AMOBILE HEALTH APPLICATION FOR SUPPORTING PHYSICAL EXERCISES AND DIET OF TYPE 2 DIABETIC PATIENTS DURING SELF MANAGEMENT

CASE STUDY: MBARARA REGIONAL REFERRAL HOSIPITAL OUTPATIENT DIABETIC CLINIC

A dissertation presented to

FACULTY OF SCIENCE

in partial fulfillment of the requirements for the award of the degree

Master of Science in Information Systems

UGANDA MARTYRS UNIVERSITY

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2021-M132-20373

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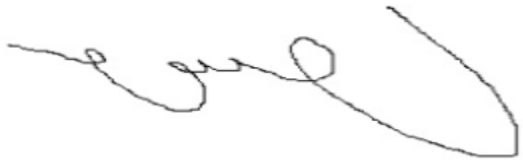
September 2024

APPROVAL

This dissertation has been submitted for Examination with my approval as the University Supervisor.



Signature……. Date: 01/09/2024

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DEDICATION

I would like to dedicate this dissertation to all Type 2 Diabetes patients specifically my relatives who are/have been battling with Type 2 Diabetes. I am committed to improving your health through physical exercises and diet management. I hope that this Type 2 manager mobile application will provide you with the support and guidance you need to reach your health goals and live a fulfilling life. This dissertation is dedicated to you.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my Supervisor Mr. Duncan Naigende for his extra ordinary guidance, continued support, and encouragement throughout the writing of this dissertation. Your time and commitment have been invaluable in shaping my research and I am truly thankful for your dedication to my academic growth.

I would like to acknowledge the support of my colleagues Dr. Ojur Marcellino, Ms. Mugabirwe Beatrice, Ms. Mary Mukyeyaya, Ms.Oucha France Akullo, Mr. Alex Ssendege, Ms Tabitha Nalumansi, Mr.Okechsam Kamar, Ms Ursula Eyer, Rubaijaniza Margaret and classmates who have provided me with valuable feedback and encouragement during my research. Special thanks to the staff and management of Mbarara Regional Referral Hospital for all the support during the data collection process. Your insights and perspectives have been incredibly helpful in shaping my thinking and I am grateful for your collaboration.

Finally, I would like to thank my friends and family for their unwavering support and encouragement. Your belief in me has been a constant source of strength throughout this process and I am thankful for your patience and understanding.

Thank you to everyone who has been a part of this journey and has helped me to reach this milestone. Your support meant the world to me.

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List of Abbreviations

BMI	Body Mass Index
CVD	Cardiovascular Diseases

NCDsNon-Communicable Diseases.

IS	Information Systems
MRRH	Mbarara Regional Referral Hospital
Mm/Hg	Millimeters of mercury
UMU-REC	Uganda Martyrs University Research Ethics Committee
SMS	Short Message Service
SSA	Sub Saharan Africa
T2DM	Type 2 Diabetes Mellitus
T2MA	Type 2 Manager Application
TAM	Technology Acceptance Model
WHO	World Health Organization

ABSTRACT

Background: Self-management is an important factor in control of type 2 diabetes mellitus and preventing of its complications**.**Global statistics have indicated steady increase in this chronic disease and at Mbarara Regional Referral Hospital (MRRH) with prevalence rate of 9%This is attributed by sedentary lifestyle, decreased health services and aging population. Diabetic patients always find challenges in management of this chronic condition with poor medication,

improper follow up, lack of knowledge and information on disease management, high burden of expensive costs, reduction of patient's productivity and cause of psychosocial distress.There have been advancements in mobile applications for diabetes self-management. However, physical exercises and diet are neglected. This study shows how to designand developa type 2 manager application that supports physical exercise and diet which improves their lifestyle.

Objective: This study aimed at improving type 2 diabetes self-management by designing and developing a type 2 manager application with a recommender algorithm on physical exercises, diet and availing educative information to type 2 diabetes patients during self-management.

Methods:The study used scope review methodology approach to get quick overview of existing applications and theirgaps. Following agile methodology type 2 diabetes manager was designed and developed with iterative approach from various user feedback to meet their needs. Latertested among purposively recruited Participant with technologyacceptance model (TAM) serving as the conceptual framework to assess feasibility and acceptability.

Results: The application was named "Type 2 manager".it comprised of features like Type 2 diabetes mellitus Monitor to capture data on self-management assessment and information board to provide educativeinformation. User feedback demonstrated application feasibility and acceptability with improved health status of patients adjusting to participate in physical exercises and dietary changes. Barriers to application usewere language, technicaldifficulties. Recommendations centered on customizing Type 2 manager application in local languages, organizing training to potential app users and involving health workers.

Conclusions: The incorporation of user centered features which engage Type 2 diabetes Mellitus patients in self-management can improve health outcomes. Self-management is a significant factor in blood sugar control. Future applications developers should extend this technology in other chronic diseases management considering cost implication of the application in mind.

CHAPTER 1

INTRODUCTION

1.1 Background

Diabetes and Cardiovascular diseasesconstitute 50% of Non-Communicable Diseases worldwide(Gowshall and Taylor-Robinson, 2018; Yuyun *et al.*, 2020; Abdulkadri *et al.*, 2021) with sub Saharan Africa experiencing the highest burden (Yuyun *et al.*, 2020). Diabetes is among the leading cause of premature deaths globally(Kalra, Jena and Yeravdekar, 2018; Petrie, Guzik and Touyz, 2018; Lin *et al.*, 2020), this is evidenced by the steady rise in number of diabetes from 4.7% in the 1980s to 8.5% in 2014 (El-Kebbi *et al.*, 2021) and its projected to be the 7th leading cause of more deaths by 2035. A number of studies indicate that diabetes in sub-Sahara Africa (SSA) is a widespread problem and has increased rapidly over the last years at 5.7% and expected to steadily increase to 6% in 2035 (Stephani, Opoku and Beran, 2018; Zimmermann *et al.*, 2018). According to WHO, the prevalence of diabetes and its related risk factors has been steadily increasing in Uganda and in males it stands at 2.7% and female at 3.0%, overall prevalence rate being at 2.8%(Asiimwe, Mauti and Kiconco, 2020; Kubiak *et al.*, 2021). In Mbarara City south-western Uganda the prevalence rate of type 2 diabetes is at 9% (Twinamasiko *et al.*, 2018). In Mbarara Uganda, Patients report long movements to health facilities and service related delays, other underlying conditions, different commitments and engagements as the reasons for non-adherence to medication and poor management of diabetes (Twinamasiko *et al.*, 2018; Saasita *et al.*, 2021). It is therefore logical to address diabetes so that its consequences are avoided, managed, or delayed.

Initially diabetes was considered a developed world problem. However nearly 80% of people with diabetes, mainly T2DM,now live in low and middle-income countries, with its prevalence rising rapidly in Africa. This is attributed by increase in certain unhealthy lifestyle factors, such as diet and sedentary lifestyles especially in low income setting countries(El-Kebbi *et al.*, 2021). Management of T2DMin these settings is often a challenge especially in access to medication, correct information about T2DM, physical exercises, and dietary changes due to patients typically pay out of pocket and lack the basic knowledge in the management of their disease. T2DM leaves patients with a high burden of expensive costs(Afroz *et al.*, 2018), reduces patient

productivity (Cabeceira *et al.*, 2019; Afroz *et al.*, 2020), as well as cause psychosocial distress (Kalra, Jena and Yeravdekar, 2018). Severe long-term health complications such as hypertension (Cheung and Li, 2012; Petrie, Guzik and Touyz, 2018; Saasita *et al.*, 2021), stroke, kidney issues etc. (Nayak-Rao and Shenoy, 2017) are also attributed to Type 2 diabetes mellitus.

Mobile health (mhealth) and Electronic health (ehealth)applications have been embraced in chronic disease management (Mugabirwe *et al.*, 2021). In fact, health technology with different models, frameworks and e-health tools have been embraced to help in self-management of non-communicable diseases(Mugabirwe *et al.*, 2021) such as Positive Links Interventions and short message service (SMS) texting(Asiimwe *et al.*, 2011; Siedner *et al.*, 2012) for hypertension.

However, Diabetes especially type 2 is partly neglected especially dietary changes and exercise are not covered in most innovations. Type-2 diabetes is the leading cause of premature deaths (Afroz *et al.*, 2018, p. 2). Improper management of this condition can lead to a number of health issues, including heart diseases, stroke, kidney disease (Nayak-Rao and Shenoy, 2017), blindness, nerve damage, leg and foot amputations, and death. Minor changes in your lifestyle can greatly reduce your chances of getting this disease. Therefore, to prevent this condition, action should be taken regarding the modifiable factors that influence its development-lifestyle and dietary habits. However, with proper testing, treatment (Wylie-Rosett and Delahanty, 2017) and lifestyle changes, healthy eating as a strategy, promotion of walking, exercise, and other physical activities (Colberg *et al.*, 2016) have beneficial effects on human health and prevention or treatment of diabetes, promoting adherence to this pattern is of considerable public health importance.The researcherdesigned and developed a Type 2 Managerapplication for engaging Type 2 diabetes mellitus patients in physical exercises and dietary changes and used TAM model to assess its feasibility and acceptability.

1.2 Problem Statement

Diabetes, once considered a problem primarily affecting developed countries, now impacts nearly 80% of the global diabetic population in low and middle-income countries, with Type 2 Diabetes Mellitus (T2DM) prevalence rising rapidly in Africa (Afroz et al., 2018). This increase is largely attributed to unhealthy lifestyle factors such as poor diet and sedentary behaviors, particularly in low-income settings. Managing T2DM in these regions poses significant challenges, including limited access to medication, inadequate information about the disease, and

difficulties in implementing necessary lifestyle changes like physical exercise and dietary modifications. Patients often bear the financial burden out of pocket and lack essential knowledge for effective self-management, leading to high costs (Afroz et al., 2018), reduced productivity (Cabeceira et al., 2019; Afroz et al., 2020), and psychosocial distress (Hackett and Steptoe, 2016; Kalra, Jena and Yeravdekar, 2018). Moreover, T2DM is associated with severe long-term complications such as hypertension (Cheung and Li, 2012; Petrie, Guzik and Touyz, 2018), stroke, and kidney issues (Nayak-Rao and Shenoy, 2017).

Despite these challenges, recent advancements in health technology have shown promise in the management of diabetes, particularly through mobile health (mHealth) applications (Doupis et al., 2020; Sunil Kumar et al., 2021). Applications like the Diabetex exercise platform (Timurtaş and Polat, 2020), Sweet Mama, and mySugar mHealth app (Debong, Mayer, and Kober, 2019) offer personalized medical advice and have demonstrated the ability to enhance patients' self-management awareness and compliance (Krošel et al., 2016; Muralidharan et al., 2017). However, these applications face limitations: Diabetex struggles with usability due to design complexity and the need for technical knowledge, Sweet Mama does not adequately address physical exercise and diet, and mySugar lacks a recommender functionality for T2DM self-management.

In response to these gaps, this research proposed the design and development of a Type 2 Manager application with a recommender algorithm to support and guide T2DM patients in physical exercises and dietary changes while providing them with essential educational information for effective self-management.

1.3 General Objective

This study aimed atimprovingT2DM self-management by designing and developing a Type 2 Manager Application for supporting physical exercises and diet as well as availing educative information among T2DM patients during self-management.

1.4 Specific Objectives

1. To investigate the strengths and weaknesses of existing mobile health applicationsfor physical exercises and diet among T2DM patients.
2. To design and develop a Type 2 Managerapplicationfor supporting physical exercises and diet among T2DM patients.

3. To evaluate the feasibility and acceptability of the Type 2 Manager application in supporting physical exercise and dietary management among T2DM patients using the Technology Acceptance Model (TAM).

1.5 Research Questions.

1. What are the strengths and weaknesses of existing mobile health applications for supportingphysical exercises and diet among T2DM patients?
2. How can a Type 2 managerapplicationfor supporting physical exercises and diet among T2DM patients be designed and developed?
3. What are the feasibility and acceptability levels for evaluating Type 2 manager application in supportingphysical exercises and diet during self-management by T2DM patients?

1.6 Scoping

1.6.1 Geographical Scoping

The patients were recruited from Mbarara Regional Referral HospitalOutpatient diabetic clinic Southwestern Uganda. According to WHO (Roglic and World Health Organization, 2016), the prevalence of diabetes and its related risk factors has been steadily increasing in Uganda and in males it stands at 2.7% and female at 3.0%, overall prevalence rate being at 2.8% (*Diabetes*, no date) whereas inter-district, Mbarara has a 9% prevalence of Diabetes (Twinamasiko *et al.*, 2018). The diabetic clinic provides care to patients with a history of diabetes. All patients receive a fixed dose combination depending on their diabetes type every Thursday weekly and this is supposed to take them a month until the next clinical visit. There is no follow-up of patients because the clinical care does not extend beyond clinical day.

1.6.2 Functionality Scoping

The content of the study waslimited to: Type 2 managerapplication, physical exercises, diet, educative messages, and enabled self-management among diabetes patients. Type 2 Managerapplication contained features such as T2DM monitor to capture data on self-monitoring, and these included physical exercise assessment, diet,and information board. The

Information board provided educative information regarding T2DM following the mobile healthapplication.

1.6.3 Time Scoping

The studyinvolved period for literaturereview, Literature search, Type 2 manager application design and development(Mock-up designs,User requirements,design, development and, Pretest for validity, Usage by actual participants. Enrollment and follow-upinvolvedFeasibility and acceptability assessment, Preliminary impact measurement for a period of 30 days among Type 2 diabetes patients.

1.7Justification of the Study

According to the 2016, World Health Organization (WHO) Global Report on Diabetes, for Effective blood sugar control during self-management, there was a need to develop blood sugar self-management applications and evaluate their feasibility and acceptability levels to ensuresustained effectiveness onNutrition, Education, Exercises, Drugs,and self-management among diabetic patients.

1.8 Significance and expected contribution of the research

Uganda, has embraced the use of e-Health and m-Health applications as a means to improve primary healthcare delivery and public health for their population(Kiberu, Mars and Scott, 2017).

Despite the enthusiastic these embracement health applications, implementation of optimal diabetes management requires an organized application approach and the involvement of a coordinated and dedicated team, which can often be lacking in clinical practice.

Adoption of m-health applications have been embraced in T2DM. However, there areless interventions in physical exercise and diet as well as correct information to manage T2DM among patients. The design of Type 2 manager application with enabled self-management of physical exercises and dietary changes in T2DM patients helped in reducing lifestyle complications for instance heart disease, kidney disease, stroke, Foot damage, blood vessels damageand eye damage among T2DM and in the end reduced the morbidity and mortality rates of diabetes in Mbarara, Uganda.

CHAPTER 2

LITERATURE REVIEW

2.1 Diabetes

Diabetes mellitus is a chronic disease (*Diabetes*, 2020) that has a negative effect on people's quality of life and results in a series of unfavorable outcomes (Doyle-Delgado and Chamberlain, 2020). According to WHO (World Health Organization, 2016), the prevalence of diabetes and its related risk factors has been steadily increasing in Uganda, with overall prevalence rate of diabetes is at 2.8% (*Diabetes*, 2020). Diabetes leads to other underlying conditions such as stroke, hypertension, myocardial infarction etc. if left untreated and unmanaged. All diabetes subtypes share the same behavioral risk factors, such as inactivity and unhealthy diets. Efforts in lifestyle modifications, such as daily physical exercises(Colberg *et al.*, 2016) and healthy diets(Bekele *et al.*, 2020), can reduce the risk of prediabetes, improve the health level of people with diabetes, and prevent complications.

Exercise (Colberg *et al.*, 2016) and diet improves blood glucose control inT2DM, reduces cardiovascular risk factors (Sami *et al.*, 2017), contributes to weight loss, and improves well-being (Wylie-Rosett and Delahanty, 2017).The designing and adoption of physical exercises and diet mhealth application could help in managing diabetes and its consequences avoided or delayed with diet, physical exercises, medication, regular screening and treatment for complication.

2.2 Type 2 Diabetes Mellitus (T2DM)

Type-2 diabetes (Asif, 2014) is a major, non-communicable disease with increasing prevalence at a global level (Asif, 2014; Mohammed, Shenkute and Gebisa, 2015). Type-2 diabetes (Barreira *et al.*, 2018) results when the body does not make enough insulin or the body cannot use the insulin it produces(van Smoorenburg *et al.*, 2019). Type-2 diabetes is the leading cause of premature deaths (Afroz *et al.*, 2018, p. 2). Therefore, to prevent this condition, action should be taken regarding the modifiable factors that influence its development-lifestyle and dietary habits. However, with proper testing, treatment (Wylie-Rosett and Delahanty, 2017) and lifestyle

changes, healthy eating as a strategy, promote walking, exercise, and other physical activities (Colberg *et al.*, 2016) have beneficial effects on human health and prevention or treatment of diabetes, promoting adherence to this pattern is of considerable public health importance (Asif, 2014).

2.3 Mobile Health application for Diabetes

2.3.1 Diabetex exercise platform

According to a study conducted by Eren Timurtas(2020)to compare usability of Diabetex exercise platform, as digital platform designed for individuals with T2DM (Timurtaş and Polat, 2020) to provide exercise and physical activity tracking on smartphone and smartwatch devices, the results of this study demonstrated that participants encountered some difficulties to use the smartwatch that is due to the advance technically features of smartwatch in comparison to smartphone(Timurtaş and Polat, 2020). Usability of Mobile Health Application for Individuals with Type 2 Diabetes Mellitus and Clinicians. Clinical and Experiemental Health Sciences, pp. 54-59. The study showed that usability of Diabetex exercise platform when delivered through smartphone has higher acceptability than delivered through smartwatch. An understanding of usability smartphone and smartwatch for exercise application in individuals with T2DM and clinician will shed light on mobile app developers (Timurtaş and Polat, 2020). The study findings reveal that this technology faced a number of challenges that limited its usability by the intended target, most of these challenges were in relation to design, complexity and need for technical knowledge to use the technology (Timurtaş and Polat, 2020). .

2.3.2 A mobile phone-based system for supporting lifestyle changes among people with T2DM.

The study by Eirik Årsand(2012) to assess a mobile phone-based system for supporting lifestyle changes among people with T2DM, the mobile system comprised a BG monitor connected to a Bluetooth adapter, a tailored step counter, an eating habit registration system, and an educational system with practical tips (Årsand *et al.*, 2012). The study findings indicated good system usability and user acceptance. The system was found to challenge patients to think about how they can improve their situation, because it provides them a way to capture and analyze relevant personal information about their disease(Årsand *et al.*, 2012). Furthermore, it provides users with

feedback on how they perform in relation to their own personal aims or general recommendations regarding nutrition habits, physical activity, and Blood glucose levels; the three main basic elements that influence personal diabetes management. The findings also reported that the tool was feasible and useful to use on a daily basis, the Blood glucose function was the most popular, and many users recorded food intake, but the personal goal-setting function was seldom used (Årsand *et al.*, 2012)..

2.3.3 Sweet Mama, a mobile health product

(Yee et al.2020), in their study about SweetMama, a mobile health product developed based on established health behavior theories as well as feedback from a prior text message-only phase. SweetMama involved users receiving three motivational and/or informational tip messages, and one individualized goal message, per week (Yee *et al.*, 2020). Messages are designed to promote self-efficacy, healthcare engagement, and health knowledge. Given that low health literacy has been identified to be a barrier to Diabetes Mellitus self-management in this population, content was also delivered via simple and straightforward language, tailored such that the majority of content was at a sixth-grade reading level or less (Yee *et al.*, 2020). The findings of the study to analyze SweetMama reported that whereas the users enjoyed the mobile design and the information provided by the application in addition to the personalization of feedback, the application registered some negative feedback which included that the applications' aesthetic features needed improvement, mobile app color designs and having a message disappear from the home screen after interacting with it (Yee *et al.*, 2020). The feedback collected also suggested that the mobile application be updated with enough information such as Diabetes specific pregnancy education information (Yee *et al.*, 2020).

2.3.4 MySugr mHealth app, a mobile health application

Debong(2019)., presents mySugr mHealth app, a mobile health application designed to support patients in the diabetes self-management (Debong et al., 2019). Data from self-monitoring of blood glucose (SMBG) and continuous glucose monitoring devices can be uploaded automatically, directly via either Bluetooth or, for instance, Apple Health, and can be synced between devices via a cloud-based service. Additionally, insulin data can be entered manually into the app. When users want to make a new entry, they can add pictures and other information to document meals, medications, and activities(Debong et al., 2019). Other information (e.g.,

times, locations) and physical activity levels can be imported automatically from other apps, adding context to the clinical data. Users can access and download all their data as CSV, Excel spreadsheets, or PDF report, giving patients, as well as clinicians, an accurate therapy overview that presents statistics and detailed logs(Debong et al., 2019). This mobile health applications offers extra functionalities and data visualization functionalities that help present data to the app users in various ways as well as the ability to download this data on to their local devices (Debong et al., 2019). Nevertheless, the solution lacks the recommender functionality for diabetes patients to help them in their self-management(Debong et al., 2019).

2.4Other Applications in Diabetes Self-Management

Author and App Name	**Brief description**	**Strength**	**Weakness**
Glucose Buddy (*Glucose Buddy Diabetes Tracker*, 2021)	The intervention features are medication reminders, blood glucose measurements and diabetes education.	This mobile application is simple with smart solutions;it is connected to SMART meters for accurate, real time blood sugar measurements, affordable, hassle-free test supplies delivered door to door and for easy everydaymanagement.	This application is specific to only blood sugar measurements and does not have diet and physical exercises features, which are important aspects in diabetes management.
Diabetes Interactive Diary (DID+) (Rossi *et al.*, 2010)	This has a Nutrition database and EMR connection. This Measures standard carbohydrate counting in terms of metabolic and weight control, time required for education, quality of life, and	DID is at least as effective as traditional carbohydrate counting education, allowing dietary freedom for a larger proportion of type 1 diabetic patients. DID is safe, requires less time for education, and is associated with lower	This application is specific to only carbohydrate diet and does not have physical exercises features which are important aspects in diabetes management

	treatment satisfaction.	weight gain. DID significantly improved treatment satisfaction and several quality-of-life dimensions.	
BlueStar Diabetes (*BlueStar Diabetes*, 2021)	Can be accessed on different operating applications (iOS and android), features include dietary advice, medication reminders, BG level alerts, diabetes education, Connection to EMR Connects to wearables. This application offers guidance, education, motivation, accountability, and connects with your health care team	The application has a privacy policy. BlueStar makes tracking easy, receives customized guidance and has on-demand education, it's secure and protects users from third parties.	BlueStar should not be used by people with type 1 diabetes, gestational diabetes or who use an insulin pump. BlueStar is not intended to replace the care provided by a licensed health care provider. This application also Lacks the physical exercises feature.
DiabeoTelesage(LLC, 2021)	Can be accessed on different operating applications (iOS and android), in as much as it is freely available, the user needs permission through subscription.	This mobile application does self-adjusting insulin calculator and digital diary for long and short-acting insulin doses based on their doctor's prescription, tailored to nutritional intake and physical exercises (2 and enhances follow-up with their doctor and/or	The user needs permission through subscription, making its usage costly.

		broader healthcare team.	
MyFitnessPal (Popper, 2015)	This is one of the most popular health apps around. Offers functionalities such as tracking diets and exercise, location of products and nutrition information.	It is an exercise tracker, giving you space to log your physical exercises and synchronizing with many exercise-tracking devices.	Unlock features since its premium, such as a food analysis tool that reveals which foods rank highest in nutrients you want to keep an eye on and setting calorie goals by meal and workout session.
Carb Manager(Manager, 2021)	This app focuses on tracking carbs, as well protein, fat, and calories, with a database of foods and a bar code scanner. You can also log your meals with photos and voice memos.	It lets you set and track a weight loss goal, as well as log exercise, though synchronizing with fitness trackers requires an upgrade to the subscription service. Note that this app includes features for those following a low-carbohydrate diet or the ketogenic diet.	Primary care givers are not included in the management of carb and keto diets and therefore it's important to be cautious about taking dietary advice from an app and check with your primary care health personnel or nutritionist.

2.4Conclusions regarding mobile health applications for management of Type 2 Diabetes Mellitus

Different Mobile phone apps (Krošel *et al.*, 2016; Veazie *et al.*, 2018) have been used widely in both developed and developing countries and have shown great potential to deliver personalized medical advice, they also demonstrated ability to facilitate patients' health promotion by improving their self-management awareness and compliance. Furthermore, apps for

T2DMmanagement have shown great promise toward improving mental and physical health (Sekhon, Cartwright and Francis, 2017).

Research has shown that the use of apps has statistically significant effects in improving self-efficacy, increasing disease knowledge, enhancing physician-patient communication, and lowering diabetes incidence (Veazie *et al.*, 2018; Fleming *et al.*, 2020a). This is through delivering information, education, self-management, therapeutic advice, and drug guidance (Krošel *et al.*, 2016; Muralidharan *et al.*, 2017; Veazie *et al.*, 2018). Mobile health (mHealth) technology is a promising avenue for promoting sustainable behavior change, addressing disparities, and promoting self-efficacy (Lynn M. Yee, 2021).

Increasingly, clinicians, pharmacists, and patients have started to use mHealth (Krošel *et al.*, 2016) ("mobile and wireless technologies to support the achievement of health objectives") to assist with diabetes self-management. In 2017, there were more than 318,000 mobile health applications available to consumers worldwide (Veazie *et al.*, 2018). Diabetes apps accounted for 16% of the total number of disease-specific apps available to consumers, second only to mental health apps (Muralidharan *et al.*, 2017). Diabetes apps vary in the functions they provide, including tracking blood glucose measurements (Fleming *et al.*, 2020a), nutrition database(Rossi *et al.*, 2010), and carbohydrate tracking, physical exercises(Colberg *et al.*, 2016) and weight tracking, sharing data with clinicians or peers, social support, messaging, and reminders (Muralidharan *et al.*, 2017).

Theoretically, the use of these features could help patients adhere to diet, exercise, and medication management plans, which could lead to improved diabetes-related outcomes (Krošel *et al.*, 2016; Veazie *et al.*, 2018). There is considerable variability in how mobile apps are designed and used in care. Some apps only provide a single function, while others provide a group of functions (Krošel *et al.*, 2016; Muralidharan *et al.*, 2017; Veazie *et al.*, 2018). Mobile apps can be delivered as a stand-alone app, through an app and Web site combination, or through a Web site alone (Krošel *et al.*, 2016; Veazie *et al.*, 2018). Availability of apps also varies by the types of device and operating system required (i.e., platform) (Krošel *et al.*, 2016). Some, but not all, apps are configured for multiple devices and operating applications. Mobile apps vary in the extent to which they connect to other aspects of patient care (Krošel *et al.*, 2016; Muralidharan *et al.*, 2017; Veazie *et al.*, 2018).

2.5 Literature Gap

The literature review identified several critical gaps in the existing research on Type 2 Diabetes Mellitus (T2DM) and mobile health applications. One significant gap is the limited focus on the effectiveness of mobile health applications specifically designed for T2DM patients. While there is a substantial body of literature addressing diabetes management, few studies have rigorously evaluated how mobile health technologies can enhance self-management and improve health outcomes for this population. This lack of targeted research underscores the necessity for further investigations that assess the practical implications and benefits of these applications in real-world settings (Mugabirwe et al., 2021).

Another notable gap is the insufficient attention given to contextual factors that influence the adoption and effectiveness of mobile health technologies. The existing literature often fails to consider the diverse health systems, cultural attitudes, and patient preferences that can significantly impact the success of mobile health interventions. Understanding these contextual elements is crucial for tailoring applications to meet the specific needs of different populations, particularly in low and middle-income countries where the prevalence of T2DM is rapidly increasing (Afroz et al., 2018). Addressing this gap could lead to more culturally sensitive and effective health interventions.

Moreover, there is a scarcity of studies that explore user engagement and adherence to mobile health applications among diabetic patients. Engaging users and ensuring their sustained interaction with these applications are vital for promoting positive health behaviors and achieving desired health outcomes. The literature indicates that understanding the factors that motivate users to engage with mobile health technologies is essential for designing effective tools that encourage long-term use (Rollo et al., 2016). This gap highlights the need for research that investigates user experiences and identifies strategies to enhance engagement.

Finally, the existing literature lacks robust frameworks for evaluating the impact of mobile health applications on clinical outcomes, patient satisfaction, and overall quality of life. Comprehensive evaluation metrics are necessary to assess the effectiveness of these interventions and to provide evidence-based recommendations for their implementation (Davis et al., 2010). By developing and applying such frameworks, future research can contribute to a more nuanced understanding

of how mobile health applications can support diabetes management and improve patient outcomes.

CHAPTER 3

METHODOLOGY

This chapter discusses the philosophical orientation, research design, study population, data collection, validation of the type 2 manager application and data analysis plan in line with Saunder's research onion. (Saunders et al., 2007).

3.1 PhilosophicalOrientation

This study adopted a pragmatism philosophy, which believes that reality is constantly changing, and we learn best through applying our experience and thoughts to the problems as they arise. This allowed the researcher and participants to well understand the research from the practical point of view and draw conclusions based on participants' responses and decisions.

3.2Research Approaches

This study adopted triangulation methodology (a mixed methods) approach of both qualitative and quantitative to gain a better understanding of the experiences of using the Type 2 Manager application in self-management of T2DM using interviews and questionnaires among thePatients with Type 2 diabetes, residents of Mbarara,receiving clinical care at Mbarara Regional Referral Hospital (MRRH) outpatient diabetes clinic, southwestern Uganda. The study investigated the existing M-health applications of physical exercises and diet for T2DM patients to find out their strengths and weaknesses following the scoping review methodology approach. The researcher designed and developedaType 2 Managerapplicationfollowing the agile methodology using android to support physical exercises and diet of T2DM patients during self-management, and then did a preliminary assessment of individuals to enable the researcher to get the potential

participants for the study. Type 2 manager application was then piloted, after which an evaluation to assess its feasibility and impact was carried out. The researcher carried out a sample size calculation for the pilotstudy but targeted at least 30 participantsto efficiently evaluate feasibility, usability, and preliminary effectiveness of the mobile health application while minimizing resource use and ethical concerns. The research was carried out among adults aged 20 years and above, ownership of smart phones, have knowledge of using smartphones and reside within Mbarara town.The 20 years and above age range was chosen to ensure the inclusion of a broad spectrum of adult Type 2 diabetic patients, who are likely to benefit from and use a mobile health application for self-management of physical exercises and diet. This design was chosen to understand the experiences and short-term outcomes in a population that is reachable for easy follow-up.

3.3 StudyDesign and Setting

Theoutpatient diabetic clinic at MRRH provides care to patients with a history of diabetes 23.7% annually. All patients receive a fixed dose combination depending on their diabetes type every Thursday weekly and this is supposed to take them a month until the next clinical visit. There is no follow-up of patients because the clinical care does not extend beyond clinical day and hospital. Our target population consisted of adult participants aged 20 years and above diagnosedwith T2DM, residents of Mbarara City, receivingdiabetes clinical care at Mbarara Regional Referral Hospital. Mbarara is a rapidly growing Peri-urban area of a resource poor setting.Mbarara Referral Regional Hospital (MRRH) is in Mbarara City, southwestern, Uganda, it serves as the referral center for Mbarara, Isingiro, Bushenyi, Rukungiri,Ntungamo, Kiruhura and Ibanda. Mbarara Regional City is about 290 kilometers (180 miles), southwest of Kampala, Uganda's capital and largest city. The coordinates of the Mbarara central business district are 00 36 48S, 30 39 30E (Latitude: -0.6132; Longitude: 30.6582). The public health facility was chosen purposively because it is in a public setting and as such, has a big catchment area and its findings may be generalizable to similar public health facilities.

3.4 Research strategy.

3.4.1To investigate the strengths and weaknesses of existing mobile health technologies for physical exercises and diet for T2DM patients

Following the scoping review methodology approach, the researcher did a literature search and review of different mobile health applicationsof physical exercises and diet for T2DM patientsto find out their strengths and weaknesses. The researcher usedto identify the research questions, identifying relevant studies, study selection, charting data, collating, summarizing, and reporting results and consultation guided this review. The researcher chose this methodology of review to obtain a quick overview of thestrengths and weaknesses to identify the research gap. This methodology enabled inclusion of various types of studies, which is advantageous. Articles to be included in this research were between 2015-2021, Mobile health technology, framework, m-health, e-Health globally, physical exercises, diet, diabetic patients. All works that do not cover the mentioned keywords were excluded from the study. The researcher employed databases and search engines to access these papers. The researcher employed MS excel to make the reviewed tables and used purposive sampling.

3.4.1.1 Identification of Studies

The researcher followed a careful search strategy to identify, screen and analyze all previous studies regarding mhealth frameworks discussed in the context of Mobile health applications, framework, m-health, e-Health globally, physical exercises, diet, T2DM, diabetic patients. Articles that were considered must have been published between 2017-2022.

3.4.1.2 Search Strategy

The researcher employed Google Scholar, Web of Science, LILAC, PUBMED, IEEE Xplore and Science Direct databases for a period of 2 weeks because of their high indexing and integration capacity. This search aimed at finding the different research articles that contain our information of interest such as Mobile health application, framework, m-health, e-Health globally, physical exercises, diet, T2DM, diabetic patients.

3.4.1.3 Study selection criteria

The researcher peerreviewed, Full research papers, Empirical research (qualitative and quantitative), Clearly explained research methods, explicitly described mHealth applications for

diet, physical exercise, and educative information in self-management of T2DM, the effectiveness in terms of preliminary impact, short-term outcomes, Published between 1st January 2017 and31st December 2022, forstudies available in English. All studies that did not meet the inclusion criteria were excluded.

3.4.1.4Data extraction and analysis

Different characteristics were extracted using an excel file from the included studies and these include study setting, study design, sample size, mHealth intervention used, their strengths and weaknesses, and the study duration as well as the authors and the country of origin.

3.4.2 To design and develop a Type 2 Manager application for supporting physical exercises and diet among diabetic patients

3.4.2.1 Agile Methodology

The researcher first defined the requirements needed for type 2 manager application regarding application interfaces, finances, programming, and database software needed as well as allocation of time, and then developed the software based on the requirements. The iterative process dominated the agile software development lifecycle. Each iteration resulted in the next piece of the software development puzzle. While designing Type 2 manager application, I ensured documentation and making this available to users until a final product is complete for use. Each iteration took 1-2 weeks and the longest fixed date to accomplish the work was within 1 month. Multiple iterations took place during the agile software development lifecycle, and each follows its own workflow. During an iteration, ensured that users provide feedback to ensure the features meet their needs.

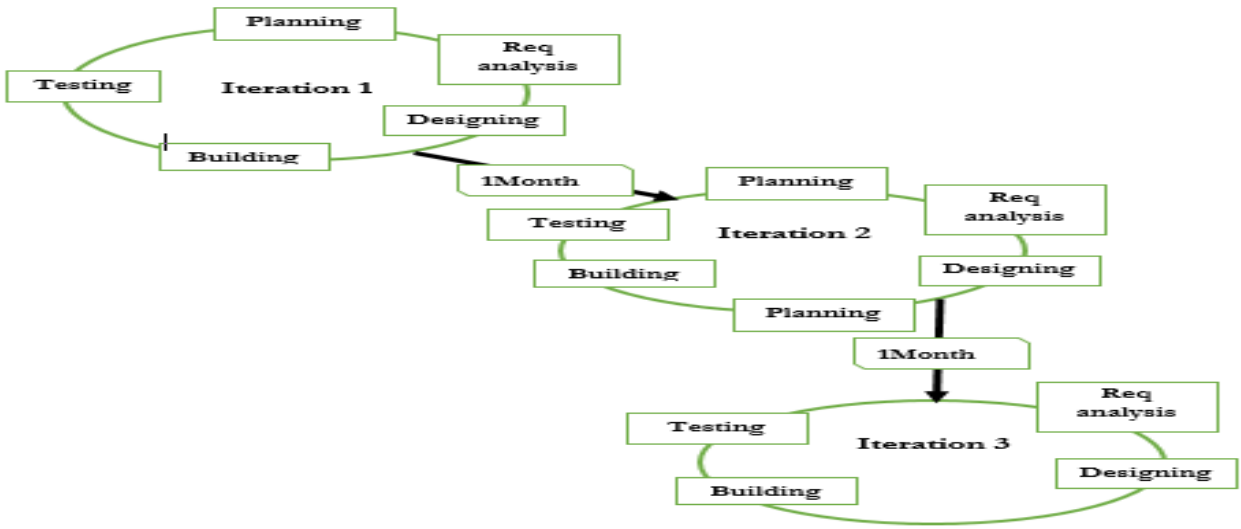


Figure 1: The figure above shows the agile software development cycle.

3.4.2.2 Planning

During this phase, the researcher looked at the different existing mobileapplications, their weaknesses, followed the proposal to look at the different requirements needed for the application, came up with different mock-ups of how Type 2 manager application would look like. It is at this phase that the mobile application wasnamed "*Type 2 Manager*".

3.4.2.3 Requirement analysis

The requirements for the Type 2 Manager application were achieved through a combination of agile development practices, user engagement, thorough analysis of existing solutions, and iterative testing and refinement. This comprehensive approach ensured that the application was tailored to meet the specific needs of T2DM patients effectively.

3.4.2.4 Designing

The design of the Type 2 Manager application was guided by a combination of user-centered principles, agile development practices, theoretical frameworks like TAM, insights from existing literature, technical requirements, and a focus on health education and support for T2DM patients. This comprehensive approach aimed to create an effective and user-friendly tool for diabetes management.

3.4.2.5 Building

After the Iteration, the researcher began building the Type 2 Managerapplication based on the designed mockups.The environment was set up for the flatter framework and from there the researcher used visual studio code to develop the Type 2 Managerapplication following the recommendations from the users. Type 2 Managerapplication was developed and another phase of iteration 2 was carried outamongst the users. These users included the researcher, a diabetic patient and a clinician who noted that Type 2 manager application was not availing notifications, identified how it was not secure, and the application not suggesting health tips and recommendations concerning physical exercises and diet and new users do not have access to any information on cold start using the Type 2 Managerapplication. After Iteration 2 and looking at several recommendations from the users, the researcher thought of a recommendation algorithm following Pearson's' correlation formula to predict and suggest physical exercises and diet to type 2 diabetic patients using the Type 2 Managerapplication. The researcher used Microsoft Word to design the flow chart of the algorithm as shown in **Chapter 4 Section 4.2.** A security detail for the Type 2 Manager mobile health technology was implemented that is a username and password.

3.4.3To evaluate the feasibility and acceptability of the Type 2 manager application in supporting physical exercises and dietary management among T2DM patients using Technology Acceptance Model (TAM).

Type 2 manager applicationwas tested and evaluated to facilitate self-monitoring during physical exercise assessment, diet changes and educative information during engagement in care by T2DM patients.Users were prompted to enter patients' username and password to test Type 2 manager application functionality, the algorithm computed their similarities using predictions and correlations to send physical exercises and diet changes notification reminders and recommendations basing on usage. The new user on cold start gets recommendations based on the popular strategy. Following this Type 2 Manager application with recommendation algorithm was ready for use to facilitate self-monitoring during physical exercise assessment, diet changes and educative information during engagement in care by T2DM patients.

Selection criteria

Inclusion criteria

1. Type 2 Diabetic patients consecutively (receiving clinical care concurrently) attending the diabetic outpatients' clinic at Mbarara Regional Referral Hospital.
2. Aged 20 years and above
3. Adults owning smart phones, and usage knowledge.
4. Residents residing within Mbarara Town
5. The participants use the application for 30 days (1 month).

Exclusion criteria

The researcher excludedall participants who were unable or unwilling to give consent.

Participant selection

All participants were chosen using purposive sampling. For this objective, a call was made to potential Individuals to take part in using Type 2 manager application, these were chosen from the Mbarara Regional Referral Hospital outpatient diabetic clinic diabetes clinic. All participants were trained on usage and functionality of Type 2 manager application for example using application features and information board and recording their physical exercises and diet details). As a pilot study to demonstrate the feasibility of the Type 2 manager application in physical exercises and diet among T2DM patients, the researcher did not carry out a sample size calculation but enrolled30 participants and followed them until the 30^{th} day.

Data collection tools

Quantitative Questionnaire: a quantitative questionnaire for baseline assessment before enrollment to ask subjective questions to explore participants' socio-demographic characteristics, history of diagnosis of diabetes, medication adherence and phone usage and knowledge was used.

Qualitative Interview guide: The researcher conducted an interview to explore participants' perspectives and experiences of use of the application and their response concerningphysical exercises, diet, and T2DM control and management. This was done after 30 days during study exit. All questions in the interview guide were in English but for full comprehension and understanding by the participants, all interviews were conducted in English. They were digitally

recorded. We appliedthe TAM model to assess the feasibility and acceptability of Type 2 manager application. This research concentrated on the user experience and understandingperformance, ease of use, effectiveness, and behavior intentions of Type 2 manager application.

Data presentation and analysis plan

For Quantitative data, I usedSTATA 16.0 statistical software(*Stata: Software for Statistics and Data Science*, 2021) for data analysis. Quantitative data was summarized as median (IQR) for skewed data, means for normally distributed data, and categorical data were summarized as counts and percentages.

For qualitative data, TAM (Chao, 2019; Ayaz and Yanartaş, 2020), served as the conceptual framework for this analysis of this objective. In this model, Type 2 manager application adoption and use weregauged through these major constructs per individual as follows; (1) Perceived usefulness, (2) Perceived ease of use, (3) attitude towards using, (4) social influence, (5) facilitating conditions. TAM model provided the available tools to enable us understand the factors driving the mobile health application acceptance and feasibility (Huang and Kao, 2015) and thus facilitating for the adoption of type 2 manager application by T2DM patients. The researcher used an inductive analysis by content analytics approaches through a coding scheme using the initial review of a randomly selected subset of the interview transcripts, sections of texts that appear to address concepts of analytical interest such as acceptance and feasibility. These were assigned descriptive labels/codes. Operational definitions were for the codes to create a coding scheme, which was used to code the data. The researcher usedDedoose a mixed methods data management computer web application software program(*Home | Dedoose*,2021)to code the data, which will then be repeatedly sorted and reviewed to identify a broader set of concepts. The categories were constructed from this second, more general set of concepts through assignments of descriptive labels, formulation of operational definitions and selection of illustrative citations from the data. Once the categories were in place, they formed a basis for comparative analysis across phases and the intervention to identify similarities and differences in interview responses. The researcher reviewed content relevant to feasibility and acceptability drawing from the TAM model, and the codes from the data were sorted and reviewed to develop descriptive categories in line with the domains of the TAM model (Ayaz and Yanartaş, 2020).

Quality assurance procedures

Consolidated Criteria for Reporting Qualitative Research (COREQ)(Tong, Sainsbury and Craig, 2007) were followed for data quality assurance. The researcher used study instruments in English and translated into Runyankole to ensure optimal comprehension and collection of desired measures by all participants. Research was carried out using electronic data capturing instruments, synchronized with the electronic study database (server and backup) to minimize transcription errors. To avoid bias during close engagement with the participants, the researcher recognized and clarified for participants their social demographic characteristics to improve credibility of the results. For transparency, the researcher identified and stated their assumptions and personal interests in the research topic to avoid effecting participant responses. To ensure quality, content analysis was applied to systematically organize data in a structured format, and participants were selected using purposive random sampling. For privacy and confidentiality, the researcher described the context in which the data was collected because it illuminates participants' responses, the questions asked enhanced the participants' understanding of the researcher's focus and give the participant the ability convey their viewpoints.

3.5 Ethical considerations and review

Researcher obtained approval from the Research Ethics Committee from Uganda Martyrs University (UMU-REC). I met with MbararaRegional Referral Hospital (MRRH) leadership head of department for internal medicine to provide information about my planned study and seek permission to carry out research from this public health facility.

3.6 Dissemination of study findings

Results of this research will be availed to the participants, community authorities, District Public Health Officers, and community members through presentations in Department of Information Technology, Manuscripts published in scientific and technology journals.

CHAPTER 4

RESULTS

This chapter presents the presentation, analysis, and interpretation of the research findings about the objectives of the study.

4.1 To investigate the strengths and weaknesses of existing mobile health applications for physical exercises and diet for T2DM patients

According to a variety of scholarly publications, m-health applications may be seen as a useful addition to the management of chronic illnesses; however, it was found that most of these works are hypotheses, and many applications fail to address the issue of cold start users, as the table below illustrates.

Author, Year, and Country	**Study design**	**Key findings**	**Strengths**	**Weaknesses**
Nwolise et al.,2017(United Kingdom)	A mixed-methods study design adopting a quasi-experimental approach to assess women's knowledge and attitudes related to preconception care, and level of patient activation before and after the three-month intervention period- Participants recruited from two National Health Service (NHS) hospitals in the South of England and via social media (i.e.	PADI is designed to improve awareness of PCC and to support women with T1DM and T2DM adopt behaviors that support a healthy pregnancy and baby such as regular blood glucose monitoring, folic acid intake, lifestyle modification and use of contraception until optimum blood glucose levels are	Reminder to take BG reading and help keep a regular BG reading schedule. Planning for pregnancy to Promote knowledge of PCC and pregnancy planning. Blood glucose diary to record and keep track of BG reading. Progress	A mixed-methods protocol to examine the acceptability and feasibility of the PADI app intervention. PCC education has been widely recommended as an effective strategy to promote PCC knowledge and encourage behavioural

	twitter)(Nwolise, Carey and Shawe, 2017)	achieved.	to display the user's progress and help monitor trends.	change
Degroote et al.,2019(Belgium)	Healthy participants between the age of 18 and 65 years were recruited using purposive sampling. More specifically, participants of previous studies who indicated to have interest in other research were contacted by email. In total, 47 people showed interest in the study, and were invited via e-mail to fill out the IPAQ(Degroote *et al.*, 2020).	'MyDayPlan' was well-received and seems to be feasible and acceptable with inactive adults. The straightforward layout and ease of use of the app were appreciated. Furthermore, the incorporation of the techniques 'action planning', and 'prompting review of behavioral goals' was positively evaluated.	MyDayPlan' is an mHealth intervention, consisting of a mobile application, targeting PA in adults from the general population. As 'MyDayPlan' is one of the first PA interventions implementing several self-regulation techniques using a one-day cycle, evaluating its 'feasibility and acceptability is essential before evaluating its effectiveness. This study revealed that 'MyDayPlan' is	Using 'MyDayPlan' app, users cited the need a pedometer or activity tracker to have the ability to constantly track steps/active minutes (7/20), implementing a social aspect to compare or share action plans, coping plans and results with family and/or friends (2/20).

			well received and seems to be feasible and acceptable in a general adult population.	
Lukkahatai et al.,2021(Thailand)	The study is a pilot study using a wearable device (Garmin Vivofit) in a two- full day's period. We recruited 114 Thai heritage adults' ages 18 years or older, diagnosed with type 2 diabetes (T2DM), who were followed up at two local health-promoting rural area hospitals in the Northern Thailand region(Lukkahatai *et al.*, 2021).	The results demonstrate the feasibility of the use of the wearable device among people living with chronic conditions. Participants found that the step count screen provided immediate physical performance feedback that was helpful with their exercise. The behavioral changes, however, could not be examined due to the short duration of the usage.	The device suggests potential benefits of the instant display of the step counts on the wearable device among individuals with diabetes and had a duration	The duration of the device lasted only 2 days to investigate the possibilities of usage issues, and participants' acceptability and satisfaction with the device, however this was optimal.
Khare et al.,2021(USA)	Step-2-It was a pilot study to assess the feasibility, acceptability, and	Findings demonstrated that providing pedometers along	Our study shows that texting is a feasible and acceptable way to	A pilot studied with a small sample size and lack of a

	effectiveness of text messaging combined with a pedometer to promote PA, specifically walking among English-speaking women, aged 40 and older, living in a rural, northwest Illinois county(Khare *et al.*, 2021).	with motivational and informational text messages increased walking in rural women. Additionally, texting is an effective way to reach residents in rural communities where broadband accessibility is limited. Future studies using comparison groups and an objective PA measure, such as accelerometers, are warranted.	provide health promotion messages to a geographically isolated, hard-to-reach population of rural women.	comparison group. Additionally, the study was unable to capture a true baseline for PA.
Torbjørnsen et al., 2019(Norway)	The study had a qualitative descriptive design. MR and LR interviewed 26 persons with type 2 diabetes living independently in the north and south of Norway(Torbjørnsen *et al.*, 2019)	The overall theme was that the use of a digital diabetes diary app required hard work, but also that the app could ease the effort in aiming for a lifestyle change and for better-controlled blood glucose levels.	Our findings might be of interest not only to persons with type 2 diabetes but also for those with other chronic illnesses using other kinds of self-management apps. This is	The study sample comprised participants provided with a diabetes diary app for self-management. The focus of the participants' experience was solely concerned with the use of a

			because the acceptability of such technology depends on finding a way to utilize such apps to meet present patient needs and incorporate their use in a self-management fellowship with qualified professionals.	single app, and this might have provided less rich information in terms of answering the research question. In addition, other sources of information such as login data and observational data could have given a richer contribution to our understanding of the app's acceptability.
Ang et al.,2021(Singapore)	Patients with type 2 diabetes or prediabetes were enrolled on the Singapore Armed Forces and offered a 3-month intervention program in addition to the usual care they received.	The personalized mHealth program was feasible, and acceptable, and produced significant reductions in HbA_{1c} (P=.004) and body weight (P<.001) in individuals with type 2 diabetes.	This study evaluated a real-world context-sensitive mHealth-anchored intervention program with free-living patients. The program also	The program was conducted only with military personnel, which could have been expanded to include other professions so that the results could be more generalizable. A

		Such mHealth programs could overcome challenges posed to chronic disease management by COVID-19, including disruptions to in-person healthcare access(Ang *et al.*, 2021).	coincidentally began during the start of the COVID-19 pandemic, with the bulk of the encounters occurring during the national-level lockdown in Singapore. This allowed for a timely study of the use of mHealth for chronic disease management just as the world needed to move toward embracing more digital solutions to limit in-person interactions.	single intervention arm with no control group. Without a control group, there is a possibility that patients not undergoing the same program might still experience the same improvements with usual care during the same period. Close to one-third of the patients had dropped out of the program.
Owolabi et al., 2019(South Africa)	The study adopted a multicenter, two-arm, parallel, randomized controlled trial design and was conducted at the outpatient departments of six	Unidirectional text messaging was acceptable and feasible amongst adults living with diabetes in this setting. However,	The study clearly demonstrated a high level of acceptability and feasibility of the SMS intervention and a low level of	SMS is an acceptable and feasible measure and serves as an adjunct to standard clinical care in the

	selected primary healthcare centers in two districts in Eastern Cape, South Africa(Owolabi, Goon and Ajayi, 2019).	its efficacy in improving glycemic status and other clinical outcomes remains doubtful.	efficacy among the participants in this study. The true experimental design employed was a significant strength. The use of a multi-centre approach added further credence to the study.	promotion of health amongst patients living with diabetes in this study setting. Although there was little improvement, the efficacy of unidirectional text messaging in promoting glycemic control and improving other clinical variables in this study setting is still doubtful.
Sowah et al., 2020(Ghana)	The food recognition model was evaluated with cross-entropy metrics that support validation using Neural networks with a backpropagation algorithm. (Sowah *et al.*, 2020).	The model achieved specified goals by predicting with high accuracy, labels of new images. The food recognition and classification model achieved over 95% accuracy levels for specific calorie intakes. The performance of the	Developed a meal recommender application using the knowledge-based approach where the recommended meal will meet the users' needs based on knowledge of the	This intervention did not address hardware modules for insulin pumps and control, as discussed by others in the review, and that may constitute a fatal limitation since insulin

		meal recommender model and question and answer Chabot was tested with a designed cross-platform user-friendly interface using Cordova and Ionic Frameworks for software development for both mobile and web applications.	required nutrients obtained from the user's details. They implemented the application using a Genetic algorithm where a random number of meals were selected, and a fitness function was calculated using the difference between calories in meals and calories required by the user.	control is crucial. It concentrates principally on developing software for diabetes management with a machine-learning algorithm.
Salari et al., 2021(Iran)	A theory-based mobile- and cloud-based application that delivers a set of tailored messages. A Kreuter algorithm was used to determine the customization of interventions based on a behavioral model, aimed to deliver customized messages to	Using a cloud- and mobile-based application had many advantages for people with diabetes and health care providers. These apps could be helpful for persons receiving online education in self-management,	The self-management app enabled people with diabetes to manage their required care by monitoring blood glucose, physical exercises, and diet as well as advantage of the behavioral stage	Although some positive evaluation metrics were observed, a limited sample size did not allow any concrete conclusions to be drawn from this study's findings. More in-depth

	help the self-management ability of diabetes persons(Salari *et al.*, 2021)	relevant messages, and tips for their needs. The developed mobile app includes modules that support several features. The theoretical foundation of behavioural intervention is the trans-theoretical model. Users were able to receive customized messages based on the behavioral change preparation stage using the Kreuter algorithm. The clinician's portal was used by health care providers to monitor the patients. The results of the usability evaluation revealed overall user satisfaction with the app.	by receiving customized messages using smartphones. The app includes 5 modules that provide a platform for facilitating diabetes management, as suggested by the American Diabetes Association.	exploratory analysis of usability issues is needed to inform the design of clinical trials in this field.

4.2 To design and develop Type 2 manager application for supporting physical exercises and diet among T2DM patients.

4.2.1Type 2 manager application Flow chart

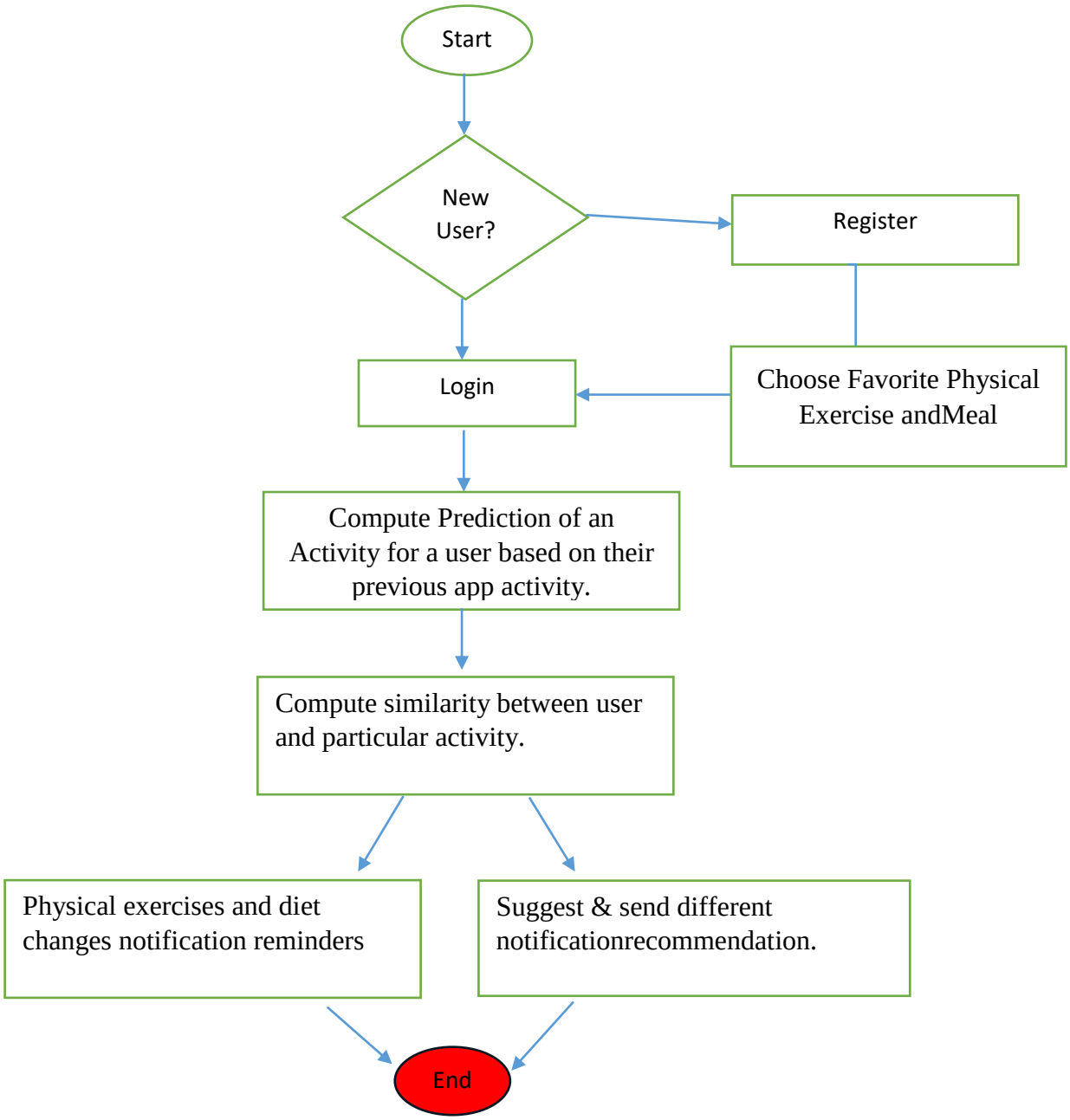


Figure 2: Type 2 manager application Flow chart

Type 2 manager application manager application was designed, where a new user or existing user was prompted to login, if a user is existing user, login in with username and password if new user, register your account (using username and password), then after logging in choose your favorite physical exercise for instance cycling, walking, swimming, aerobics dance, weightlifting and diabetic meal for the day. Type 2 manager application compute prediction of an activity for a user based on their previous login activity with the application then it uses Pearson correlation to generate similarity between user and particular activity. Then the application uses embedded algorithm to suggest physical exercises and dietary changes to targeted user on the application monitor. Educative messages are displayed inform of notification to type 2 diabetes patients.

4.2.2 A recommendation algorithm embedded within the Type 2 Manager application steps following the Pearson formulae

A recommendation algorithm that uses a Pearson' correlation formula to suggest physical exercises and diabetic meals to type 2 diabetic patients using the Type 2 manager application was embedded.After patients' username and password entry, the embedded algorithmcomputes their similarities using predictions and correlations to send physical exercises and diet change notification reminders and recommendations based on usage. The new user gets recommendations based on the popular strategy.

Output: physical exercises and diabetic meals to target user

1. Begin
2. Step 1: Register patient user name and password w,x,y,z
3. Step 2: New user
4. Step 3: Suggests for the new user to choose their favorite physical exercise and meal using popularity strategy equation (1).
5. Step 4: Existing users.
6. Step 5: Compute prediction of an activity for a user based on your previous app activity x using the prediction equation (2).
7. Step 4: Compute similarity between user b and activity x according to the Pearson correlation equation (3).
8. Step 5: Use the constructed algorithm to suggest physical exercises and diet changes to targeted users.

9. Step 6: Compute similarity notifications using Pearson correlation.
10. Step 7: Suggests and sends different notifications recommendations to the targeted user.
11. Step 8: Physical exercises and diet changes notification reminders.
12. Step 9: End

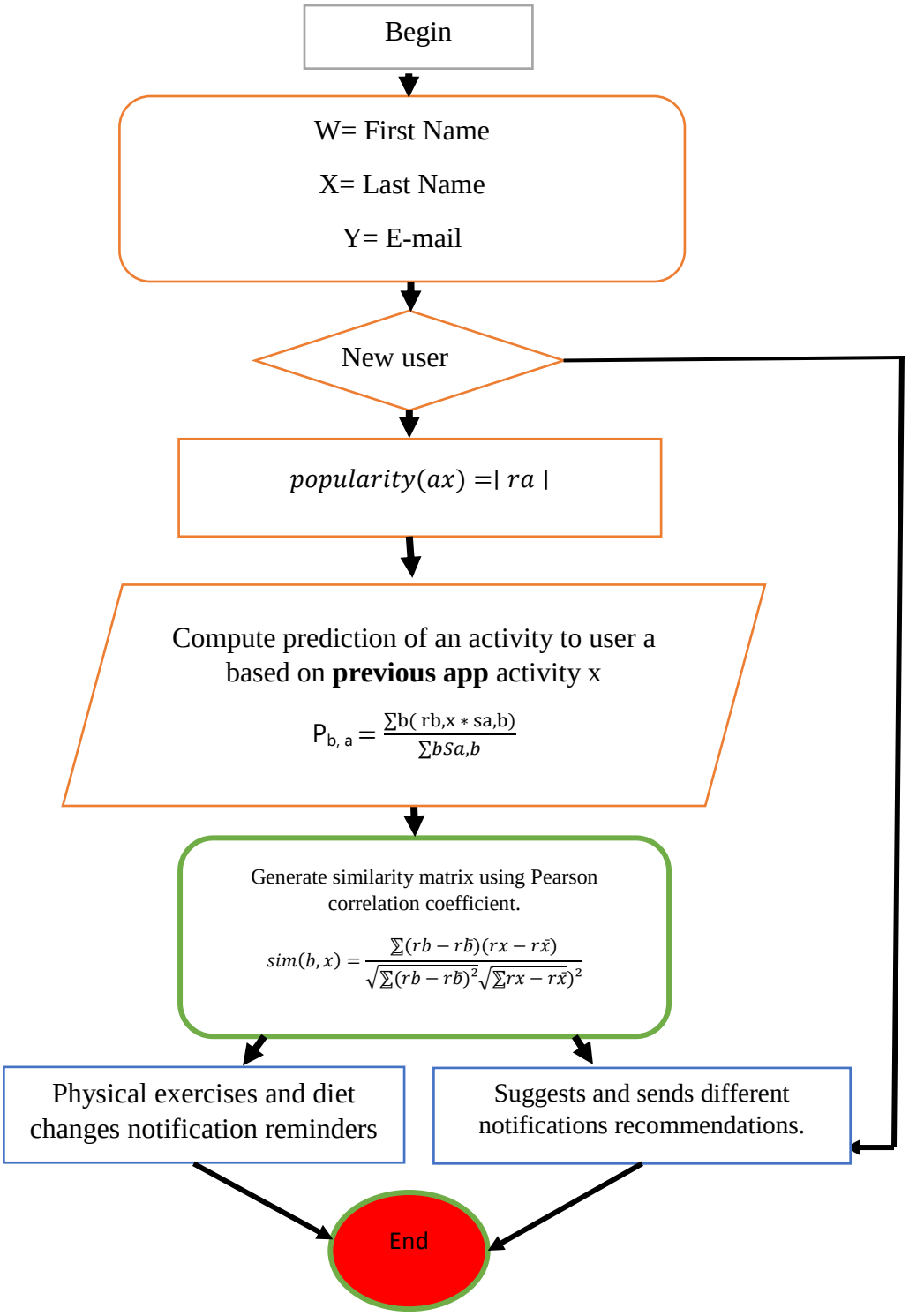


Figure 3: Type 2 Manager Application embedded Algorithm Flow Chart

Interpretation of Type 2 Manager application embedded Algorithm

The algorithm captures patients' similarities following their interaction with the physical exercises and diet change features and then sends out notification reminders and recommendations such as meal dietary changes and tips, exercise tips and educative information while using the type 2 manager application. The algorithm collects user feedback through interaction usage of items in a specific domain to determine which items to recommend.

Type 2 manager application has two types of cold starts

1. New user cold start
2. New activity cold start

New user cold start meant that a new user was introduced in the dataset without previous history. Using a popularity-based strategy, following up favorite recommendations among the application users, the algorithm would recommend favorite items to the new user.

$popularity(ax) =| ra |$ (1)

Using Type 2 Manager application, the algorithm bases on the similarities and associations of targeted *user a* with an activity *x*, predicts and suggests that activity for the user using prediction equation:

The prediction $P_{aa}$is given by $P_{a,\,x} = \frac{\sum a(\,ra,x * sa,b)}{\sum aSa,b}$ (2)

In the formula provided above, $Px_{,\,a}$ was the prediction of an activity.

ra, x was the rating given by a user a to an activity x.

Sa, b was the similarity between users.

The interactions of an activity by a user were provided; this was predicted on the interactions of the user the following steps.

1. For predictions, we needed the similarity between the *user b* and *activity x* using Pearson correlation.

   $sim(b,x) = \frac{\sum(rb-r\bar{b})(rx-r\bar{x})}{\sqrt{\sum(rb-r\bar{b})^2}\sqrt{\sum rx-r\bar{x})^2}}$ (3)

Pearson’s correlation told us how much the two activities correlated. The higher the correlation, the more the similarity

2. We found the activities used most by both the users, based on their behaviour, and calculated the correlation.
3. The notification recommendations were calculated using similarity and interaction values using the algorithm.

4.2.3Type 2 Manager application recommender algorithm Output

The Type 2 Manager application with a recommender algorithm output for diet and physical exercises. The user is prompted to enter a username and password. The application shows the dietary changes and physical exercises for use by the user. The notification suggestionsare due to the algorithm, which computes their similarities using correlations to send physical exercises and diet changes notification reminders and recommendations based on usage. Type 2 Manager mobile health technology with a recommendation algorithm is used to facilitate self-monitoring during physical exercise assessment, diet changes and educative information during engagement in care by T2DM patients.

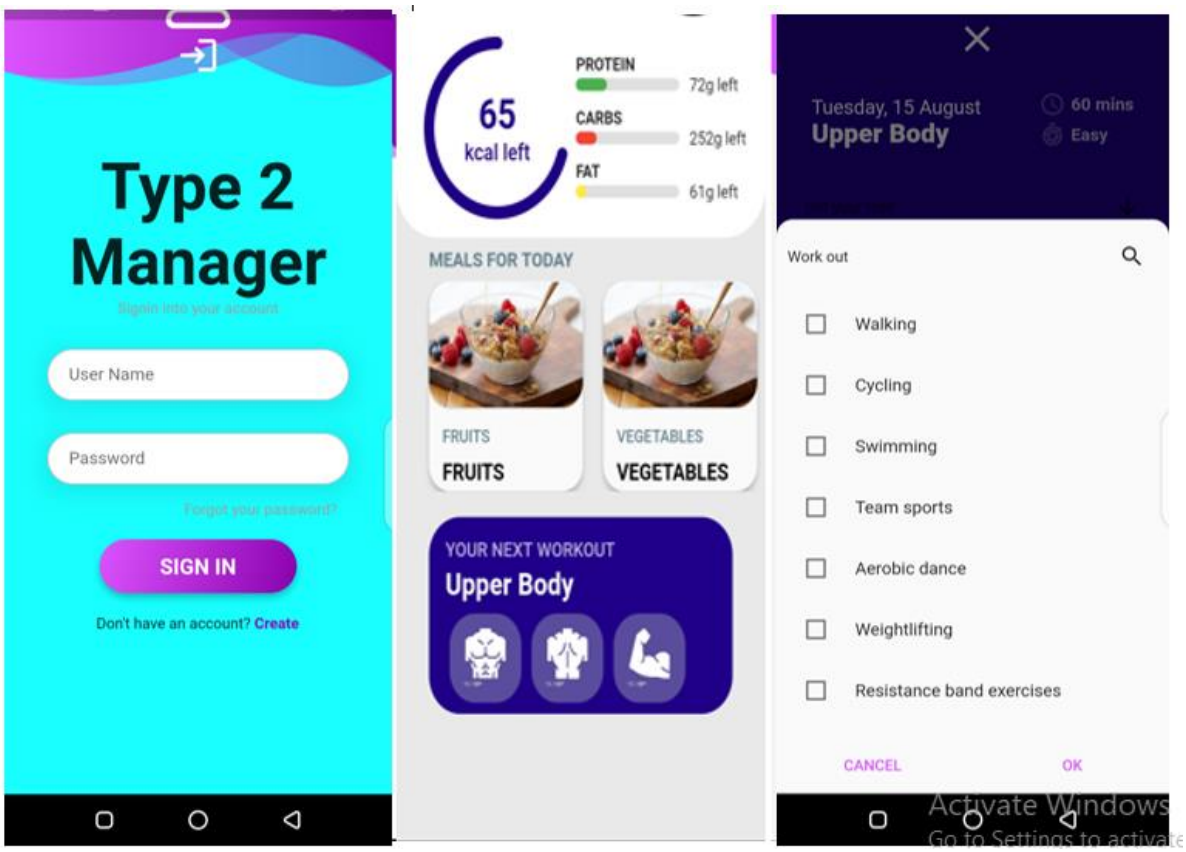


Figure 4: Type 2 Manager application recommender algorithm Output.

4.2.4 Code Sample of Type 2 Managerapplication with a recommender algorithm

```dart
class Meal {
  final String name, imagePath;
  final List foods;

  Meal({required this.name, required this.imagePath, required this.foods});
}

final meals = [
  Meal(name: "FRUITS", imagePath: "assets/fruit_granola.jpg", foods: [
    'apples : 20',
    'oranges : 20',
    'berries : 20',
    'melons : 20',
    'pears : 20',
    'peaches : 20'
  ]),
  Meal(name: "VEGETABLES", imagePath: "assets/fruit_granola.jpg", foods: [
    'Broccoli : 20',
    'Cauliflower : 20',
    'Spinach : 20',
    'Cucumbers : 20',
    'Zucchini : 20',
  ]),
  Meal(name: "GRAINS", imagePath: "assets/fruit_granola.jpg", foods: [
    'quinoa : 20',
    'couscous : 20',
    'oats : 20',
    'brown rice : 20',
    'farro : 20',
  ]),
  Meal(name: "LEGUMES", imagePath: "assets/fruit_granola.jpg", foods: [
    'beans : 20',
    'lentils : 20',
```

Ln 9, Col 8 Spaces: 2 UTF-8 LF Dart Dart DevTools

Figure 5: Code Sample of Type 2 Manager application with a recommender algorithm.

Software used to build and implement Type 2 Manager application with a recommender algorithm

I used:

- **I)** Adobe after effects for designing Mock-ups
- II) Visual studio code (application editor)
- III) flatter for developing and designing applications and algorithms.
- IV) MySQL for the database
- V) Microsoft Word for designing the flow chart of the algorithm.
- **VI)** Pearson correlation for the algorithm

4.3 To assess the feasibility and acceptability of the Type 2 Manager application with a recommender algorithm for supporting physical exercises and diet among type 2 diabetic patients.

4.3.1 Preliminary Assessment

To get potential participants for the app usage, 30 participants were purposively chosen, and a questionnaire was administered to do the socio-medical assessment to get actual participants for the Type 2 Managerapplication usage. Of the 30 participants, the mean (median) age of all respondents was 57(58) years with most of the respondents being females 18(60 %), the majority of which were married 15(50 %). In addition, the mean duration of type 2 diabetes of all the respondents was 9 years. Most of the respondents had taken their medication before this survey 27(90 %), however, most of the respondents do miss taking their medication 25(83.3 %). Mobile phone ownership was high 29(96.7%) among respondents. Most of the respondents owned smartphones 25(83.3 %) with 25(83.3 %) knowing smartphone usage as captured in **table 3 below.**

The socio-medical characteristics of the 30 participantsin the study

Characteristics		**Statistics**
Gender	Male	12(40 %)
	Female	18(60 %)
Mean (Median) Age		57(58)
Marital status	Married	15(50 %)
	Divorced	5(16.7 %)
	Widowed	5(16.7 %)
	Single	5(16.7%)

Employment	Self-employed	20(66.67%)
	Government or non-profit organization	2(6.67%)
	Private employer	3(10%)
	Retired	1(3.33%)
	Unemployed	4(13.33%)
Education	None	2(6.67%)
	Primary school	3(10%)
	Secondary school	15(50%)
	College or university	10(33.33%)
Mean duration of T2DM	9 years	
Medication Adherence	**Yes**	**No**
Did you take your T2DM medication yesterday?	27(90 %)	3(10 %)
Do you miss taking your medications for reasons other than	25(83.3%)	5(16.7%)

forgetting?		
When you travel or leave home, do you sometimes forget to bring along your T2DM medication?	5(16.7%)	25(83.3%)
Phone Ownership and Knowledge		
Own mobile phones	Yes	No
	29(96.7%)	1(3.3%)
Type of Phone	Analogue Phones	4(13.3%)
	Smart phones	25(83.3%)
	None	1(3.3%)
Do you know how to use a smartphone	Yes	No
	25(83.3 %)	5(16.7%)

4.3.2 Participants' social demographic characteristicsin Type 2 Managerapplication usage

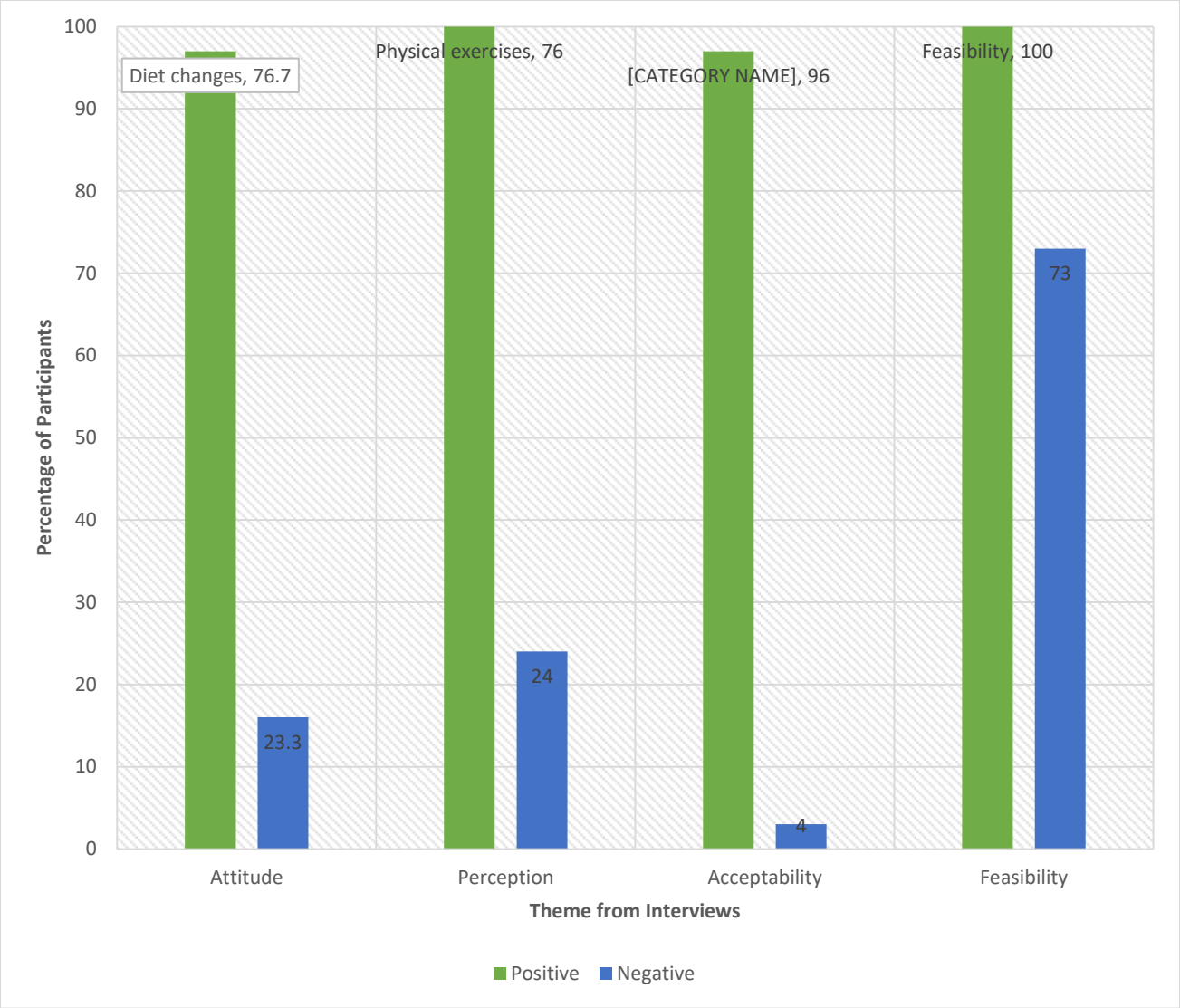
Of the 30 patients with T2DM assessed, 25(83.3 %) participants were enrolled for the study. The researcher excluded 4(13.3%) who did not have smartphones and 1 (3.3%) who had no phone at all for the Type 2 Managerapplication usage.

Of the 25 participants who completed the 30-day interviews, the mean age was 58 years, 18(72%) were female, median duration of T2DM diagnosis was 5 years (3-5 years) as seen in Table 4 below. Twenty-four (96 %) participants reported positive acceptability, and all participants (100%) reported positive feasibility. For each code, more participants expressed positive than negative experiences. Participants reported positive changes in their physical

exercise routine 19(76%), and participants also reported positive dietary changes 23(76.7%) hence improvements in their diabetes self-management 19(76%). Interviews were carried out duringthe study exit as follows:

Characteristics		**Statistics**
Participants Included in the intervention		25(83.33%)
Participants who completed the study, n (%)		25(100%)
Gender	Male	7(28%)
	Female	18(72%)
Overall mean (SD) age		58
Median T2DM duration		5(3-5 years)

Interview expression Results for the Type 2 Managerapplication usage


Diet changes, 76.7
Physical exercises, 76
[CATEGORY NAME], 96
Feasibility, 100
23.3
24
4
73
100
90
80
70
60
50
40
30
20
10
0
Percentage of Participants
Attitude
Perception
Acceptability
Feasibility
Theme from Interviews
Positive
Negative

4.3.3 Organization of qualitative data on acceptability and feasibility following Technology Acceptance Model (TAM)

Results details are presented according to the unified theory of acceptance and use of technology acceptance model (TAM) as shown in the figure associated with the components of the study, which are physical exercises,diet, and self-management among T2DM patients.Acceptability and feasibility evaluation of the application were carried out drawing from TAM using the parameters of the models that include (1) perceived usefulness, (2) perceived ease of use, (3) social norms, and (4) facilitating conditions.

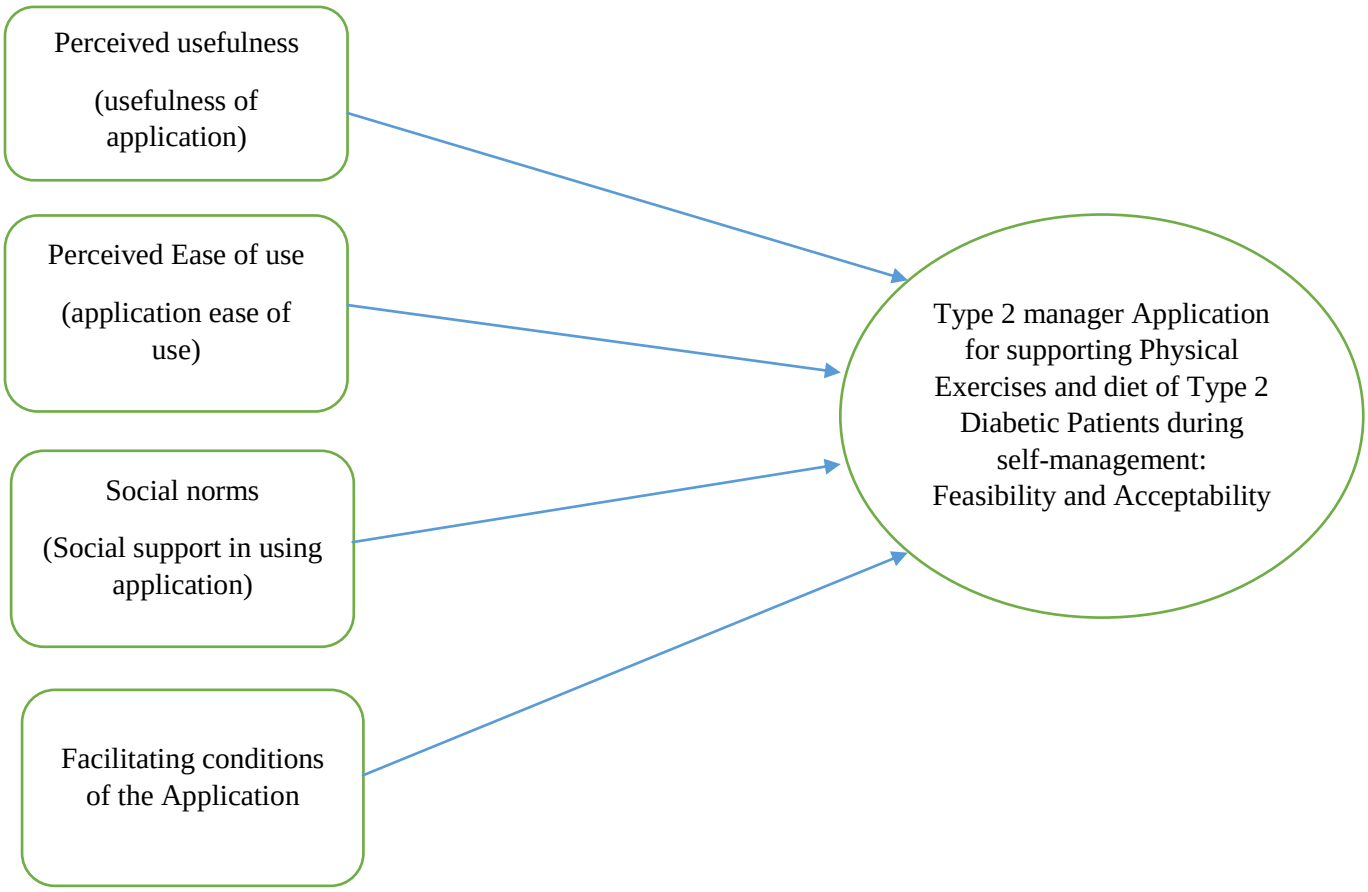


Figure 6: Type 2 manager Application TAM model.

Perceived Usefulness

Study participants found that Type 2 Managerapplication useful, especially in supporting physical exercises and dietary changes. They described feeling motivated by the notification reminders because they felt cared for.

"It's a good thing because this application reminds me to change my diet and do physical exercises depending on the day, suggest health advice such as exercises and what to eat, this makes me feel cared for and energized to take care of my health and I feel some change in my health." ***(Male, 34 years)***

Participants found the Type 2 Managerapplication useful in helping them change their meals/diet following the application suggestions. In addition, they stated that application helped in taking their medication. Diet and physical exercise Notification reminders addressed forgetfulness to exercise and change their diet as advised.

*" Well, the good thing is, this application is like my reminder now it ensures that I do not forget to take my exercises and have my meals. Do you know I even take my medication on time because of the reminders?" (**Male, 44years old)***

*"Well, it has helped me in monitoring my routine physical exercise and knowing how I am daily. I feel a little lighter and better compared to when I used, I did not know when and how to exercise minus monitoring." (**Female, 33 years old**)*

*"Aaah personally, I think this application is okay, it's perfect because it reminds me of the different diabetic meals and advises me on my diet, this application sends me all sorts of reminders and educative messages, I am grateful, it warns me that it's important to take my diet seriously I think to me it's perfect." (**Female, 48 years**)*

Perceived Ease of Use

Participants found ease in using Type 2 manager application during self-management.

*"No challenges so far, it's very easy to use and I know that when do my physical exercises and I take my diet seriously, my sugar levelshave greatly improved, I have no challenge because it's very easy to use (**Male,45 years)."***

Some participants reported stability in their sugar levelswhile usingType 2 manager application.

"Yes, I have seen the change, as I said earlier, my sugar levelshas stabilized in good figures because before I started using Type 2 manager application, whenever I would go to the hospital,

*my diabetes would be high but now it has stabilized with physical exercises and the reminders are doing a wonderful job. (**Male, 50 years old)**"*

Participants also reported easiness while using Type 2 Manager application. Diabetic patients said that the features of the physical exercises and diet were so easy to use this enabled them to know how best to control and self-manage their T2DM, and they stated that there is a positive change in their T2DM than before.

*"Type 2 manager app has helped me love and care for myself, I take my meals on time anddo my day-to-day work and over overthinking has reduced. I'm at peace, my weight has slightly reduced than before." (**Female, 50Years**)*

Social Norms/influence

Patients felt happy and cared for by the Type 2 manager application than before when family members were responsible for reminding them when to take their medication

*"It's a good thing, because sometimes it's my wife and son that have been reminding me whento exercises, what to eat and when to take my drugs." **(Male, 56 years)***

Educative messages using the Type 2 manager application among participants gave lifestyle tips on diet and exercise to control their diabetes.

*"The advantage was leaving me with theapp for a month, the user interface of the appmade using the application easy, I can easily choose the meals I want for the day because the educative messages also encourage me." (**Female, 40 years old)***

Facilitating Conditions

Participants generally liked the User interface design of Type 2 manager application with a recommender algorithm, which was easy to use and motivated users to use the technology. The technology used multimedia features for visualization of dietary changes and physical exercises thus accommodating even those with reading issues.

*"The advantage was leaving me with the app, it had pictures of the meals for the day so I did not have to strain my eyes to read, I could easily choose the meals I want." (**Female, 49 years old)***

Internet

Reliable internet access was provided to the participants.

*I had enough data and thus nothing could hinder me from seeing the notification reminders or accessing the technology for monitoring myself." (**Female, 62 years old)***

Intervention Feasibility

Type 2 Managerapplication was generally feasible (100%)however, it did come with some feasibility issues such as technical difficulties, language barrier while using the application.

Challenges which hindered the use of Type 2 managerapplication.

Participants stated difficulty in using the application sometimes due to language barrier.

*"Well, the problem is, I don't know how to use this application well due to language barrier, I call my son who helps me, so I use few features in the application." (**Female, 33 years old)***

Participants reported technical difficulties using the phone while interfacing with the Type 2 Managerapplication.

"Most times, the phone could freeze whenever I open this app, and this frustrates me a lotthis hindered me a lot from seeing the notification reminders." (Male, 37 years)

*Well, the problem is, I don't know how to use the application well, sometimes due to the language barrier, I call my son who helps me to read the information when such issues arise, so I use a few features of this application." (**Female, 57years old)***

Type 2 manager application improvements as suggested by participants

More training on application use: Some participants stressed the need for extra training on how to exactly use Type 2 Managerapplication in the self-management of T2DM.

"Much as I loved this app, I did not understand some things and wanted more information, I suggest that us the users be trained more and enough time is allocated to training so that we get

to understand much more about our condition and how to manage it, especially with this initiative." (Male, 39 years old)

Health worker involvement: Participants suggested that health workers should be part of Type 2 manager application during self-management of type 2 diabetes.

"I think health workers should be involved, because I do not know who to call when I am not feeling well, having just this app without guidance from doctors is not helpful so kindly add health workers." (Female, 58 years old)

CHAPTER 5

DISCUSSIONS, CONCLUSION, RECOMMENDATIONSAND LIMITATIONS

This study evaluated the acceptability and feasibility of Type 2 Managerapplication with a recommender-based algorithm in the management of type 2 diabetes in Mbarara City, Southwestern Uganda. We aimed to involve patients in the care and self-monitoring of their blood glucose through physical exercises and dietary changes.

For objective 1, different articles published by scholars indicated thatmobile applications and frameworks could be regarded as an effective complement to chronic disease management to some extent (H, 2008; Beratarrechea *et al.*, 2014; Ayanlade, Oyebisi and Kolawole, 2019; Fleming *et al.*, 2020b). According to literature reviews, there's a positive role played by these mobile health applicationsin disease management(Ayanlade, Oyebisi and Kolawole, 2019; Fleming *et al.*, 2020b), as well as improving the health outcomes of T2DM patients overall.
The increasein smartphone coverage in recent years has provided hope for the possibility of the remote management of patients with chronic diseases. Furthermore, in this research, we found a positive impact on using mobile health frameworks for supporting physical exercises and diet of diabetic patients during self-management on our patients and thus saw the importance and need of using m-health applications to help care providers and patients during self-management of T2DM(Rollo *et al.*, 2016; Jeffrey *et al.*, 2019; Abd-alrazaq *et al.*, 2021; Salari *et al.*, 2021). M-health applications if well utilized, could be well accepted by patients in cardiovascular disease management.

For objective 2, Type 2 Manager application with a recommender algorithm suggested physical exercises and dietary changes reminders and recommendations related to type 2-diabetes self-management such as healthy tips, diet change and physical exercises etc. These recommendations improved the health status of patients(A *et al.*, 2013; Sl *et al.*, 2015) as self-reported during application use. However, there's need to extend this application to other Non-Communicable Diseases such as heart diseases and hypertension as it is also necessary for their treatment as recommended(Davis *et al.*, 2010; A *et al.*, 2013; Wan Ahmad, Zaki and Ahmad

Fauzi, 2015). There is need to do an analysis of the health devices and application available on the market to ensure the correct performance of the application with the smallest investment. This fact will allow the application to be accessible for most people. Future efforts should focus on a private social network with the application to enable social support among users as well as customizing the application in local languages to overcome possible language barrier issues.

5.3 To assess the feasibility and acceptability of the Type 2 Managerapplication with a recommender algorithm for supporting physical exercises and diet among type 2 diabetic patients

Following the preliminary assessment, the researcher explored the medical and socio-economic factors of T2DM patients during diagnosis and perspective on medication plus phone ownership and knowledge. Most of the respondents were females at 18(60%), which showed that many female patients try to receive care compared to men. The majority of the respondents owned phones 29(96.7%) which was reassuring especiallyin the Ugandan context considering patients with phones can bebeyond the geographical clinical settings augmenting the reach of an overstretched health application('Reports and Publications – UCC: Uganda Communications Commission', no date). These findings areconsistent with those in other settings that showed mobile applications are generally acceptable by users and efficient in the management of Type 2 diabetes(Labrique *et al.*, 2013; Georgsson and Staggers, 2016). The majority of the respondents had poor medication adherence, as one of the most important modifiable barriers to diabetes control in patients with T2DM (Bagonza, Rutebemberwa and Bazeyo, 2015; Adu *et al.*, 2019; Nyirongo *et al.*, 2021), which could be attributed to travel costs associated with clinic visits for those patients living far from the clinic, clinic operating hours, waiting times and the under dispensing of prescribed medications(Bagonza, Rutebemberwa and Bazeyo, 2015; Nyirongo *et al.*, 2021).

Drawing from the TAM model theory(Ayaz and Yanartaş, 2020), the researcher found that Type 2 Managerapplicationwith a recommender algorithm was generally acceptable and feasible for supporting T2DM patients' self-management of T2DM, receive social support through educative messages, manage their diet and exercise fully in Mbarara City, Southwestern Uganda.

These findings are reassuring in the Ugandan context where facilitators suchas phone coverage is 81% whilst broadband coverage is 37% according to studies done recentlyconsidering increased access to phones and the internet enables use of health-intervention and disease-prevention tools (mHealth or eHealth tools) that reach patients beyond the geographical clinical settings such as augmenting the overstretched health application. Our findings contrast those in other settings that showed mobile applications are generally acceptable by users and effective in type 2 diabetes management (Garabedian, Ross-Degnan and Wharam, 2015; Doupis *et al.*, 2020; Rangraz Jeddi *et al.*, 2020)

Acceptability and feasibility of Type 2 manager application with a recommender algorithm was deemed important by the performance expectancy, perceived usefulness and ease of use, and later participants' satisfaction. Participants severally pointed out the ability of the applicationto aid physical exercises, dietary change and provision of important educative information using reminders/notifications. Thephysical exercise reminders improved weight and blood glucose management and diet changes enabled participants to have diabetic meals improving their blood glucose and reducing their stress. Physical exercises and self-care can help to prevent negative psychological effects (Sharma, Madaan and Petty, 2006; Anderson, Burford and Emmerton, 2016; Lee *et al.*, 2019) among T2DM patients using mobile applications.

5.4 Strength

This research had many strengths. (1) It used a well-known model theory called TAM to assessType 2 manager application acceptance (2) It used an in-depth qualitative investigation to explore the experiences of the participants in using type 2manager application (3) This study was conducted in a rural-urban low-income African setting, Mbarara City, which has potential implications for acceptability and feasibility of mobile health interventions in similar settings.

5.5 Limitations

As much as the Intervention was generally acceptable and feasible, the findings have limited generalizability as the study was based on a small pilot study of 30 participants. Chronic disease management needs lifelong treatment and thus a long-term follow-up, which is very important.

5.6 Conclusion

In conclusion, we found that convenient, real-time self-care, physical exercises and dietary change improves the T2DM management. T2DM adult patients wereinvolved in this research context indicating that T2DM affects majorly old people. Future efforts should focus on a private social network within the application to enable social support among users as well customizing Type 2 manager application in local languages to overcome possible language barrier issues. Cost-effectiveness evaluation would also be important to investigateT2DM patient'sfollow-up clinical outcomes(reporting).

5.7 Implications

Several important implications for further use and development of this type of intervention arose from this study. A mobile health intervention can be successfully deployed in low-resource settings and help patients manage T2DM outside of clinical visits. Other chronic diseases could also be managed through similar methods, by promoting self-care, physical exercises, dietary changes, and medication adherence. However, cost is an important consideration not fully explored in this study. Type 2 manager application was supplied free of charge to the participants, as well as support for data usage needed for the application. The participants may not have access to reliable data outside of the study context, affecting sustainability. This study did not examine the potential benefits of a stand-alone application, delivered without data support. Issues of access to diabetes measurement, medications, and data would need to be considered for larger-scale implementation of this program and other studies seeking to deploy mobile health interventions in comparable settings. Further research is needed to address external factors that may affect this intervention and other strategies for chronic disease management.

APPENDIX

WORK PLAN

Activities	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Concept drafting and proposal writing.												
Bi-Monthly reports.												
Ethical reviews and consideration												
APPdesigns,literature review,Follow-up, Datacollection,Analysis, dissertation writingsubmission to the university												
Dissertation Review with supervisor												
Dissemination of findings												

BUDGET

Total amount		**USD**	**USD**
Item	**Quantity**	**Unit cost**	**Amount**
PARTICIPANTS RELATED COSTS			
a. Stationery			
Box files	5	2	8
Notebooks	5	1	5
Pens	5	1	5
Printing and photocopy		20	20
b. Approvals			
UNCST	1	50	50
c. COMMUNICATION			
Internet modem	1	Present	-
Phone Airtime	1	50	50
d. Equipment			
Recorder	Available	-	
TOTAL FOR ALL ACTIVITIES			**176**
GRAND TOTAL			**176**

INTERVIEW GUIDE

We are conducting a study whose purpose is to evaluate the acceptability and feasibility of Type 2 Manager mobile health technology with a recommender algorithm for supporting physical exercises and diet among type 2 diabetic patients.*(Remind the participant how the details of the intervention were explained in the consent form). Before we start, do you have any questions?*

1. Acceptability

Introducing Question: In your opinion, what major role do you think Type 2 Managerapplicationwith a recommender algorithm has played in the improvement and management of type 2 diabetes?

Probes

- Please give me more detailed information
- Any suggestions on what else to improve in the application?

Introducing Question: As a patient do you think Type 2 Manager application with a recommender algorithm was useful to you?

Probes

- Explain its usefulness
- How effective wasit to use?

Introducing Question: What challenges have you met while using Type 2 Managerapplication with a recommenderalgorithm?

Probes

- Please give reasons for this.
- Was there anything that could sometimes hinder you when using Type 2 manager? Please tell me more about it.
- Was there any immediate technical support in case of a breakdown of the technology?

2. Feasibility

Introducing Question: Do you think Type 2 Managerapplication with a recommender algorithm should be used by others?

Probes

- Why? (explain)

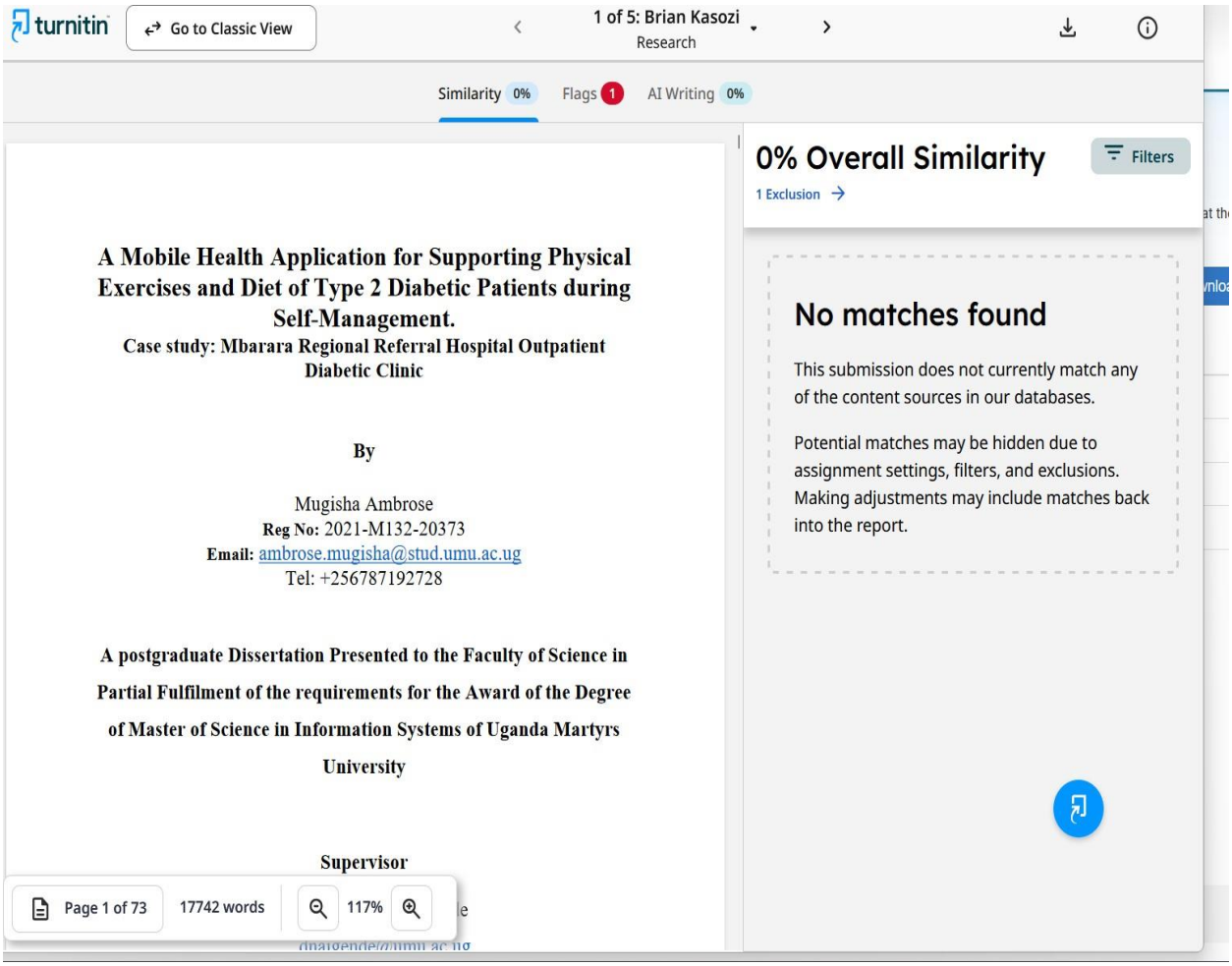
Any advantages did you find while using thisapplication?

- Please give more detailed information.

What do you think can be done to improve on the Type 2 Managerapplicationwith a recommender algorithm from the mentioned challenges?

Do you feel any change after using Type 2 Managerapplication with a recommender algorithm in control and management of yourT2DM?

PLAGIARISM CHECK REPORT



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