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A Review of Diabetes Apps: Features, Limitations, and Improvement Suggestions

(Semakan Apl Diabetes: Ciri, Had dan Cadangan Penambahbaikan)

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Abstract

Mobile applications (apps) for type 2 diabetes mellitus (T2DM) management are gaining global attention. These apps have been reported to facilitate better clinical outcomes and patient adherence. However, the specific features that contribute to improvements in T2DM management remain unclear. This study aims to analyze prevalent features in commercially available T2DM apps and identify limitations and areas for future development. A scoping review was conducted on literature published from June 2012 to May 2023. Databases such as Ovid, PubMed, and Scopus were extensively searched. The study adhered to PRISMA-Scr guidelines for reporting scoping reviews. Study inclusion and exclusion criteria were based on the PCC framework. The primary outcome was identifying patterns in app features. Fourteen review papers, covering over 900 diabetes management apps, were included in the analysis. The most common features were self-monitoring of blood glucose, blood pressure, and body weight. However, significant limitations were noted, including the lack of automatic data entry, medication management tracking, psychological support, and comprehensive disease education. Concerns about health data security and privacy were found to contribute to patient hesitancy in adopting these apps. This review highlights several essential features and limitations of diabetes management apps. Future app development should prioritize enhancing patient motivation and incorporating heuristic design principles like instructional videos and help features. Collaboration between healthcare providers, policymakers, and app developers is crucial to improving the quality, usability, and engagement of T2DM apps.

Keywords: Type 2 diabetes mellitus, health education, mobile application, digital health, app features

Abstrak

Aplikasi mudah alih (apps) untuk pengurusan diabetes mellitus jenis 2 (T2DM) semakin mendapat perhatian di seluruh dunia. Aplikasi-aplikasi ini dilaporkan dapat membantu meningkatkan hasil dapatan klinikal dan kepatuhan pesakit. Namun, ciri-ciri spesifik yang menyumbang kepada peningkatan pengurusan T2DM masih kurang jelas. Kajian ini bertujuan untuk menganalisis ciri-ciri dominan dalam aplikasi T2DM yang tersedia secara komersial serta mengenal pasti kekurangan dan bidang yang memerlukan pembangunan lanjut. Kajian skoping dijalankan terhadap literatur yang diterbitkan dari Jun 2012 hingga Mei 2023. Pangkalan data seperti Ovid, PubMed, dan Scopus telah digunakan untuk pencarian yang menyeluruh. Kajian ini mematuhi garis panduan PRISMA-Scr dalam pelaporan kajian skoping. Kriteria inklusi dan eksklusi kajian ditentukan berdasarkan kerangka PCC. Hasil utama kajian ini adalah mengenal pasti corak dalam ciri-ciri aplikasi. Sebanyak empat belas kertas tinjauan yang merangkumi lebih daripada 900 aplikasi pengurusan diabetes telah dianalisis. Ciri-ciri yang paling kerap ditemui adalah pemantauan kendiri terhadap glukosa darah, tekanan darah, dan berat badan. Namun, beberapa kekurangan dikenalpasti, termasuk ketiadaan kemasukan data secara automatik, kurang penjejakan terhadap pengambilan ubat, sokongan psikologi dan pendidikan penyakit yang menyeluruh. Kebimbangan tentang keselamatan dan privasi data kesihatan juga didapati menyumbang kepada keraguan pesakit dalam menggunakan aplikasi-aplikasi ini. Kajian ini menekankan beberapa ciri penting dan kelemahan aplikasi pengurusan diabetes. Pembangunan aplikasi pada masa hadapan perlu memberi keutamaan kepada peningkatan motivasi pesakit serta menggabungkan prinsip reka bentuk heuristik seperti video arahan dan ciri bantuan. Kerjasama antara penyedia penjagaan kesihatan, penggubal dasar, dan pembangun aplikasi adalah penting untuk meningkatkan kualiti, kebolehgunaan, dan penglibatan dalam penggunaan aplikasi T2DM.

Kata kunci: Diabetes mellitus jenis 2, pendidikan kesihatan, aplikasi mudah alih, kesihatan digital, ciri aplikasi

INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia due to insulin resistance (Yameny 2024). It is a major public health concern worldwide, with its prevalence rising sharply over the past decades. The International Diabetes Federation (IDF) reported that 537 million adults aged 20-79 years were living with diabetes in 2021, and the number is expected to rise to 643 million by 2030 and 783 million by 2045 if current trends continue (IDF Diabetes Atlas. 2025). In 2022, the global diabetic population, including undiagnosed cases, had already exceeded 830 million (World Health Organization: WHO, "Diabetes. 2024). This growing crisis is putting immense pressure on healthcare systems, as diabetes raises the risk of serious complications like cardiovascular disease, kidney failure, blindness, and neuropathy (IDF Diabetes Atlas. 2025). Individuals with diabetes are at a heightened risk of developing heart attacks, strokes, and other severe complications due to the progressive damage the condition causes to blood vessels and vital organs (De Amorim Salazar et al. 2024).

Malaysia has one of the highest diabetes prevalence rates globally, with 20% of adults diagnosed in 2021 (Akhtar et al. 2022). This marks a significant rise from 11.2% in 2011 to 18.3% in 2019, highlighting a rapid increase and growing risk of diabetes nationwide (Akhtar et al. 2022). Several factors contribute to this surge, including urbanization, sedentary lifestyles, unhealthy diets, and rising obesity rates (Akhtar et al. 2022). The growing number of diabetes cases underscores the urgent need for effective management strategies to prevent complications and reduce the burden on healthcare systems

Diabetes health education is essential for enhancing self-care management and disease knowledge. Effective diabetes health education has been shown to improve HbA1c levels, lipid profile and body mass index, as well as knowledge related to T2DM management (Velázquez–López et al. 2017). Diabetes self-care management consists of healthy eating, physical activity, regular blood sugar monitoring, taking prescribed medication, performing diabetic foot care, having good problem-solving skills, healthy coping skills and risk-reduction behaviours (IDF Diabetes Atlas. 2024). Poor health education is consistently associated with undesirable outcomes, such as increased rate of hospitalization, greater use of emergency care and poor medication adherence (Velázquez–López et al. 2017).

In 2023, approximately 85.95% of the global population, or over 6.92 billion people, used smartphones (Kandula et al. 2009). Notably, young people are the most prevalent smartphone users (Kandula et al. 2009). Approximately 94.8% of Malaysians were found to be smartphone users (Statista. 2023). Globally, mobile phones have become an essential mode of communication, with technological advancements significantly enhancing the dependability of smartphones across various applications (Kahn et al. 2010). Mobile applications, commonly known as mobile apps or apps, are software tools that provide a wide range of capabilities and services across multiple domains, including entertainment, commerce, education, and self-management. These apps have also been incorporated into the management and prevention of chronic disease, specifically in the context of T2DM self-care management (Kahn et al. 2010).

Smartphones can effectively facilitate illness management through the utilization of health-related mobile applications. According to a study conducted in 2015, the Android market had approximately 25,000 health-related mobile applications for various disease. By the end of 2022, the number of these apps available on the Google Play Store had already exceeded 54, 000 (Statista. 2024). Multiple studies have demonstrated that these apps have the potential to significantly improve T2DM self-care (Scheibe et al. 2015). Mobile apps play a crucial role in facilitating effective therapy management, promoting treatment protocol adherence, and reducing the risk of disease complications (Eng and Lee. 2013; Scheibe et al. 2015). For example, a user-friendly interface in the apps may enhance user engagement, making therapy management more accessible and intuitive (Scheibe et al. 2015). Mobile applications that facilitate data sharing among multiple users was believed to promote collaboration and information exchange, leading to better therapy management outcomes (Scheibe et al. 2015).

Despite the proliferation of mobile applications designed to aid in the management of T2DM, there remains significant variability in their effectiveness and user satisfaction (Eng and Lee. 2013). This inconsistency stems from a lack of standardized features and the presence of various limitations within these applications. While numerous systematic reviews have evaluated the effectiveness of individual mobile apps (Lum et al. 2019), there is a paucity of research synthesizing these reviews to identify common features and limitations across the spectrum of available apps. Therefore, this review is needed to consolidate existing knowledge, pinpoint critical design elements that contribute to app efficacy, and highlight recurrent limitations that impede optimal DM management.

METHODS

Information sources and search strategy

Aligned with the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) guidelines to ensure transparency and reproducibility in reporting scoping review findings. Adhering to PRISMA-ScR enhances the comprehensiveness and clarity of the review process, thereby improving the overall quality and reliability of the research outcomes (Tricco et al. 2018).

This study employed a comprehensive search strategy across multiple databases, including Ovid Medline, PubMed, and Scopus, to identify related systematic reviews for inclusion in the final analysis. Furthermore, records were also gathered from Google Scholar using the manual checking of the references listed in each relevant article to ensure all relevant systematic reviews was considered for this study.

The search strategies utilized in this study were based on specific keywords and phrases related to the research topic, as well as manual searching of reference lists from included studies to identify any additional relevant articles. This comprehensive approach ensured that all relevant literature was captured for analysis.

On Pubmed

((((((((((diabetes mellitus[MeSH Terms]) OR (type 2 diabetes mellitus[MeSH Terms])) AND (health education[MeSH Terms])) OR (patient education[MeSH Terms])) OR (health information[MeSH Terms])) AND (mobile apps[MeSH Terms])) OR (apps features[MeSH Terms])) OR (digital health[MeSH Terms])) AND (change behavior[MeSH Terms])) OR (medication adherence[MeSH Terms])) OR (self-efficacy[MeSH Terms])) OR (self-management[MeSH Terms])

On Scopus

Advanced searches on: diabetes apps self-management and diabetes app features for medication adherence

On Ovid Medline

To achieve optimal sensitivity, we created strategies that combine keywords with controlled or index terms:

A: “Diabetes mellitus” or “Type II Diabetes mellitus”

B: “Health education” or “patient education” or “health information”

C: “mobile apps” or “apps features” or “digital health”

D: “Change behavior” or “medication adherence” or “self-efficacy” or “self-management”

The following terms were added at various points in combination to refine and filter results.

The EndNote reference management software was utilized to organize the search results, in which duplicate articles were removed automatically and through manual double-checking. The screening process involved assessing the publications’ titles and abstracts and conducting independent evaluations. Full-text papers of potentially eligible references were obtained and evaluated for eligibility with the pre-determined selection criteria. Following this, three investigators (NSY, TMTM and EMH) assessed the full-text articles and determined their admissibility. Any discrepancies between investigators were resolved through discussion.

Eligibility criteria

The studies included in this review had to be primary research, published in peer-reviewed journals, and written in English. Additionally, the studies focus on identifying common features in mobile apps designed for diabetes self-management in patients with T2DM. The study should also analyse the patterns and limitations of features in existing mobile apps for T2DM.

To ensure only relevant studies were included, eligibility criteria for study inclusion and exclusion Table 1 were developed using the acronym PCC (Population, Concept, Context). This approach enables a thorough examination of the available literature, helping to identify key themes and supporting evidence. It also revealed gaps in the literature and provided a comprehensive understanding of the research landscape surrounding T2DM mobile apps.

Figure 1 displays a flow diagram illustrating the literature search process and the subsequent selection of studies. The initial database search produced a total of 1260 articles, and supplementary sources revealed an additional 86 articles. After removing 466 duplicates, 880 articles remained for screening based on their objectives. From these, 713 articles were excluded as they did not align with the research questions or objectives. This screening process yielded 167 articles that met the predefined inclusion criteria for the review process. Subsequently, a comprehensive analysis, including data extraction and synthesis, was conducted on

these 167 publications. However, 142 articles were excluded from the analysis due to not meeting the research type, intervention, and outcome criteria. Furthermore, 11 articles were removed after a thorough evaluation of their entire texts, based on the predetermined inclusion and exclusion criteria. Finally, 14 articles were included in this scoping review.

Data extraction

Data extraction was first done by a single investigator (NSY) following predetermined criteria, and two study supervisors (TMTM and EMH) then evaluated the resulting findings. The extracted data encompass various elements such as the journal, publication, year, databases searched, period, setting, objective, intervention type, number of apps reviewed, study design, whether a systematic review or meta-analysis was conducted, outcomes, main results and limitations.

Data Synthesis and Analysis

Thematic analysis was used in the data synthesising process to identify recurring themes and patterns within the literature. By utilising this method, a greater understanding of the various aspects and shared characteristics discovered in the reviewed studies was achieved. The findings were categorized according to the PCC framework, with a focus on the key features of T2DM mobile apps, their usage patterns, and the limitations found in previous studies. The synthesis aimed to provide a comprehensive overview of the current landscape of T2DM mobile apps to identify gaps in the literature that require further research and development on mobile app technologies for diabetes management.

Three independent evaluators (NSY, TMTM, and EMH) appraised each review, and the relevant data were imported into an Excel data collection template. Disagreements among evaluators were resolved through discussion. A consensus was achieved based on the principle that the judgement of the most experienced raters in each group would be taken as final in cases of ambiguity

RESULTS

Study Characteristics

Fourteen review articles included in this study were published in 13 different journals from 2012 to 2022. The number of apps reviewed in each article varied, encompassing approximately 926 mobile applications. See Table 2 for the description of the study characteristics. Out of 14 articles, seven were conducted in the United States, two in Singapore, and two in China. The remaining reviews were conducted in Germany, Malaysia, and the United Kingdom, each represented by one article.

The common features of T2DM mobile applications

Table 3 shows the features identified in the diabetes mobile health applications included in the final analysis. The analysis identified that most apps offered essential tools for self-monitoring, including features like tracking blood glucose levels, monitoring diet intake, and recording physical activity (Demidowich et al. 2012; Gao et al. 2017; Hoppe at al. 2016; Huang et al. 2019; Jimenez et al. 2019; Izahar et al. 2017; Martinez et al. 2017; Nie et al. 2016; Sneha et al. 2020; Veazie et al. 2018; Ye et al. 2018). These features were often enhanced with reminders and alerts and promoting consistent self-management. Additionally, some apps provide personalised feedback through features like goal-setting based on user data, resulting in a significant increase in user engagement (Hoppe at al. 2016). However, the degree of personalisation varied widely, for instance, some apps offered basic functionalities like generic tips, while others provided comprehensive, tailored advice based on individual user data (Hoppe at al. 2016; Huang et al. 2019; Izahar et al. 2017; Jimenez et al. 2019; Martinez et al. 2017; Sherazi et al. 2022).

Educational resources were another common feature among the apps, offering articles, videos, and practical tips for diabetes management (Gao et al. 2017; Hoppe et al. 2016; Huang et al. 2019; Izahar et al. 2017; Jimenez et al. 2019; Martinez et al. 2017; Sherazi et al. 2022). These resources aim to improve users' knowledge and self-efficacy. Furthermore, certain apps seamlessly integrate with electronic health records (EHRs) to provide a comprehensive overview of the user's health history while enabling direct communication with healthcare providers for personalised guidance in diabetes management (Hoppe et al. 2016; Huang et al. 2019; Izahar et al. 2017; Jimenez et al. 2019; Martinez et al. 2017; Sherazi et al. 2022).

Challenges in Current T2DM Mobile Apps

Many apps lacked content that was fully aligned with evidence-based guidelines, which could lead to inconsistent or suboptimal management practices (Gao et al. 2017; Jimenez et al. 2019). User interface and accessibility issues were prevalent, particularly for older adults or individuals with limited digital literacy (Darby et al. 2016). Furthermore, there was a notable variability in app quality across different platforms, with some apps performing well on one

platform but poorly on another. Concerns about data privacy and security were also raised, as many apps did not clearly communicate how user data was stored or shared, posing potential risks to users (Sneha et al. 2021)

Suggestions for Developing Future T2DM Apps

To address these gaps, the study recommends enhancing app design and functionality by focussing on areas such as aligning content with clinical guidelines, providing personalised advice based on user data, and improving user interfaces for better accessibility (Darby et al. 2016; Fu et al. 2020; Sneha et al. 2021). Developers are urged to collaborate more closely with healthcare professionals to ensure that app content aligns with the latest clinical guidelines (Gao et al. 2017; Hoppe et al. 2016; Huang et al. 2019; Jimenez et al. 2019; Nie et al. 2016). Additionally, there is a need for greater personalisation in apps, utilising advanced algorithms to provide more tailored advice based on individual user data (Demidowich et al. 2012; Gao et al. 2017; Huang et al. 2019; Izahar et al. 2017). Improving user interfaces is also essential, particularly for those with limited digital literacy, to ensure that all users can effectively navigate and benefit from the app (Fu et al. 2020; Martinez et al. 2017). Finally, developers should prioritise data privacy and security by implementing robust measures and communicating these practices to users (Sneha et al. 2021).

DISCUSSION

The pattern of features of the T2DM mobile applications

The primary features identified in the T2DM mobile applications are centred on data recording, primarily self-monitoring of blood glucose (SMBG), blood pressure and body weight (Demidowich et al. 2012; Gao et al. 2017; Hoppe et al. 2016; Huang et al. 2019; Izahar et al. 2017; Jimenez et al. 2019; Martinez et al. 2017; Nie et al. 2016; Sneha et al. 2021; Veazie et al. 2018; Ye et al. 2018;). However, more advanced technologies, such as automatic data entry, were lacking. Automatic data transfer via Bluetooth from glucose meter to mobile devices can significantly reduce manual errors and improve convenience (Izahar et al. 2017).

Medication management features were present in many apps but lacked depth. While reminders and basic education were common, advanced features apps like drug interaction monitoring, detailed drug information or prescription selection based on specific patient needs and insulin dose calculator were rare (Sherazi et al. 2022; Demidowich et al. 2012; Fu et al. 2020; Jimenez et al. 2019; Nie et al. 2016). This is a critical shortcoming, as robust medication management is a key aspect of diabetes care, especially for patients managing complex medication regimens.

The mobile app features related to behaviour change techniques (BCTs) were also limited (Hoppe et al. 2016). BCTs such as goal setting, action planning, self-monitoring, and problem-solving, are integral in diabetes management strategies aimed at reducing blood glucose levels (Van Rhoon et al. 2020). These techniques have proven effective in aiding individuals with diabetes to better manage their condition and improve their overall health outcomes (Van Rhoon et al. 2020). Eighteen of 40 applications proved that BCTs demonstrated the greatest efficacy to the users (Hoppe et al. 2016). This indicates a significant opportunity to enhance the effectiveness of these apps by incorporating more comprehensive BCT strategies, for instance, goal-setting, feedback mechanisms, and motivation could help users sustain long-term behaviour changes, ultimately improving their management of diabetes (Rad et al. 2024; Van Rhoon et al. 2020).

Limitations in existing T2DM mobile applications

Many T2DM apps lack critical features like psychological support and comprehensive disease education management, despite their importance in managing a chronic condition (Nie et al. 2016). Holistic diabetes management requires addressing the emotional and mental health needs such as providing stress management tools and psychological support (Nie et al. 2016).

Social support also has a proven positive impact on diabetes treatment (Demidowich et al. 2012). However, only 22.5% of diabetes apps allow users to communicate with each other (Demidowich et al. 2012; Hoppe et al. 2016). Incorporating features that facilitate peer communication and community support could significantly improve patient outcomes. Furthermore, regular patient follow-ups by healthcare providers have been shown to prevent long-term complications (Sherazi et al. 2022).

Recommendations for the development of future T2DM mobile applications

Health data security and privacy concerns also represent a significant barrier to the adoption of T2DM mobile applications. Regulatory uniformity could reduce variance in-app features, cost, and monitoring capabilities, thereby increasing self-care participation and enhancing diabetes outcomes (Sneha et al. 2021). This governing body could also help establish guidelines for data protection and

encryption to address patients' concerns about the security of their personal health information when using mobile health applications (Sneha et al. 2021).

Regulatory guidelines, such as those issued by the FDA in 2021, distinguished between medical devices and healthy apps can help ensure that apps labelled as "medical" meet rigorous safety and efficacy standards (U.S. Department of Health and Human Services. 2022). Many endocrine and diabetes apps in the app store are labelled as 'medical' by the developers, but this designation often lacks a specific review organization's endorsement. The FDA guidelines distinguish between medical mobile apps and apps for health and wellness, but consumers may not be made aware of this distinction, potentially mistaking the ' medical' label as a sign of efficacy endorsement (U.S. Department of Health and Human Services. 2022). By promoting transparency and accountability in the development and use of these technologies, patient trust in digital health solutions can be strengthened, leading to greater adoption and improved health outcomes.

Another key challenge is the lack of features tailored to older adults and other specific patient populations, such as those addressing sexual health, falls, and pain management, which are common concerns for elderly patients with diabetes (Gao et al. 2017). Older adults used diabetes apps with fewer features more effectively, likely because simpler interfaces and less complex navigation made the apps easier to use **(**Darby et al. 2016**).** The review of all the apps exhibited readability challenges, such as unclear colour coding and small font sizes (Fu et al. 2020). This can hinder users from understanding their glucose data (Fu et al. 2020). Adding personalized features that meet the specific needs of older patients could greatly improve the effectiveness of these apps. Including educational resources and support within the app can also help those less familiar with technology better use the apps (Gao et al. 2017; Huang et al. 2019).

Most diet tracking features in the apps focused on total calories rather than nutritional balance and fluid intake, which were largely ignored (Gao et al. 2017). While these apps are widely used for weight management and chronic disease management, they often neglect comprehensive dietary needs. Many apps struggle with user adherence due to their limited functionalities, which often do not include tracking of micronutrients or hydration levels (Gao et al. 2017). This highlights the need for future app developments to prioritize a more holistic approach of dietary tracking, incorporating not only calorie counts but also micronutrients and hydration levels. By addressing these limitations, apps can better support user in achieving their health and wellness goals.

Collaboration between patients, healthcare providers, policymakers and app developers is crucial to creating apps that truly meet user needs (Gao et al. 2017; Hoppe et al. 2016; Huang et al. 2019; Jimenez et al. 2018**;** Nie et al. 2016). Directly involving patients in the development process aids developers in understanding their real-world needs and preferences (Jimenez et al. 2018). Patients offer valuable insights into their daily challenges, which can guide the design of an intuitive interface and relevant features. For example, making navigation simpler and providing easy-to-understand instructions can greatly enhance the user experience (Gao et al. 2017; Hoppe et al. 2016; Jimenez et al. 2018; Nie et al. 2016). Working with medical experts like endocrinologists ensures that the app's recommendations and data tracking align with the latest medical guidelines and research (Gao et al. 2017; Hoppe et al. 2016; Jimenez et al. 2018; Nie et al. 2016). Involving regulatory experts from the beginning guarantees the app's compliance with healthcare regulations and standards, essential for patient safety and legal adherence (Gao et al. 2017; Hoppe et al. 2016; Jimenez et al. 2018; Nie et al. 2016).

Limitations of studies and Recommendations for future research

The findings are dependent on the quality and scope of reviews included, which may restrict the dept of understanding of user experience, long-term engagement, and direct clinical outcomes linked to T2DM mobile apps. The study also highlights the inconsistency in evaluating app features across different reviews, which poses challenges in comparing the effectiveness and functionality of the apps comprehensively. Furthermore, the study overlooked the essential aspect of sustained use of these mobile apps over time, critical for comprehending patient adherence and long-term benefits. Another methodological limitation is that the included studies primarily focused on common features and patterns, but there is a lack of detailed exploration into the reasons behind user engagement or disengagement with these apps. This limits the study's ability to fully address how design and functionality impact user satisfaction and sustained use. Furthermore, the study encountered challenges due to the variability in app quality across different platforms, adding complexity to any consistent analysis of their effectiveness

For future research, prioritizing longitudinal studies to evaluate the long-term impact of T2DM mobile apps on clinical outcomes, such as blood glucose levels, medication adherence, and overall diabetes management, is recommended (Öcal.

2023). Moreover, app developers should concentrate on designing features customized to meet the varied needs of different user populations, especially older adults and individuals with limited digital literacy (Rebus et al. 2024). Enhanced personalization through advanced algorithms and behaviour change techniques (BCTs) could help improve user engagement and health outcomes. Furthermore, enhancing the user interface is crucial to ensure that apps are user-friendly and accessible for all patients, particularly those who may find complex technology challenging (Öcal. 2023). Taking a regulatory perspective, implementing standardized guidelines for the development and evaluation of health apps would enhance consistency in functionality, security, and adherence to medical guidelines (Saidi et al. 2023). Enhancing collaboration among healthcare providers, app developers, and regulatory bodies is crucial to further improve the quality and effectiveness of future T2DM apps, ensuring they are reliable, evidence-based, and tailored to patient needs (Öcal. 2023).

CONCLUSION

This study identifies several key features that contribute to the success of diabetes apps, including user-friendly interfaces, personalized feedback, and seamless integration with healthcare providers. These elements improve patient engagement and the overall management of T2DM. However, significant limitations, such as inconsistent functionality, lack of standardization, and inadequate user engagement persist, which hinder the effectiveness of many apps.

By analyzing the prevalent features and identifying these limitations, this study highlights areas for future development. Enhancing the consistency of app functionality, aligning content with clinical guidelines, and improving user experience, particularly for diverse user groups.

This research offers valuable insights for app developers, healthcare providers, researchers, and policymakers to guide the next generation of T2DM apps. By addressing these identified gaps and incorporating comprehensive, patient-centred care, future apps can optimized to improve health outcomes and quality of life for individuals managing T2DM.

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CONFLICT OF INTEREST STATEMENT

The authors have declared that no competing interests exist.

REFERENCES

Akhtar, S., Nasir, J.A., Ali, A., Asghar, M., Majeed, R. & Sarwar, A. 2022. Prevalence of type-2 diabetes and prediabetes in Malaysia: A systematic review and meta-analysis. *PLoS ONE, 17*(1): e0263139.

Darby, A., Strum, M.W., Holmes, E. & Gatwood, J. 2016. A Review of Nutritional Tracking Mobile Applications for Diabetes Patient Use. *Diabetes Technology & Therapeutics, 18*(3): 200–212.

De Amorim Salazar, B., Ortega, F.R.G. & Da Cruz Kalschne, I. 2024. Complicações Crônicas Do Diabetes Mellitus Tipo 2. *Revista Fisio&Terapia*, : 05–06.

Demidowich, A.P., Lu, K., Tamler, R. & Bloomgarden, Z. 2012. An evaluation of diabetes self-management applications for Android smartphones. *Journal of Telemedicine and Telecare, 18*(4): 235–238.

Eng, D.S. & Lee, J.M. 2013. The Promise and Peril of Mobile Health Applications for Diabetes and Endocrinology. *Pediatric Diabetes, 14*(4): 231–238.

Fu, H.N.C., Rizvi, R.F., Wyman, J.F. & Adam, T.J. 2020. Usability Evaluation of Four Top-Rated Commercially Available Diabetes Apps for Adults with Type 2 Diabetes. *CIN Computers Informatics Nursing, 38*(6): 274–280.Gao, C., Zhou, L., Liu, Z., Wang, H. & Bowers, B. 2017. Mobile application for diabetes self-management in China: Do they fit for older adults? *International Journal of Medical Informatics, 101*: 68–74.

Hoppe, C.D., Cade, J.E. & Carter, M. 2016. An evaluation of diabetes targeted apps for Android smartphone in relation to behaviour change techniques. *Journal of Human Nutrition and Dietetics, 30*(3): 326–338.

Huang, Z., Lum, E., Jimenez, G., Semwal, M., Sloot, P. & Car, J. 2019. Medication management support in diabetes: a systematic assessment of diabetes self-management apps. *BMC Medicine, 17*(1).

IDF Diabetes Atlas. (n.d.). . https://diabetesatlas.org/ [9 Februari 2025].

Izahar, S., Lean, Q.Y., Hameed, M.A., Murugiah, M.K., Patel, R.P., Al-Worafi, Y.M., Wong, T.W. & Ming, L.C. 2017. Content Analysis of Mobile Health Applications on Diabetes Mellitus. *Frontiers in Endocrinology*, 8.

Jimenez, G., Lum, E. & Car, J. 2018. Examining Diabetes Management Apps Recommended From a Google Search: Content Analysis.

JMIR Mhealth and Uhealth, *7*(1): e11848.

Kahn, J.G., Yang, J.S. & Kahn, J.S. 2010. 'Mobile' Health Needs and Opportunities In Developing Countries. *Health Affairs*, *29*(2): 252–258.

Kandula, N.R., Nsiah-Kumi, P.A., Makoul, G., Sager, J., Zei, C.P., Glass, S., Stephens, Q. & Baker, D.W. 2009. The relationship between health literacy and knowledge improvement after a multimedia type 2 diabetes education program. *Patient Education and Counseling*, *75*(3): 321–327.

Lum, E., Jimenez, G., Huang, Z., Thai, L., Semwal, M., Boehm, B.O. & Car, J. 2019. Decision Support and Alerts of Apps for Self-management of Blood Glucose for Type 2 Diabetes. *JAMA*, *321*(15): 1530.

Martinez, M., Park, S.B., Maison, I., Mody, V., Soh, L.S. & Parihar, H.S. 2017. iOS Appstore-Based Phone Apps for Diabetes Management: Potential for Use in Medication Adherence. *JMIR Diabetes*, *2*(2): e12.

Nie, L., Xie, B., Yang, Y. & Shan, Y.M. 2016. Characteristics of Chinese m-Health Applications for Diabetes Self-Management. *Telemedicine Journal and e-Health*, *22*(7): 614–619.

Öcal, P. 2023. The use of mobile health applications in empowering self-management of type 2 diabetes: a literature review. *The European Research Journal*, :1–9.

Rad, F.S., Hendawi, R., Yang, X. & Li, J. 2024. Personalized Diabetes Management with Digital Twins: A Patient-Centric Knowledge Graph Approach. *Journal of Personalized Medicine*, *14*(4): 359.

Rebus, D., Iskander, A., Deonarine, F., Almas, A., Rattigan, D., Henn, P., Fadahunsi, K.P. & O'Donoghue, J. 2024. Compliance of Type 2 Diabetes Applications to International Guidelines: Protocol for a Quantitative App Assessment. *JMIR Research Protocols*, *13*: e48781.

Saidi, S., Halim, N.A.A. & Hassan, N.H. 2023. A Review of Evidence on The Effectiveness of Mobile Health Applications in Improving the Clinical Outcomes and Supporting the Self-Management of Patients with Type 2 Diabetes Mellitus. *Malaysian Journal of Public Health Medicine*, *22*(3): 92–102.

Scheibe, M., Reichelt, J., Bellmann, M. & Kirch, W. 2015. Acceptance Factors of Mobile Apps for Diabetes by Patients Aged 50 or Older: A Qualitative Study. *Medicine 2 0*, *4*(1): e1.

Sherazi, B.A., Laeer, S., Krutisch, S., Dabidian, A., Schlottau, S. & Obarcanin, E. 2022. Functions of mHealth Diabetes Apps That Enable the Provision of Pharmaceutical Care: Criteria Development and Evaluation of Popular Apps. *International Journal of Environmental Research and Public Health*, *20*(1): 64.

Sneha, S., Thalla, S., Rischie, I. & Shahriar, H. 2021. Health Internet Technology for Chronic Conditions: Review of Diabetes Management Apps. *JMIR Diabetes*, *6*(3): e17431.

Statista. 2023. Smartphone ownership in Malaysia 2021, by income. https://www.statista.com/statistics/973669/malaysia-smartphone-ownership-by-income/.Statista. 2024. Google Play: number of available medical apps as of Q2 2024. https://www.statista.com/statistics/779919/health-apps-available-google-play-worldwide/.Tricco, A.C., Lillie, E., Zarin, W., O'Brien, K.K., Colquhoun, H., Levac, D., Moher, D., Peters, M.D.J., Horsley, T., Weeks, L., Hempel, S., Akl, E.A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M.G., Garritty, C., Lewin, S., Godfrey, C.M., Macdonald, M.T., Langlois, E.V., Soares-Weiser, K., Moriarty, J., Clifford, T., Tunçalp, Ö. & Straus, S.E. 2018. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Annals of Internal Medicine*, *169*(7): 467–473.

U.S. Department of Health and Human Services, Food and Drug Administration, Center for Devices and Radiological Health, Center for Biologics Evaluation and Research. 2022. Policy for Device Software Functions and Mobile Medical Applications.

Van Rhoon, L., Byrne, M., Morrissey, E., Murphy, J. & McSharry, J. 2020. A Systematic Review of the Behaviour Change Techniques and Digital Features in Technology-Driven Type 2 Diabetes Prevention Interventions. *Digital Health*, *6*: 205520762091442.

Veazie, S., Winchell, K., Gilbert, J., Paynter, R., Ivlev, I., Eden, K.B., Nussbaum, K., Weiskopf, N., Guise, J.-M. & Helfand, M. 2018. Rapid Evidence Review of Mobile Applications for Self-management of Diabetes. *Journal of General Internal Medicine*, *33*(7): 1167–1176.

Velázquez–López, L., Muñoz-Torres, A.V., Medina-Bravo, P., Vilchis-Gil, J., Klünder-Klünder, M. & La Peña, J.E. 2017. Multimedia Education Program and Nutrition Therapy Improves HbA1c, Weight, and Lipid Profile of Patients with Type 2 Diabetes: A Randomized Clinical Trial. *Endocrine*, *58*(2): 236–245.

World Health Organization: WHO & World Health Organization: WHO. 2024. Diabetes. https://www.who.int/news-room/fact-sheets/detail/diabetes [9 Februari 2025].

Yameny, A.A. 2024. Diabetes mellitus overview 2024. *Journal of Bioscience and Applied Research/Journal of Bioscience and Applied Research*, *10*(3): 641–645.

Ye, Q., Khan, U., Boren, S.A., Simoes, E.J. & Kim, M.S. 2018. An Analysis of Diabetes Mobile Applications Features Compared to AADE7™: Addressing Self-Management Behaviors in People with Diabetes. *Journal of Diabetes Science and Technology*, *12*(4): 808–816.