup Language and JavaScript, is a foundational technology of the World Wide Web. Cascading style sheet was utilized in the design and development of this project, together with Hypertext Markup Language, JavaScript, and Python, to construct a web gateway for medical staff to assign devices and receive data from devices.

(iii) Python

Python is a high-level, general-purpose programming language that is interpreted. With the utilization of extensive indentation, its design philosophy stresses code readability. Its language components and object-oriented approach are meant to aid programmers in producing clear, logical code for small and large-scale applications. As a consequence, a significant demand for developing the web portal employing the Django framework, which is based on Python for the web application's backend.

(iv) Django (framework)

Django is a Python web framework that promotes quick development and clean, pragmatic design. It was built by experienced developers to take care of most of the bother of web development, allowing us to focus on building the web portal rather than reinventing the wheel. The benefits include the fact that it is free and open-source, which is the primary justification for using it for web portal creation.

(v) MySQL

MySQL is a relational database management system (RDBMS). It is popular due to the fact that it is free and open-source. Because it is popular, it is employed by many active and successful businesses. As a result, it is ideal for database administration in the establishment of the fetal heart rate monitoring web page.

(vi) Arduino IDE

An arduino is both a hardware platform and programming tools that are both free and open source. Artists, designers, hobbyists, and anybody else interested in creating interactive goods or environments will be able to learn more about electronics using Arduino. Because the Arduino board's hardware design is open source, it may either be bought pre-assembled or built by hand. Users may update and share their boards, as well as make changes to them as they see fit.

Arduino is a free and open-source electronics platform or board, as well as the software that is used to program it. Arduino is intended to make electronics more accessible to artists, designers, amateurs, and anybody else interested in developing interactive products or surroundings. Because the hardware design is open source, an Arduino board may be purchased

pre-assembled or made by hand. In any case, users may customize the boards to their own needs, as well as update and share them.

Figure 8: Arduino IDE logo

Figure 9: Proteus IDE logo

(vii) Blynk Application

Blynk is a new platform that lets you easily create interfaces for managing and monitoring your hardware projects from your iOS or android mobile. You may construct a project dashboard and arrange buttons, sliders, graphs, and other widgets on the screen after downloading the Blynk software. You may use the widgets to toggle pins on and off or to display sensor data.

Figure 10: Blynk App logo

3.6 Hardware components for development

3.6.1 Global System for Mobile Communication module (GSM)

A GSM Module is a GSM Modem connected to a PCB with different types of output taken from the board, say TTL Output for Arduino and other microcontrollers and RS232 Output to interface directly with a personal computer. The board will also have pins or provisions to attach the mic and speaker to take out +5V or other values of power and ground connections. For this project research of connecting a GSM module to Arduino ESP23 and hence send and receive text massages using Arduino GSM.

Figure 11: GSM module image

3.6.2 Real-Time Clock (RTC)

A real-time clock (RTC) is a computer clock, usually in the form of an integrated circuit that is solely built for keeping time. Naturally, it counts hours, minutes, seconds, months, days and even years. Real time clock (RTC) can be found running in personal computers, embedded systems and servers, and are present in any electronic device that may require accurate time

keeping. Being able to still function even when the computer is powered down through a battery or independently from the system's main power is fundamental.

Figure 12: Real Time Clock (RTC)

3.6.3 Arduino ESP23

The arduino ESP32 is a series of the low-cost, low-power system on a chip microcontroller with integrated Wi-Fi and dual-mode Bluetooth. This microcontroller is compatible with the Arduino developing environment, programming language and libraries. It is also simple to program and more robust, and easier to set up.

Figure 13: Arduino ESP23

3.6.4 Global Positioning System (GPS) module

The GPS is an acronym for the Global Positioning System. The technology utilizes signals from satellites in orbit to locate a gadget and track its movement over a certain period. On its own, GPS has limits since it only offers the most basic data like coordinates and statistics; but, when coupled with other technologies like maps and integrated into navigation systems, it becomes an extremely useful tool. Navigation, low cost, ease of use, safety, accessibility, and up-to-date and well-maintained functionality are some of its many benefits.

Figure 14: GPS module

3.6.5 Temperature sensor (Thermistor)

Thermistors alter their resistance to temperature, using different semiconductor materials and fabrication processes, thermistors can carry either an NTC or a PTC. As the temperature increases, NTC thermistors decrease their resistance value, while PTC thermistors increase their resistance value.

Figure 15: Temperature sensor (thermistor)

3.6.6 Organic light-emitting diode (OLED) Display

An organic light-emitting diode, also known as an organic electroluminescent diode, is a light-emitting diode in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. This organic layer is situated between two electrodes. Typically, at least one of these electrodes is transparent. OLEDs are used to create digital displays in devices such as television screens, computer monitors, and portable systems such as smartphones and handheld game consoles.

Figure 16: OLED display

3.6.7 Heart beat sensor (MAX30100)

The MAX30100 is integrated pulse oximetry and heart-rate monitor sensor solution. It combines two LEDs, a photodetector, optimized optics, and low-noise analogue signal processing to detect pulse oximetry and heart-rate signals. This sensor is specifically used to measure the pregnant woman's heartbeat in a worst-case scenario when the pregnant woman is unconscious to be able to rescue the unborn baby in case the pregnant woman does not respond.

Figure 17: Heart beat Sensor (MAX30100)

3.6.8 Doppler (transducer) sensor

This sensor is specifically for measuring and recording data from the fetal's heart pulse rate to ensure the unborn child's wellbeing. This sensor is the core of the design since it's the main purpose of the whole device development.

Figure 18: Doppler (transducer) sensor

3.6.9 Resistors

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, divide voltages, bias active elements, and terminate transmission lines.

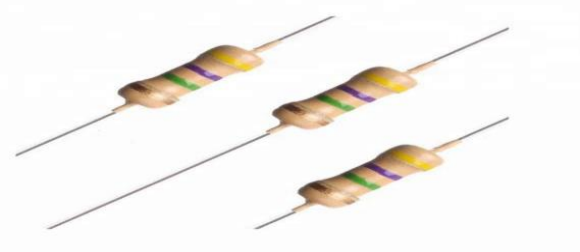


Figure 19: Resistors

3.6.10 Capacitor

A capacitor is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals. Capacitance exists between any two electrical conductors in proximity to a circuit. A capacitor is a component designed to add capacitance to a circuit.

Figure 20: Capacitor

3.6.11 Buzzer

A buzzer or beeper is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke.

Figure 21: Buzzer

3.6.12 Battery

It works as the source of electric power consisting of one or more electrochemical cells with external connections for powering electrical devices. Thus, the fetal heart rate device will require to battery-powered.

Figure 22: Battery

3.6.13 Jumper wires

These wires are specifically for connecting sensors and other devices to the ESP32 boards to each other to enable the circuit to run correctly.

Figure 23: Jumper wires

3.6.14 Copper board

This is used to create a printed circuit board which is a laminated sandwich structure of conductive and insulating layers. It's the base at which all devices are connected to each other, resulting in a design device's circuit.

Figure 24: Copper board

The following are the materials used to design the housing, in particular, the wearable materials yet waterproof too which the circuit is embedded in for it to be won easily and comfortably.

Figure 25: Water proof fabric for the inner design of the housing

Figure 26: Leather fabric for the outer part of the housing of the device

Figure 27: Thin mattress material for the inner part between leather and waterproof fabric

Figure 28: The wrapping fabric

This chapter included all requirements, technologies, languages, software and hardware components that were used to accomplish the design, development and implementation in the whole of the fetal heart rate support belt for pregnant women diagnosed with mild pre-eclampsia in Tanzania. All the software, hardware and technologies used were necessary for the foreseen achievement since it was with respect to the requirements gathered that led to the use of all that has been mentioned in this chapter. The availability of these items was a

challenge, especially in this time of the pandemic. It was challenging to purchase items from up countries. Despite all the drawbacks, the items required were used to accomplish the system to which the results and discussion are well illustrated and elaborated in chapter four.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter is the successful outcome of all the preceding chapters implementation, a detailed summary of the requirements and data gathered with respect to the need to develop the fetal heart rate monitoring device and system that is the requirements analysis data analysis and interpretation. The prototype designs and circuits of the development of the fetal heart rate monitoring support system. This chapter is the core of the project. It provides full details on how the device is designed, created, tested and implemented.

4.2 Data analysis and management

Here follows the summary of responses from 100 women who participated in the women's perception in an antenatal health survey. There were three groups of women who participated, women how have ever been pregnant but did not have children, women who have ever been pregnant and a large part of a group of women who have ever been pregnant and had children. The women's perception on antenatal health questionnaire was created to cover and capture all the requirements to gain understanding from all the women mentioned before. This resulted to very interesting responses that have answered the research questions to this project and improved the requirements that were put in place initially for the design of the fetal heart rate monitoring support belt for pregnant women diagnosed with mild pre-eclampsia.

4.2.1 Responses for the women's perception in antenatal health survey

(i) Demographics of the respondents

A total of 100 responses were collected from several regions within Tanzania. Women who participated were of legal age, from 18 years of age and above. Thus, 50% of the respondents were of 18 years and 25 years of age, inclusive thus 50 women, 37% of the respondents were of the age 26 years and 35 years of age inclusive, being 37 women and 13% of the respondents were of 36 years of age and above, thus 13 women. This response was of much significance since the rate at which women have children with respect to their ages brought much sense since women at the age of 18 years to 35 years are most likely to get pregnant with the relation

of our country's cultures. This survey was specifically for women, that being a reason for all, including one gender. See the illustration of the respondents on age analysis.

(ii) Analysis of Ages of respondents

Figure 29, shows the analysis of ages of respondents who participated on the survey for requirement gathering.

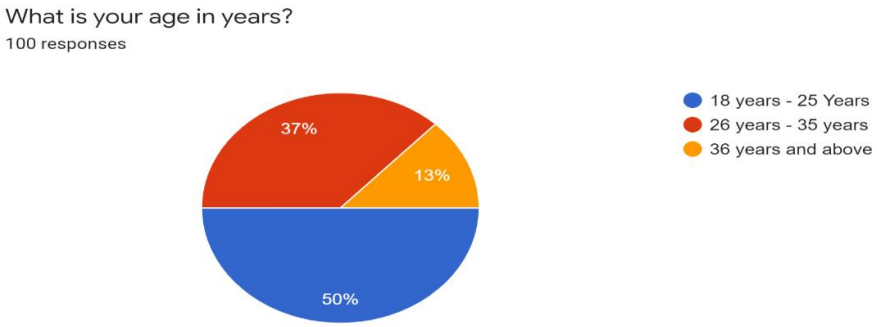


Figure 29: A chart showing analysis of ages of respondents

This survey's main objective was to collect information from Tanzania, of which respondents from several regions in Tanzania participated in the women's perception of antenatal health. Respondents from Dar es salaam-32%, Arusha-26%, Kilimanjaro-17%, Dodoma-7%, Tanga-6%, Manyara-2%, Mbeya-2%, Mwanza-2%, Morogoro-2%, Tabora-1%, Iringa-1% and Kahama-1%, the respondent's area of residence with respect to the mentioned regions in percentages.

(iii) Areas of residence of the survey participants

Figure 30 shows the chart's analysis with respect to regions in Tanzania.

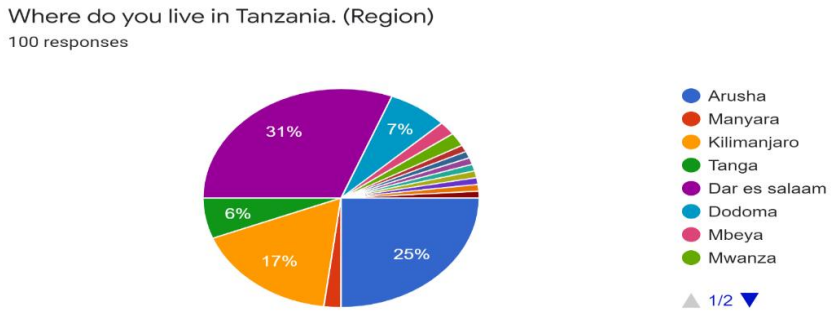


Figure 30: This chart is an analysis of the areas of residence of the survey participants

(iv) Previous history of pregnancy

Figure 31 shows a sampling that was done from the 100 respondents, which resulted in two groups of women, 61% of respondents have been pregnant before and have children, also 39% of whom have not been pregnant before. From these women of two groups, several questions were responded to towards their perception of antenatal health and the future of maternity.

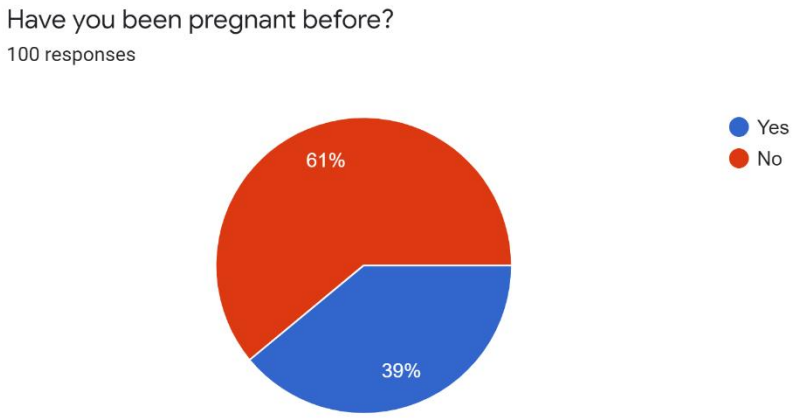


Figure 31: A chart showing the history of pregnancy

(v) Expectations to having future pregnancies

Figure 32 displays the women who had not been pregnant before all answered to be interested in the coming future to have children; thus, all were planning to experience the pregnancy journey.

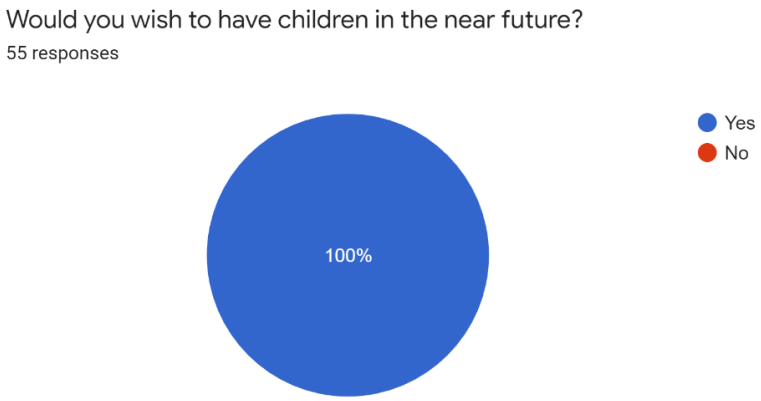


Figure 32: A chart showing response to having future pregnancy

(vi) Response to using the device in the future

Figure 33 displays the summary of the responses from participants towards their perception on the use of the fetal heart rate monitoring belt device and their responses where 87.3% yes thus

who have agreed to use the device it is available, and the 12.7% of whom did not agree to use the device most of the 12.7% who change their minds if the belt was available in the health facilities.

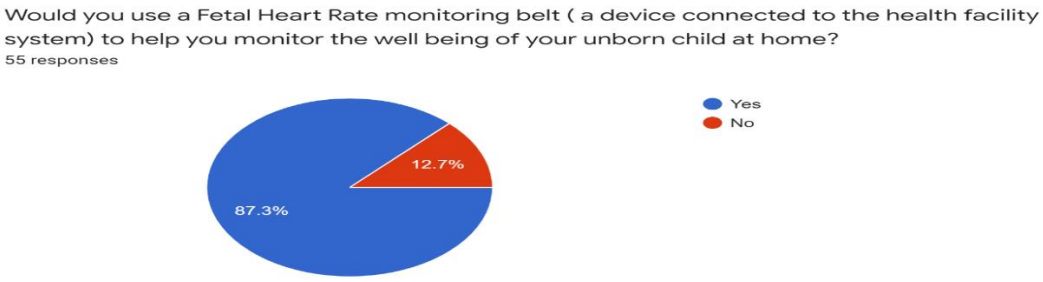


Figure 33: A chart showing response to using the device in the future

(vii) Device's usefulness

Figure 34 showing, in summary, the responses from participants on their perception on whether the fetal heart rate monitoring belt would be useful and helpful to reduce the number of stillbirths caused by high blood pressure in pregnancy. 90.9% strongly agreed, and 9.1% still preferred not to rely on the device.

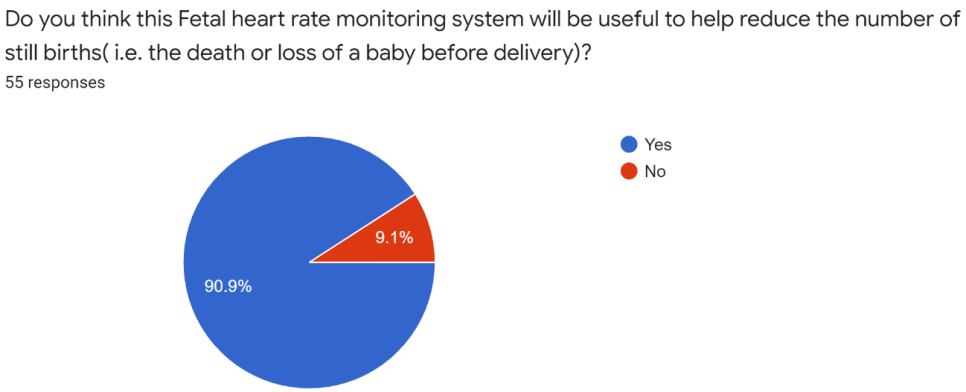


Figure 34: A chart showing the response of usefulness of the device

All the above charts were responses from women who had not been pregnant before, of which have responded positively and strongly supporting the use of the device to enable women to have a safe pregnancy journey and avoid still births. More than 90% of the respondents agreed to the main objective of developing the fetal heart rate monitoring device for safety benefits of future pregnancies.

4.3 Women's experience during pregnancy

This is the continuation of the responses only that it's from the women who have had children and have been pregnant before. The responses support the main objective strongly.

4.3.1 Antenatal clinical attendance

Figure 35 shows the summary of the responses of the women's perception on attending health facilities for antenatal service and routines. 84.1% of the respondents went to health facilities during their pregnancy and attended the clinic routinely for pregnant women until they delivered. The 15.9% had not attended any health facility for care from medical personnel, but some had family doctors come to their home places and attend them when there was any complication.

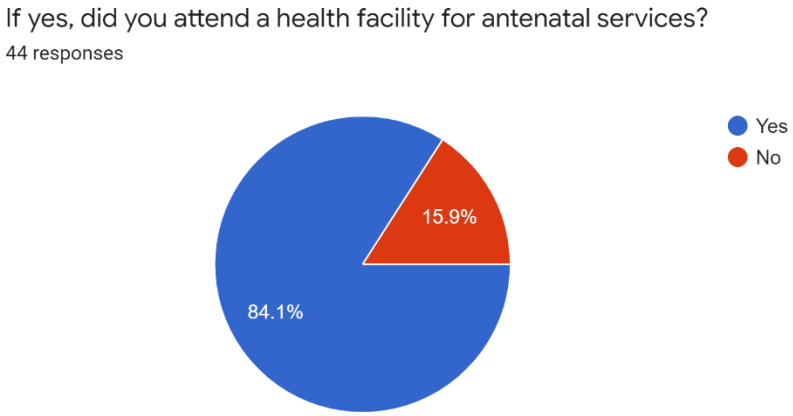


Figure 35: A chart showing attendance for antenatal services visits per month

On Fig. 36, the responses of the number of visits done per month to health care facilities have been analyzed in the chart below, showing 81.8% of women were scheduled to attend antenatal clinic visits once per month until delivery date or expected delivery date where 18.2% had to visit the health care facility more than once in a month. This strongly supports the use of a fetal heart rate monitoring belt since most of the women spend more time at the area of residence without visiting hospitals.

Figure 36: A chart showing visits per month

4.3.2 Challenges during pregnancy

Challenges or complications on Fig. 37, during pregnancy were experienced by 56.8% of the respondents being caused by different causes, including high blood pressure in pregnancy and other normal complications. Below is the summary of the analysis done.

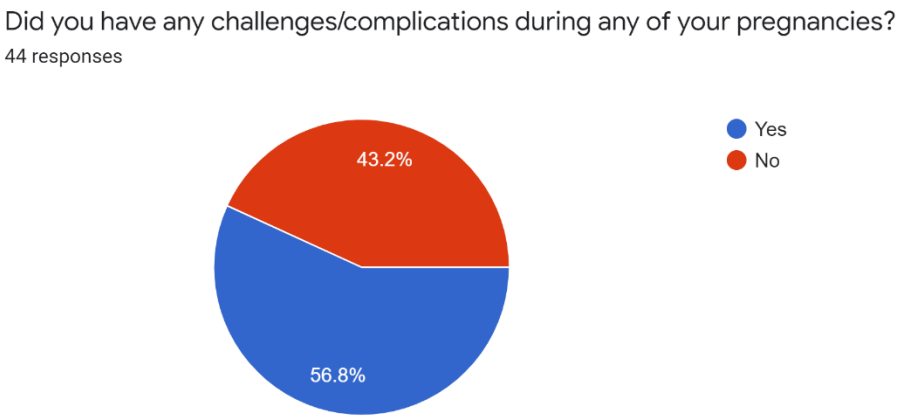


Figure 37: A chart showing respondents with challenges during pregnancy

4.3.3 Complications related to high blood pressure in pregnancy

Figure 38, the complications in pregnancy showed to be caused by high blood pressure in pregnancy by 52%, and 47.7% were other complications in pregnancy.

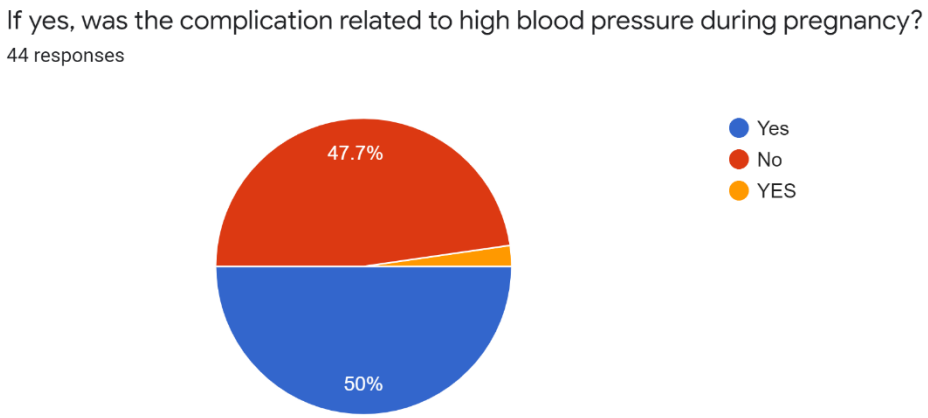


Figure 38: A chart showing complications related to high blood pressure in pregnancy

4.3.4 Treatment from the health care facility

The following chart shows a summary or analysis of the pregnant women with complications in pregnancy, specifically with the hypertensive condition in pregnancy, of whether they had received treatment for their illness when they attended their scheduled antenatal visits, 52.4% had received medication or treatment from the health care facility, and it was to be used until the next scheduled visit. 47.6% had not received treatment.

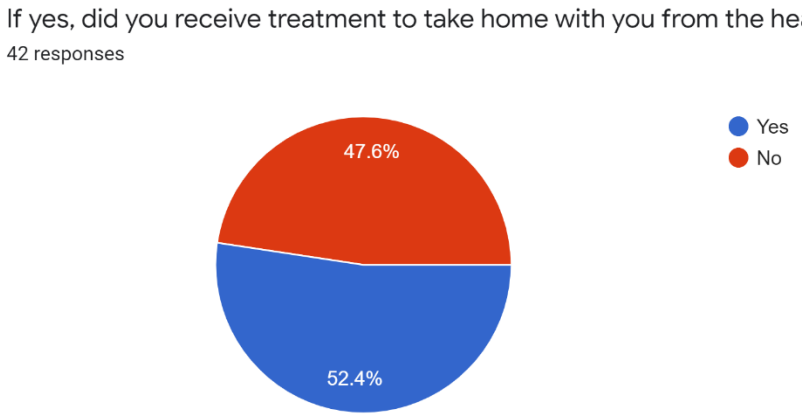


Figure 39: A chart showing respondents who received treatment

Thus, for the case of pregnant women with high blood pressure in pregnancy, they will be at high risk of harming the unborn child, thus the need to self-monitoring the fetal heart rate at their area of residence, which brings up the necessity of having the fetal heart rate belt at home.

4.3.5 Assurance of unborn child's wellbeing

Women had no adequate method of formula to ensure the wellbeing of their unborn other than when they visited the health facility during their scheduled antenatal visit days. Figure 40

shows the summary of how pregnant women ensure their unborn child's wellbeing, 54.3% of respondents did self-monitoring at home by listening to the baby's kicks while 41.3% of the respondents had to wait to ensure their wellbeing by visiting the health care facility regularly.

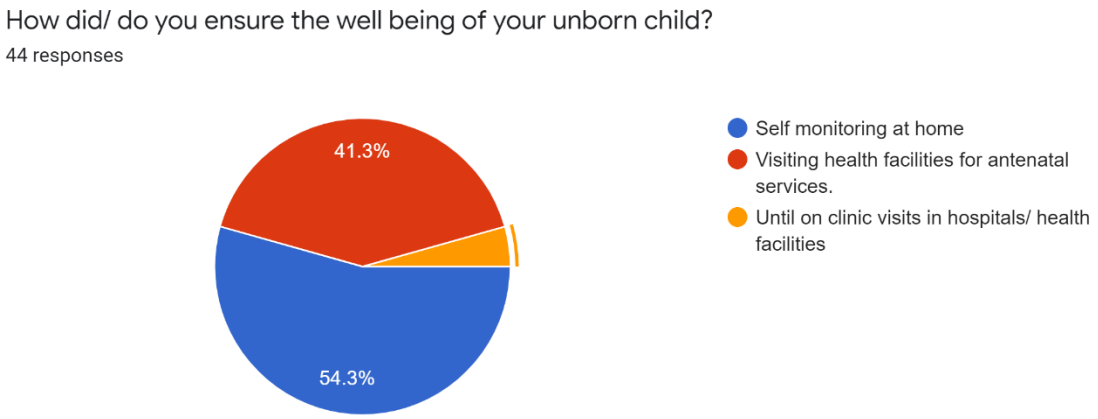


Figure 40: A chart showing assurance of unborn child's wellbeing

4.3.6 Insecurities during pregnancy

On Fig. 41, 65.9% of the pregnant women who responded to be monitoring themselves at home claimed to have so many doubts of the effectiveness of their method, while 34.1% were satisfied by that method since it has been in use since Stone Age times.

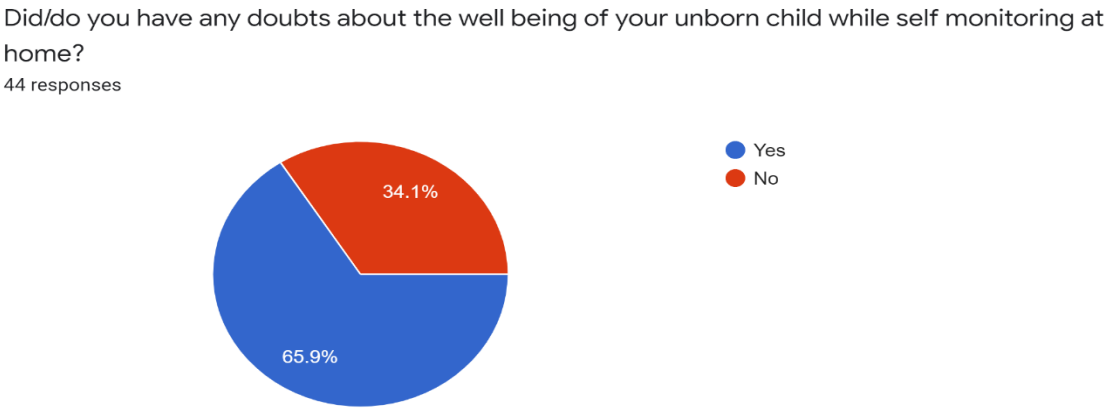


Figure 41: The chart above shows respondents insecurities during pregnancy regarding the well-being of their unborn child

4.3.7 Response to using the device in the future

Women's perception of whether they will use the device if available was shown on Fig. 42, 79.5% yes, and 20.5% disagreed since they had no idea how it looked like and if it was necessary.

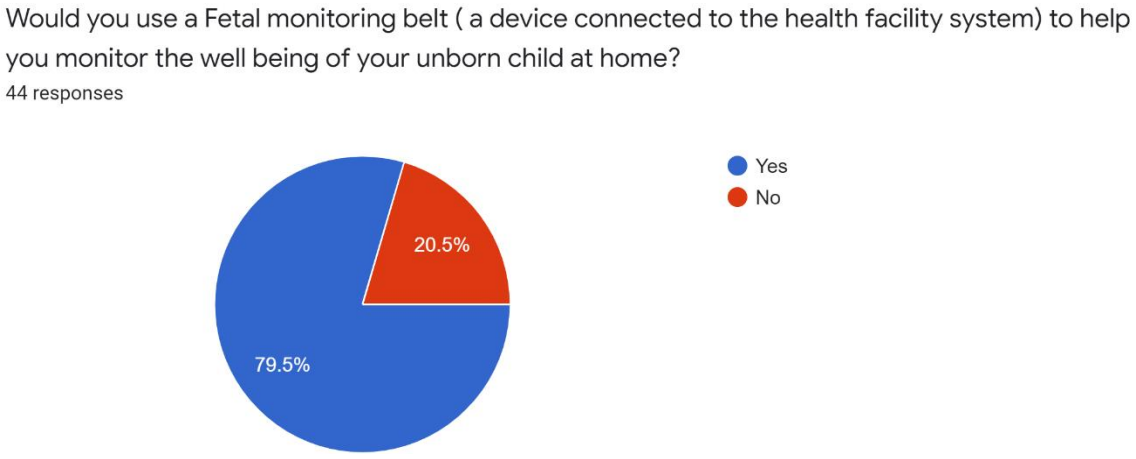


Figure 42: A chart showing response to using the device in the future

4.3.8 Adherence to wearing the device at least thrice a day

For the women who agreed, as shown in Fig. 43, 81.8% were willing to wear the device at least thrice a day for the wellbeing of their unborn child, and 18.2% were not willing to wear the device more than once.

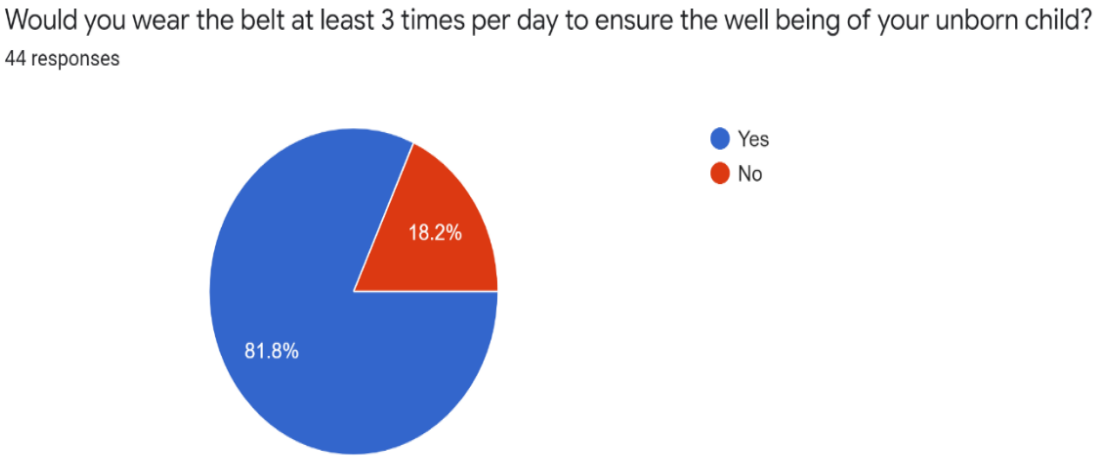


Figure 43: A chart showing adherence to wearing the device at least thrice a day

4.3.9 Data sharing

The question on data accessibility, where the data collected from the device will be shared, was the most crucial part since the majority of expecting mothers in the African culture would prefer any sort of information to remain confidential until they have delivered their infants safe and healthy. Thus, there was a concern of whether the pregnant women would provide consent for their data to be accessed and shared by the medical personnel in charge of the fetal heart rate monitoring system. Figure 44 shows, 88.6% agreed, and 11.4% disagreed with the concern of data sharing.

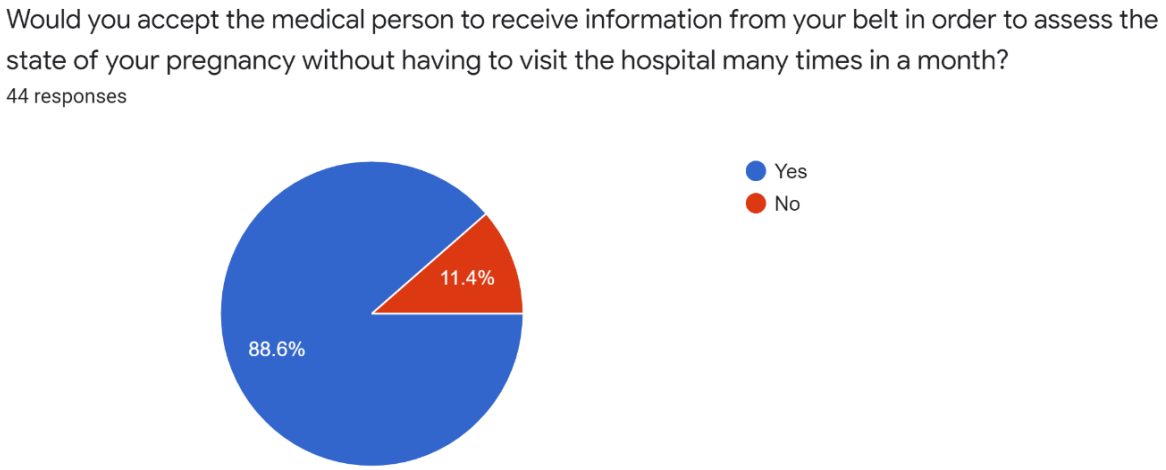


Figure 44: A chart showing acceptance of respondents regarding sharing of their data with medical personnel

4.3.10 Respondents with internet access

Figure 45 showed that 93.2% of the respondent's answered to have access to smartphones and internet access on a daily basis for the case of the participants who will use the Blynk application if they use the device. While 6.8% responded no in terms of internet availability.

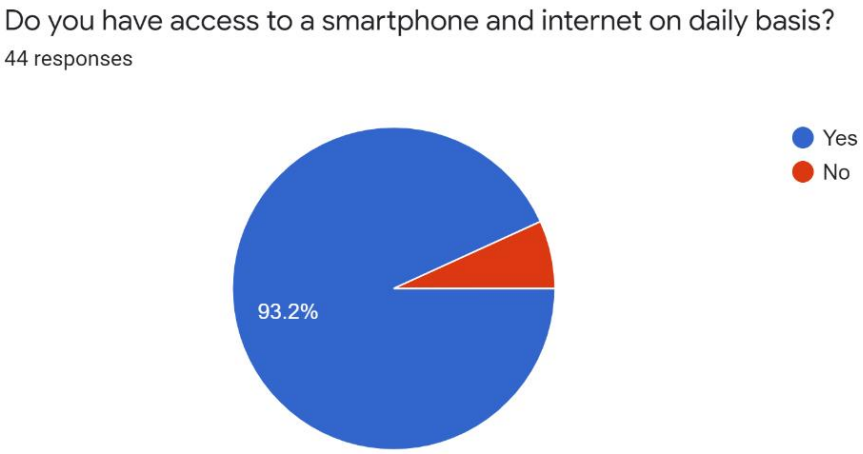


Figure 45: A chart of respondents with internet access

4.3.11 Usefulness of the device

The usefulness of the device to be developed was assessed prior to its development by the respondents, Fig. 46 showed that, 95.5% found this device use, and 4.5% did not see it to be necessary for use.

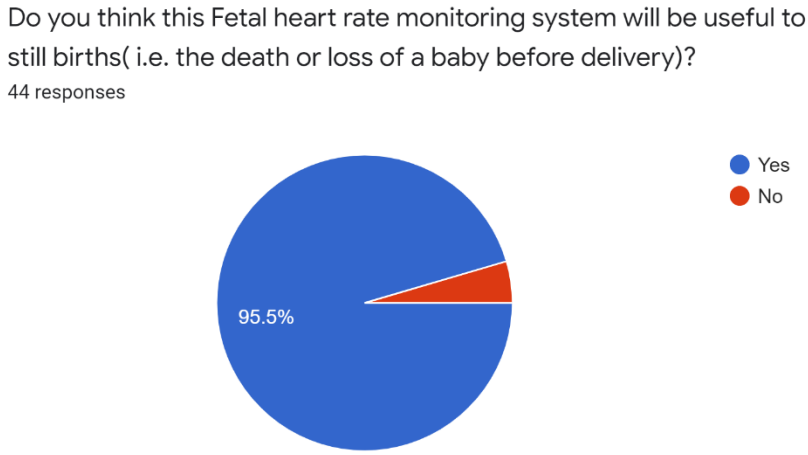


Figure 46: A chart showing responses regarding the usefulness of the device

4.3.12 Understanding of safe pregnancy different responses form participants

“Safe pregnancy is when a woman gets pregnant willingly, and it happens that the pregnancy grows in a womb and not otherwise”, “the one you get when planned”,” Having a baby without troubles”, “Take all precautions instructed by medical partitioners”, “Pregnancy under proper monitoring from diet to medical consultation.”, “Means pregnancy with no complication or any danger to mother and child.”, “Monitored pregnancy from the beginning to end by attending the clinic and taking necessary supplements”. ” Safe pregnancy means

that the unborn child is free from any damage that can cause difficulties during their growth.", "It deals with ensuring sustainable progress for children before they are born; hence every child has a fair chance to survive no matter what circumstances they are in.".

"Pregnant which will not put both mother and baby in any danger.", "Getting pregnant at the right time and having good environment supportive for maternity", "Pregnancy in which both parents attends to the clinic", "A pregnant woman should get a well-balanced diet and should be free from any stress", "Is a pregnancy that the security of a baby is highly ensured", "safe antenatal period with no any complications that can put at risk the mother or the baby.", "Means having good health for mother and baby during and after pregnancy.", "Take a prenatal vitamin. Exercise regularly. Write a birth plan. Educate yourself. Change your chores (avoid harsh or toxic cleaners, heavy lifting) Track your weight gain (normal weight gain is 25-35 pounds) Get comfortable shoes. Eat folate-rich foods (lentils, asparagus, oranges, fortified cereals)"," A pregnancy with fewer complications.", "No risks are imposed to mother's health and the unborn child welfare. The child's growth rate should always be within the anticipated range without any hindrances due to external or internal factors." "A safe pregnancy is the way a mother follows a proper way of birth example going clinic.", "State of conceiving a baby"," attending the clinic and following all the procedures during pregnancy and practicing a good practice in pregnancy time", "Is a pregnancy with no or fewer complications in both mother and fetus. Pregnancy with less disease to mother, with no problem to a fetus, both being in a healthy situation.", "I believe it is the one that was planned for and follow-ups for reproductive health for both is conducted like visiting the gynecologist", "Safe pregnancy means that the unborn children and the prenatal mother have right to have life and health before the new baby is born and within those pregnancy weeks a mother should consider being safe without any miscarriages.", "No troubles catching pregnancy, smooth health condition of mother and child for 9month without complications or miscarriage.", "Well protected pregnancy".

"A pregnancy with no complications whatsoever", "Checkup regularly", "having a baby in good health", "Safe pregnancy is a situation in which both mother and fetus do not experience any complications for all nine mother before and after delivery. ", "Giving birth without any complications safely", "Being pregnant in a stable health", "Having no complications from conception to birth and after birth, and easy access of health care services in time of pregnancy, delivery and the postpartum period. ", "Refer to have a

pregnancy without any complication which can cause problems to both women and fetus", "it's a good thing when it comes at the right time. ", "Both mother and child are safe during pregnancy".

"This is the state where a pregnant woman is to be physically and mentally safe from all risk factors that would endanger her health as well as the health of her unborn child", "I don't have any", "Eating healthy food", "pregnancy without any complications", "Without serious health complications", "Safety of both mother and infant", "when a woman follows all rules of pregnancy before conceiving. it involves eating a well-balanced diet, exercises and other medicines taken by pregnant women", "Safe pregnancy involves good health so that ending a safe delivery", "All mother and baby to be okay", "Safe pregnancy means a pregnant woman and the expected baby are not exposed to any danger during pregnancy, delivery and after pregnancy."

"Being able to deliver safely for my child and me. And also having a good pregnancy period, with full knowledge of the progress and health of my baby and me during the pregnancy period.", "good birth weight", "Having no health issues during the pregnancy and during birth."

(i) Briefly explain your understanding of complications in pregnancy?

(a) Responses

"Is when a women get trouble during her pregnancy, for instance, the pregnancy growing outside the womb", "miscarriage", "Death of child or mother while giving birth", "Anything that threatens the health life of the mother and expected child", "abnormal progress in fetus development, any medical disorders to the mother due to the pregnancy that may endanger her life or the unborn baby. ", "Not having a normal pregnancy, for example, having a c-section", "Complications occurring during pregnancy such as hypertensive disorders in pregnancy. ", "Complications in pregnancy include; premature birth, poor growth and some conditions suffered by mothers, are associated with infant and child mortality as well as problems with brain development. ", "high blood pressure, gestational diabetes, a loss of pregnancy, ", "Miscarriage", "High blood pressure, Anemia in pregnancy and STI".

"These are conditions that occur during pregnancy that act as a threat towards an unborn child's and mother's health. For example, complications like high blood pressure, anemia,

viral and bacterial infections and miscarriage are very dangerous since once not solved properly, and in a time it can lead to mortality.

(ii) What would your advice be added to the Fetal heart rate monitoring system to ensure the safety of the mother and the unborn child?

(a) Responses:

- It should be designed in a way that cannot cause stress to both mother and unborn baby.
- To design well the fetal belt in a way that will not affect the life of the unborn child.
- It should not be done at home locally, but with the help of a professional doctor
- To ensure and increase Fetal heart rate monitoring system is working at high efficiency its capacity of working should not bring cause a problem to the users
- To measure temperature due to the current situation of COVID-19
- More awareness should be given to mothers for them to understand the essence of this monitoring system. Bad thoughts about it should be eliminated.
- The Fetal heart rate monitoring system should be sterile in a careful condition in order to ensure safety to the mother and newborn baby. Should include a Timer.
- "Interpretation of different changes detected by the device"
- "Heart rate monitoring of the mother."
- "Temperature monitoring device"

(iii) Kindly share a summary of your experience during your pregnancy, 14 responses

(a) The responses were:

"Pregnancy can be risky, especially if their complications involved.", "It is safe to attend the clinic and follow all the advice given by medical practitioners", "it was my first

pregnancy it had ups and downs, but it was worth it", "when I had any worries about my pregnancy I had to go to my doctor", "It was fine, no complications developed", "It was worth a wait", "Pressure causes placenta rupture which leads to child death and mom sometimes, still in a way to find out about pressure I think it's the main core problem and if we find a way to control pressure we will find a way to solve this problem in pregnancy", "it was fine, but if I didn't take the BP medication my pressure was rising, and I had to deliver early before the predicted day to save my child.", "I went to the clinic as it was scheduled in the card. So it was safe".

(iv) What would your advice be added to the Fetal heart rate monitoring system to ensure the safety of the mother and the unborn child? 14 responses

(a) The responses were:

"It should measure temperature due to pandemic situation", "I have no experience with that belt', "I haven't seen it", "I think it will help women enjoy pregnancy period.", "not be tight", "It will be useful", "Should be User friendly", "I think it would help", "It's enough" and one respondent wish to know "Where is that device is it in pharmacy?"

4.4 Block diagram for the fetal heart rate monitoring device

The block diagram illustrates the sensing side and the actuation side of the fetal heart rate monitoring device. All sensors used on the input side as the sensing side are corresponding to the actuation side. Thus the output side of the device where the data collected from the sensors is displayed and shared on the actuation side with respect to the ESP32 microcontroller as the centre of all interactions within.

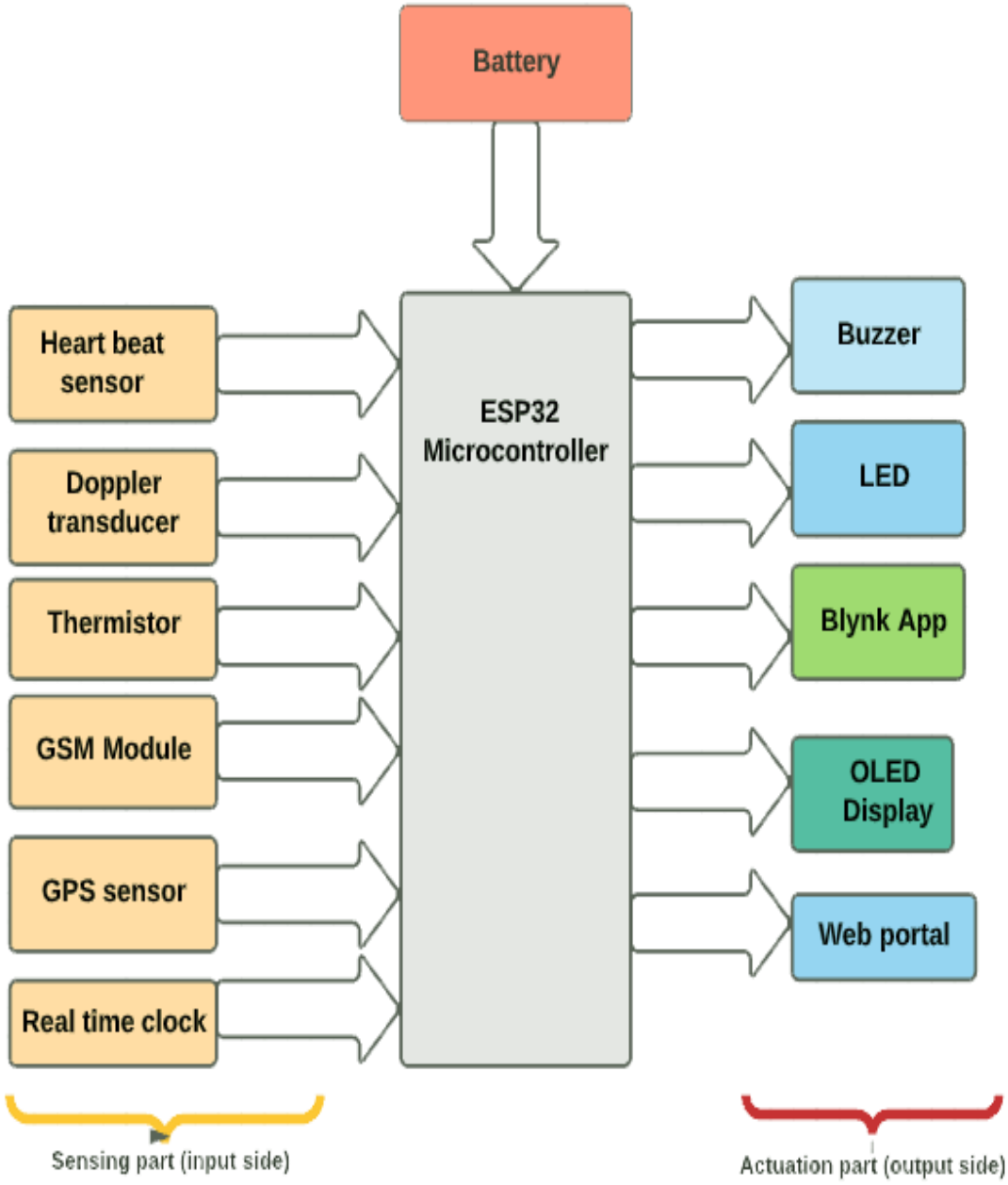


Figure 47: Block diagram for the fetal heart rate monitoring device

4.4.1 Schematic layout

Figure 48 shows the connection of components to the printed circuit board in a detailed clearer diagram generated from the proteus 8 proffesional software.

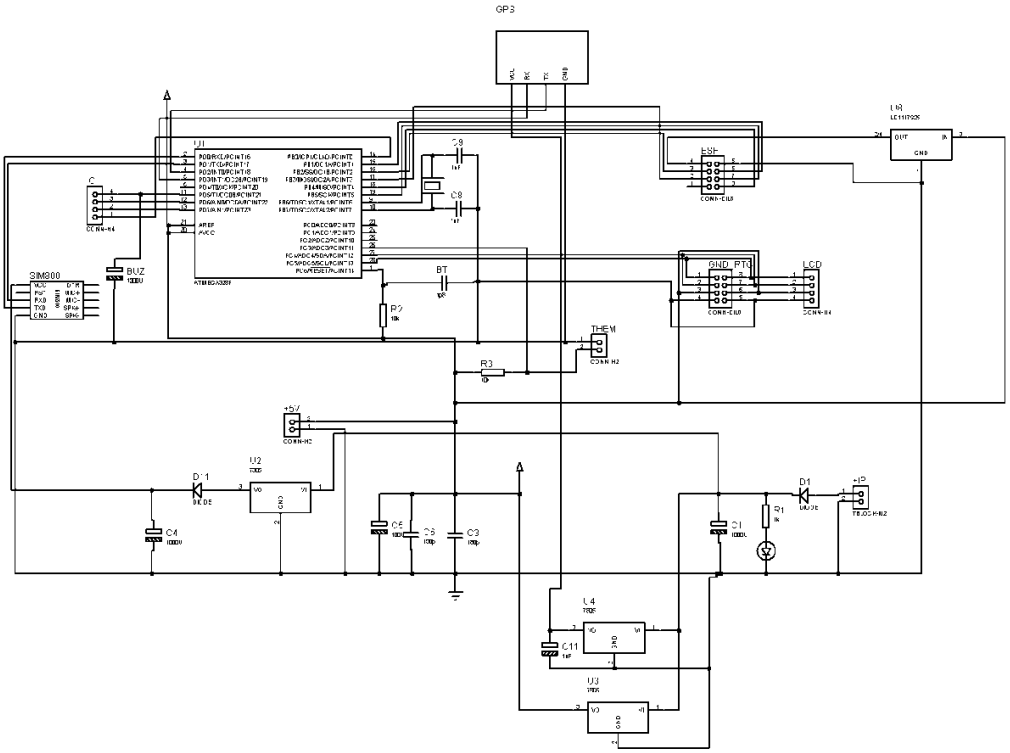


Figure 48: Schematic capture showing connection of components of the printed circuit board

4.4.2 Printed circuit board layout

The Fig. 49 shows the layout image of the schematic capture.

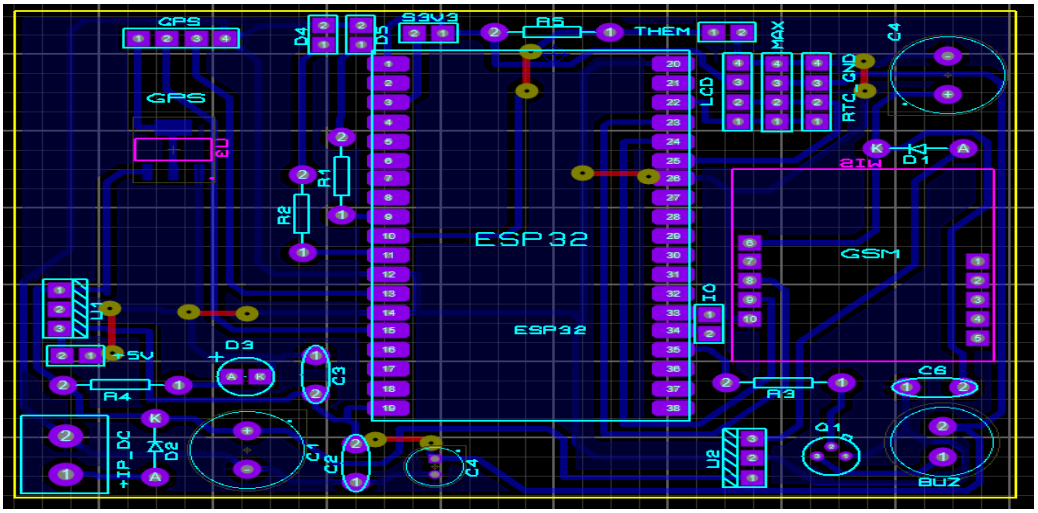


Figure 49: Printed circuit board layout image

(i) 3D Printed circuit board image without components

Figure 50 shows the image of 3D Printed circuit board image without components.

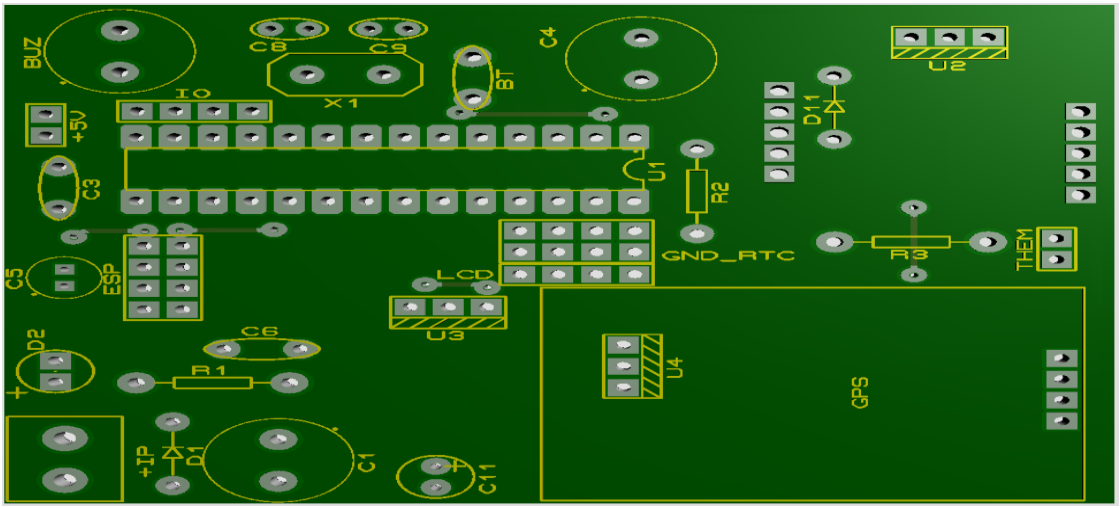


Figure 50: 3D Printed circuit board image without components

(ii) 3D Printed circuit board image with components connected

Figure 51 shows the image of 3D Printed circuit board image with components.

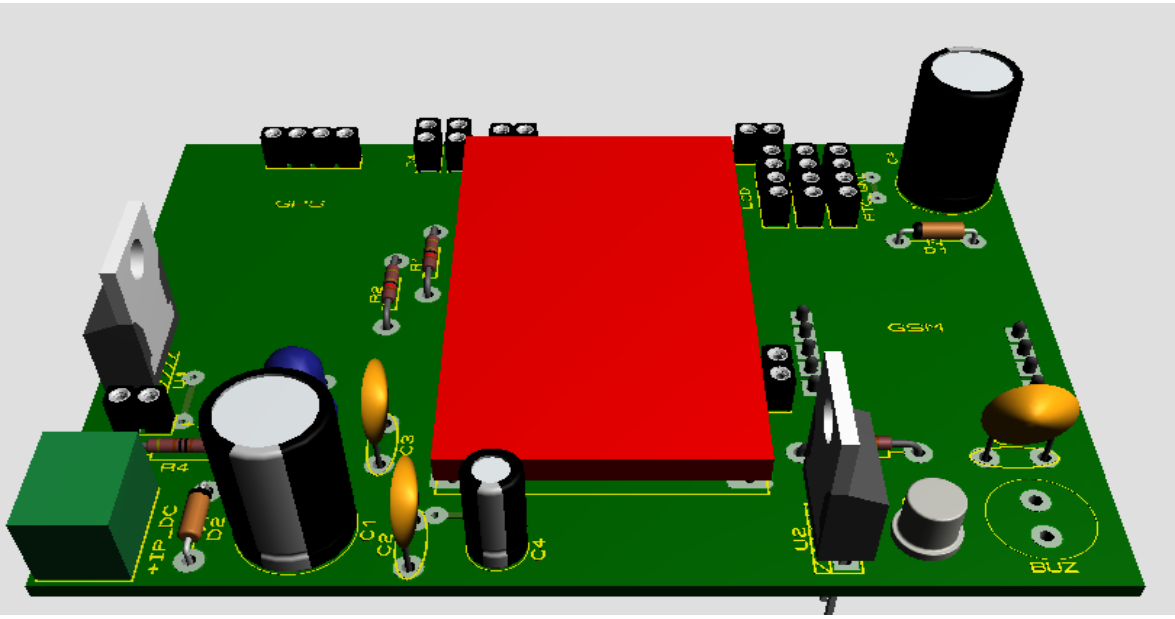


Figure 51: 3D Printed circuit board image with components.

(iii) Quantities and values of components used

Figure 52 shows in detail ordered format the qauntities and values of all the hardware components that are connected to the printed circuit board and with reference to the initial

images from Figs. 48, 49 and 51 the hardware components that were used to create or develop the fetal heart beat rate monitoring device.

Quantity	References	Value
Sub-totals:		
8 Capacitors		
Quantity	References	Value
2	C1,C4	1000U
2	C3,C6	180p
1	C5	100U
2	C8-C9	1nF
1	C11	1uF
Sub-totals:		
3 Resistors		
Quantity	References	Value
1	R1	1k
2	R2-R3	10k
Sub-totals:		
5 Integrated Circuits		
Quantity	References	Value
1	U1	ATMEGA328P
3	U2-U4	7805
1	U8	LD1117S25
Sub-totals:		
0 Transistors		
Quantity	References	Value
Sub-totals:		
3 Diodes		
Quantity	References	Value
2	D1,D11	DIODE
1	D2	LED-GREEN
Sub-totals:		
12 Miscellaneous		
Quantity	References	Value
2	+5V,THEM	CONN-H2
1	+IP	TBLOCK-M2
1	BT	1p8
1	BUZ	1000U
2	ESP,GND_RTC	CONN-DIL8
2	GPS,SIM800	
2	IO,LCD	CONN-H4
1	X1	CRYSTAL

Figure 52: Quantities and values of components used

(iv) Flow chart diagram

Flow chart diagram od chart is a clear and easy representation of the algorithms in terms of pictorial diagrams were a step-by-step flow of activities represented by shapes while logical flows are represented by arrows to the desired end or output. In this research project study, the flow chart diagrams were used to design decision algorithms which are used during the reading

and transfer of sensors data over the network but also during the analysis of the sensor information to check if they adhere to the predefined standards values.

4.5 Flow chart diagram for the developed device

Figure 53 shows the series of activities on the technical part of the design of the fetal heart rate monitoring support device.

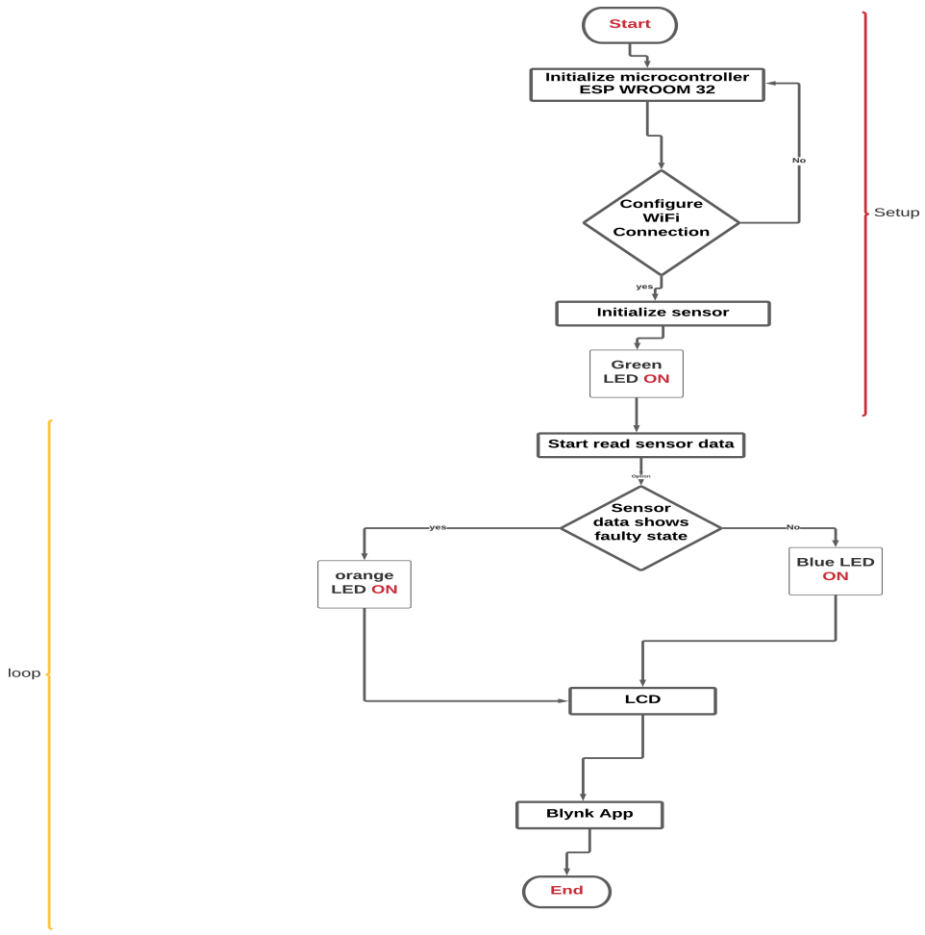


Figure 53: A flow chart diagram for the developed device

Figure 54 shows in detail the whole system, thus the device, the Blynk app, the web portal and the pregnant women wearing the device. It is a clear image of how data will be navigated from the pregnant woman's stomach to the endpoints such as the OLED display, the blynk application, the system's web portal for medical personnel, and the SMS sent back to the mother of the data that has been harvested in realtime so she may have a copy since the device will only display the data at the moment of use.

The house indicated the area of residence of the pregnant woman and the Hospital or health facility to which the medical personnel will access the data from the web portal. The Admin will be responsible for the maintenance of the web portal to ensure it is at all times connected to the device via the internet. The maintenance of the device and configuration of the blynk application will be done by the medical personnel with the assistance of the technician assigned in health facilities.

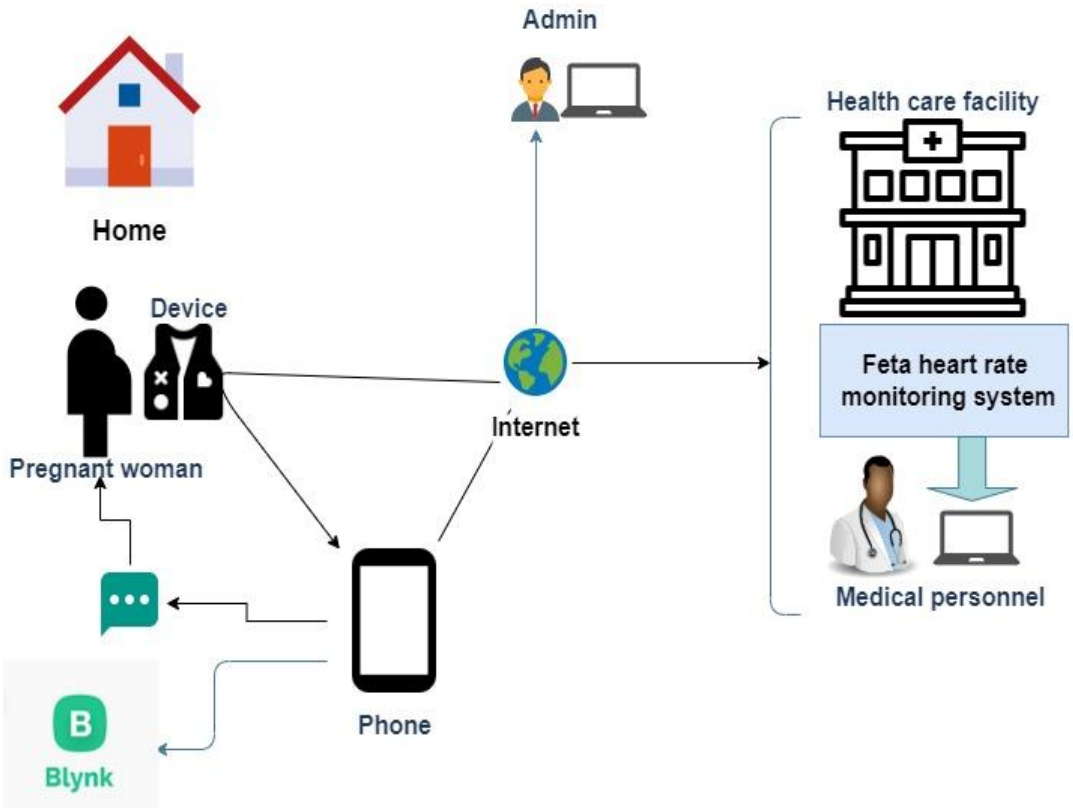


Figure 54: The system design network diagram

4.6 A diagram illustrating the flow of activities

Figure 55 shows the illustration of activities that happen when the woman is using the fetal heart rate monitoring belt at home, the woman will collect the device, wear it as instructed during the assignment of the device into the health facility and after switching the device on the sensors will sense all required measurements and the data and information will be transferred to the assigned endpoints.

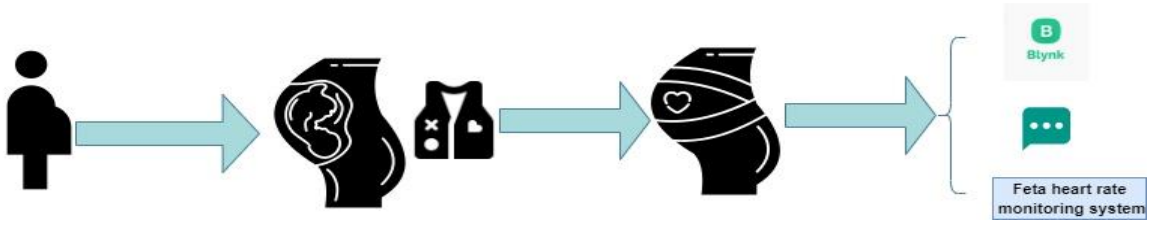


Figure 55: A diagram illustrating the flow of activities

4.7 A flow chart diagram illustrating the flow of activities

Flow chart in Fig. 56 showing the series of activities from the begging of the use to the end in detail with respect to the above system design.

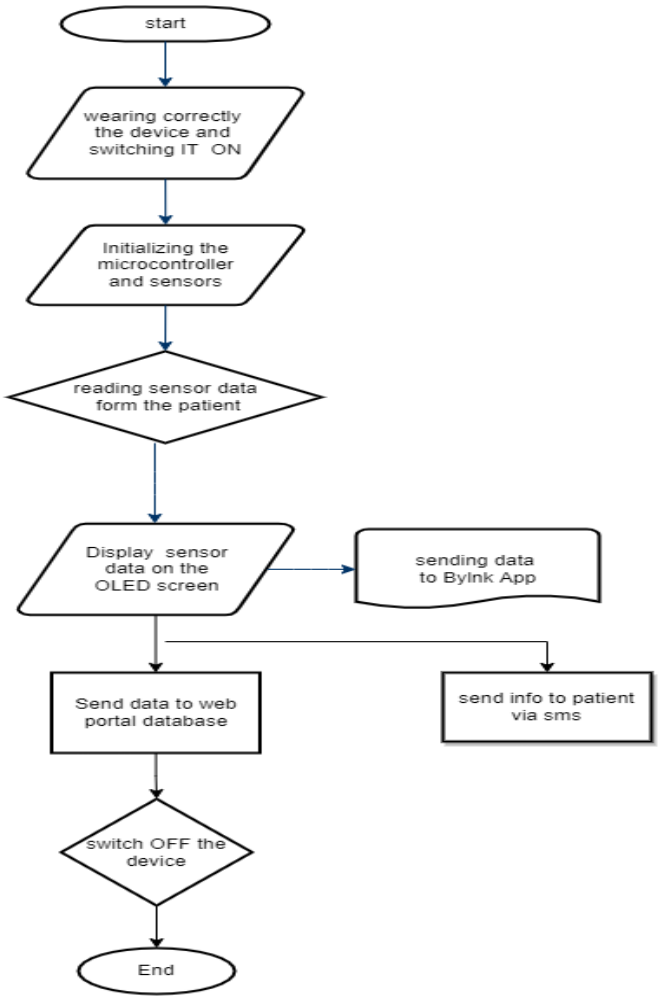


Figure 56: A flow chart diagram illustrating the flow of activities

4.8 Fetal heart rate monitoring device

Figure 57 shows the phenotypical appearance of the fetal heart beat rate device designed with water resistant fabrics and an adjustable rapper with respect to the different sizes of the pregnant woman's stomach.

Figure 57: Fetal heart rate monitoring device

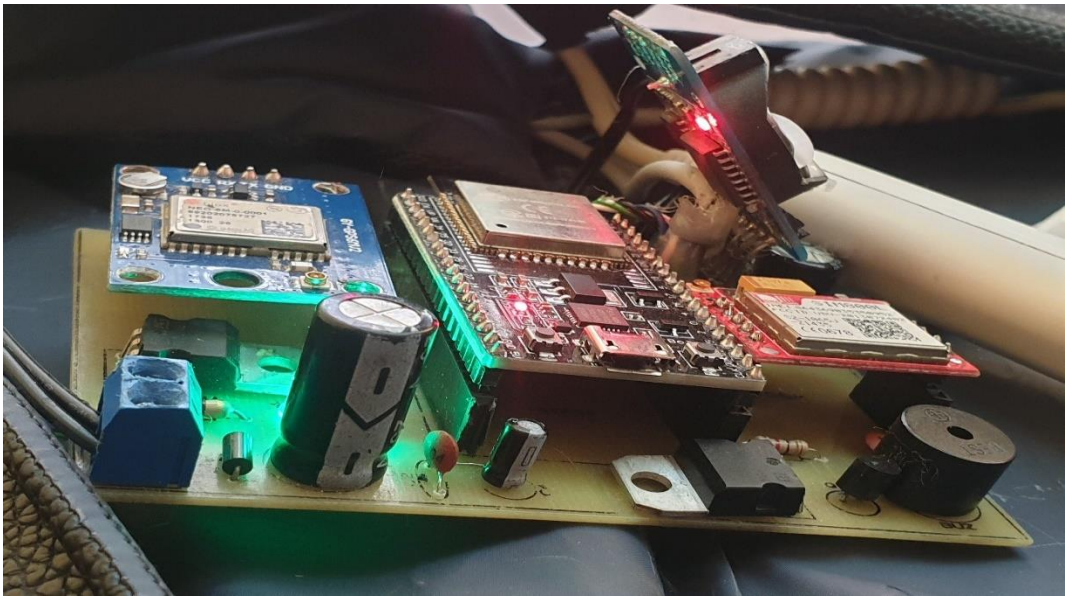
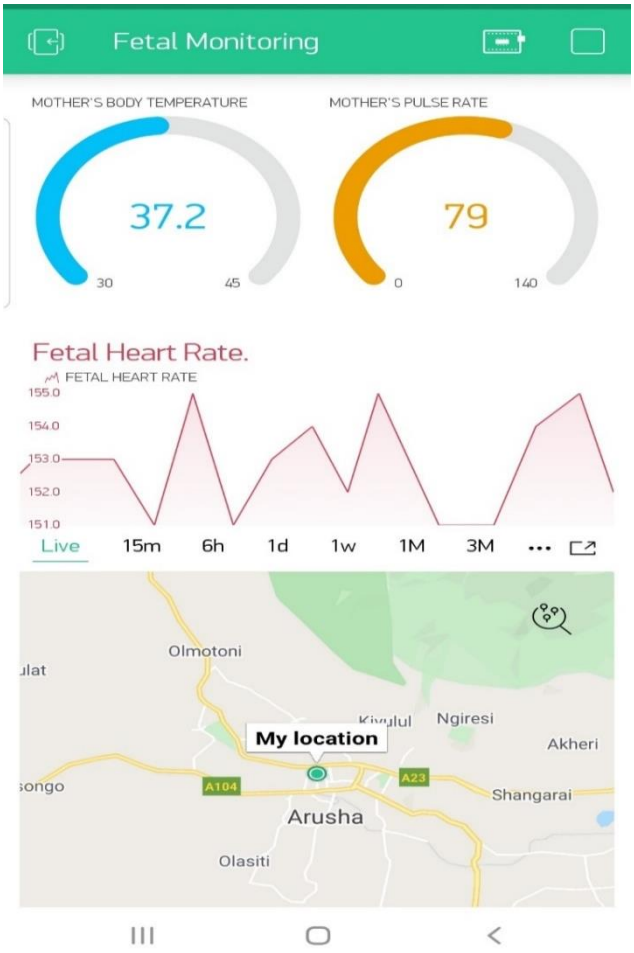


Figure 58: The circuit for the fetal heart rate monitoring device

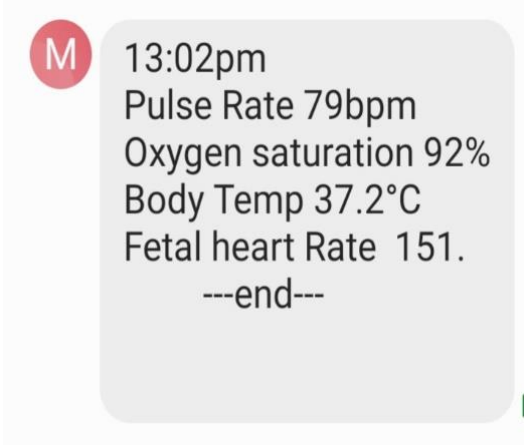
4.9 Results

4.9.1 First participants (pregnant woman's) outputs

Figure 59 shows the reading of information when the device was used by the first participant.



Blynk display



Text messege sent to woman

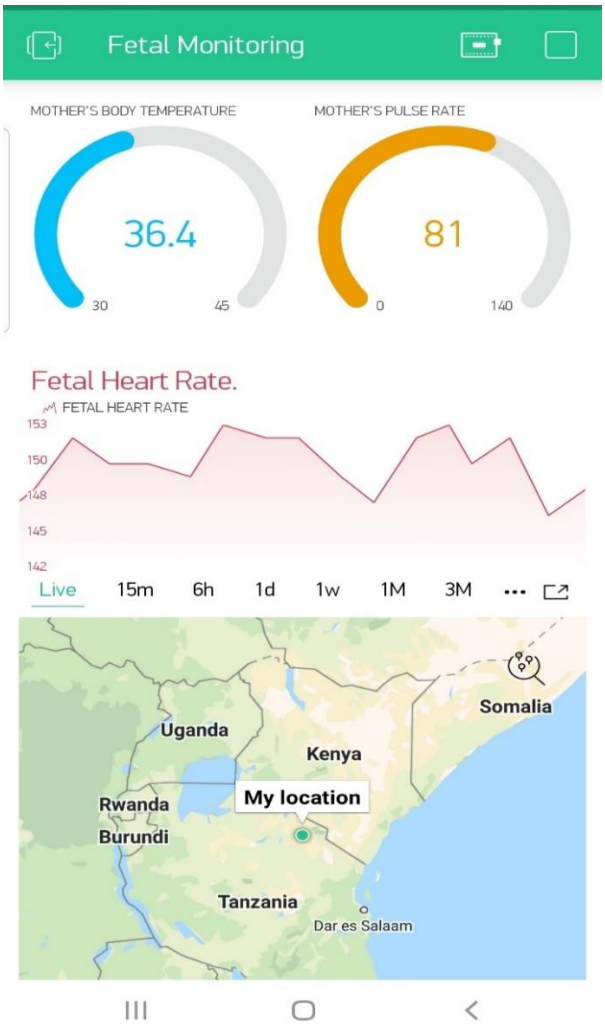
The mother measurements

Unborn child's FHR

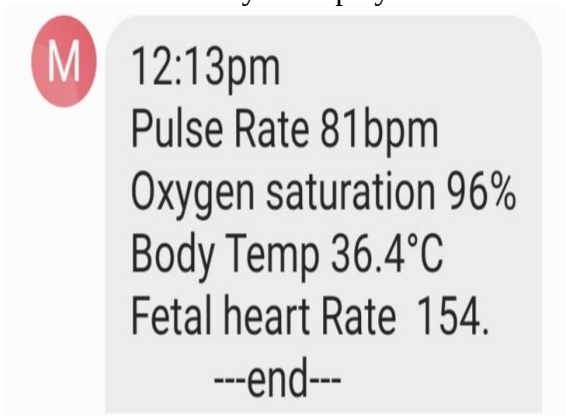
Figure 59: The images of the output information from the first participant

4.9.2 Second participant's (pregnant woman's) outputs

Figure 60 shows the reading of information when the device was used by the second participant.



Blynk display



Text message sent to mother

Mother's measurements

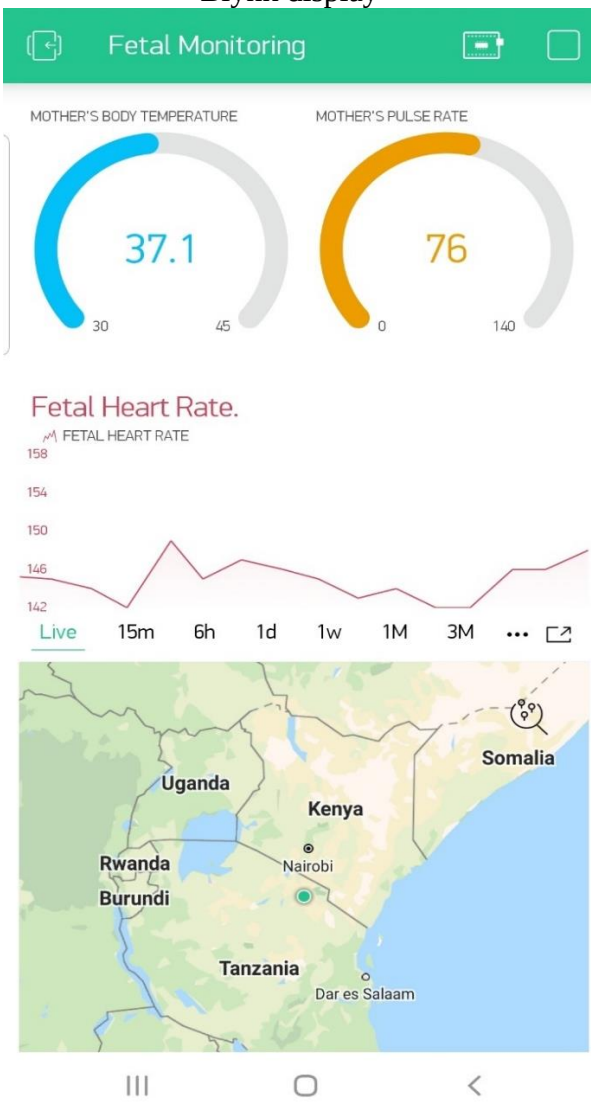
Unborn child's FHR

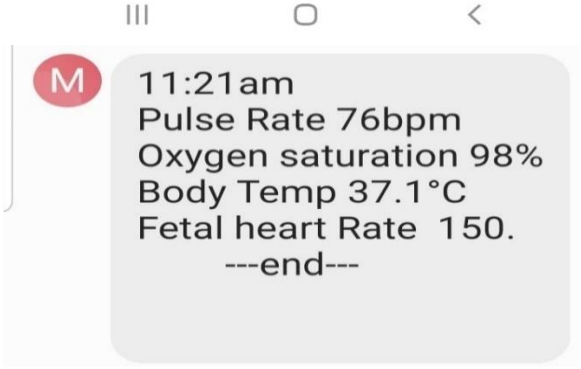
Figure 60: The images of the output information from the second participant

4.9.3 Third participant's (pregnant woman's) outputs

Figure 61 shows the reading of information when the device was used by the third participant.

Blynk display





Text message sent to mother

Mother's measurements

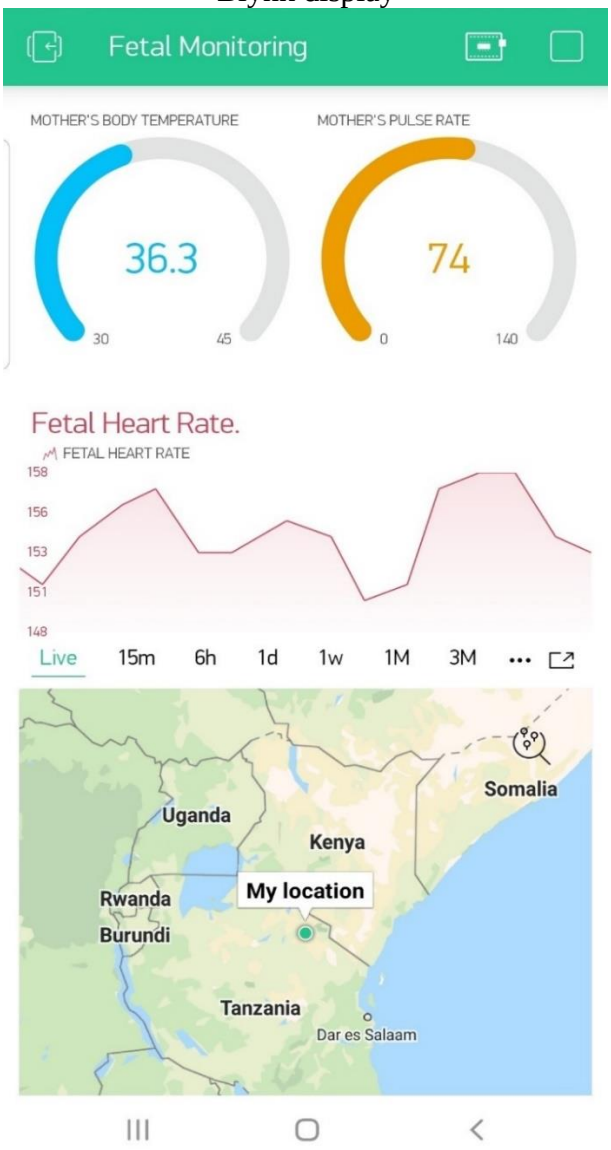
Unborn child's FHR

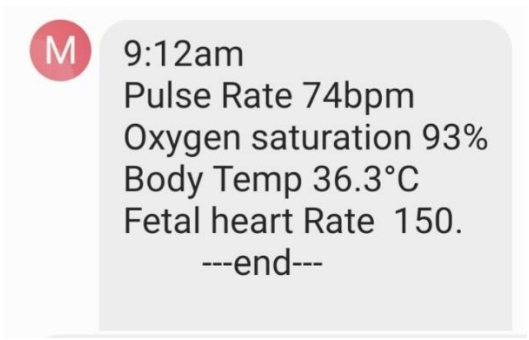
Figure 61: The images of the output information from the third participant

4.9.4 Fourth participant's (pregnant woman's) outputs

Figure 62 shows the reading of information when the device was used by the fourth participant.

Blynk display





Text message sent to mother

Mother's measurements

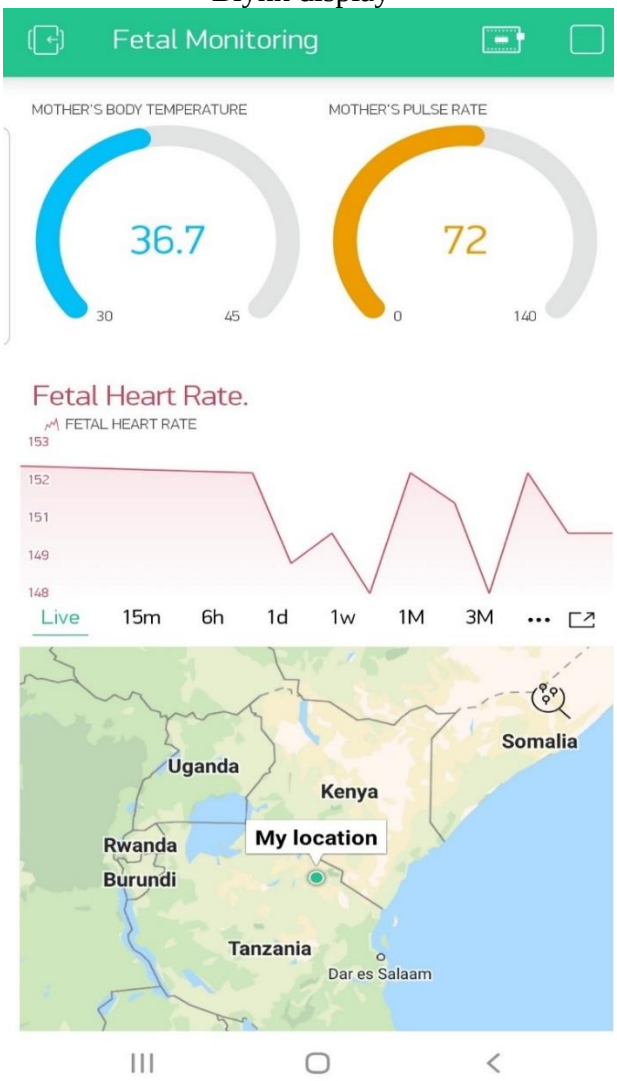
Unborn child's FHR

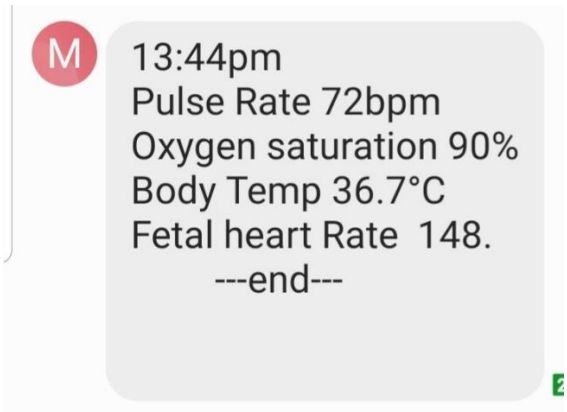
Figure 62: The images of the output information from the fourth participant

4.9.5 Fifth participant's (pregnant woman's) outputs

Figure 63 shows the reading of information when the device was used by the fifth participant.

Blynk display





Text messesge sent to mother

Mother's Measurements

Unborn child's FHR

Figure 63: The images of the output information from the fifth participant

4.10 Use case diagram

The use case diagram illustrates the activities done by three actors in the project are the admin, the medical personnel and the device itself. Here the admin will be responsible for registering the medical personnel or health worker who will be accountable attend patients who are pregnant women who are likely to use the device for close monitoring, but also responsible for all maintenance and regular updates on the system with respect to the additional requirements from the health facilities.

The medical personnel will be responsible for adding pregnant women or registering them to the system as they are assigned with the devices. Here the system will be accessed by only the administrator and the medical personnel with provided login credentials with protected passwords. The device will send information directly to the system locally and online with respect to the health facilities0' requirements. Figure 64 shows a use case diagram for the fetal heart rate system web portal.

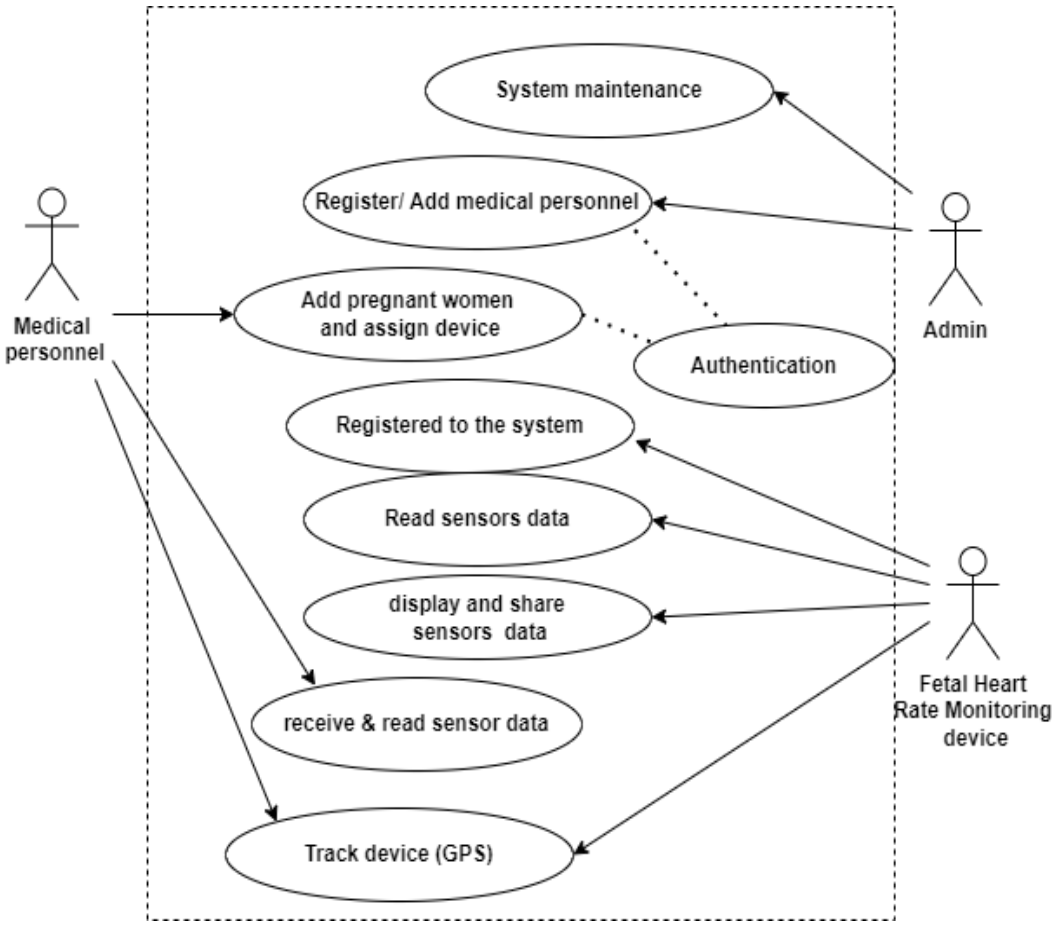


Figure 64: The use case diagram for the fetal heart rate monitoring system for medical personnel

4.11 The Fetal Heart Rate Monitoring Support System for Pregnant Women (FHRMSSPW)

A web portal for medical personnel's side feedback from the device and the pregnant women is of great significance since it gives up-to-date information on how the unborn child and their mother are progressing.

There are two log-in screens for the administrator and the medical personnel who would have been registered by the administrator. Referring to the use case diagram preceding, Fig. 65 shows the screenshot images of the web portal.

4.11.1 Admin's interfaces

Figure 65 show the log in interface for fetal heart rate support system for pregnant women which will be used by admin to access the system.

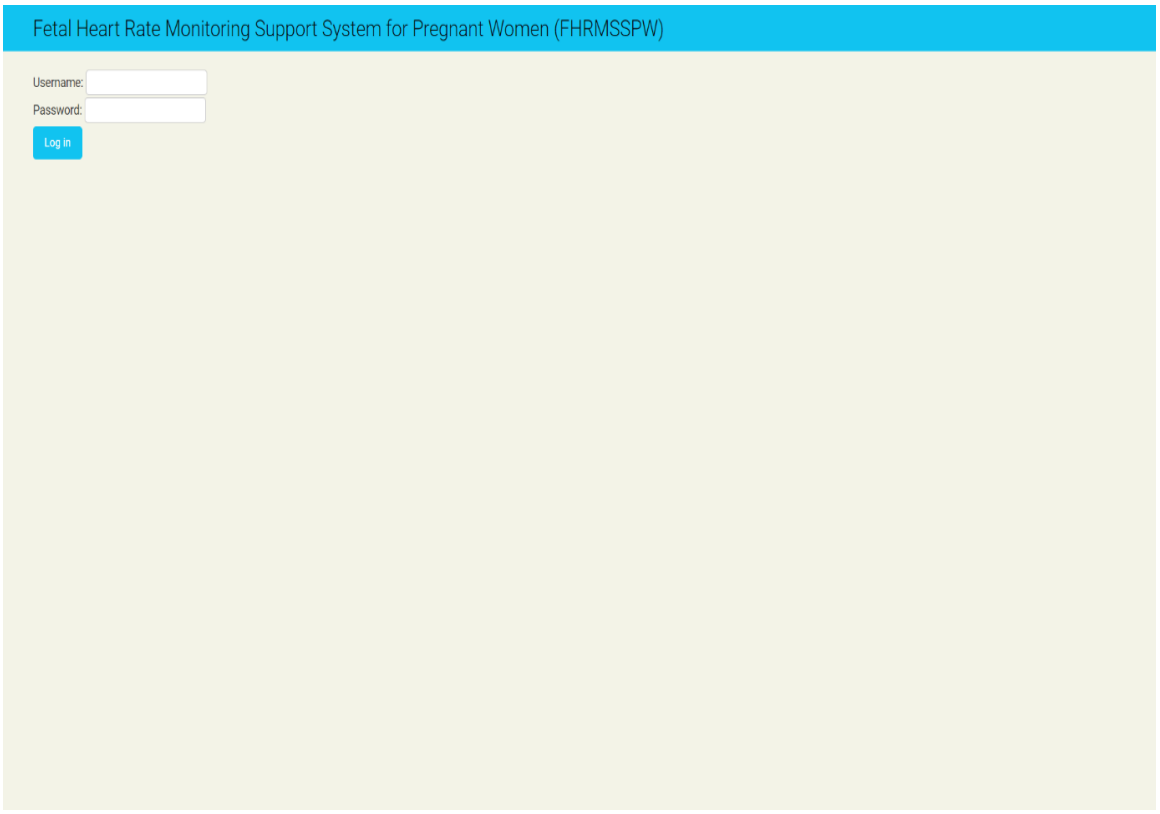


Figure 65: Admin's login screen

This image in Fig. 66 shows the administrators interface, where they will add the user (Medical personnel) and assign them names and passwords.

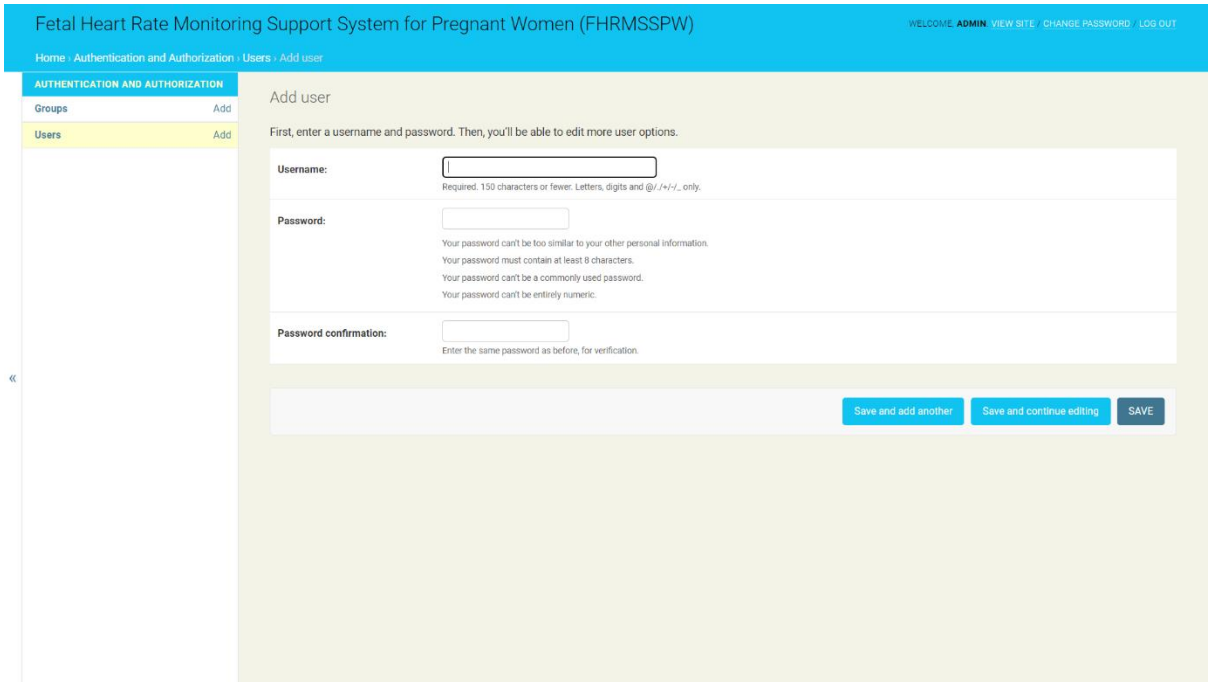


Figure 66: Administrator registering user's screen

The image in Fig. 67 shows the administrator has added or registered two medical personnel on this interface of the system.

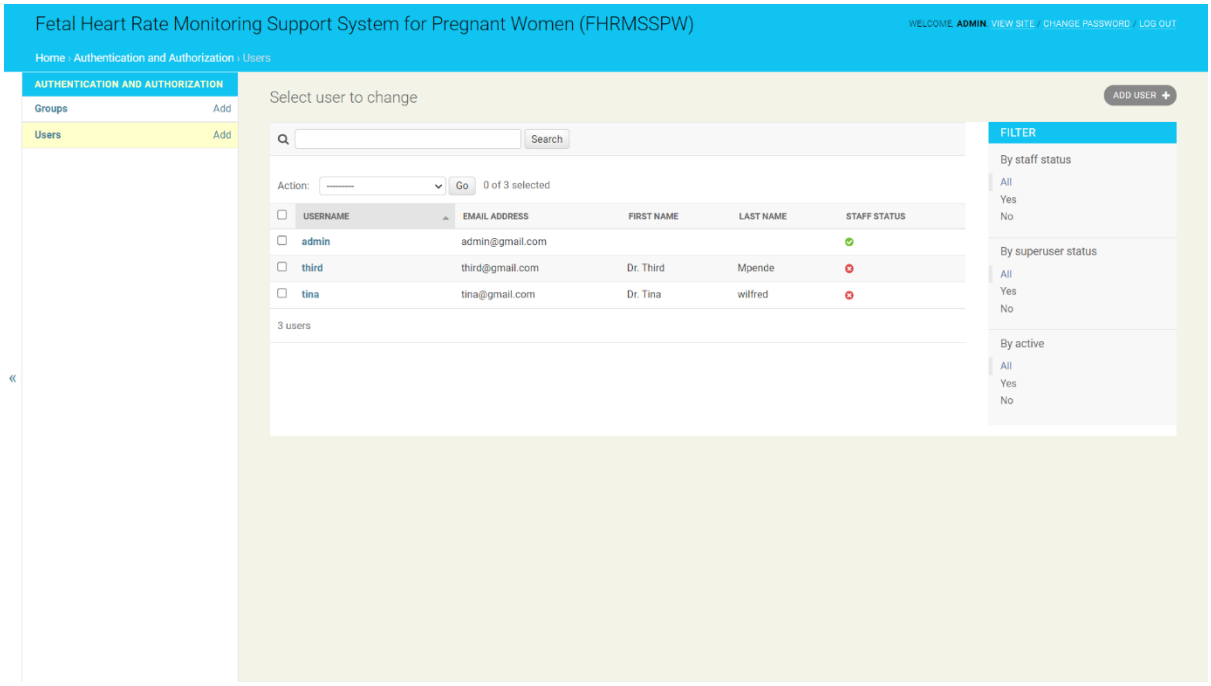


Figure 67: List of medical personnel registered by the administrator

Figure 68 shows the medical personnel's interface as they use the assigned credentials to log on to the system in order to start using it for adding and registering pregnant women with

respect to the given fetal heart Rate device. The passwords will be managed by the administrator in cases of any inconveniences within the health facility or in cases of annual leave of work transfer to other locations.

Figure 68: Medical personnel's log-in interface

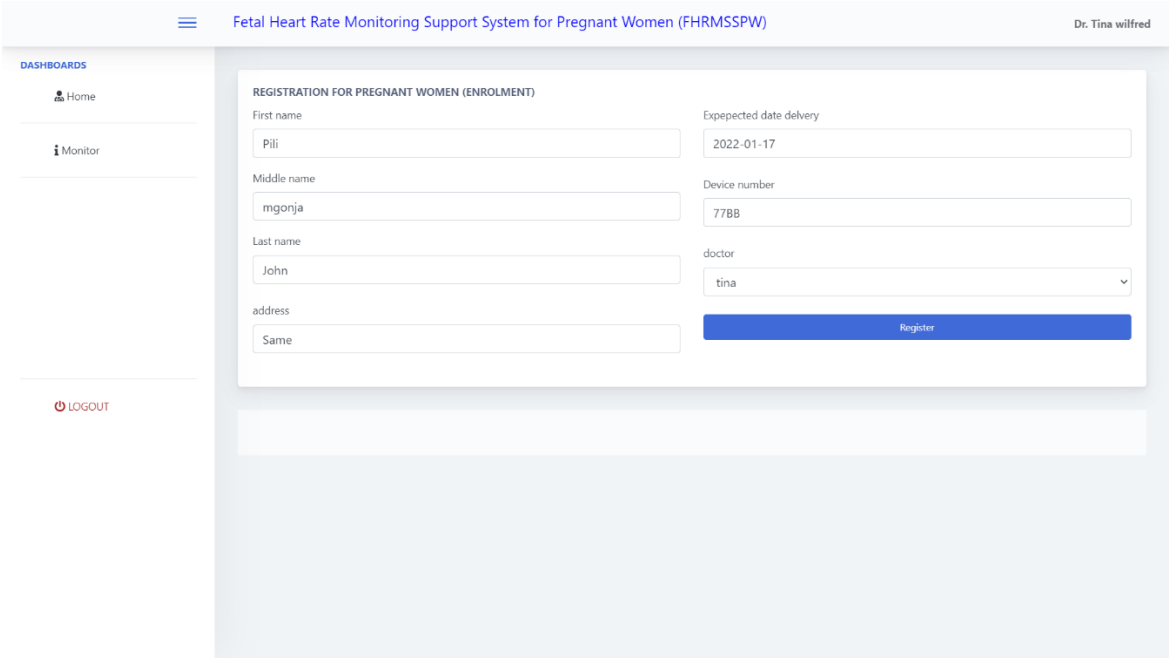


Figure 69: Medical personnel's interface for adding women and device

Figure 70 shows medical personnel named Dr. T. Wilfred has added of registered five women whose details such as names, location of the area of residence, registration date, expected delivery date (EDD) and the device id. The doctor has permission to edit for the case where the

woman has changed the area of residence and delete the patients if the patient is no longer available to use the device or they have delivered successfully unless otherwise.

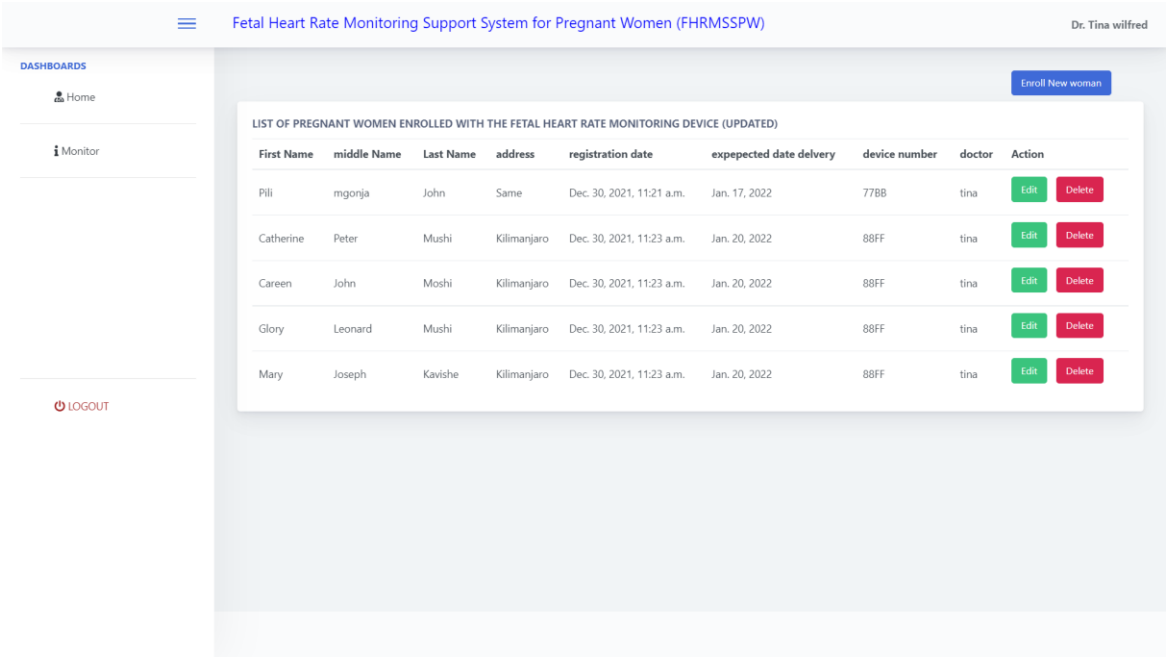


Figure 70: Medical Personnel's patients' list interface

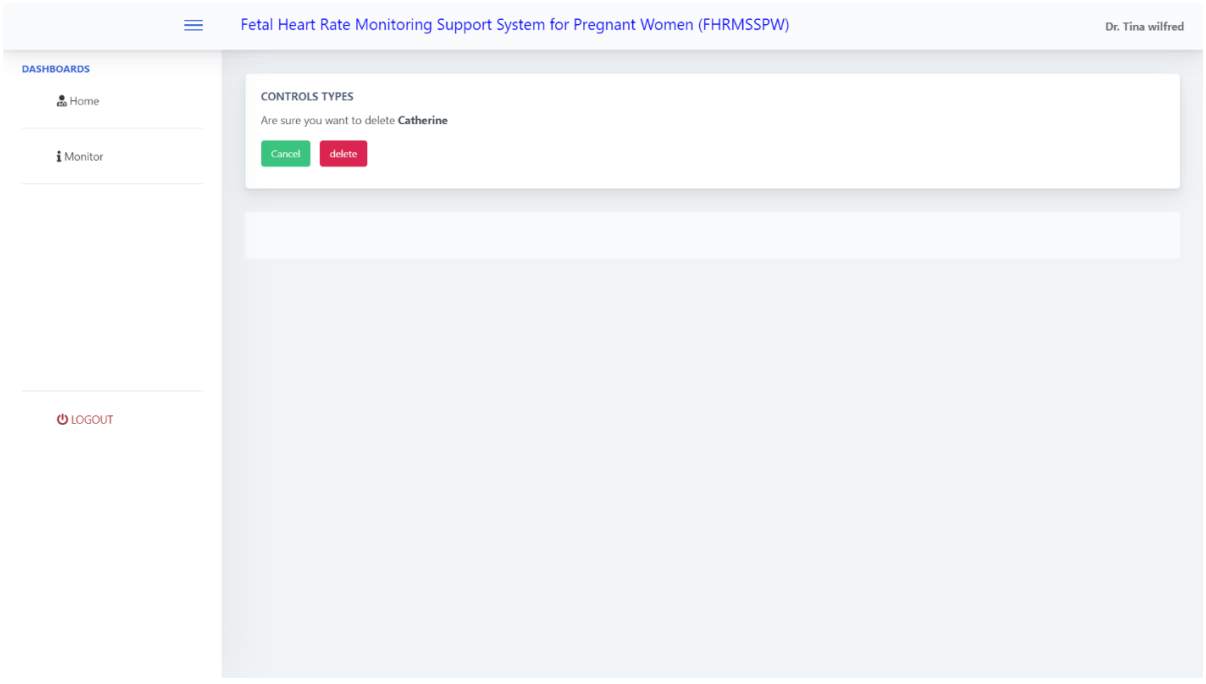


Figure 71: Medical Personnel's delete confirm

4.12 Discussion

This research project has provided a significant input to the health or medical research in Tanzania in the journey to improving and delivering the best antenatal care for pregnant women with complications during pregnancy, specifically those with high blood pressure in pregnancy. The design of the prototype of the fetal heart rate support belt has proven the ability of medical personnel to monitor the patient's wellbeing remotely at this time of the COVID19 pandemic outbreak where movement is limited and health facilities populated.

The design of the solution for a safety monitoring device for pregnant women diagnosed with mild pre-eclampsia. The development of the device for safe and self-monitoring of fetal's heart rate for pregnant women. Data sharing to the health facility via the device's web portal. Information trail of the data from the device to the pregnant woman via text messages. Raise awareness on the availability of a better method to self-monitoring of fetal heart rate at their area of residence to women.

The results and discussion chapter were generally where the project had been implemented. It has in detail elaborated all phases of the design and development, including putting to test the device and sharing the outputs. Successfully the objectives have been achieved, and the research questions in the first chapter have clearly been answered through illustrations and detailed explanations of the implemented work.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The previous chapters, Introduction, literature review, methods and materials, results and discussion of this research project work have led on to this conclusion chapter which is a clear and well-detailed summary of all that was done from the begging of the development of the fetal heart rate support belt for pregnant women diagnosed with mild pre-eclampsia in Tanzania to the final phase. All the above chapters lead to the analysis of both requirements and the information collected from women, and results were achieved from different steps of conducting the development and implementation of the project, which was clearly guided by those findings and requirements. The story of the Fetal heart rate support belt for pregnant women diagnosed with mild pre-eclampsia will involve the collection of information through the developed device. The data was collected from sensors embedded in the support belt. There is a temperature sensor collecting temperature data in centigrade from the pregnant women's body, and heartbeat sensor max30100 sensing the pregnant woman's pulse rate and their oxygen saturation level, the doppler sensor measuring the fetal heart rate, GPS to identify the location of the device, real-time clock for time and a very comfortable wearable housing.

The fetal heart rate support belt has an OLED display on the left-hand side of the support belt, which has been used to display clearly all the information, both reading from the mother and the unborn baby are shown with a time difference of five seconds. Initially, the mother's data is displayed, followed by the unborn baby's data. This data will be displayed a few seconds after the device has been switched on immediately after the pregnant woman has won the support belt. This is of great importance since, in some cases, their phones may not be nearby or may not have been powered on, so this simplifies the activity by directly reading from the display OLED.

The data is transmitted to the Blynk mobile application in real-time, and the woman receives a text message from the device with a clear summary of the readings with respect to the time taken to wear and sensors obtaining data. The Blynk application was configured to accommodate all the sensed data to be displayed, but with no editing of any kind, the user will only be able to observe the displayed data. The Blynk application serves as one of the actuation parts of the developed system, which will be accessed by the pregnant women who will use the

device. The GSM module will serve women who women do not own smartphones; they will receive a text message immediately after the device is switched off.

In the Medical personnel's perception, the data will be sent to the fetal heart rate medical personnel's system. In real-time, the medical personnel will receive notifications of precisely the same data that was sent to the pregnant woman phone and the one displayed on the OLED screen. This is for the primary purpose of closely monitoring done remotely, here with respect to the results the medical personnel receive. They would contact the patient respectfully if it is required or needed for the pregnant woman's safety to avoid any kinds of complications that could cause stillbirth or Intrauterine fetal death or even cause premature birth. This allows the health facilities to be well informed of the states of their patients and to know when to act accordingly with respect to the data transmitted.

The developed fetal heart rate support belt for pregnant women was tested valid in all phases and seen to be helpful to future generations. Unlike the current fetal heart rate monitoring methods, the fetal heart rate support monitoring belt for pregnant women diagnosed with mild pre-eclampsia ensured secure transmission and storage of sensor measurements using advanced encryption standards algorithms. In addition, the system was able to be accessed remotely by the medical personnel to read and receive data from the devices.

5.2 Recommendations

This project research has innovatively captured the needs of the health sector's challenge regarding the reduction of the number of stillbirth and neonatal deaths caused by a lack of continuous monitoring of the fetal heart rate. The device designed and developed would be of much help and would bring a lifetime solution to the existing problems in maternal and antenatal service management.

We were conducting clinical trials in the country under the supervision of the national institute of medical research (NIMR) and other regulatory organizations responsible for all innovations research in the medical field to test for the accurateness and accountability of the innovative ideas developed by students and researchers to improve the science and technology field in the country but also practiced the patriotism to using the technology developed in our country in order to reduce costs, increase assurance of the knowledge acquired from the country's academic institutions and inspire the young generation to invent and innovate ideas creatively.

The device is one solution for one of the challenges, but it can be innovated to a broader way to solve more than one challenge in the health sector. It could be used for patients who cannot express their feelings due to mental disorders or dumb patients. This would help to make the health worker's job more accessible but also have more accurate data.

REFERENCES

Chuwa, F. S., Mwanamsangu, A. H., Brown, B. G., Msuya, S. E., Senkoro, E. E., Mnali, O. P., Mazuguni, F., & Mahande, M. J. (2017). Maternal and fetal risk factors for stillbirth in Northern Tanzania: A registry-based retrospective cohort study. *PLoS One, 12*(8), 1–10. https://doi.org/10.1371/journal.pone.0182250

Fu, J., Li, C., Gou, W., Lee, A., Li, X., & Chen, Q. (2019). Expectant or outpatient management of preeclampsia before 34 weeks: safe for mother but associated with increased stillbirth risk. *Journal of Human Hypertension*, *33*(9), 664–670. https://doi.org/10.1038/s41371-019-0175-1

Hirose, A., Alwy, F., Atuhairwe, S., Morris, J. L., Pembe, A. B., Kaharuza, F., Marrone, G., & Hanson, C. (2019). Disentangling the contributions of maternal and fetal factors to estimate stillbirth risks for intrapartum adverse events in Tanzania and Uganda. *International Journal of Gynecology and Obstetrics*, *144*(1), 37–48. https://doi.org/10.1002/ijgo.12689

Hlongwane, T. M. A. G., Cronje, T., Nkosi, B. S. S., & Pattinson, R. C. (2021). The prevalence of abnormal Doppler's of the umbilical artery in a low-risk pregnant population in South Africa. *EClinicalMedicine, 34*, 1-20. https://doi.org/10.1016/j.eclinm.2021.100792

Kamala, B. A., Kidanto, H. L., Wangwe, P. J., Dalen, I., Mduma, E. R., Perlman, J. M., & Ersdal, H. L. (2018). Intrapartum fetal heart rate monitoring using a handheld doppler versus Pinard stethoscope: A randomized controlled study in Dar es salaam. *International Journal of Women's Health*, *10*, 341–348. https://doi.org/10.2147/IJWH.S160675

Kidanto, H. L., Wangwe, P., Kilewo, C. D., Nystrom, L., & Lindmark, G. (2012). Improved quality of management of eclampsia patients through the criteria-based audit at Muhimbili National Hospital, Dar es Salaam, Tanzania. Bridging the quality gap. *BMC Pregnancy and Childbirth*, *12*(1), 1-7. https://doi.org/10.1186/1471-2393-12-134

Kidanto, H. L., Mogren, I., Massawe, S. N., Lindmark, G., & Nystrom, L. (2009). Criteria-based audit on the management of eclampsia patients at a tertiary hospital in Dar es Salaam, Tanzania. *BMC Pregnancy and Childbirth*, *9*. https://doi.org/10.1186/1471-2393-9-13

Lai, J., Nowlan, N. C., Vaidyanathan, R., Shaw, C. J., & Lees, C. C. (2016). Fetal movements as a predictor of health. *Acta Obstetricia et Gynecologica Scandinavica*, *95*(9), 968–975. https://doi.org/10.1111/aogs.12944

Massawe, A., Kidanto, H. L., Moshiro, R., Majaliwa, E., Chacha, F., Shayo, A., Mdoe, P., Ringia, P., Azayo, M., Msemo, G., Mduma, E., Ersdal, H. L., & Perlman, J. M. (2018). A care bundle including antenatal corticosteroids reduces preterm infant mortality in Tanzania, a low resource country. *PLoS One*, *13*(3), 1–16. https://doi.org/10.1371/journal.pone.0193146

Mdoe, P. F., Ersdal, H. L., Mduma, E., Moshiro, R., Dalen, I., Perlman, J. M., & Kidanto, H. (2018). Randomized controlled trial of continuous Doppler versus intermittent fetoscope fetal heart rate monitoring in a low-resource setting. *International Journal of Gynecology and Obstetrics*, *143*(3), 344–350. https://doi.org/10.1002/ijgo.12648

Mdoe, P. F., Ersdal, H. L., Mduma, E., Moshiro, R., Kidanto, H., & Mbekenga, C. (2018). Midwives' perceptions on using a fetoscope and Doppler for fetal heart rate assessments during labor: A qualitative study in rural Tanzania. *BMC Pregnancy and Childbirth*, *18*(1), 1–10. https://doi.org/10.1186/s12884-018-1736-y

Mol, B. W. J., Roberts, C. T., Thangaratinam, S., Magee, L. A., De Groot, C. J. M., & Hofmeyr, G. J. (2016). Pre-eclampsia. *The Lancet*, *387*(10022), 999–1011. https://doi.org/10.1016/S0140-6736(15)00070-7

Plotkin, M., George, J., Bundala, F., Tibaijuka, G., Njonge, L., Lemwayi, R., Drake, M., Bishanga, D., Rawlins, B., Ramaswamy, R., Singh, K., & Wheeler, S. (2020). Scale-up of doppler to improve intrapartum fetal heart rate monitoring in Tanzania: A qualitative assessment of national and regional/district level implementation factors. *International Journal of Environmental Research and Public Health*, *17*(6), 1-17. https://doi.org/10.3390/ijerph17061931

Plotkin, M., Kamala, B., Ricca, J., Fogarty, L., Currie, S., Kidanto, H., & Wheeler, S. B. (2020). A systematic review of Doppler for detecting intrapartum fetal heart abnormalities and measuring perinatal mortality in low- and middle-income countries. *International Journal of Gynecology and Obstetrics*, *148*(2), 145–156. https://doi.org/10.1002/ijgo.13014

Tlaye, K. G., Endalfer, M. L., Kassaw, M. W., Gebremedhin, M. M., & Aynalem, Y. A. (2020). Preeclampsia management modalities and perinatal death: A retrospective study in Woldia general hospital. *BMC Pregnancy and Childbirth*, *20*(1), 1–9. https://doi.org/10.1186/s12884-020-02909-9

APPENDICES

Appendix 1: Introduction letter

THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

THE NELSON MANDELA AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY (NM-AIST)

OFFICE OF THE DEAN – SCHOOL OF COMPUTATIONAL AND COMMUNICATION SCIENCE AND ENGINEERING (CoCSE)

Direct Link:
Mobile Phone:
Fax:
E-mail:dean-cocse@nm-aist.ac.tz

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

In reply please quote:
Ref. No NM-AIST/M023/T19

Date: 04th October 2021

To Whom It May Concern.

Dear Sir/Madam,

RE: INTRODUCTION TO Ms. CHRISTINA WILFRED MARIKI

Kindly refer to the above heading.

I wish to introduce Ms. Christina Wilfred Mariki, a Masters student at the Nelson Mandela African Institution of Science and Technology in the School of Computational and Communication Science and Engineering with Registration No. M.023/T.19.

As part of the requirement for Master degree, Ms. Christina is undertaking a research project titled ***"Developing a Fatal Heart Rate Monitoring System for Pregnant Women Diagnosed with Mild Preeclampsia: A Case Study of Tanzania".***

In order to accomplish his project objectives, she would like to conduct a survey to some institutions. The intention of the survey is assess tto easier the facilitation of the intended project activity and application for the ethical clearance.

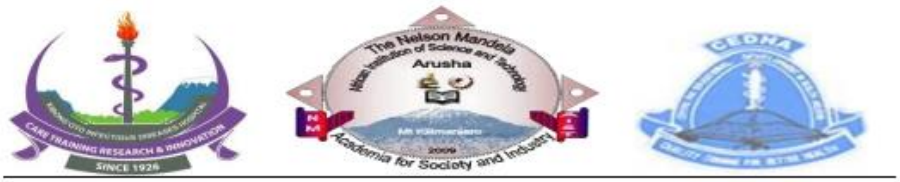
It is my sincere hope that you will assist the student in accomplishing her survey.

Looking forward to your cooperation.

Sincerely,

Shubi Kaijage, *Dr.Eng.*
Ag. Dean, School of CoCSE

Appendix 2: Ethical clearance application letter



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

To **The Chairperson**
Health Research Ethics Committee
Coordinating site; Kibong'oto Infectious Diseases Hospital
Mae Street, Lomakaa road.
Sanya Juu-Siha
Kilimanjaro
Tanzania

From Christina Wilfred Mariki
The Nelson Mandela African Institution of Science and Technology
P.O Box 447,
Arusha, Tanzania.

Dear Sir/Madam:

Re: Application for Ethical Clearance

Proposal/Protocol Name: Fetal heart beat monitoring support device for pregnant women diagnosed with mild preeclampsia/hypertension in Tanzania.

The aim of this research is to develop an expert system that will provide knowledge to pregnant women about the importance of continuous monitoring of their unborn child during pregnancy and also self-care tips that can be administeredat home to avoid still birth. The expert system is expected to help women monitor fetal heart rate and movement in a more advance manner and become more proactive during their visitsthat they can receive adequate care.

The research is expected to take place in February for Data collection for requirements gathering in Arusha, Manyara, Morogoro, Tanga Mwanza and Dar-es-salaam for one month. Data collection is mainly based collecting data that will be used to improve the proposed design so as to give the most accurate recommendations and will be collected from medical personnel and pregnant women. Then a system will be developed and tested.

Yours sincerely

Christina Mariki

Appendix 3: 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 "
Fetal Heart Beat Monitoring Support Device For Pregnant Women Diagnosed With Mild Preeclampsia/Hypertension 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 Internet of things to help pregnant women diagnosed with mild preeclampsia gain knowledge on the danger symptoms during pregnancy improving wellbeing of the unborn child to avoid still birth rate in Tanzania. If you agree to answer this questionnaire, please put your signature in this form to confirm that you have agreed the termsand 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 Christina Wilfred Mariki +255 743162017

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

CERTIFICATE OF CONCENT
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 4: Questionnaire

Women's questionnaire

Women perception on antenatal health

This study focuses on requirement gathering for developing a Fetal Heart Rate Monitoring Support System for pregnant women diagnosed with mild pre- eclampsia in Tanzania. This survey aims to gain or acquire knowledge and understanding on the perception of medical practitioners on assuring safety for pregnant women diagnosed with mild pre-eclampsia to help diminish the number of still birth caused by their hypertensive condition.

* Required

Questions

1. What is your age in years? *

Mark only one oval.

- ◯ 18 years - 25 Years
- ◯ 26 years - 35 years
- ◯ 36 years and above

2. Where do you live in Tanzania. (Region) *

Mark only one oval.

- ◯ Arusha
- ◯ Manyara
- ◯ Kilimanjaro
- ◯ Tanga
- ◯ Dar es salaam
- ◯ Other: _____

3. Have you been pregnant before? *

Mark only one oval.

- ◯ Yes *Skip to question 10*
- ◯ No *Skip to question 4*

Future maternity

4. Would you wish to have children in the near future? *

Mark only one oval.

- ◯ Yes
- ◯ No

5. Briefly explain your understanding of safe pregnancy? *

6. Briefly explain you understanding of complications in pregnancy, give examples . *

7. Would you use a Fetal Heart Rate monitoring belt (a device connected to the health facility system) to help you monitor the well being of your unborn child at home? *

Mark only one oval.

- ◯ Yes
- ◯ No

8. Do you think this Fetal heart rate monitoring system will be useful to help reduce the number of still births(i.e. the death or loss of a baby before delivery)? *

Mark only one oval.

- ◯ Yes
- ◯ No

9. What would you advice to be added to Fetal heart rate monitoring system to ensure safety of the mother and the unborn child? *

What you experienced during pregnancy.

10. If yes, did you attend a health facility for antenatal services? *

Mark only one oval.

- ◯ Yes
- ◯ No

11. How many times per month did you visit or schedule to visit the antenatal Clinic? *

Mark only one oval.

- ◯ Once per month
- ◯ more than once per month

12. Did you have any challenges/complications during any of your pregnancies? *

Mark only one oval.

- ◯ Yes
- ◯ No *Skip to question 10*

13. If yes, was the complication related to high blood pressure during pregnancy?

Mark only one oval.

- ◯ Yes
- ◯ No

14. If yes, did you receive treatment to take home with you from the health facility?

Mark only one oval.

- ◯ Yes
- ◯ No

15. How did/ do you ensure the well being of your unborn child? *

Mark only one oval.

- ◯ Self monitoring at home
- ◯ Visiting health facilities for antenatal services.

16. Did/do you have any doubts about the well being of your unborn child while self monitoring at home? *

Mark only one oval.

- Yes
- No

17. Would you use a Fetal monitoring belt (a device connected to the health facility system) to help you monitor the well being of your unborn child at home? *

Mark only one oval.

- Yes
- No

18. Would you wear the belt at least 3 times per day to ensure the well being of your unborn child? *

Mark only one oval.

- Yes
- No

19. Would you accept the medical person to receive information from your belt in order to assess the state of your pregnancy without having to visit the hospital many times in a month? *

Mark only one oval.

- Yes
- No

20. Do you have access to a smartphone and internet on daily basis? *

Mark only one oval.

- ◯ Yes
- ◯ No

21. Do you think this Fetal heart rate monitoring system will be useful to help reduce the number of still births(i.e. the death or loss of a baby before delivery)? *

Mark only one oval.

- ◯ Yes
- ◯ No

22. Kindly share summary of your experience during your pregnancy. *

23. What would you advice to be added to Fetal heart rate monitoring system to ensure safety of the mother and the unborn child? *

Appendix 5: Medical personnel's interview guide

MEDICAL PERSONNEL INTERVIEW

A summary introduction.

This interview aims to gain or acquire knowledge and understanding on the perception of medical practitioners on assuring safety for pregnant women diagnosed with mild pre-eclampsia to help diminish the number of stillbirths caused by their hypertensive condition.

This study focuses on requirement gathering for developing a Fetal heartbeat monitoring support system for pregnant women diagnosed with mild pre-eclampsia in Tanzania.

Interview questions.

1. What is your role in the medical field?
    a. Medical Doctor
    b. Nurse
    c. Specialist
2. What is the duration of your practicing experience in the medical field?
    a. Less than five years
    b. Five years to 10 years
    c. More than ten years
3. Are you currently working in the medical field (practicing)?
    a. YES
    b. NO
4. If yes, what is your current work location (a region in Tanzania)?

    ……

5. What other regions have you worked in before your current location (including your internship)?

    …….
6. Have you attended/ treated pregnant women? Or have you worked in the RCH clinics?
    a. YES
    b. NO

7. Have you treated or attended to pregnant women diagnosed with eclampsia?
    a. YES
    b. NO
8. What is/ was the standard of care for pregnant women diagnosed with mild pre-eclampsia

    ……
    ……
    ……
9. Is the current method of the standard of care for pregnant women diagnosed with mild pre-eclampsia effective enough to avoid stillbirth caused by a mother's hypertensive condition?
    a. YES
    b. NO
10. Which method is currently used to check for the unborn child's well-being in terms of Heartbeat and movement monitoring when the pregnant woman is at home (a far distance from the health facility)?

    ……
    ……
    ……
    …….
11. Is the current method effective for assuring safety for the unborn child whose mother is diagnosed with mild pre-eclampsia?

    ……
    ……
    ……
    ……
    ……..
12. Currently, I am developing a fetal Heartbeat monitoring system that will have a belt embedded with sensors to monitor the unborn child and send real-time data to the health facility/ medical personnel. Do you think this will be useful to help reduce the number of stillbirths in Tanzania?
    a. YES
    b. NO

13. What more do you think will be helpful to be added to our system for more effectiveness in ensuring safety?

    ……

    ……

    ……..

14. Do you think our system will help medical personnel?
    a. YES
    b. NO
15. Would you advise this system to be used by pregnant women with hypertensive conditions?
    a. YES
    b. NO.

End of the Interview

Many thanks to you for taking the time to participate in this interview.

They are prepared by Christina Mariki. A master's student from Nelson Mandela African Institute of Science and Technology.

Appendix 6: HTML code for the medical personnel's web application

Login page frontend code

```
{% load static %}
{% static 'images' as imageUrl %}
<!DOCTYPE html>
<html lang="en">
<head>
   <meta charset="utf-8">
   <meta name="author" content="Kodinger">
   <meta name="viewport" content="width=device-width,initial-scale=1">
   <title>Doctor Login Page</title>
   <link rel="stylesheet"
href="https://stackpath.bootstrapcdn.com/bootstrap/4.3.1/css/bootstrap.min.css"
integrity="sha384-
ggOyR0iXCbMQv3Xipma34MD+dH/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T"
crossorigin="anonymous">
   <link rel="stylesheet" type="text/css" href="{%static 'css_login/my-login.css' %}">
</head>
<body class="my-login-page">
   <section class="h-100">
      <div class="container h-100">
         <div class="row justify-content-md-center h-100">
            <div class="card-wrapper">
               <div class="brand">
               </div>
               <div>
                  {% for message in messages %}
                   <div class="alert alert-danger alert-dismissible " role="alert">
                    <button type="button" class="close" data-dismiss="alert" aria-
label="Close"><span aria-hidden="true">×</span>
                    </button>
                    <strong>Error!</strong> <span>{{message}}</span>
                   </div>
                  {% endfor %}
                 </div>
               <div class="card fat">
                  <div class="card-body">
                     <h4 class="card-title">Login</h4>
                     <form method="POST" class="my-login-validation" novalidate="">
            {% csrf_token %}
                        <div class="form-group">
                           <label for="email">USERNAME</label>

                           <input type="text" name="username" class="form-control" required
autofocus />
                           <div class="invalid-feedback">
                              Username is invalid
                           </div>
                        </div>
```

```
                        <div class="form-group">
                            <label for="password">PASSWORD
                        </label>
                            <input id="password" type="password" name="password"
class="form-control" required data-eye />
                            <div class="invalid-feedback">
                                Password is required
                            </div>
                        </div>
                <div class="clearfix"></div>
                        <div class="form-group">
                        </div>
                        <div class="form-group m-0">
                            <button type="submit" class="btn btn-primary btn-block">
                                Login
                            </button>
                        </div>
                        <div class="mt-4 text-center">
                            OPEN ADMINISTRATION PANEL <a href="/admin">OPEN</a>
                        </div>
                    </form>
                </div>
            </div>
            <div class="footer">
                                <footer>
            <div class="pull-right">

            </div>
            <div class="clearfix"></div>
          </footer>

            </div>
          </div>
        </div>
      </div>
    </section>
    <script src="https://code.jquery.com/jquery-3.3.1.slim.min.js" integrity="sha384-
q8i/X+965DzO0rT7abK41JStQIAqVgRVzpbzo5smXKp4YfRvH+8abtTE1Pi6jizo"
crossorigin="anonymous"></script>
    <script src="https://cdnjs.cloudflare.com/ajax/libs/popper.js/1.14.7/umd/popper.min.js"
integrity="sha384-
UO2eT0CpHqdSJQ6hJty5KVphtPhzWj9WO1clHTMGa3JDZwrnQq4sF86dIHNDz0W1"
crossorigin="anonymous"></script>
    <script src="https://stackpath.bootstrapcdn.com/bootstrap/4.3.1/js/bootstrap.min.js"
integrity="sha384-
JjSmVgyd0p3pXB1rRibZUAYoIIy6OrQ6VrjIEaFf/nJGzIxFDsf4x0xIM+B07jRM"
crossorigin="anonymous"></script>
    <script src="{%static 'js_login/my-loginlogin.js' %}"></script>
</body>
</html>
```