

2021-08

Development of self-monitoring mobile system for diabetes management in adult population of Tanzania

Mshana, Shakila

NM-AIST

<https://doi.org/10.58694/20.500.12479/1348>

Provided with love from The Nelson Mandela African Institution of Science and Technology

DEVELOPMENT OF SELF-MONITORING MOBILE SYSTEM FOR DIABETES MANAGEMENT IN ADULT POPULATION OF TANZANIA

Shakila Mbaraka Mshana

**A Project Report Submitted in Partial Fulfilment 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

August, 2021

ABSTRACT

Diabetes is a chronic disease that affects millions of people globally and the number alarmingly increases annually. Since it results in an excessive amount of glucose in the blood, if not well managed and controlled, diabetes can cause severe complications such as cardiovascular and renal issues, blindness and nerve damage. Apart from the medication and injections that patients get from their health centers to control it, the biggest responsibility falls on the patient themselves to take the medication, eat proper diet, maintain good weight and regularly exercise to manage the illness. It is for this reason that this mobile platform is developed. DiabAssistant is a mobile and web app developed using Flutter and Django respectively with an API to bridge the two. This supportive platform helps diabetic patients be able to follow the trends of their glucose levels, get suggestions of possible reasons for the spikes based on the data they entered as well as get recommendations of what to do next to lower the glucose level. They can also choose to share with their doctor the reports generated from the app to better help the doctors come up with a more efficient treatment plan based on real data from the patient. Patients and endocrinologists were involved in different stages of the project to capture what a Tanzanian diabetic patient needs and the most user-friendly way to deliver those needs. The platform was found useful among diabetic patient as well as their doctors since it served as an assistant in aiding in the control and management of the disease.

DECLARATION

I, Shakila Mbaraka Mshana do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this Report is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other university.

Ms. Shakila Mbaraka Mshana
Candidate Name



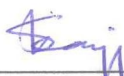
Signature

6/8/2021

Date

The above declaration is confirmed by;

Dr. Shubi Kaijage
Supervisor 1



Signature

6-8-2021

Date

Dr. Judith Leo
Supervisor 2



Signature

6/8/2021

Date

COPYRIGHT

This project report is copyright material protected under the Berne Convention, the Copyright Act of 1999 and other international and national enactments, in that behalf, on intellectual property. It must not be reproduced by any means, in full or in part, except for short extracts in fair dealing; for research private study, critical scholarly review or discourse with an acknowledgement, without the written permission of the office of Deputy Vice Chancellor for Academic, Research and Innovation, on behalf of both the author and NM-AIST.

CERTIFICATION

The undersigned certify that they have read and hereby recommend for submission to the Nelson Mandela African Institution of Science and Technology (NM-AIST) a project report titled: *Development of a patient self-monitoring mobile system for diabetes management in adult population of Tanzania* in fulfilment of the requirements for the Master of Science in Embedded and Mobile Systems of the Nelson Mandela African Institution of Science and Technology.

Dr. Shubi Kaijage

Supervisor 1



Signature

6-8-2021

Date

Dr. Judith Leo

Supervisor 2



Signature

6/8/2021

Date

ACKNOWLEDGEMENT

First and foremost, I would like to express my utmost gratitude to my Almighty Creator for giving me life, the intellect, strength, spirit, wisdom and perseverance to accomplish my project.

My immense gratitude goes to my supervisors Dr. Shubi Kaijage and Dr. Judith Leo for their guidance, advice and constant support throughout my work.

Special thanks to my sponsors CENIT@EA, who through their generous scholarship, I am able to study here at Nelson Mandela African Institution of Science and Technology. I am also very appreciative of their full support with the resources for making this project come to life. I am utterly grateful now and forever.

I would also like to thank all faculty members and staff of the school of Computational and Communication Science and Engineering (CoCSE), Nelson Mandela African Institution of Science and Technology for all the help during my study period and the project itself.

Last but not least, I would like to express our sincere gratitude to Nelson Mandela African Institution of Science and Technology (NM-AIST) for shaping and molding me into a better future scientist.

TABLE OF CONTENTS

ABSTRACT.....	i
DECLARATION	ii
COPYRIGHT.....	iii
CERTIFICATION	iv
ACKNOWLEDGEMENT	v
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF APPENDICES	x
LIST OF ABBREVIATIONS.....	xi
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background of the problem	1
1.2 Statement of the problem.....	2
1.3 Rationale of the study	2
1.4 Objectives	5
1.4.1 General objective.....	5
1.4.2 Specific objectives.....	5
1.5 Research questions.....	6
1.6 Significance of the study.....	6
1.7 Delineation of the study	6
CHAPTER TWO	7
LITERATURE REVIEW	7
2.1 Framework proposal for diabetes patient’s self-control	7
2.2 Mobile computing technologies for diabetes control.....	7

2.3	Awareness and prevalence of type 2 diabetes in Mwanza, Tanzania	7
2.4	Sensors and real time data processing monitoring system for diabetes	8
2.5	Mobile data service for insulin treatment of type 1 diabetes mellitus	8
2.6	Conclusion	9
CHAPTER THREE		10
MATERIALS AND METHODS.....		10
3.1	Project design and overview	10
3.2	Participants.....	11
3.3	Duration	11
CHAPTER FOUR.....		13
RESULTS AND DISCUSSION		13
4.1	Intervention Mobile App, DiabAssistant	13
4.2	Beta testing.....	19
4.3	Discussion	22
CHAPTER FIVE		23
CONCLUSION AND RECOMMENDATIONS		23
5.1	Conclusion	23
5.2	Recommendations.....	23
REFERENCES		24
APPENDICES		25
Poster presentation		40

LIST OF TABLES

Table 1: Assessment of usability, efficiency, and reception of the platform by patients20

Table 2: Assessment of usability, efficiency, and reception of platform by endocrinologist21

LIST OF FIGURES

Figure 1:	Age-adjusted comparative prevalence of Diabetes in Africa on adults aged 20-29 years in 2019	3
Figure 2:	Top five countries in Africa with highest number of adults with diabetes with age and gender distribution	4
Figure 3:	General architecture of the platform	11
Figure 4:	Entity relation diagram	14
Figure 5:	Record blood glucose levels use case.....	15
Figure 6:	Record meal intake use case.....	16
Figure 7:	Record physical activity use case	17
Figure 8:	Record emotions use case.....	18
Figure 9:	Language switch option.....	19
Figure 10:	Patients' assessment.....	21
Figure 11:	Endocrinologists' assessment.....	22

LIST OF APPENDICES

Appendix 1: Questionnaire to Evaluate the Systems Performance by Patients	25
Appendix 2: Questionnaire to Evaluate the Systems Performance by Endocrinologists.....	26
Appendix 3: Code for random blood glucose card can be found at CoCSE Lab at Nelson Mandela	27

LIST OF ABBREVIATIONS

CSS	Cascading Style Sheet
DRF	Django Rest Framework
IDF	International Diabetes Federation
LAB	Laboratory
NM-AIST	Nelson Mandela African Institution of Science and technology
TCRA	Tanzania Communications Regulatory Authority
TDA	Tanzania Diabetes Association
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the problem

According to the World Health Organization (WHO, 2020) Diabetes is a chronic disease that happens when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces. It is currently the sixth-leading cause of death worldwide jumping one position up from being the seventh in 2016. The prevalence of this chronic disease is rapidly rising in low-income and middle-income countries than in high-income countries. It is also reported by the International Diabetes Federation (IDF) that, about 463 million adults worldwide are currently diabetic and the number is expected to rise to 700 million adults by 2045 of the 463 million adults, 79% of them are from low- and middle-income countries like Tanzania.

There are two types of diabetes: Type 1, which is characterized by the pancreas producing little or no insulin at all by itself. Whereas Type 2 diabetes is characterized by the body becoming resistant to insulin produced by the pancreas, of the two types, Type 2 diabetes is the most common and affects a larger number of people mostly adults. This chronic disease is dangerous because it requires close monitoring of blood glucose levels daily or the patient is at risk of developing more serious and complicated health problems in major body parts such as the heart, kidneys, nerves and blood vessels which can be fatal. This is why it is very important to keep the glucose level in check at all times.

It is quite a challenge for patients to manage the condition by themselves without any assistant as it requires a complete change in lifestyle and their daily routine. To simplify people's lives, this self-monitoring mobile system with an easy-to-understand data visualization service will allow patients with diabetes to be able to record, observe and interpret their symptoms, blood glucose tendencies and fluctuations over different timeframes in a day as well as being able to share all that with their doctor(s). Moreover, the system will serve as an education platform about the disease such as ways of prevention, risk factors, symptoms of diabetes, the right diet, chronic complications, symptoms of developing complications and other helpful insights. With the mobile system serving as a data entry tool equipped with analysis and visualization tools it will help both the doctors and patients to manage the illness easily and comfortably.

1.2 Statement of the problem

Most diabetic patients in Africa live with the condition without their knowledge due to lack of regular checkups and knowledge on symptoms. Currently in Tanzania, diagnosed patients have monthly clinic appointments with their doctor where they are given a small exercise book referred to as a 'file' to record their self-test glucose level values before and after every meal. They then have to bring these 'files' every time they visit the clinic for their endocrinologist to analyze. This approach faces many challenges as it cannot be friendly exercised. Patients either fail or forget to regularly conduct a test because they are busy with their daily responsibilities. It is also time consuming, expensive and exhausting to visit the hospital daily just for the glucose tests. Additionally, having glucose values alone without any other supporting data isn't enough. The glucose levels are affected by a number of other factors in a patient's life like food intake, emotional, mental and physical state and other factors. All these need to be well documented and analyzed before a decision on a patient's health is made.

Furthermore, it's challenging to control and manage the disease after diagnosis because a patient has to adapt to a complete change in lifestyle. This includes taking tests and taking medication sometimes several times a day, monitor what they eat and drink as well as keeping their body active by exercising. While all this is very necessary and very important to follow, it can be a drastic change from the lifestyle that a patient is used to, therefore difficult to keep up with without assistance.

1.3 Rationale of the study

Diabetes has affected over 400 million people, resulting in approximately 4.2 million deaths and caused an expenditure of at least 760 billion USD in healthcare worldwide. As the disease shows a rapid rise in low- and middle-income countries, Africa had 19 million adults living with diabetes as of 2019 and the figure is projected to increase to 47 million by 2045. On top of that, IDF report shows that, Africa has the highest percentage of undiagnosed cases with over 60% of adults living with diabetes without knowing (International Diabetes Federation [IDF], 2019). Not everyone can get all the necessary services and support from health centers thus this intervention. The app helps improve healthcare for people with limited access to diabetes care by assisting them in managing the illness by themselves.

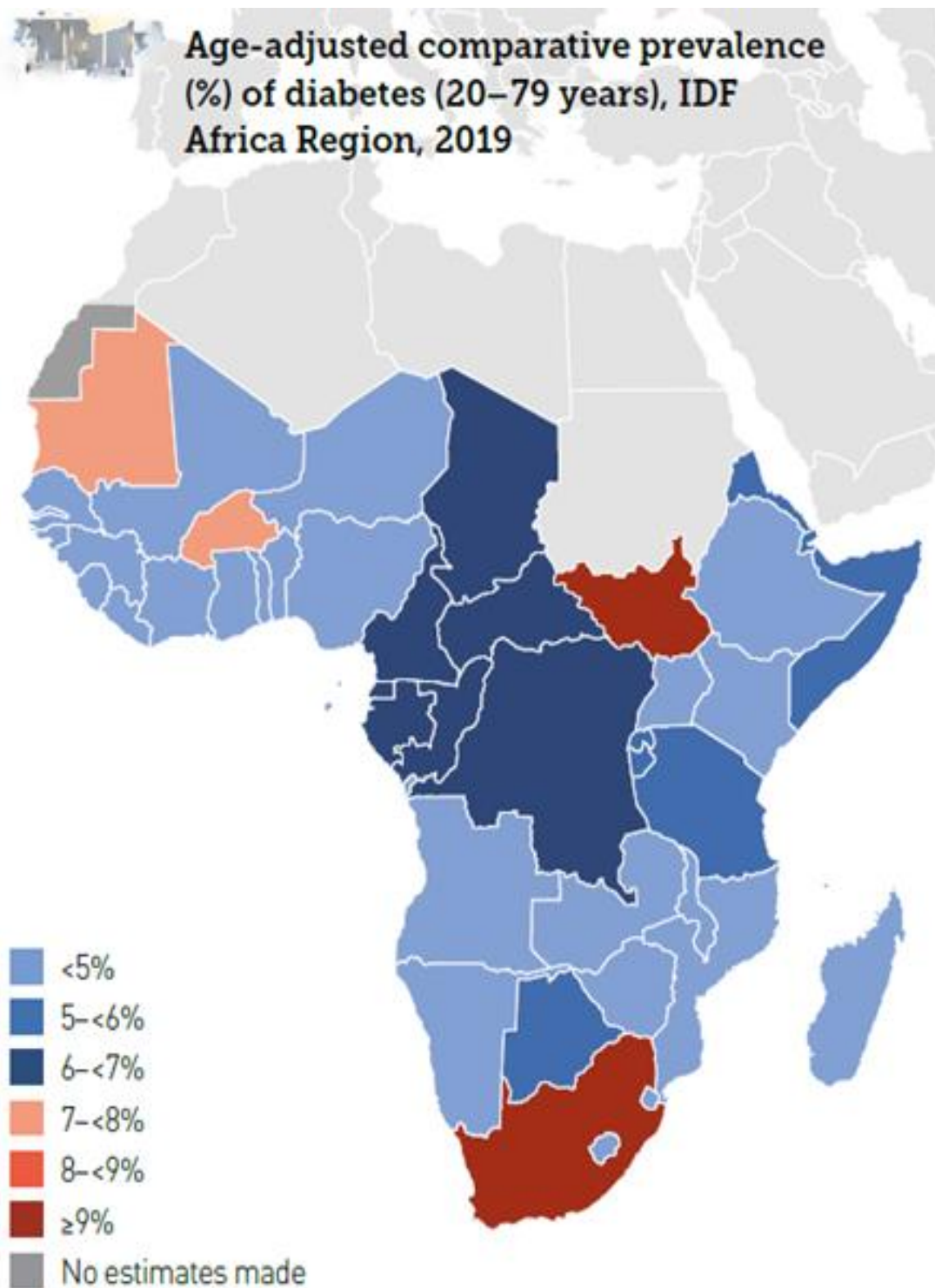


Figure 1: Age-adjusted comparative prevalence of Diabetes in Africa on adults aged 20-29 years in 2019

Top five countries for number of people with diabetes (20–79 years), 2019

	Millions
South Africa	4.6
Nigeria	2.7
Democratic Republic of the Congoⁱ	1.8
Ethiopia	1.7
United Republic of Tanzania	1.0

ⁱ Data were extrapolated from similar countries.

Prevalence of diabetes by age and sex, 2019

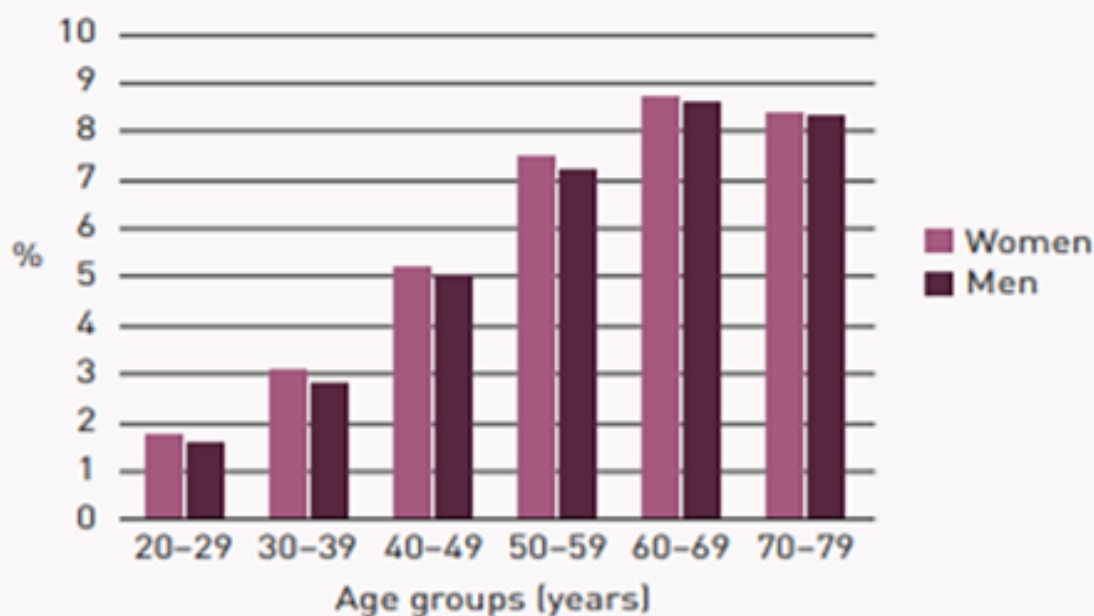


Figure 2: Top five countries in Africa with highest number of adults with diabetes with age and gender distribution

In 2019, Tanzania was among the top five countries in Africa with the highest number of people with diabetes (IDF, 2019), making the need to create this platform a necessity so as to help people manage the disease and bring awareness of ways to prevent, know symptoms and complications and even cure for the disease when symptoms are managed well early. This deems DiabAssistant very necessary. The data from the system may also be analyzed and used to give insight as to the patterns of the disease like the age, gender and region of the most affected number of people with diabetes in Tanzania and help take necessary steps to combat the problem.

Furthermore, the system will assist both doctors and patients to keep track of the disease and be in control at all times. For patients, being able to do self-check and have the system interpret the readings based on the time of the day checkup and the food consumed will surely help them understand the important relationship between food intake and glucose levels in their bodies thus make better choices. As for the doctors, having continuous records of their patients will help them better diagnose and develop a fitting treatment plan that works well to the patient.

Moreover, based on statistics from Tanzania Communications Regulatory Authority (TCRA) there is a huge surge in adoption of smartphones in Tanzania that is pushing further internet penetration as well. By the end of 2019, the internet penetration rate was 46% from 43% in 2018 and mobile phone subscribers was 49.1 million from 43.3 million in 2018 where 25.7 million of these were connected to the internet through their mobile devices (Tanzania Communications Regulatory Authority [TCRA], 2020). This gives further reason to create digital solutions such as this one rather than the old excise book method to help manage patients' issues as the number of people using smart phones is increasing.

1.4 Objectives

1.4.1 General objective

To develop a self-monitoring mobile system for diabetes management in adult population of Tanzania

1.4.2 Specific objectives

- (i) To analyze requirements for the proposed system.
- (ii) To develop the proposed system.

- (iii) To validate the developed system.

1.5 Research questions

- (i) Is there a need of doing self-tests and electronically record glucose levels, diet intake and lifestyle activity by patients daily?
- (ii) Is the continuous data from self-check readers/devices as well as diet intake and lifestyle information of patients important for doctors to make informed decisions?
- (iii) Will a digital platform that assist in managing and controlling of diabetes as well as gives knowledge on prevention, risk factors, symptoms and other related information about diabetes help in reducing secondary complications of the disease in Tanzania?

1.6 Significance of the study

The platform is beneficial to both patients and endocrinologists. It provides an environment for patients to get assistant in interpreting their blood glucose level values and trends, understand the relationship between the blood glucose values and other factors such as food intake, emotional state and physical activity. It also provides a dashboard for doctors to access patient's data and visualize these data in any given time frame. It will help doctors come up with a more efficient treatment plan based on real data from the patient.

1.7 Delineation of the study

This was a small project thus the size of participants was limited. On top of that, they were from urban and semi urban communities therefore missing representation of diabetic patients' rural areas. Most of the participants were also either employed or retired, meaning they could afford some of the resources needed to control and manage diabetes while a small percent was unemployed and poor and could not afford any of the resources apart from free medication given to them in the clinics. This made the basic functionalities of the app to be useless for this latter group because the whole idea lies on a patient having a glucometer device to check their blood glucose levels. Differences in education levels and basic knowledge of digital devices among the participant was also a challenge. On top of this lack of knowledge and understanding of the disease had a negative influence on a patients' ability to understand the app or its significance.

CHAPTER TWO

LITERATURE REVIEW

2.1 Framework proposal for diabetes patient's self-control

Villarreal *et al.* (2009) proposed a Patients' Mobile Monitoring for diabetes that made it possible to generate and define profiles for users with diabetes, create modules and information structures between checkup device and the mobile phone of the patient. It navigates how patterns can be used to allow self-control modules and patient profiles to be generated. The patterns work by creating relations between each module and the other. After having patient's device data, profile and the modules, the framework can now generate the applications for the doctor and the patient on a mobile phone. Through the applications they now allow monitoring of the patients' glucose, patient self-control and communication to their doctor.

2.2 Mobile computing technologies for diabetes control

In another paper, Mashael (2016) points out that Diabetes has to frequently be monitored and a treatment plan that is every so often revised by the endocrinologist has to be followed in order to keep blood glucose levels low. Its time consuming, expensive and exhausting to frequently visit the hospital for daily checkups to both the patient and the doctors as well. All these nuisances can be avoided with a remote monitoring system and the paper introduces an implementation of an integrated monitoring tool for patients with diabetes. The proposed system provides day to day and monthly monitoring capabilities. Daily analysis of data entered by a patient through their mobile device is recorded then transferred to a centralized database. For the monthly services, the patient is required to visit a nearby health facility center in their home town to do the medical examination and checkups also known as diabetes clinic. Afterward the result of this visit is recorded into the system then synchronized with the centralized database as well. From here the doctor can monitor the patient remotely and alter the treatment plan accordingly.

2.3 Awareness and prevalence of type 2 diabetes in Mwanza, Tanzania

Ruhembe *et al.* (2014) did a study to assess the rate of occurrence and awareness of type 2 diabetes mellitus in Tanzania. Random sampling was used to get study subjects. Information collected was about causes and risk factors for diabetes. Aside from that, random blood glucose

testing was activated to find those at risk of getting or having diabetes. Subjects who had ≥ 200 mg/dl on the next day were subjected to a fasting blood glucose test to affirm or negate if they had diabetes. The study found that a very small number of the participants knew about the causes and/or symptoms of diabetes. It concluded that education about diabetes should be stressed and routine checkups of blood glucose levels is highly recommended.

2.4 Sensors and real time data processing monitoring system for diabetes

Alfian *et al.* (2018) uses a different approach to monitoring diabetes through the use of Bluetooth Low Energy (BLE)-based sensors instead of the native devices. The BLE-based sensor device offers real-time data processing combined with machine learning algorithms to help them manage the disease much easier. The sensors were used to gather more than just blood glucose data but also patients' vital, blood pressure and weight from sensor nodes to smartphones, while real-time data processing was employed to manage the large amount of continuously generated sensor data. The processing of real time data was utilized by Apache Kafka as a streaming platform and for storage MongoDB was used. The machine learning-based methods were tested on patients' dataset and showed that through the Multilayer Perceptron early prediction of diabetes can be provided given the user's sensor data as the input. It was revealed that short-term and long-term memory can accurately predict the future blood glucose levels based on the current sensor data. Furthermore, the proposed classification and blood glucose predictions could be combined with personalized diet and physical activity of a patient in order to improve the health of patients and to avoid critical complications in the future.

2.5 Mobile data service for insulin treatment of type 1 diabetes mellitus

Kollmann *et al.* (2007) found that mobile phones could be used to provide a global, easy-to-use, and cost-efficient solution for management of type one diabetes. The feasibility study they did was to find how much mobile phone-based service could be accepted by diabetes patients, and how much of those services can actually assist type one diabetes patients who are on intensive insulin treatment. They developed a software called Diab-memory that supports patients with recording their information such as blood-glucose level, insulin doses, food intake and physical activities. This data was then remotely synchronized to a central database. The result was focused on patients' obedience to the therapy, availability of the monitoring system

itself and the effects of the therapy in their metabolic status. The results were that the system was accepted in general.

2.6 Conclusion

Most of the reviewed work shows the systems developed are general and follow the assumption that the users have all the resources such as calorie measure for meals and wearables for physical activity as well as enough digital knowledge and language skills to use these systems. This is not the case for most patients here in Tanzania. With the proposed system, patients in Tanzania are able to input data based on their normal day-to-day life thus making the platform easy and user friendly for Tanzanians. They also get an option to select the language they are comfortable in between Swahili and English. Thus, this platform offers a solution based on specific unique needs of a diabetic patient in Tanzania as opposed to the general platforms being developed out there.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Project design and overview

The platform was designed around the needs of its users, that is, diabetic patients and in an indirect way their endocrinologists. This was done through Agile software development methodology where both patients and doctors were involved in each stage of development.

A thorough literature review of previous research done related to the topic as well as the existing systems and platforms for self-monitoring of diabetes was done. This involved works done globally as well as in Tanzania to best capture the gaps that the platform will need to address.

DiabAssistant is a mobile and web app. The mobile app was developed using Flutter, an open-source Google UI toolkit used for building native apps for both Android as well as and iOS all from one codebase. It was a better option because it made it easier and faster to create a multiplatform mobile app that will accommodate both users of Android and iOS thus eliminating the problem of users of one platform missing out on using the app. Apart from that it includes innumerable widgets and has a great set of testing and debugging tools to optimize the app. The web app was done through Django, a python framework. The front end of the web app was done by Django template with additional JavaScript and CSS. To bridge the mobile app with the web app is a web service API created by Django Rest Framework (DRF).

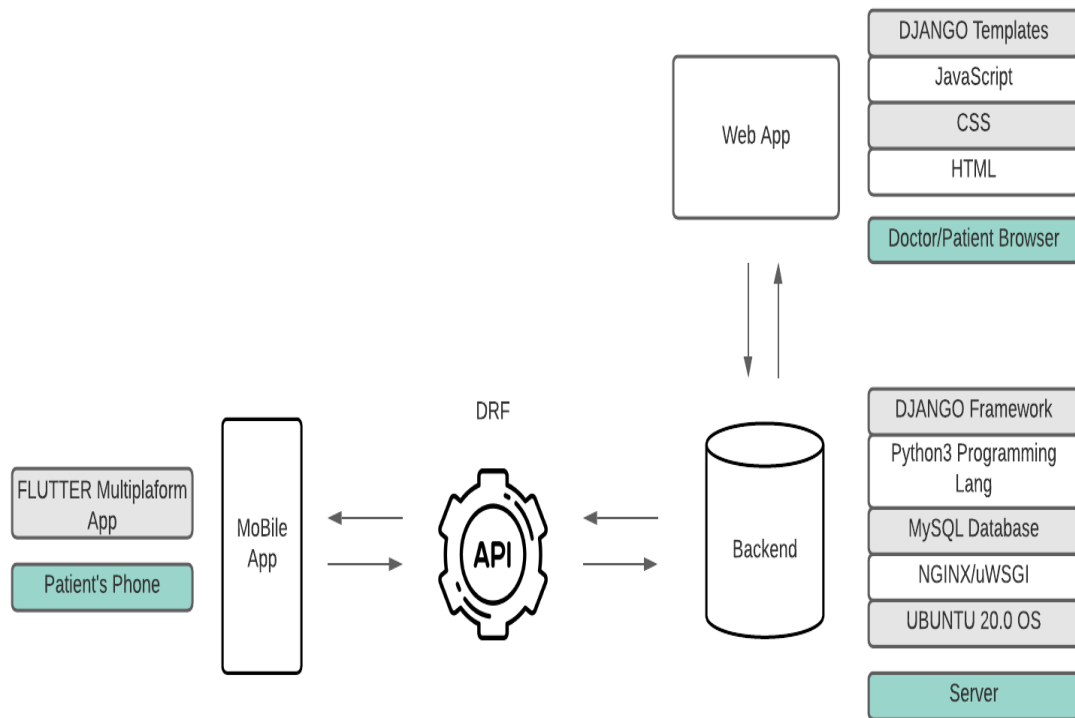


Figure 3: General architecture of the platform

3.2 Participants

Participants in this project were from 3 different health centers in Arusha and Dar es Salaam cities, informally but consensually involving 30 patients and 2 endocrinologists. Inclusion criteria included both females and males aged between 35-70 years old with varying levels of digital knowledge. The group involved patients that had been diagnosed within the past 10 years which means it included early stage diagnosed patients as well progressive chronic patients. Within the group also were patients who were already in a treatment plan and those that haven't started a modern medicine treatment plan but control the disease with diet and herbal medicine.

3.3 Duration

The entire project was done in a duration of five months including producing this report. Within those 5 months the activities done included:

- (i) Requirement analysis
- (ii) Designing of the platform

- (iii) Developing the platform
- (iv) Testing and validation
- (v) Documentation

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Intervention Mobile App, DiabAssistant

DiabAssistant is a result of systematic review of previous apps and literary works with close collaboration of users themselves. It has a logging tool to document relevant information including Blood Glucose, meals intake, physical activity and state of emotions. This data is used to discover patterns and modify lifestyle as well as treatment plan for diabetic patients.

It takes records of four main indicators, blood glucose, meal intake, physical activity and emotional state of a patient. Apart from these indicators, the platform offers an optional for patients to input their vitals such as heart rate, weight and others on a daily basis. On top of this it provides room for patients to record other medications apart from diabetes medication that they are taking, for example hypertension medication etc. this information is important to their doctors as some medications don't interact well with diabetes medication and so makes them less functional.

DiabAssistant also provides an education platform from reliable sources such as WHO, IDF and TDA where users can get a lot of information about diabetes as well as current news about the disease. The platform also gives remainder notifications if patients have not taken a blood glucose test and record it in the app as well as if they haven't taken medication. This helps users keep up with their blood glucose tests and medication/insulin injections daily and thus control the disease well.

DiabAssistant offers an option for a patient to share all their medical data with others specifically their Endocrinologists for a specific period of time. This data will be viewed on a dashboard in a webapp by the doctor in two forms, in summary charts and a detailed report. This will be crucial for Endocrinologists to make a well-informed decision about their patients rather than the old way. DiabAssistant uses both cellular data and/or WIFI to connect to the internet.

A sample code for the Mobile app is provided in Appendix 3. An entity relationship diagram below shows how the database for the app looks like.

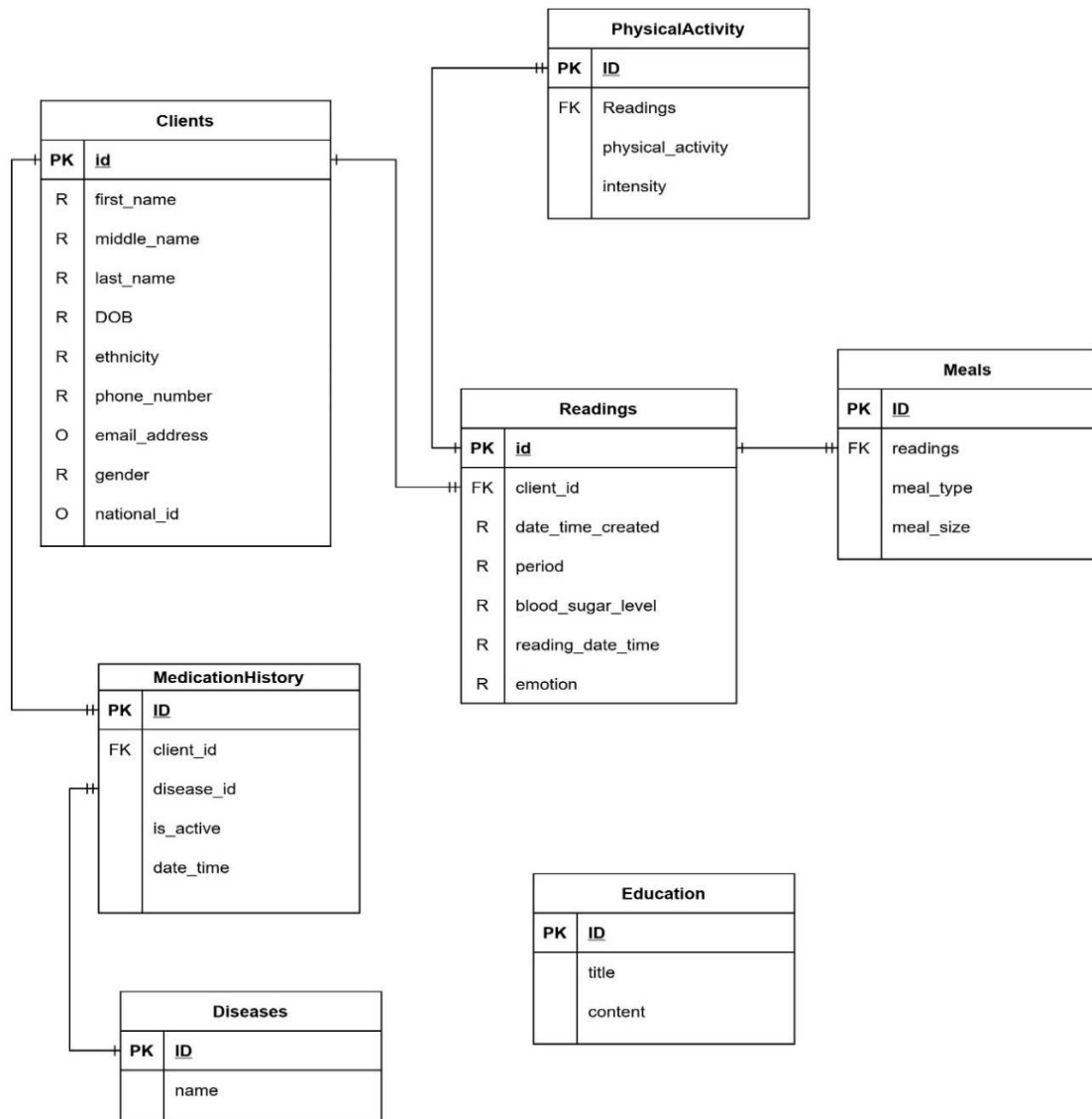


Figure 4: Entity relation diagram

With four main use cases as explained below, DiabAssistant intends to address the challenges from previous works in relation to control and management of Diabetes on a Tanzanian citizen.

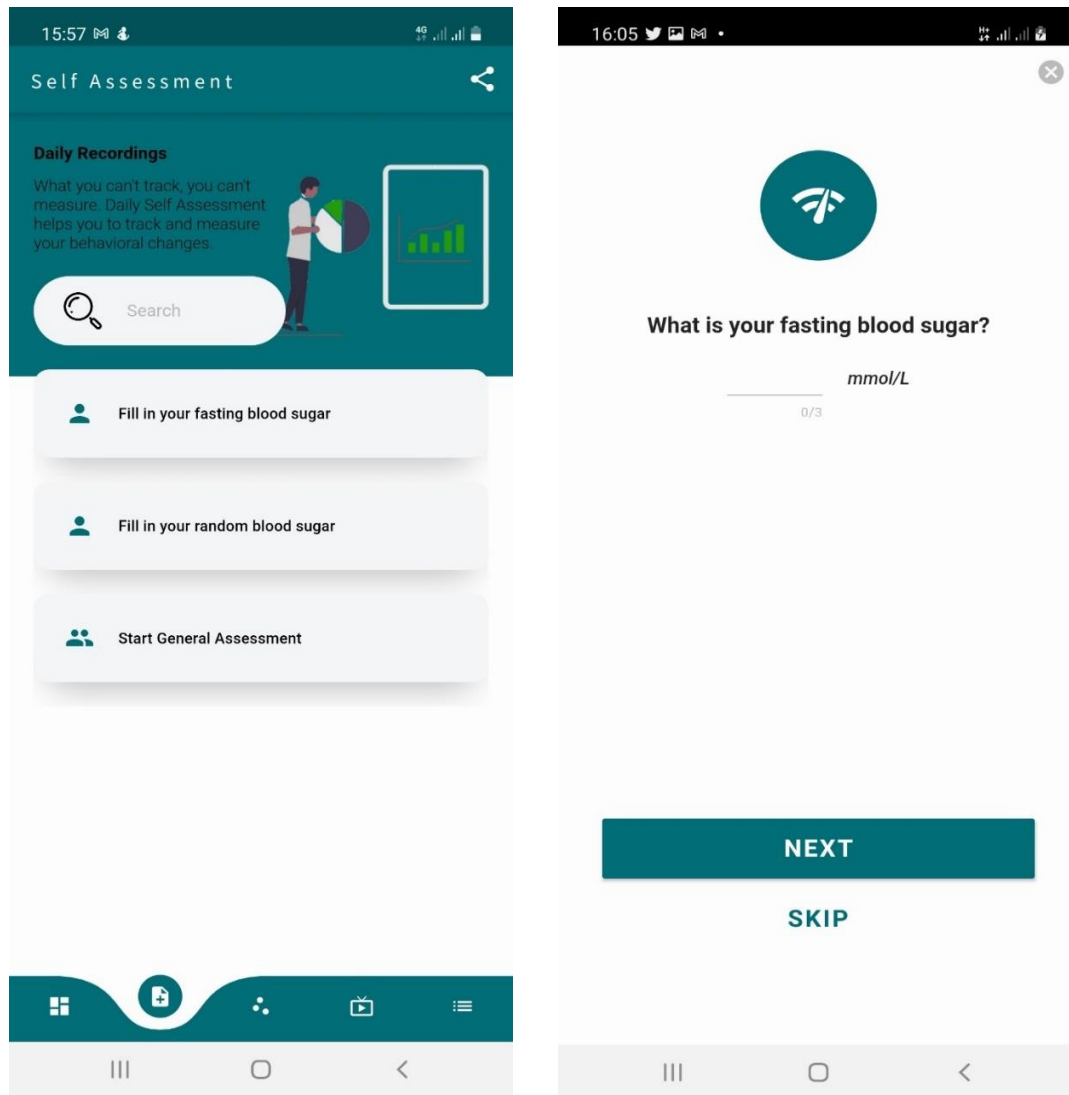


Figure 5: Record blood glucose levels use case

A patient has an option to record their blood glucose level based on the time of the day, either before breakfast called the Fasting blood sugar or after any meal but preferably before bedtime called random blood sugar. Each measure has its own definition and value during analysis that when measure against other factors will give a sensible meaning to the value against that particular time and factor. At all times the patient is also asked to specify if they already have taken diabetes medication or insulin injection. It is expected that patients have their own glucometer devices to do these measures with. In a normal setting these measures have to be done six time a day, before and after every meal but due to high expenses related to diabetes test strips in Tanzania, patients can afford only one or maximum two tests per day.

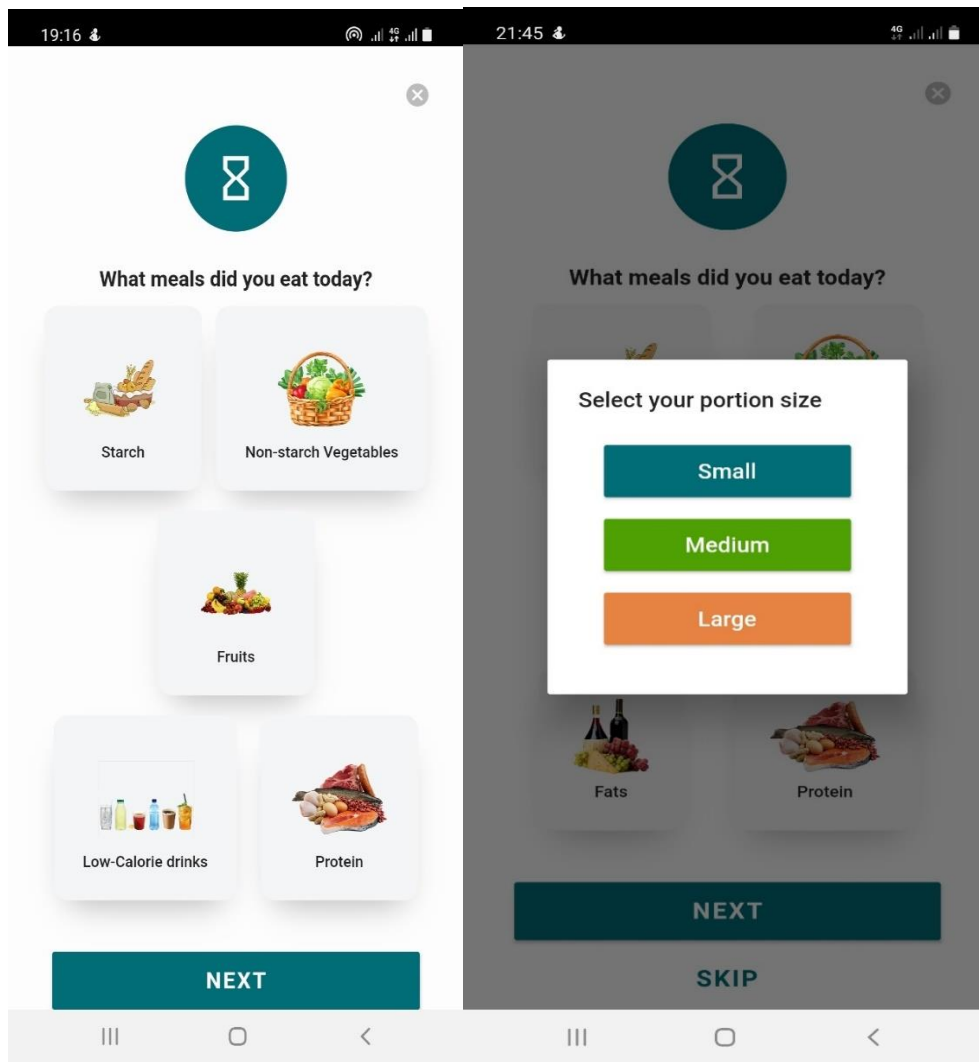


Figure 6: Record meal intake use case

Patients are given an option to choose a meal from the five main groups of meal. The options are not limited to just one choice but a patient can select even all food groups because it is normal for people to eat more than one food type per meal. Then they select based on their own criteria if the food they ate was small, medium or large portion. The app cannot measure portion size but capture the input value from users. There is no simple way to quantify food portions with an app like this because users are the ones eating and defining the measure of their food portion. DiabAssistant will advise users on different ways they can use to understand the portion sizes. For example, they can weigh their food using food weighing-scale, use label-sized dining tools like label-sized serving spoons, read food labels for calories and serving-sizes etc. These measures will help them understand which portion size is the correct for them to select in the app. Both the food group type and portion size are then combined and processed to give what effect they will have on the blood glucose of a patient.

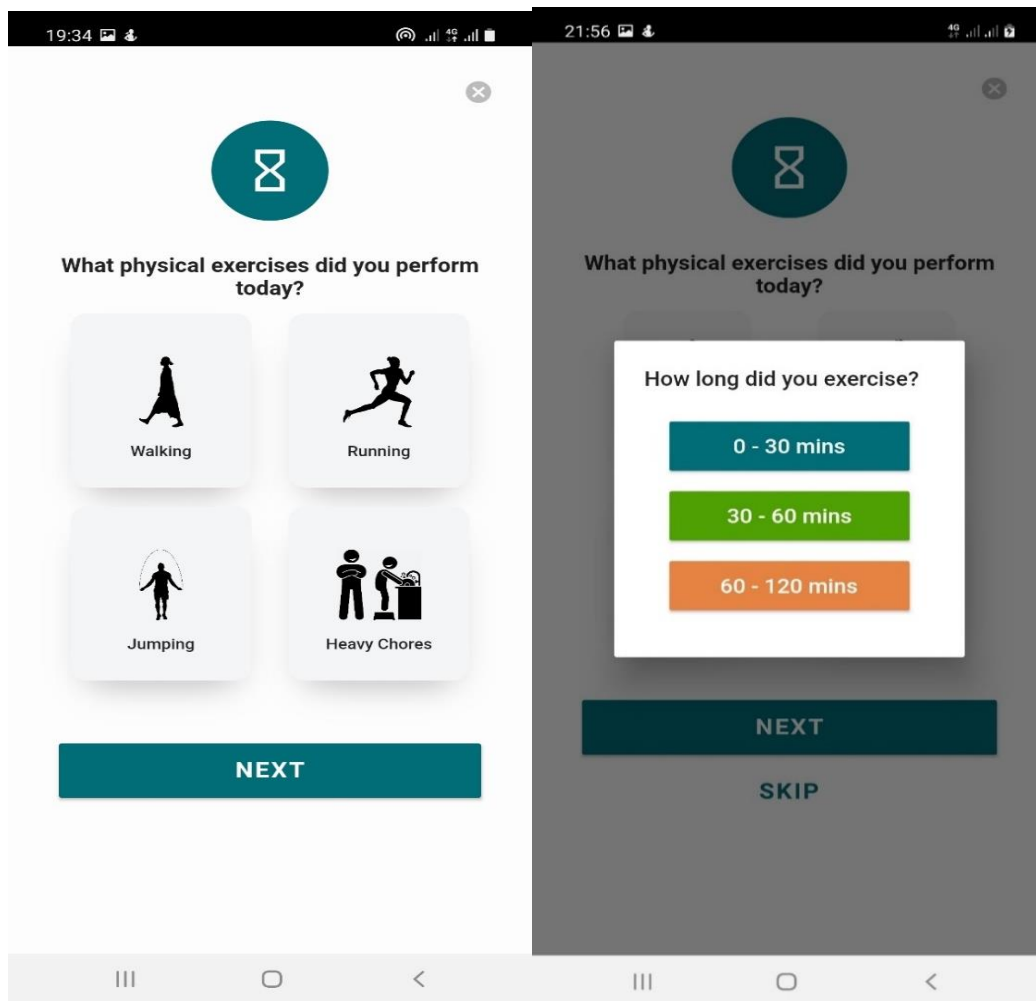


Figure 7: Record physical activity use case

On this use case a patient is given the most common forms of physical exercises that are usually advised by their doctors to do. Again, since most people do not own wearables to measure their vitals, the app was improvised to capture a period of time with the assumption that a physical exercise of a certain duration equates to a certain number of calories burnt and thus have an impact on the blood glucose.

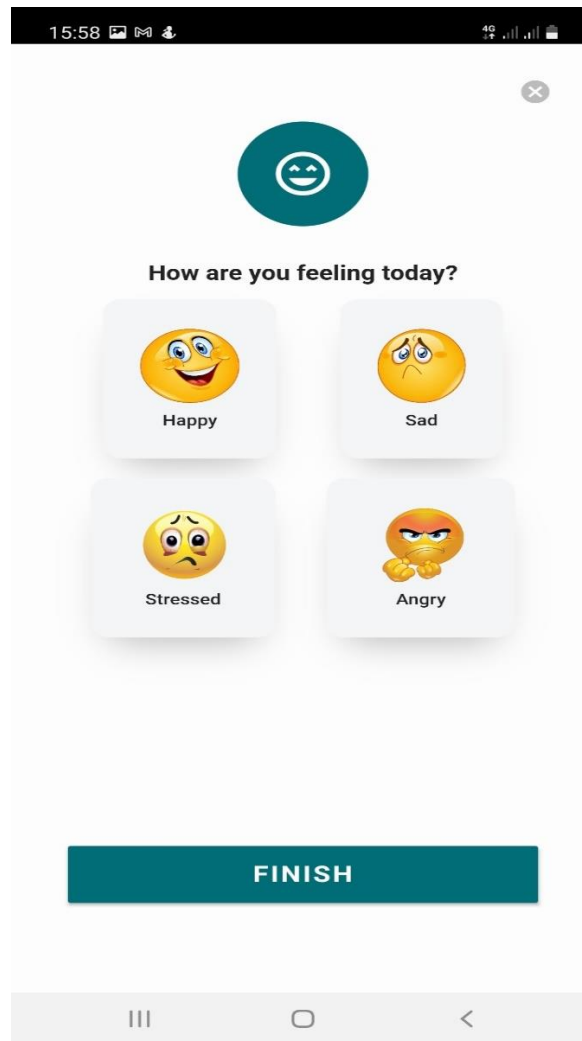


Figure 8: Record emotions use case

This is a use case was added after users mentioned that when their emotional state is negative sometimes it affects their blood glucose levels as well as functionality of their medication. This could be due to a number of factors related to the emotional states of patients that the app cannot fully capture, further research is needed to prove this but for now the app will capture this data and measure it against blood glucose level and analyze to see if there is a change when a patient is in a positive emotional state or a negative emotional state when all other factors remain constant.

Furthermore, being that DiabAssistant aims for inclusivity thus is a multiplatform system, that is, it's available for both android and iOS users, it also has the option for users to switch languages between Swahili and English. This gives users flexibility to a language they are comfortable with and this way cater to a huge number of people.

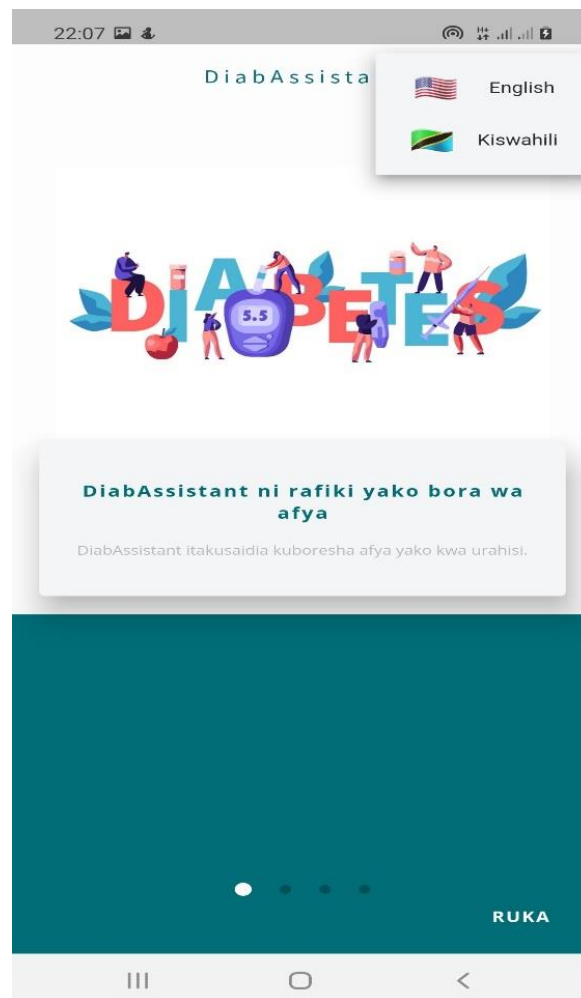


Figure 9: Language switch option

4.2 Beta testing

A small beta test session was done for the full functioning app apart from the unit tests that were done throughout the development stages. This stage involved three diabetic patients and two endocrinologists using the platform for several days. The session allowed to prove the usability, efficiency and acceptance of the multiplatform system and solve any issues that are expected to come up in the long-term use of the platform. At the end of the test, participants filled a questionnaire assessing the platform based on following metrics:

- (i) Usability and platform design

(ii) Efficiency of the platform

(iii) Reception and satisfaction of the platform

A scale of 10 points starting from 1 to 10 was used for rating in the questionnaire, with 7-10 scores representing the best rating, 4-6.9 scores representing a better rating and 1-3.9 score representing a poor rating of the system based on the questions given. Patients and Endocrinologists gave their assessment as shown in Tables 1 and 2. The questionnaire forms can be found at Appendix 1 and 2.

Table 1: Assessment of usability, efficiency, and reception of the platform by patients

Participants (Patients)	Qn1 Grade	Qn2 Grade	Qn3 Grade	Qn4 Grade	Qn5 Grade	Qn6 Grade	Qn7 Grade	Qn8 Grade	Qn9 Grade
P1	7	7	8	7	6	8	7	7	9
P2	8	9	6	7	6	8	8	8	9
P3	5	7	6	7	5	8	7	8	8
Sum	20	23	20	21	17	24	22	23	26
Average for each on	6.7	7.7	6.7	7	5.6	8	7.3	7.6	8.7
	Usability and Platform Design			Platform Efficiency			Reception and satisfaction		
Average per Metric	7			6.98			8.15		

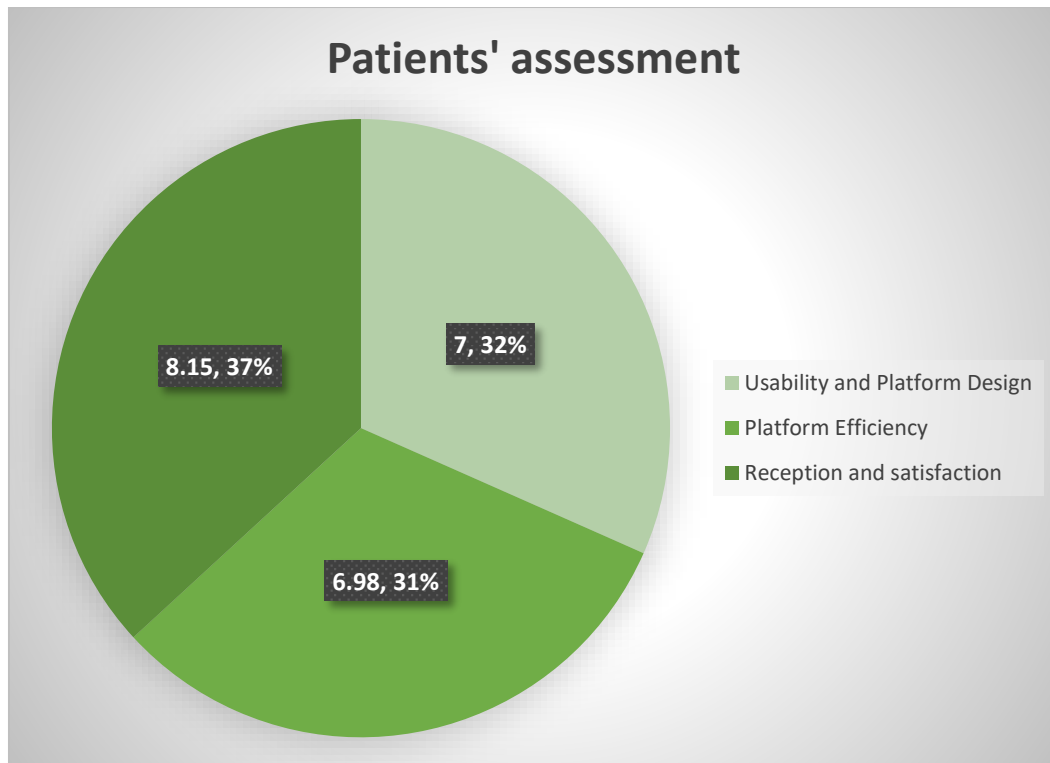


Figure 10: Patients' assessment

Table 2: Assessment of usability, efficiency, and reception of platform by endocrinologist

Participants (Endocrinologist)	Qn1 Grade	Qn2 Grade	Qn3 Grade	Qn4 Grade	Qn5 Grade	Qn6 Grade	Qn7 Grade	Qn8 Grade	Qn9 Grade
P1	8	7	8	7	6	8	9	8	9
P2	8	9	7	7	7	8	8	8	9
Sum	16	16	15	14	13	16	17	16	18
Average for each Qn	8	8	7.5	7	6.5	8	8.5	8	9
		Usability and Platform Design			Platform Efficiency			Reception and satisfaction	
Average Metric	per	7.6			7.6			8.5	

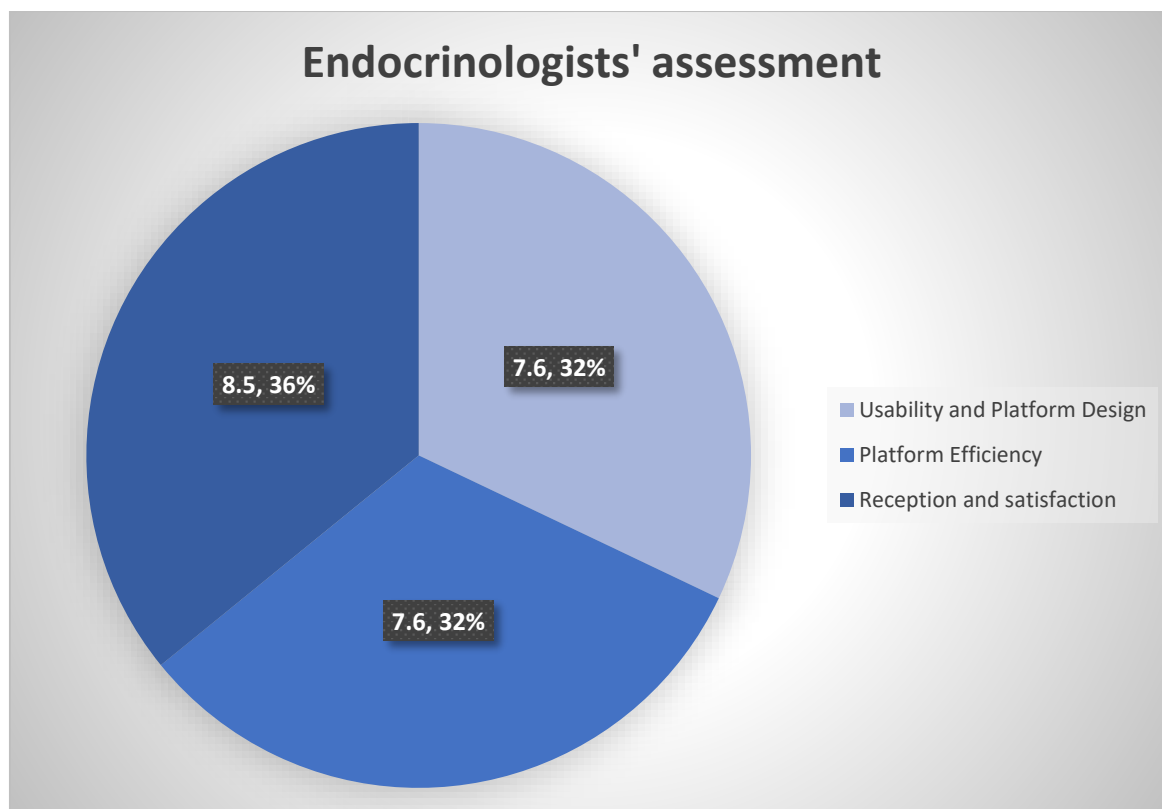


Figure 11: Endocrinologists' assessment

4.3 Discussion

This project demonstrated the feasibility of implementing a mobile app for self-control and management of diabetes. From the beta test it was proven that the need for doing self-checks and electronically record glucose levels, diet intake and lifestyle activity by patients daily is necessary and important in managing diabetes. Endocrinologist found data from self-check readers/devices as well as diet intake and lifestyle information of patients important for them to make informed decisions.

A few challenges were encountered and reported by users. Some of these were related to the design and of the app specifically in relation to the demographic of users. These were fixed to better the platform. The participants reported a very good experience in using the interface. They also loved the recommendation, feedback and timely reminders that the app gave them. The general feedback on the application was positive.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As diabetes prevalence increases annually in Tanzania, there is a need for patients to control and manage it to avoid secondary complications that may be fatal. This project presents and proves the need for a mobile application for the management of diabetes by patients themselves using their mobile devices. It was discovered that having a platform that assist in managing and controlling of diabetes as well as giving knowledge on prevention, risk factors, symptoms and other related information about diabetes does help in reducing secondary complications of the disease in Tanzania. DiabAssistant mobile platform was found to be useful and acceptable by users and has the potential to improve health and wellbeing of diabetes patients, further proving the need for a production ready app.

5.2 Recommendations

The platform is at a working point as a prototype, but the project is not complete. More Research and Development is needed to best capture the needs of diabetic patients in Tanzania. This is because, as mentioned above, most diabetic patients here in Tanzania still do not have access to a lot of products that assist in getting correct state of their health such as glucometer devices, blood glucose strips for tests, blood pressure monitors and weighing scale. This makes the design of an app used here in Tanzania different from an app used in other parts of the world where access to these things is not a problem. Not only that but the reliability, security, robustness and correctness of the platform still needs more work to be done preferably involving a team of experts. From the users' point of view, it was recommended that the app be able to connect with wearables as well as other health apps so that the information about their vitals is automatically collected and synched to the app to remove the manual process of entering the data on the app. It was also pointed out that the app should be more inclusive and put consideration to patients with different kinds of disabilities. Lastly, the government needs to improve diabetic healthcare in Tanzania, making it easy and less expensive for patients to have access to resources that they are dependent on to control and manage diabetes.

REFERENCES

- Alfian, G., Syafrudin, M., Ijaz, M. F., Syaekhoni, M. A., Fitriyani, N. L., & Rhee, J. (2018). A personalized healthcare monitoring system for diabetic patients by utilizing BLE-based sensors and real-time data processing. *Sensors (Switzerland)*, 18(7), 1-25. <https://doi.org/10.3390/s18072183>
- IDF. (2019). International Diabetes Federation. *The Lancet*, 266, (6881), 134-137. [https://doi.org/10.1016/S0140-6736\(55\)92135-8](https://doi.org/10.1016/S0140-6736(55)92135-8)
- Kollmann, A., Riedl, M., Kastner, P., Schreier, G., Ludvik, B., Alfian, G., Syafrudin, M., Ijaz, M. F., Syaekhoni, M. A., Fitriyani, N. L., Rhee, J., & Atlas, I. D. F. D. (2007). A personalized healthcare monitoring system for diabetic patients by utilizing BLE-based sensors and real-time data processing. *Sensors (Switzerland)*, 266(6881), 134–137. [https://doi.org/10.1016/S0140-6736\(55\)92135-8](https://doi.org/10.1016/S0140-6736(55)92135-8)
- Mashael, S. B., & Mznah, A. A. R. (2016). Diabetes Monitoring System Using Mobile Computing Technologies. *International Journal of Advanced Computer Science and Applications*, 4(2), 23–31. <https://doi.org/10.14569/IJACSA.2013.040204>
- Ruhembe, C., Mosha, T. C. E., & Nyaruhucha, C. (2014). Prevalence and awareness of type 2 diabetes mellitus among adult population in Mwanza city, Tanzania city, Tanzania. *Tanzania Journal of Health Research*, 16(2), 1–11. <https://doi.org/10.4314/thrb.v16i2.4>
- TCRA. (2020). *Quarterly communications statistics July - September 2020*. [https://www.tcra.go.tz/uploads/text-editor/files/TelCom%20Statistics%20March %202021_1623060175.Pdf](https://www.tcra.go.tz/uploads/text-editor/files/TelCom%20Statistics%20March%202021_1623060175.Pdf)
- Villarreal V., Laguna J., López S., Fontecha J., Fuentes C., Hervás R., D., & Jose, B. (2009). *A Proposal for Mobile Diabetes Self-control: Towards a Patient Monitoring Framework A Proposal for Mobile Diabetes Self-control: Towards a Springer-Verlag Berlin Heidelberg 2009, June*. <https://doi.org/10.1007/978-3-642-02481-8>
- WHO. (2020). *World Health Organization (WHO)*. <http://www.who.int/mediacentre/factsheets/fs312/en/index.html>

APPENDICES

Appendix 1: Questionnaire to Evaluate the Systems Performance by Patients

Question One: How frequently could you effectively use the system?

Question Two: How easy was it for you to manage the application?

Question Three: How would you assess data input options and design of the mobile app?

Question Four: How would you assess the data output options and visualization of the mobile app?

Question Five: How would you rate the design of the app?

Question Six: How much does this mobile platform motivate you to use it for the control of your blood glucose levels?

Question Seven: Did the recommendations, reports and feedbacks from the app help in your diabetes management process?

Question Eight: Would you wish to continue using this mobile platform for managing your diabetes?

Question Nine: Would you recommend this platform to other diabetic users?

Appendix 2: Questionnaire to Evaluate the Systems Performance by Endocrinologists

Question One: How difficult was it for you to use the web app on your pc or phone?

Question Two: How would you rate the design of the web app dashboard?

Question Three: How often could you effectively use the system?

Question Four: How would you rate the representation of patient's data on the dashboard?

Question Five: How would you rate the periodic representation of patient's data on different charts?

Question Six: How do you appreciate the summarizing of all important patient's data in one page?

Question Seven: Is the provided information in dashboard enough to make informed decision?

Question Eight: Would you wish to continue using the platform for evaluation of your patients?

Question Nine: Would you recommend the system to other medical stuffs?

Appendix 3: Code for random blood glucose card can be found at CoCSE Lab at Nelson Mandela

```
import 'package:diab_assistant/src/screens/core/self_assessment.dart';
import 'package:diab_assistant/src/widgets/meal_assessment_card.dart';
import 'package:flutter/material.dart';

class RandomBloodSugarAssessmentCard extends StatefulWidget {
  final int clientId;
  final String type;
  const RandomBloodSugarAssessmentCard({
    Key key,
    this.clientId,
    this.type,
  }) : super(key: key);

  @override
  _RandomBloodSugarAssessmentCardState createState() =>
    _RandomBloodSugarAssessmentCardState();
}

class _RandomBloodSugarAssessmentCardState
  extends State<RandomBloodSugarAssessmentCard> {
  final TextEditingController _randomSugarController = TextEditingController();

  @override
  Widget build(BuildContext context) {
    var size = MediaQuery.of(context).size;
    return SafeArea(
      child: Scaffold(
```

```

body: SingleChildScrollView(
  child: Column(
    crossAxisAlignment: CrossAxisAlignment.center,
    children: <Widget>[
      Align(
        alignment: Alignment.topRight,
        child: Padding(
          padding: const EdgeInsets.all(10.0),
          child: GestureDetector(
            onTap: () {
              Navigator.pushReplacement(
                context,
                MaterialPageRoute(
                  builder: (context) => AssessmentScreen()));
            },
            child: Icon(
              Icons.cancel,
              color: Theme.of(context).hintColor,
            ),
          ),
        ),
      ),
      SizedBox(height: size.height * .05),
      Container(
        height: 92,
        width: 93,
        decoration: BoxDecoration(
          color: Theme.of(context).primaryColor,

```

```

        shape: BoxShape.circle,
      ),
      child: Icon(
        Icons.network_check,
        color: Colors.white,
        size: 46,
      ),
    ),
    SizedBox(height: size.height * .05),
    Text(
      "What is your random blood sugar?",
      textAlign: TextAlign.center,
      style: Theme.of(context)
        .textTheme
        .title
        .copyWith(fontWeight: FontWeight.bold, fontSize: 20),
    ),
    //SizedBox(height: size.height * .010),
    Container(
      width: size.width * .35,
      child: Row(
        children: <Widget>[
          Flexible(
            child: TextFormField(
              style: TextStyle(color: Theme.of(context).hintColor),
              textAlign: TextAlign.center,
              controller: _randomSugarController,
              cursorColor: Theme.of(context).hintColor,

```



```

    SizedBox(height: size.height * .035),
    Align(
      heightFactor: 3.5,
      alignment: Alignment.bottomCenter,
      child: Container(
        child: Column(
          children: <Widget>[
            Padding(
              padding: const EdgeInsets.only(
                left: 35.0, right: 35.0, top: 10.0),
              child: Container(
                height: 50,
                width: double.infinity,
                child: RaisedButton(
                  color: Theme.of(context).primaryColor,
                  child: Text("NEXT",
                    style:
                      Theme.of(context).textTheme.title.copyWith(
                        color: Colors.white,
                        fontWeight: FontWeight.bold,
                        letterSpacing: 1.5,
                        fontSize: 22.0,
                      )),
                  onPressed: () {
                    Navigator.pushReplacement(
                      context,
                      MaterialPageRoute(
                        builder: (context) => MealAssessmentCard(

```



```

Theme.of(context).textTheme.title.copyWith(
  color: Theme.of(context).primaryColor,
  fontWeight: FontWeight.bold,
  letterSpacing: 1.5,
  fontSize: 22.0,
)),
),
),
),
l,
),
),
),
l,
),
),
),
);
}
}

```

```

createRunningAlertDialog(BuildContext context) {
  return showDialog(
    context: context,
    builder: (context) {
      return AlertDialog(
        title: Text("How long did you exercise?"),
        content: Container(
          height: 200,
          child: Column(
            mainAxisAlignment: MainAxisAlignment.spaceEvenly,
            children: <Widget>[
              Padding(
                padding: const EdgeInsets.only(
                  left: 20.0, right: 20.0, bottom: 10.0),
                child: Container(
                  height: 45,
                  width: double.infinity,
                  child: RaisedButton(
                    color: Theme.of(context).primaryColor,
                    child: Text(
                      "0 - 30 mins",
                      style: Theme.of(context).textTheme.title.copyWith(
                        color: Colors.white,
                      ),
                    ),
                  ),
                onPressed: () {
                  Navigator.pushReplacement(
                    context,

```

```

MaterialPageRoute(
  builder: (context) =>
    PhysicalExerciseAssessmentCard(
      clientId: widget.clientId,
      type: "${widget.type}",
      walkingExercise:
        "${widget.walkingExercise}",
      runningExercise: "L",
      jumpingExercise:
        "${widget.jumpingExercise}",
      trottingExercise:
        "${widget.trottingExercise}",
      randomSugar: "${widget.randomSugar}",
      starchsMeal: "${widget.starchsMeal}",
      vegetablesMeal:
        "${widget.vegetablesMeal}",
      diaryMeal: "${widget.diaryMeal}",
      fatsMeal: "${widget.fatsMeal}",
      proteinMeal: "${widget.proteinMeal}",
    )),
  ),
),
),
Padding(
  padding: const EdgeInsets.only(
    left: 20.0, right: 20.0, bottom: 10.0),
  child: Container(

```

```

height: 45,
width: double.infinity,
child: RaisedButton(
  color: kRecordingsColor,
  child: Text(
    "30 - 60 mins",
    style: Theme.of(context).textTheme.title.copyWith(
      color: Colors.white,
    ),
  ),
  onPressed: () {
    Navigator.pushReplacement(
      context,
      MaterialPageRoute(
        builder: (context) =>
          PhysicalExerciseAssessmentCard(
            clientId: widget.clientId,
            type: "${widget.type}",
            walkingExercise:
              "${widget.walkingExercise}",
            runningExercise: "M",
            jumpingExercise:
              "${widget.jumpingExercise}",
            trottingExercise:
              "${widget.trottingExercise}",
            randomSugar: "${widget.randomSugar}",
            starchsMeal: "${widget.starchsMeal}",
            vegetablesMeal:

```

```

        "${widget.vegetablesMeal}",
        diaryMeal: "${widget.diaryMeal}",
        fatsMeal: "${widget.fatsMeal}",
        proteinMeal: "${widget.proteinMeal}",
    ));

    },

    ),

    ),

    ),
    Padding(
        padding: const EdgeInsets.only(
            left: 20.0, right: 20.0, bottom: 10.0),
        child: Container(
            height: 45,
            width: double.infinity,
            child: RaisedButton(
                color: kLifestyleColor,
                child: Text(
                    "60 - 120 mins",
                    style: Theme.of(context).textTheme.title.copyWith(
                        color: Colors.white,
                    ),
                ),
            ),
            onPressed: () {
                Navigator.pushReplacement(
                    context,
                    MaterialPageRoute(
                        builder: (context) =>

```

```

PhysicalExerciseAssessmentCard(
    clientId: widget.clientId,
    type: "${widget.type}",
    walkingExercise:
        "${widget.walkingExercise}",
    runningExercise: "H",
    jumpingExercise:
        "${widget.jumpingExercise}",
    trottingExercise:
        "${widget.trottingExercise}",
    randomSugar: "${widget.randomSugar}",
    starchsMeal: "${widget.starchsMeal}",
    vegetablesMeal:
        "${widget.vegetablesMeal}",
    diaryMeal: "${widget.diaryMeal}",
    fatsMeal: "${widget.fatsMeal}",
    proteinMeal: "${widget.proteinMeal}",
    ));
},
),
),
),
],
),
),
);
},
);

```

```
}
```

```
createJumpingAlertDialog(BuildContext context) {  
  return showDialog(  
    context: context,  
    builder: (context) {  
      return AlertDialog(  
        title: Text("How long did you exercise?"),  
        content: Container(  
          height: 200,  
          child: Column(  
            mainAxisAlignment: MainAxisAlignment.spaceEvenly,  
            children: <Widget>[  
              Padding(  
                padding: const EdgeInsets.only(  
                  left: 20.0, right: 20.0, bottom: 10.0),  
                child: Container(  
                  height: 45,  
                  width: double.infinity,  
                  child: RaisedButton(  
                    color: Theme.of(context).primaryColor,  
                    child: Text(  
                      "0 - 30 mins",  
                      style: Theme.of(context).textTheme.title.copyWith(  
                        color: Colors.white,  
                      ),  
                    );  
                ),  
              ],  
            ),  
          ),  
        ),  
      ),  
    ),  
  );  
}
```

Poster presentation



A PATIENT SELF-MONITORING MOBILE SYSTEM FOR DIABETES MANAGEMENT IN ADULT POPULATION OF TANZANIA



1. Shakila M. Mshana(Student) 2. Dr. Shubi kaijage & Dr. Judith Leo (Supervisors)

INTRODUCTION

Diabetes is a chronic disease that occurs when the pancreas cannot produce enough insulin or when the body cannot effectively use the insulin it produces. If not well managed and controlled, diabetes can cause severe complications such as cardiovascular and renal issues, blindness and nerve damage. This platform is a supportive mobile app and web app that helps type 2 diabetic patients be able to follow the trends of their glucose levels, get suggestions for possible reasons for the spikes based on the data they entered as well as get recommendations about the glucose trends as well as other indicators that affect blood glucose levels. It will also serve as an education platform about the disease for prevention, risk factors, symptoms, diet, chronic complications, and other helpful insights.

OBJECTIVES

General objective

To develop a self-monitoring mobile system for diabetes management in adult population of Tanzania

Specific objectives

1. To analyze requirements for the proposed system.
2. To develop the proposed system.
3. To validate the developed system.

PROBLEM STATEMENT

Currently in Tanzania, diagnosed patients have monthly clinic appointments with their doctor where they are given a small excise book referred to as a 'file' to record their self-test glucose level values before and after every meal. They then have to bring these 'files' every time they visit the clinic for their endocrinologist to analyze. This approach faces many challenges as it cannot be friendly exercised. It is also time consuming, expensive and exhausting to visit the hospital daily just for the glucose tests. Additionally, having glucose values alone without any other supporting data isn't enough. The glucose levels are affected by a number of other factors in a patient's life like food intake, emotional, mental and physical state and other factors. All these need to be well documented and analyzed before a decision on a patient's health is made. up with without assistance.

ARCHITECTURE OF THE PLATFORM

