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Mobile Application Development for Gestational Blood Sugar Prediction

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Abstract
Gestational Diabetes Mellitus (GDM) is a critical health situation that endangers pregnant women, requiring regular blood sugar monitoring to ensure both mother and fetus well-being. Many GDM patients are unaware and unable to determine their status in view of limited medical personnel and high cost of laboratory tests. This paper gave the design process of a Gestational Blood Sugar Tracker (GBST) smartphone application aimed at assisting pregnant women with predicting, managing and regulating their blood sugar. The GBST mobile app was implemented with Android Studio, the primary programming language being Java, the app uses SQLite for local database and firebase authentication. Integrated in the app is a fast forward neural network-based prediction model to predict the GDM status. The mobile app had 12 screens designed in Figma that allow data capture and result display. The FNN model with 77% accuracy was implemented for prediction of GDM status. It was recommended that the GBST app should be evaluated using the Mobile Applications Rating Scale (MARS).

Keywords: *Gestational Diabetes Mellitus (GDM), Mobile health application, Agile methodology, Nigeria*

1. Introduction

Gestational diabetes mellitus (GDM), an abnormal condition of high blood sugar during pregnancy, is harmful to mother and fetus [1]. GDM if not treated can lead to pre-eclampsia, macrosomia, and later onset type 2 diabetes in the mother and respiratory distress syndrome or hypoglycemia in the child. Traditional monitoring methods commonly involve frequent clinic visits and hand logging of blood glucose, which are time-consuming and may not support real-time insights to enable immediate action.

Against this background, gestational blood sugar prediction through mobile app development emerges as a frontier technology, offering more convenience, personalization, and improved health outcomes. At the core of such a mobile application is the concept of tapping data, algorithms, and user-friendly interfaces to empower pregnant women to control their blood sugar. In its most basic function, the app would allow users to track their blood glucose readings, food intake, exercise levels, and medication dosage. The innovation of the app, however, is its predictive capability.

Through the use of machine learning algorithms, the app is capable of learning historical and present patterns and extrapolate future trends of blood sugar readings. For instance, if a user consistently experiences a spike after a particular meal, the app could learn this correlation and provide timely alerts or dietary recommendations before the next similar meal. This proactive approach shifts the paradigm from reactive management to preventative intervention. Developing such an application involves several critical technical considerations. Firstly, data collection and integration are paramount. The dialogue has to securely record the sensitive healthcare

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information, either through manual input or, better still, through integration with Bluetooth glucometers.

The use of mobile app requires robust data protection and conformity with privacy legislation like HIPAA. Secondly, the predictive algorithm itself is the centerpiece of the app. This would likely employ advanced machine learning techniques such as recurrent neural networks (RNNs) or long short-term memory (LSTM) networks, which excel at time-series data analysis. The models would be trained on large, heterogeneous databases of pregnant women to achieve accuracy and representativeness for different populations and physiological responses. Furthermore, the user interface (UI) and user experience (UX) need to be effectively implemented to guarantee uptake and adherence. The application should be intuitive, well-organized, and aesthetically pleasing, with transparent visualizations of blood sugar patterns, individualized feedback, and actionable recommendations. All the features such as medication reminders, meal tracking, exercise tracking, and even GDM educational content can further increase its usability. Despite the tremendous promise, there are a number of challenges that need to be overcome in the construction and release of these applications.

Lack of data and data quality are key issues; good predictive models require large, high-quality datasets capable of detecting the nuances of physiological changes over the course of pregnancy. Ethical issues of data protection and algorithmic bias are also vital. Models must be rigorously tested to ensure they do not reinforce or exacerbate health inequalities. Regulatory approval by health organizations such as the FDA is also a time-consuming and arduous process as such submissions fall under the scope of medical devices. In addition, being compatible with existing healthcare platforms and electronic health records (EHRs) would be essential for seamless data sharing between patients and care providers.

The beneficial impact of efficient mobile apps for gestational blood sugar prediction is tremendous. To pregnant women, it offers unprecedented convenience, reducing the need for frequent clinic visits and providing them with real-time management of their own health. The personalized data and predictive alerts can lead to enhanced treatment adherence, ultimately translating into tighter glycemic control. For clinicians, these apps can offer a consistent stream of information, facilitating more informed clinical decision-making and interventions in a timely fashion. It can potentially lower the complications of GDM, minimize the pressure on healthcare expenditure, and improve maternal and neonatal outcomes. Apart from individual benefits, these technologies form part of a wider shift towards preventive and individualized care utilizing digital health technologies to manage chronic diseases more effectively.

Overall, gestational blood sugar prediction mobile app development is a significant milestone in the evolution of maternal care. Through the power of mobile technology and artificial intelligence, such applications can transform GDM care from the currently reactive, clinic-based paradigm to an active, patient-enabled one. So long as challenges of data, regulation, and integration exist, the huge value in terms of improved health outcomes, increased convenience, and a more personalized health experience makes it most certainly an endeavor worth seeking out. As technology continues to evolve, these intelligent mobile solutions will increasingly play key roles in assisting in delivering healthier pregnancies and brighter futures to mothers and babies.

Global incidence and prevalence of diabetes have been rising steadily, leading to increased disability, mortality, and a significant economic burden. Despite advances in medical care, challenges such as shortage of diabetes specialists, unequal distribution of healthcare resources, suboptimal medication adherence, and poor self-management have contributed to inadequate glycemic control in patients. These challenges are prominent in Nigeria, a developing nation where most of its medical personnel have migrated to countries in Africa, Europe and Americas [2, 3]. A proposed solution is the use of artificial intelligence to provide services that were hitherto done by humans.

This study developed a mobile phone-based blood sugar tracking system that predicts GDM status using an integrated AI model. The mobile app aids pregnant women in keeping track of their diet and exercise so as to assist medical personnel in making informed decisions about their health during and after pregnancy.

2. Related Works

Sweeting *et. al.* [4] described Gestational Diabetes Mellitus (GDM) as glucose intolerance that is either onset or first encountered in pregnancy. The incidence of GDM has been rising across the world due to reasons such as increased rates of obesity among reproductive-aged women and higher maternal age. GDM is related to a range of short-term obstetric and neonatal comorbidities, most significantly elevated infant birthweight, and also referred to as a risk factor for long-term cardiometabolic morbidity in mothers and children. The article highlighted the previous lack of international consensus regarding the diagnosis of GDM, which is consistent with its complex development and practical concerns in antenatal care, as today GDM is one of the most common pregnancy complications. Current clinical practice should consider both short-term effects and long-term outcome of GDM. Maternal hyperglycemia induces a permanent adverse impact on the metabolism of children and adolescents by early exposure.

The Hyperglycemia and Adverse Pregnancy Outcomes (HAPO) study established a positive linear and continuous relationship between maternal glucose and risk of perinatal adverse outcomes [5]. Based on these findings, the International Association of the Diabetes and Pregnancy Study Groups (IADPSG) revised its criteria to propose that one abnormal glucose value from a 75-g 2-hour oral glucose tolerance test (OGTT) is sufficient for diagnosis. However, other organizations, like the American College of Obstetricians and Gynecologists (ACOG), continue to recommend a two-step testing approach. The article also discussed different international testing approaches to GDM, including universal versus selective screening and some diagnostic criteria. It clarified that a rise in GDM prevalence comes with the IADPSG criteria. Though there are reports suggesting the IADPSG strategy is cost-effective for delaying future type 2 diabetes and preventing perinatal complications, others indicate that it may not be cost-effective using perinatal outcomes alone. Management-wise, GDM should be provided by a multidisciplinary team but with patient education and lifestyle modification as a focus. Pharmacotherapy, usually insulin, is initiated if the blood glucose levels remain high after lifestyle change. Metformin can also be employed unless there are concerns regarding fetal growth restriction. Early postpartum OGTT is recommended to assess glucose status, and regular ongoing long-term follow-up to modify diabetes and cardiovascular risk factors in the mother and encourage healthy lifestyle in the child.

Zhu and Zhang [6] examined the global burden of Gestational Diabetes Mellitus (GDM) and its progression to Type 2 Diabetes Mellitus (T2DM). Despite the rising global epidemic of diabetes, there's a lack of systematically synthesized data on the global prevalence of GDM, particularly in developing countries. The hyperglycemic intrauterine environment associated with GDM pregnancies not only reflects but also contributes to the T2DM epidemic. The synthesized data revealed significant variations in both GDM prevalence estimates and the risk of GDM progressing to T2DM across different countries and regions. These variations make direct comparisons of GDM burden challenging. The article comprehensively reviewed available data from the past decade to estimate the contemporary global prevalence of GDM by country and region and to assess the risk of progression from GDM to T2DM.

Benton *et. al.* [7] outlined a protocol for a feasibility randomized controlled trial (RCT). The primary objective of the protocol is to test the feasibility of conducting a definitive trial for a diabetes prevention intervention. This intervention incorporated a smartphone app and group support. This two-arm, parallel feasibility RCT used sixty Malaysian women diagnosed with GDM during their antenatal period to either receive the intervention or standard care until 12 months postpartum. The intervention involved a smartphone app, MyManis, developed based on the Information-Motivation-Behavioral Skills (IMB) model of behavior change, coupled with group support using motivational interviewing. The app provides tailored information and support for weight loss through diet and physical activity, including weekly blog posts, information on GDM and T2DM, healthy eating recipes, and exercise programs with visual aids. The control group received standard care, which included blood glucose self-monitoring and lifestyle advice from a multidisciplinary team. The trial has received ethical approval and the findings from this feasibility study are expected to inform the design of a larger, full-scale RCT in the future.

Saparamadu *et. al.* [8] discussed the development of a mobile health (mHealth) app specifically for health professionals using a user-centered design (UCD) approach. This approach is often underutilized in the creation of mHealth apps targeted at healthcare providers. The objective of the study was to create a simple and functional UCD process for mHealth apps intended for health professionals and to share the key learnings from the design activities. The app was designed to deliver medical laboratory-related information to health professionals daily. The study employed a user-centered design approach, which emphasized understanding the end-users' needs and involving them throughout the design process. The paper highlighted the importance of UCD in creating effective and usable mHealth apps, especially for a demanding user group like health professionals who require accurate, timely, and easily accessible information. The case study demonstrated how a systematic UCD process can lead to the development of an mHealth app that is not only functional but also well-received and usable by its target audience, thereby improving information dissemination and potentially healthcare delivery.

Lee and Kim [9] examined the clinical effectiveness of mobile applications designed for diabetes management. The review focused on articles written in English that were published between January 2016 and August 2021. The review identified articles primarily focused on Type 1 diabetes (2 studies), Type 2 diabetes (6 studies), and both types of diabetes (4 studies). The studies reported on various aspects of the apps, including their functionality (5 studies), usability (4 studies), or both (3 studies). The findings indicated that diabetes mobile apps generally provide a convenient user experience and contribute to improved blood sugar levels in patients with diabetes. The authors emphasized that when developing diabetes mobile apps, usability must be comprehensively evaluated using established definitions and scales, such as the ISO9241-11 usability definition or the Mobile Application Rating Scale (MARS) developed by [10] and validated by [11]. This will ensure that the apps are not only effective in managing blood sugar but also user-friendly and accessible.

Gardner *et. al.* [12] discussed the growing global disease burden of diabetes, particularly its high prevalence in Asia and the Western Pacific regions. It raised to prominence the reality that diabetes management relies heavily on self-care, yet glycemic control is compromised in developing nations due to limited access to healthcare, low physician density, and low rates of healthcare expenditure. Mobile health technologies including mobile applications, telemedicine websites, and electronic medical records (EMRs) have a potential to bridge the gaps by enhancing patient empowerment, adherence to medication, and healthy lifestyles. They can assist in providing remote consultations, patient data management, and self-management tools such as monitoring physical activity and food intake. Despite the advantages, adoption challenges are infrastructure limitations, compliance issues, and data privacy issues. Asymmetries in digital health readiness still exist among Asian countries. Only when these adoption challenges are addressed through the enhancement of infrastructure, usability of apps, and regulatory compliance can implementation be efficient.

The paper dwelt on the aspect that diabetes care applications should have universal features like simple visual design, local language support, automatic data integration, voice commands, interactive and dynamic features, and robust cloud support with data encryption. Patient-centric features are also essential, including food libraries, comprehensive planning tools (diet, exercise, medication), individualized alerts and reminders, culturally sensitive guidance and support, healthcare professional (HCP) interaction, clinical decision support, value-added services (referrals to pharmacies, testing centers), and emergency support. Several mobile apps have evidenced positive outcomes in diabetes management, namely improvement of glycemic control and patient engagement. For example, studies on apps like OneTouch Reveal®, NexJ Systems Health Coach, Wellthy CARE™, mySugr®, and some others have unveiled HbA1c levels decrease and improved user satisfaction. Future directions must be anchored on prioritizing app acceptability and effectiveness, and the integration of machine learning and artificial intelligence-facilitated digital solutions towards ideal diabetes care. Overcoming challenges by future research and policy-making, addressing regulation and safety concerns, and optimizing digital health solutions is essential in optimizing diabetes care.

Ma *et. al.* [13] examined the latest advances in artificial intelligence (AI) applications for diabetes management, evaluating its potential to improve patient outcomes and reduce the economic burden on healthcare systems. They reviewed recent studies and clinical trials that explored the use of AI in diabetes prevention, diagnosis, and management. Key technologies such as machine learning, predictive analytics, and digital health tools were assessed for their clinical applicability and impact on patient care. AI-driven approaches, including predictive models for glycemic control, personalized treatment plans, and digital monitoring systems, showed promising results in enhancing diabetes management. However, the challenges of integrating these technologies into clinical practice, particularly regarding data privacy, algorithmic transparency, and training of healthcare providers still persist. The study concluded that AI presented substantial opportunities for improving diabetes care and reducing healthcare costs, but its successful implementation required overcoming several barriers, including regulatory hurdles and ensuring equitable access to technology.

He *et. al.* [14] assessed pelvic floor muscle training (PFMT) compliance and its effects on pelvic floor muscles in GDM puerperal women using the 'Keep' mobile fitness app. This randomized controlled trial included 72 puerperal women with GDM, recruited from November 2021 to April 2022. Participants were randomly divided into a control group (n=36) and an experimental group (n=36). The control group received routine postpartum PFMT instructions, while the experimental group performed PFMT guided by the 'Keep' app. Both groups underwent a 4-week intervention period. Compliance, International Consultation on Incontinence Questionnaire Short Form (ICIQ-SF) scores, Pelvic Muscle Self-efficacy Scale scores, and Knowledge, Attitude, Belief, and Practice (KAP) scores related to PFMT were compared pre- and post-intervention. Pelvic floor surface electromyographic biofeedback was used to compare post-intervention pelvic floor muscle strength. The experimental group showed significantly higher post-intervention maternal PFMT compliance, pelvic floor muscle strength (Class I and II), pelvic floor muscle self-efficacy, and KAP scores ($p<0.05$) compared to the control group. Incontinence scores were also lower in the experimental group ($p<0.05$). Both groups experienced improved pelvic floor muscle recovery post-intervention ($p<0.05$).

The study concluded that the 'Keep' app can significantly improve PFMT adherence, reduce urinary incontinence, enhance KAP scores and self-efficacy, and increase pelvic floor muscle strength in GDM puerperal women, thereby promoting pelvic floor rehabilitation after delivery. Limitations included the 'Keep' app's general focus (lacking GDM-specific disease care knowledge) and the single-center nature of the study. Future research should involve multicenter randomized controlled studies with larger sample sizes, extend the follow-up period to observe long-term effects, and incorporate portable instruments for home measurements to reduce subjectivity. Qualitative interviews were also suggested to identify factors influencing app usage.

3. Methodology

The Gestational Blood Sugar Tracker (GBST) mobile app was built using the Agile methodology. The operational model for GBST app is given in Figure 1. The methodology consisted of three phases: first phase is the mobile app development with integration of the AI model into the mobile app, second phase is the artificial intelligence (AI) model development and the third phase is user testing.

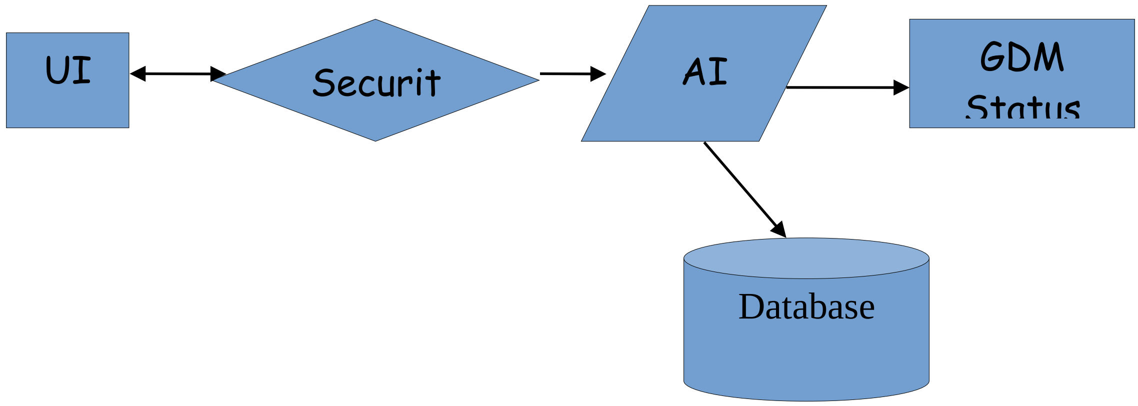

Figure 1: GBST App Operational Model

In the first phase, the application development was structured into five iterative sprints to ensure incremental delivery and continuous improvement. Sprint 1 focused on the user interface and user experience (UI/UX) by designing the interfaces using Figma and implementing the authentication using Google sign-in. Firebase handled cloud authentication and backup services, ensuring seamless synchronisation across devices. Android Studio was the primary development environment with Java as the programming language selected to ensure robust performance and maintainability. In Sprint 2, the Sqlite database was integrated into the mobile app to allow for logging of glucose level, medical history, obstetrics, exercise and diet. The app utilised SQLite for local storage to support offline functionality. During Sprint 3, the AI model for predicting Gestational Diabetes Mellitus was integrated as a module on the app dashboard. Sprint 4 involved performance testing and security enhancements, ensuring robustness and compliance with healthcare data standards. Finally, Sprint 5 handled deployment and the incorporation of user feedback, allowing changes to the mobile application based on real-world usage.

In phase 2 of the work, AI module for predicting the presence of GDM was done using the Feedforward Neural Network (FNN) algorithm. The dataset, 3525 rows and 17 columns, used for training and testing was obtained from Kaggle shared by [15]. A Feedforward Neural Network (FNN) model was obtained after training and testing on the dataset of pregnant women provided. After training and testing, the model was optimised and converted to TensorFlow Lite (TFLite) format for efficient execution on mobile devices. The mobile app seamlessly integrated real-time inference, analysing user-input data to detect potential GDM patients and notify users of their status. In the third phase, the GBST mobile app was evaluated with test data obtained at an ante-natal clinic in Ibadan, Nigeria.

4. Results and Discussion

4.1 Results

In phase 1 of the study, the GBST app is made up of 12 screen images designed with Figma. Sample screens are shown in Figures 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13.

In Figure 2, the splash screen is shown when the mobile app is launched. It shows the logo adopted for the project by the research team. The logos for the French Embassy in Nigeria and the University of Ibadan is located towards the bottom of the screen. The page in Figure 3 is where authentication is done using services provided by Google. Registration of new users via the Google Single Sign On (SSO), manual registration and recovery of forgotten passwords is available.

In Figure 4, the dashboard is displayed after authentication has been done. There are ten (10) activities that can be done through the dashboard. The activities are: view credits, input diet data, input exercise carried out, predict GDM status, do a fetal count of the child, document the sugar level tests and blood pressure readings taken, update medical history, provide Obstetrics data and any other information required.

Figure 2: Splash screen

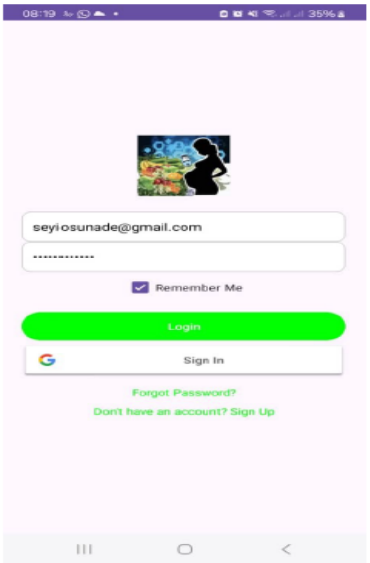

Figure 3: Authentication page

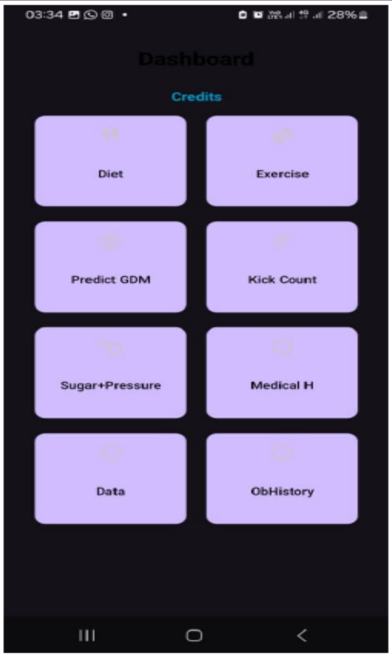

Figure 4: Dashboard

Figure 5: Diet page

Figure 6: Exercise page

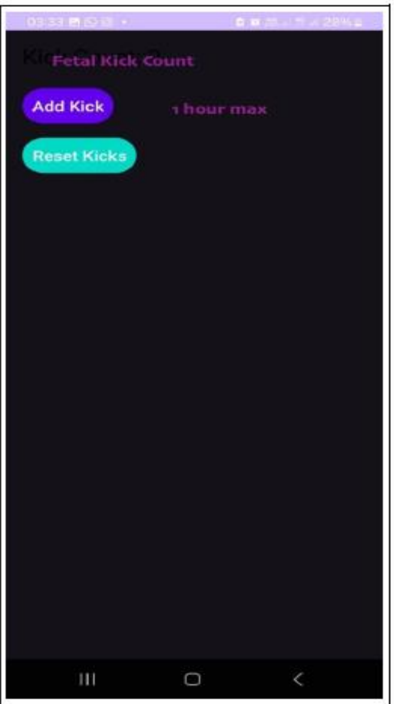

Figure 7: Fetal kick page

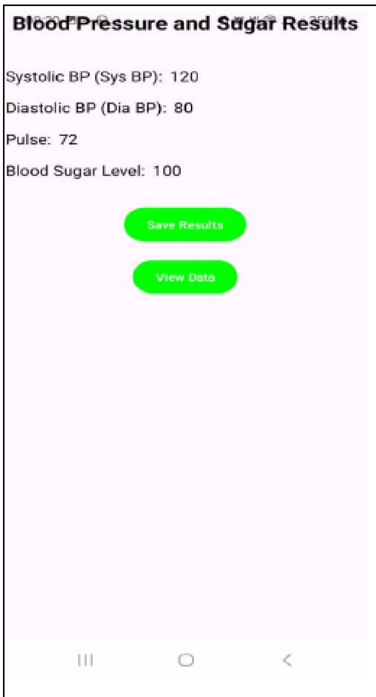

Figure 8: Blood Pressure and Sugar levels page

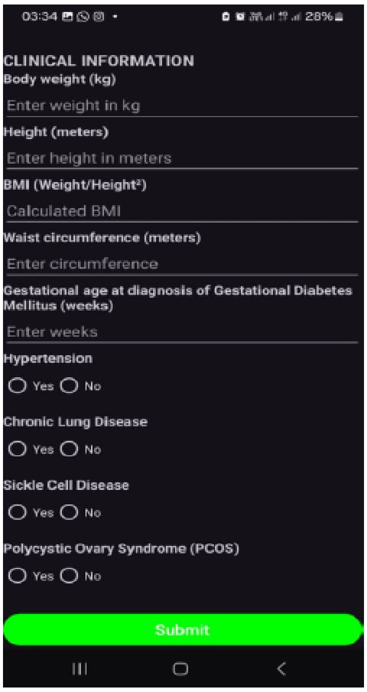

Figure 9: Medical History page

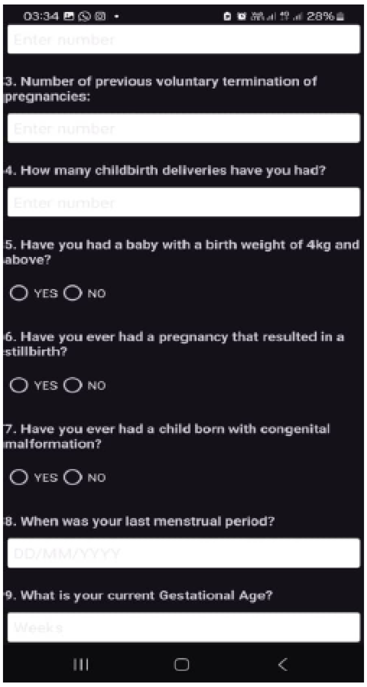

Figure 10: Obstetrics page

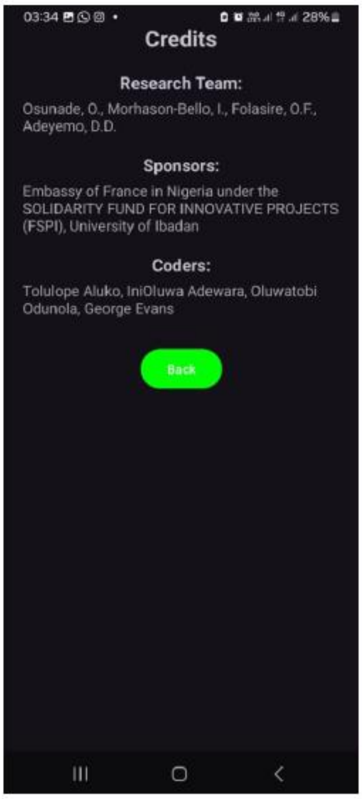

Figure 11: Credits page

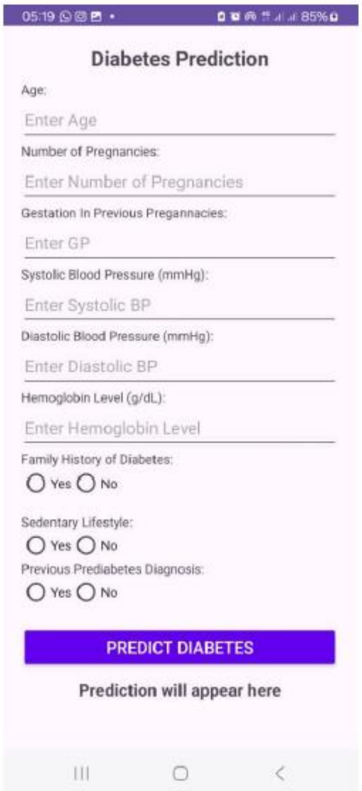

Figure 12: GDM Data Capture

Figure 13: GDM Status

Table 2: Accuracy values for 3 AI models

	Accuracy
Fast-forward Neural Network (FNN)	77%
Convolutional Neural Network (CNN)	70%
Recurrent Neural Network (RNN)	68.7%

Table 3: Fast Forward Neural Network Classification

Class	Precision	Recall	F1-score	Support
0	0.68	0.57	0.58	30
1	0.81	0.89	0.85	76
Accuracy			0.77	106

Table 4: Sample GDM prediction input and results

Age	# of pregnancies	Gestation in previous pregnancies	Systolic Blood Pressure (mmHg)	Diastolic Blood Pressure (mmHg)	Hemoglobin Level (g/dL)	Family history of Diabetes	Sedentary Lifestyle	Previous Prediabetes Diagnosis	GDM Status
41	6		120	70	12	No	No	No	0
34	4		130	70	12.3	No	Yes	No	0
38	2		100	70	12.5	Yes	No	No	0
34	1		100	80	11.3	No	No	No	0
33	2		120	80	12.3	No	No	No	0
39	1		158	93	17.8	Yes	No	Yes	1
44	1		169	92	18	Yes	No	Yes	1
45	3		143	102	17.2	Yes	No	Yes	1
38	3		150	95	17.8	Yes	No	Yes	1
38	3		150	101	17.1	Yes	No	Yes	1

Figure 8 allows data from self-tests or laboratory tests about blood pressure and blood sugar levels to be captured for medical review. Data provided by the patient about their medical history i.e. Figure 9, and Pregnancy history, Figure 10, are captured using the provided pages. The data can be used by medical personnel in supporting medical diagnosis.

The credits page in Figure 11 summarised the purpose of the mobile app and recognised the sponsors of the project, the investigators and the development team. Figure 12 uses nine (9) inputs to make the GDM prediction that is displayed on the app screen as shown in Figure 13 and stored in the database with a time stamp.

In Phase 2, the AI model was developed and integrated into the GBST app by optimising the model and converting with TensorFlow Lite (TFLite) to enable it operate on mobile devices. The module is labelled “Predict GDM.” Table 2 provides the accuracy values of three AI models tested for the detection of GDM.

The classification reports presented in Table 3 indicate how well the model classified **two**

classes (0 = No GDM, 1 = GDM) based on three key metrics: precision, recall and F1-score. The Fast Forward Neural Network Classification model showed better accuracy hence the adoption.

Table 4 provides results from user interaction with the GBST App during phase 3 of the study. The participants had all given birth before with most not living a sedentary lifestyle. The hemoglobin levels are higher for participants predicted with GDM. The systolic and diastolic blood pressures are also high for participants predicted to have GDM. Two GDM status are avilable i.e. no GDM or GDM (Diabetic) present.

4.2 Discussion

The use of mobile apps for diabetes management has been studied from different perspectives using different tools and techniques e.g. Gardner [12], Sweeting *et. al.* [4] and Lee & Kim [9]. This study focused on the design of a mobile app for gestational diabetes detection and monitoring.

The user interface was designed using Figma with a dashboard providing access to various functionalities. The choice of colour, font, font size could be improved upon. The icons used are not visual and customized for pregnant women. A qualitative study as suggested by Benton *et. al.* [7] would reveal more appropriate colours and images to use in the design.

Firebase Authentication is a comprehensive backend service provided by Google's Firebase platform that simplifies the process of authenticating users for web and mobile applications. It offers a secure and scalable solution for managing user identities without requiring developers to build and maintain their own authentication systems from scratch. The GBST app implemented the email and password method and a popular federated identity provider such as Google. Adeniyi *et. al.* [16] suggested the use of blockchain for protecting medical data. The security options for protecting the medical data can be improved upon.

The GBST app captures data about diet and exercise of the patient using a touch icon to prevent errors. The diet options such as carbohydrates, protein, fruit and vegetable provided are not localised to Nigeria. The exercise options such as walk and house chores are relatable to women. However for both diet and exercise, appropriate images can be integrated for better visualisation and great user experience. Catalano and Shankar [5] highlighted the need for diet and exercise data in the management of diabetes while American Diabetes Association [17] believed that changes in diet and exercise help manage gestational diabetes.

The results in Table 4 suggested that GDM status is a function of the Systolic blood pressure, Diastolic blood pressure, family history of diabetes and previous diagnosis of diabetes. The work of Buchanan, T. A. and Xiang [18] recommended the use of oral glucose tolerance test (OGTT) for clinical detection of GDM.

User testing of GBST app was done by medical personnel as recommended by 8]. The feedback included the number of variables or factors used for prediction, the accuracy of the prediction and the sovereignty of the blood sugar test.

5. Conclusion

This paper showed the development of a mobile application focused on prediction of Gestational Diabetes Mellitus (GDM) using an artificial intelligence (AI) model. The software development took the agile methodology approach with three phases and five sprints. The user interface was designed with Figma to make the user experience consistent. The AI model was built externally with 17 features and integrated into the mobile app during phase two using TensorFlow Lite. The patient’s medical data was stored on the local mobile device using Sqlite and Room. User testing indicate above average accuracy in the prediction of GDM.

In future it is expected that enhancements such as integration with wearable devices to enable real-time diet and exercise data tracking, and nutrition/exercise recommender systems will be included. The mobile app could also be evaluated using the Mobile Applications Rating Scale (MARS).

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