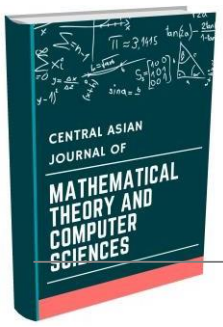

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Analysis of mobile applications created to assess the risk of developing gestational diabetes mellitus

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Abstract

In today's world, the fields of application of digital technologies are expanding day by day. One of the areas where modern technologies are widely and effectively used is the healthcare sector. In the field of healthcare, mobile technologies are becoming increasingly important in keeping patients under continuous monitoring and preventing the risk of the development of disease. This paper reviews mobile applications developed by researchers around the world on diabetes, one of the most common serious diseases in the world, including gestational diabetes. Commercially available mobile applications for gestational diabetes development risk assessment were also analyzed.

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Introduction.

Gestational diabetes mellitus (GDM) represents a significant health concern affecting pregnant women worldwide. Defined as glucose intolerance first recognized during pregnancy, GDM poses risks not only to the immediate well-being of the mother but also to the developing fetus. The prevalence of GDM has been on the rise in recent years, paralleling the global increase in obesity and sedentary lifestyles.

As per the statistical analysis report of 2019, the total number of people worldwide suffering from diabetes was 463 million, which accounts for 9.3% of the world's adult population between the age group of 20-79 years. This number is expected to rise to 578 million (10.2%) by 2030 and 700 million (10.9%) by 2045. The prevalence of diabetes in 2019 was 9.0% among women and 9.6% among men. People aged 65-79 years contributed to a significant increase of 19.9% (111.2 million) in the prevalence of diabetes [1].

Approximately 786,000 newborns are born in Uzbekistan each year. The prevalence of gestational diabetes (GDM) during pregnancy is around 10.5%, which means approximately 83,000 pregnant women are diagnosed with this condition every year.

In recent years, interest in conducting research in the fields of embedded systems, robotics and Artificial Intelligence in healthcare has increased in the world, including in Uzbekistan [2-5].

The rest of the paper follows this structure: The section “Analysis of developed mobile applications for the risk assessment of the development of gestational diabetes mellitus” is dedicated to up-to-date research done in the related field. The section “Commercially available mobile applications for the risk assessment of the development of gestational diabetes” presents an overview of the currently commercially available apps for GDM. The section “Conclusion” concludes this paper.

Analysis of developed mobile applications for the risk assessment of the development of gestational diabetes mellitus.

This section analyzes mobile applications developed in recent years to assess the risk of developing gestational diabetes. Over the last decade, researchers worldwide have conducted numerous studies aimed at developing mobile apps for assessing the risk of gestational diabetes.

In [6], it is proposed a mobile application that simplifies communication with healthcare professionals and provides users with health and nutrition recommendations to manage blood glucose levels. The application is mainly intended for use by women with gestational diabetes. It works by providing healthcare professionals with access to glucose readings through cloud technologies. The app also provides recommendations for diet and physical activity.

In [7], it is given a systematic review of patients’ experiences of using mobile health apps to manage gestational diabetes. The study includes primary research of qualitative data around patients' experiences of using these applications, as well as barriers and facilitators to technology use. The study searched for articles from the following electronic databases: Medline, Embase, PsycINFO, Global Health, Web of Science, Cochrane Central Register of Controlled Trials (CENTRAL), AMED, and CINAHL. The study used primary research that included direct user interviews and the results were analyzed using qualitative methods.

In [8], it is evaluated mobile applications using a grounded theory evaluation system to determine their applicability for patients at risk of gestational diabetes. This study evaluated the suitability of existing mobile applications on the market for the information and monitoring needs of patients with GDM and assessed the feasibility of integrating these applications into patient care. The Apple iTunes and Google Play stores were searched for mobile apps containing keywords related to the following nutrition concepts: diet, tracking, diabetes, and pregnancy. Evaluation criteria have been developed to evaluate mobile applications on five dimensions. In general, the apps scored well on the educational and informative functions and scored poorly on the engaging functions. Several apps provide comprehensive evidence-based educational content, tracking tools, and integration with electronic health records. This study demonstrated the need to develop applications with complete content, tracking tools, and two-way data-sharing capabilities.

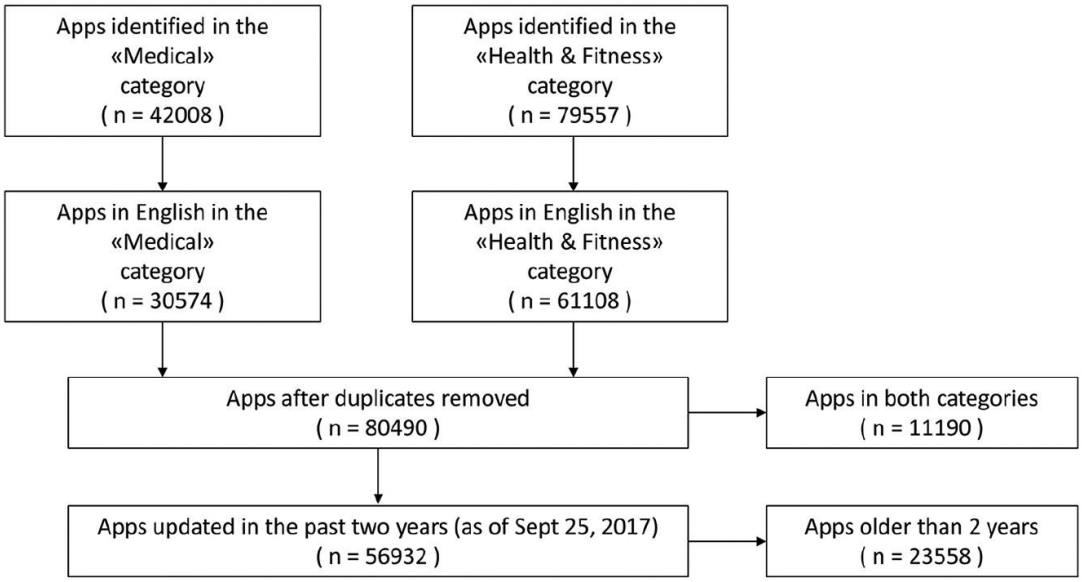

Fig. 1. Flowchart of apps identified from the US iTunes App Store in the initial search on May 31, 2017. The same procedure was followed in the Google Play Store [8]

In [9], the purpose of the study was to assess the level of awareness and usage of the Pregnant with Diabetes smartphone application locally, nationally, and internationally. In the study, in 2013, the "Pregnant with Diabetes" application was developed in cooperation with the staff of the Center for Pregnant Women with Diabetes in Rigshospitalet and the patient's initiative. The application provides clinically important antenatal health information to women with diabetes based on the recommendations of the center (Rigshospitalet). Women with diabetes (type 1 and type 2 diabetes) completed an anonymous, structured questionnaire at their first antenatal visit during early pregnancy at the center. National and international data on the number of downloads is obtained from Google Play, App Store, and Google Analytics. The results of the study showed that of 139 pregnant women with diabetes (96 with type 1 diabetes and 43 with type 2 diabetes), 99% owned a smartphone and 75% downloaded the app, 48% of whom received information from the app before pregnancy. In July 2017, the program was downloaded 4,465 times in Denmark and 27,361 times in 183 countries.

In [10], it is addressed patient and healthcare provider barriers to GDM monitoring and management of GDM in an Asian setting. The study collected survey data from 216 women with GDM and conducted semi-structured interviews with 15 women and 8 healthcare providers treating patients with GDM. Participants were recruited from 2 specialist GDM clinics at the National University Hospital in Singapore. The results of the study showed that the patients were mainly Chinese (102/214, 47.6%), employed (201/272, 73.9%), with higher education (150/216, 69.4%) and prenatal attendance at a private clinic (138/214, 64.2%), already on diet control (210/214, 98.1%), and receiving support and information from the GDM clinic (194/215, 90.2%) and web-based sources (131/215, 60.9%). Specifically, working women reported barriers to GDM management, including lack of blood glucose monitoring, reminders to monitor diet, and insufficient time for exercise. Most women preferred to receive such care directly from health care providers at the GDM clinic (174/215, 80.9%) or elsewhere (116/215, 53.9%). Smartphone apps have been cited as the preferred method of adjunctive intervention.

In [11], it is aimed at exploring and evaluating existing smartphone applications for self-monitoring and remote monitoring of GDM with a focus on creating individualized patient feedback. Five databases were systematically searched for any studies evaluating mHealth-supported smartphone solutions for GDM management from study initiation to January 2022. Finally, 17 studies involving 1871 patients from 11 different countries were included. The PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) conceptual framework was used to extract and categorize data.

In [12], 18 articles identified 11 discrete mHealth applications based on GDM, but only 3 were of sufficient quality, of which only one is currently being used in a clinical setting. Two-thirds of the apps provided

contextual user feedback that was relevant to the patient's self-care. There are limited mHealth applications that include SI or SI-based decision support for GDM. Many are only able to reduce adverse events by recording patient information such as blood glucose readings or diet, providing general patient education or counseling, or providing drug warnings. Significant barriers remain that continue to limit the adoption of mHealth applications in clinical care settings. More research and development are needed to provide AI-powered smart holistic mHealth applications that can truly reduce healthcare resource utilization and improve outcomes by enabling patients to self-care in the community.

In [13], it is developed mobile and user-friendly software to facilitate the diagnosis of gestational and pre-gestational diabetes mellitus. During the research, an open-source software d-GDM was developed in Java. The Android Studio integrated development environment was used as the Android operating system. The software for the diagnosis of GDM used the criteria approved by the International Diabetes and Pregnancy Study Group, modified by the World Health Organization. The results of the study showed that the criteria for the diagnosis of GDM were not easy to follow, so errors or inconsistencies in the diagnosis are expected and may delay appropriate treatment. d-GDM was developed to aid in the diagnosis of GDM with accurate and consistent diagnostic reports. Open-source software is easy to manage. The operator requests information about the period of pregnancy and selects the appropriate glycemic marker options from the menu. Pressing the diagnostic button on the screen during operation provides information for diagnosis and further investigation. d-GDM is available in Portuguese or English and can be downloaded from the Google PlayStore. A responsive web version of d-GDM is also available. The utility and accuracy of the d-GDM were validated through trials involving 22 subjects and 5 mobile phone brands. User approval for ease of use and efficiency was 95% or higher. In this test, the diagnosis of pregnancy was 100% correct. d-GDM is a convenient, free diagnostic software developed for mobile devices. This has the potential to contribute to and aid in the diagnosis of GDM for healthcare professionals.

In [14], it is investigated the awareness and use of a smartphone application for the management of GDM among pregnant women. The study included a variety of relevant studies (n = 522) from 3 databases: Pub Med, Cochrane Library, and Google Scholar. To do this, the study involved the design of a 5-step review framework that included defining the research question, identifying articles, selecting articles, collecting data, and reporting results. The results of the study showed that a combination of keywords was used in the initial search criteria, with the help of which 522 literatures were found from 3 databases. After reviewing the titles and abstracts, 249 articles were excluded due to duplicate literature, and 252 articles were excluded for the following reasons: not relevant (n = 172), editorial (n = 43), not in English (n = 7), and abstract only (n = 30). Additionally, 10 articles were excluded because apps such as MobiGuide, pregnant + app, and GDm health were not mentioned in these articles. A total of 11 articles were included in the final analysis. The mobile apps described in this study (pregnant+, MobiGuide, and GDm health) have improved personalized health care, improved patient care, and improved patient blood glucose monitoring and treatment compliance.

In [15], it is designed and developed a smartphone application (Pregnant+ application) that automatically transfers blood sugar from a glucometer and provides information about healthy eating and physical activity. This formative study included expert panel discussions among health professionals, researchers, and data privacy and security experts. Conducted user engagement studies to discuss app prototypes. The final version of the app will include behavior modification techniques, such as self-monitoring and action instructions. The results of the first round of interactions show the importance of involving expert groups and patients in the development of a mobile health device.

In [16], a study was conducted on the Mobile App Rating Scale (MARS) consisting of a search and review of purpose-built apps that provided general and specific rating scores for each aspect of the Mobile App Rating Scale (MARS). In January 2019, two instances of app stores (iOS and Google Play) were searched for apps related to GDM search keywords including "pregnancy diabetes mellitus," "pregnant diabetes," and "health apps." Eligibility criteria include: running on Android or iOS operating systems, being in English, being developed specifically for gestational diabetes, and being available in Iran. Initially, after an exclusion process, 102 apps were identified, and five selected apps were downloaded and analyzed. All applications are divided

into four categories according to their content and interactive capabilities. The Pregnant with Diabetes app scored the highest in most MARS quadrants. In addition, the overall app quality score was average for the Pregnant with Diabetes app (3.10 / 5.00).

In [17], it is analyzed secondary data from different trials to determine whether a smartphone app with targeted dietary information and blood glucose monitoring influenced the behavior of women with GDM. In the study, women with a 2-hour oral glucose tolerance test level ≥9 mmol/L were individually grouped into an intervention group that received the Pregnant+ app and usual care, or a control group that received only usual care. From October 2015 to April 2017, women were enrolled in 5 diabetes outpatient clinics in the Oslo region of Norway. The Pregnant+ app promotes 10 dietary recommendations for gestational diabetes. The healthy dietary score for Pregnant+ (HDS-P+), a 41-item food frequency questionnaire, was used to assess the effect of the intervention on dietary behavior at baseline and 36 weeks gestation. Differences in diet between groups after the intervention were assessed with analysis of covariance and adjustment for baseline diet. The results of the study showed that a total of 238 women participated: 115 were allocated to the intervention group and 123 to the control group. Of the 238 women, 193 (81.1%) completed a food frequency questionnaire at baseline and around 36 weeks of gestation. All participants showed improvement from baseline on the HDS-P+. However, Pregnant + application did not significantly affect their HDS-P +.

In [18], it is developed a digital diabetes prevention intervention to prevent type 2 diabetes in Malaysian women with GDM. According to this study, it was the first study to determine the feasibility of a digital intervention in preventing type 2 diabetes in women with GDM in Malaysia. The results of this feasibility study will inform the design of a future full-scale randomized controlled trial (RCT).

In [19], it is analyzed the clinical effectiveness of specific mHealth applications on short-term and long-term outcomes related to maternal and child clinical health. A systematic literature search was performed in Medline (PubMed), Cochrane Library, Embase, CINAH, L and Web of Science Core Collection databases, as well as Google Scholar. The study included studies published from 2008 to 2020 using specific mHealth apps. GDM diagnosed women were analyzed. Controlled clinical studies and randomized controlled trials were included.

It is given an information about summarizes and differences of analyzed works in this study in Table 1.

Table 1. Summarizes and differences of analyzed works in this study

Ref.	Advantages	Outcomes
[6]	This paper proposed the use of a mobile application to manage gestational diabetes	The proposed app provides patients with a solution to self-manage their disease along with obtaining support from their health care professionals
[7]	Conducted a systematic review of patient experiences when using mobile health applications to manage gestational diabetes	To assess the quality of included studies, they used the CASP qualitative research checklist
[8]	This study evaluates mobile apps using a theory-based evaluation framework to discover their applicability for patients at risk of gestational diabetes	This study demonstrates the need to develop apps that have comprehensive content, tracking tools, and ability to bidirectionally share data with the patient's primary care provider
[9]	This study assesses the level of awareness and usage of the Pregnant with Diabetes smartphone application locally, nationally, and internationally	The results of the study showed that of 139 pregnant women with diabetes (96 with type 1 diabetes and 43 with type 2 diabetes), 99% owned a smartphone and 75% downloaded the app, 48% of whom received information from the app before pregnancy
[10]	This study aimed to understand the perception of patients and health care providers of the barriers	A GDM-focused smartphone app that is able to integrate testing, education, and

	to GDM management and preferred interventions to manage GDM in an Asian setting	communication may be a feasible and acceptable intervention to provide support to women with GDM, particularly for working women
[11]	This study examine and assess the available smartphone apps which enable self-monitoring and remote surveillance of GDM with a particular emphasis on the generation of individualized patient feedback	This comprehensive scoping review highlights the feasibility, reliability, and acceptability of app-assisted health care for the management of GDM
[12]	This study investigates mHealth apps intended for use with GDM; specifically those powered by artificial intelligence (AI) or providing decision support	There are limited mHealth apps for GDM that incorporate AI or AI- based decision support. Many exist only to record patient information like blood glucose readings or diet, provide generic patient education or advice, or to reduce adverse events by providing medication or appointment alerts.
[13]	An open source software, d-GDM, was developed in Java. The integrated development environment Android Studio was used as the Android operational system	The usefulness and accuracy of d-GDM was verify by field tests involving 22 subjects and 5 mobile phone brands. The approval regards user- friendliness and efficiency were 95% or higher
[14]	This study aims to investigate the awareness and use of the smartphone application (app) with respect to management of GDM among pregnant women	The mobile apps described in the present study (pregnant +, MobiGuide, and GDm health) provided personalized health care services, patient care improvement, and enhanced patient's compliance toward blood glucose monitoring and treatment
[15]	The aim of this study is to document the process of designing and developing a smartphone application (the Pregnant+ app) that automatically transfers blood sugar levels from the glucometer and has information about healthy eating and physical activity	The resulting app, Pregnant+, provides an automated transfer of measured blood sugar levels into the smartphone, which serves as a mobile health device for personalized diabetes care
[16]	This study aimed to search and review the apps developed for this purpose providing overall and specific rating scores for each aspect of MARS	102 apps were identified after the exclusion process, five selected apps were downloaded and analyzed. All apps were classified into four categories according to contents and their interactive capabilities. In most quadrants of MARS, the Pregnant with Diabetes app received the highest scores. Also, in general, the maximum app quality mean score belonged to Pregnant with Diabetes (3.10 / 5.00)
[17]	This study analyzes secondary data from a two-arm, multicentered, nonblinded randomized controlled trial to determine if a smartphone app with targeted dietary information and blood glucose monitoring had an effect on the dietary behavior of women with GDM	Their findings do not support the supplementation of face-to-face follow-up of women with GDM with a smartphone app in the presence of high-standard usual care, as the Pregnant+ app did not have a beneficial effect on pregnant women's diet
[18]	This study describes a randomized controlled trial (RCT) to test the feasibility of undertaking a definitive trial of a diabetes prevention intervention, including a smartphone app and group support. Secondary aims are to summarize	According to this study, this will be the first study in Malaysia that aims to determine the feasibility of a digital intervention in T2D prevention among women with GDM. Findings from this feasibility study will inform the

	anthropometric, biomedical, psychological, and lifestyle outcomes overall and by allocation group, and to undertake a process evaluation	design of a full-scale RCT
[19]	This study analyzes the clinical effectiveness of specific mHealth-Apps on clinical health-related short and long-term outcomes in mother and child	According to this study, mHealth-Apps might improve health-related outcomes, particularly glycemic control, in the manage- ment of GDM

Commercially available mobile applications for the risk assessment of the development of gestational diabetes.

The role and importance of mobile applications in diabetes control are immense. Below are mobile apps that are effective in controlling not only gestational diabetes but also all types of diabetes, grouped by function. The table 2 lists the top-rated apps in the Google Play Store and Apple App Store designed to track diabetes nutrition and exercise.

Table 2. Apps designed to monitor diet and exercise in diabetes

T/r	Application name	Google Play Store rating (max 5)	Apple App Store rating (max 5)	Price
1.	Medical ID	4.7	-	Free
2.	MyFitnessPal	4.3	4.7	Free, in-app updates available
3.	Carb Manager	4.7	4.8	Free, in-app updates available
4.	Figure Visual Food Diary (Android)	3.4	4.7	Free, in-app updates available
5.	Calorie Counter by FatSecret	4.6	4.7	Free, in-app updates available

The table 3 lists the top-rated apps in the Google Play Store and Apple App Store designed to monitor blood sugar levels in diabetes.

Table 3. Applications developed to monitor blood sugar in diabetes

T/r	Application name	Google Play Store rating (max 5)	Apple App Store rating (max 5)	Price
1.	mySugr	4.4	4.7	Free, in-app updates available
2.	Health2Sync	4.7	4.7	Free, in-app updates available
3.	DiabetesConnect	4.4	4.7	Free, in-app updates available
4.	OneTouch Reveal	3.4	4.8	Free

The table 4 lists the apps that have been developed to monitor various indicators of diabetes and have the highest ratings in the Google Play Store and the Apple App Store.

Table 4. Applications developed to control various indicators of diabetes

T/r	Application name	Google Play Store rating (max 5)	Apple App Store rating (max 5)	Price
1.	Glucose Buddy	4.0	4.8	Free, in-app updates available
2.	Diabetes Tracker by MyNetDiary (Apple)	-	4.8	$9.99
3.	MyNetDiary's Diabetes and Diet Tracker (Android)	4.5	-	$9.99
4.	Diabetes: M	3.5	4.6	Free, in-app updates available
5.	One Drop	3.7	4.5	Free, in-app updates available
6.	Noom	3.5	4.7	Free, in-app updates available

Some apps are most helpful in controlling pregnancy diabetes mellitus. These mobile apps are of great help in preventing the risk of developing pregnancy diabetes mellitus. Below is information about the apps that are most helpful in controlling pregnancy diabetes mellitus [51].

Malama Health mobile app

This application is designed to assist pregnant patients who have gestational diabetes. It provides all the necessary features that patients require, and it is completely free. The app allows you to record your meals, pre- and post-meal blood sugar readings, nutritional information (with pictures or text), exercise, sleep, stress, and open notes. It includes a carb calculator to make carb-tracking easier and provides real-time practical tips and feedback after each meal. The app also enables you to set an SMS reminder 1 or 2 hours after each meal and lets the patient generate reports to share with all medical teams via email or text. Versions of the application are available for both iOS and Android users.

Fig. 2. Malama Health mobile application

GD Tracker mobile application

This is a user-friendly and comprehensive application specially designed for pregnant patients with gestational diabetes. The app allows users to track their blood glucose levels, nutrition, exercise, weight, and medications. It also provides an option to set reminders for medications, appointments, and blood sugar checks. The app offers a visual representation of users' blood sugar levels over time, enabling them to monitor their health more efficiently. Both iOS and Android versions of the app are available.

Fig. 3. GD Trackerview of the mobile application

Glucose Buddy mobile app

This application is accessible for both iOS and Android users. It helps users to record their blood sugar readings, medications, meals, and exercise. Additionally, the app provides graphs and charts as visual aids to help you understand your blood sugar levels better. Although the primary features of this app are free, there is also a paid version that offers additional features, such as reminders, data sharing, and report generation.

Fig. 4. Glucose Buddy mobile application

mySugr mobile app

Users can track their blood sugar readings, meals, and insulin doses on the app. Additionally, the app generates personalized reports to help users understand their glucose levels. The app offers basic features for free, however, users can upgrade to the paid version to gain access to more features such as reminders, blood sugar target ranges, insulin monitoring, report generation, and integration with Apple Health. The app is available for both iOS and Android users.

Fig. 5. mySugr mobile application

One Drop mobile app

One Drop is a comprehensive app designed to help manage diabetes. It enables users to easily track blood sugar, nutrition, medications, and physical activity. The app also provides personalized coaching support from certified diabetes educators. While the primary features of the app are free to use, additional features such as blood sugar prediction, nutrition and exercise analysis, and Bluetooth blood sugar recording are available through a subscription service. The app is compatible with both iOS and Android operating systems.

Fig. 6. One Drop mobile application

Conclusion. In conclusion, the role of digital technologies, including mobile applications, in assessing the risk of developing GDM is very high. In this study, the research conducted by world scientists on the assessment of the risk of developing GDM was thoroughly analyzed. In addition, commercially available mobile apps on the market for GDM assessing the risk of developing GDM were compared in terms of their ratings in the Google Play store and the Apple App store. In the future, it is planned to develop a mobile application for assessing the risk of developing GDM in Uzbekistan using the experience gained during this analytical study.

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