science, engineering and health studies

Research Article

Science, Engineering and Health Studies
https://lio1.tci-thaijo.org/index.php/sehs
ISSN (Online): 2630-0087

Gamification and mobile health in diabetes self-care: A comprehensive review of their impact and efficacy

Muhammad Thesa Ghozali

Department of Pharmaceutical Management, School of Pharmacy, Faculty of Medicine and Health Sciences, Universitas Muhammadiyah Yogyakarta, Bantul 55183, Indonesia

Corresponding author:
Muhammad Thesa Ghozali
ghozali@umy.ac.id

Received: *5 February 2024*
Revised: *15 January 2025*
Accepted: *28 January 2025*
Published: *12 December 2025*

Citation:
Ghozali, M. T. (2025). Gamification and mobile health in diabetes self-care: A comprehensive review of their impact and efficacy. Science, Engineering and Health Studies, 19, 25050015.

ABSTRACT

This study evaluates the roles of gamification and mobile health (mHealth) in diabetes self-care, highlighting their transformative potential in diabetes management. The review methodology entailed an extensive literature search across various databases, including PubMed, Sage Publications, Taylor & Francis, ProQuest, and ScienceDirect, focusing on systematic reviews and review articles published between 2019 and 2023. Rigorous inclusion criteria were applied to ensure a comprehensive analysis, focusing on studies that provide a broad perspective. A rigorous data extraction and quality assessment were conducted to confirm the validity of the findings. The findings of this study underscore the effectiveness of gamification and mHealth interventions in elevating various dimensions of diabetes self-care. Reviewed studies indicate notable improvements in glycemic control, as evidenced by reductions in hemoglobin A1c levels and significant enhancements in self-care practices, including dietary regulation and medication adherence. Additionally, these interventions have been shown to positively influence patient engagement and overall quality of life. However, the study acknowledges limitations, including variability in study designs, potential publication bias, and challenges in sample selection, highlighting the need for more standardized and exhaustive research approaches. In summary, gamification and mHealth interventions are promising strategies for advancing diabetes self-care.

Keywords: diabetes; health; mobile health; patient engagement; self-care

1. INTRODUCTION

Diabetes, a chronic condition characterized by elevated blood glucose levels, poses ongoing challenges to healthcare systems worldwide (Avilés-Santa et al., 2020). Effective management of this disease requires rigorous self-care practices, including regular blood glucose monitoring, careful dietary management, and consistent physical activity (Choudhury & Devi Rajeswari, 2021; Galicia-Garcia et al., 2020). However, many individuals with diabetes find maintaining continuous engagement in these self-care routines challenging. This difficulty in sustaining self-care practices highlights a significant gap in current diabetes management strategies. Innovative approaches are needed to enhance patient engagement and self-management, thereby improving health outcomes.

Among the emerging strategies in this area, gamification and mobile health (mHealth) applications are particularly promising (Schmidt-Kraepelin et al., 2020; Tran et al., 2024). These tools offer novel ways to make diabetes management more interactive and accessible. Despite the potential benefits, the specific impact of gamification and mHealth applications on diabetes self-care is not fully understood. This study aimed to address this gap by systematically

evaluating the effectiveness of these interventions in improving patient engagement and health outcomes.

Gamification, characterized by the incorporation of game-design elements into nongaming contexts, has been increasingly integrated into health interventions (van Gaalen et al., 2021). Its primary goal is to use the motivational aspects inherent in gaming, such as points, levels, and challenges, to enhance engagement and encourage positive behavioral changes. In diabetes self-care, gamification presents a unique opportunity to transform routine or otherwise arduous tasks into more captivating and potentially enjoyable activities. This approach strengthens adherence to self-care regimens, which is a critical component of effective diabetes management (Cascella et al., 2023). By reimagining these self-care tasks through a gamified lens, there is significant potential to engage patients more effectively and improve their overall management of their condition, ultimately contributing to better health outcomes.

Concurrently, the rise of mHealth has transformed patient care. mHealth applications specifically designed for diabetes management offer many benefits, including real-time monitoring, personalized feedback, and expanded access to healthcare information (Ghozali, 2024; Klonoff et al., 2021). These applications typically include features such as blood glucose tracking, dietary logging, medication reminders, and a range of educational resources. The incorporation of mHealth into the routine of diabetes self-care aligns seamlessly with the demands of a modern, fast-paced lifestyle, providing patients with a practical and efficient tool for managing their condition (Doupis et al., 2020). This integration not only enhances the convenience of diabetes management and facilitates a more proactive and informed approach to personal health care.

In developing the conceptual framework for this study on gamification and mHealth in diabetes self-care, it is crucial to reference various scholarly works that have set precedents in this field. A fundamental source is Fogg's work on persuasive technology, which lays the groundwork for using technology to influence health behaviors. Fogg's behavior model, elucidating how behavior change is spurred by the amalgamation of motivation, ability, and triggers, is particularly pertinent for comprehending how gamification can drive self-care in diabetes (Sittig et al., 2020). This model offers a comprehensive lens through which the motivational aspects of gamification can be understood and applied. Another cornerstone reference is the comprehensive meta-review by Damaševičius et al. (2023) on the impacts of gamification. This analysis provides critical insights into the effectiveness of gamification across various domains, including healthcare. The findings of this study are instrumental in understanding how game elements can be strategically used to promote health-related behavior change.

Regarding mHealth, a systematic review of adoption determinants and future research agenda on mobile medical applications for diabetes management by Alaslawi et al. (2022) is of paramount importance. This research offers an extensive view of the evolution and effectiveness of mHealth tools, which is crucial for understanding their potential to foster patient engagement and self-management in chronic conditions such as diabetes. Additionally, the American Diabetes Association (ADA) guidelines and recommendations are essential for understanding the standard practices and requisites for effective diabetes management (American Diabetes Association, 2021). These guidelines are invaluable in framing the application of gamification and mHealth within the broader context of diabetes care.

The literature on the psychological dynamics of chronic disease management, particularly the work of León-Hernández et al. (2023) on self-management education, plays a critical role in this study. Exploring the psychological barriers and facilitators of managing chronic diseases is vital for tailoring gamification and mHealth interventions to effectively address these challenges. Furthermore, studies focusing on user experience and design in health technology, such as the studies by Koumpouros (2022), offer essential insights into designing user-centric mHealth apps. These applications must be functional, engaging, and accessible to patients with diverse needs and preferences. Finally, the rapidly evolving field of digital health ethics, notably Benis's contributions in 2021, provides a crucial perspective on the ethical dimensions of deploying digital health interventions (Benis et al., 2021). This aspect is especially pertinent in gamification and mHealth, where considerations regarding privacy, data security, and the risk of unintended negative consequences are of utmost importance.

This review is necessary for several compelling reasons, each underscoring the profound impact and critical need for this research (Amjad et al., 2023; Yoon et al., 2022). First, the escalating global prevalence of diabetes has established it as a public health concern. According to the International Diabetes Federation, millions of people worldwide suffer from this chronic disease, with projections indicating a continued increase in the number of patients (Yoon et al., 2022). This escalating burden underscores the urgent need for innovative and effective strategies for diabetes management that extend beyond traditional methodologies. Thus, assessing the effectiveness of gamification and mHealth applications is not merely relevant but imperative in addressing this widespread health challenge. Second, conventional diabetes management approaches often have barriers to patient engagement and adherence. Despite the availability of effective treatment plans, numerous individuals struggle to maintain the consistency and commitment essential for effective diabetes self-care. This adherence gap stems from a lack of discipline and often from deficits in motivation, understanding, or resources. Gamification and mHealth are innovative approaches to bridge this gap. By rendering self-care more engaging and accessible, these technologies can augment patient adherence and improve clinical outcomes. An exploration of their impact could yield insights into how technology can be harnessed to assist patients in their journey of self-care, which can lead to enhanced diabetes management and reduced healthcare costs.

Moreover, the rapid technological advancements in healthcare present a prime opportunity to investigate the incorporation of these innovative tools into chronic disease management. The widespread use of smartphones and the increasing sophistication of digital health applications have provided a conducive environment for the deployment of mHealth solutions. However, the real-world effectiveness of such applications, their influence on patient outcomes, and acceptance across diverse patient demographics necessitate

thorough exploration. This mini-review aims to bridge this knowledge gap by providing evidence-based perspectives on the practical application of gamification and mHealth in diabetes management.

Furthermore, comprehending gamification's psychological and behavioral dimensions in healthcare is essential. Gamification leverages the principle of augmenting intrinsic motivation through game-like elements; however, applying this approach to managing chronic diseases is multifaceted and complex. Investigating the effects of gamification on behavioral change, patient motivation, and psychological well-being could offer a more profound understanding of how to design and implement such interventions effectively. Additionally, this study aims to illuminate the potential risks and ethical concerns associated with the gamification of health behaviors to ensure that these interventions are not only efficacious but also align with patients' best interests.

Despite the growing interest in gamification and mHealth interventions for diabetes self-care, a significant research gap exists in terms of understanding their comprehensive impact. This review aims to systematically analyze the current literature on the effectiveness of interventions for improving diabetes management outcomes. Specifically, the objectives are to identify the benefits, challenges, and future directions of gamification and mHealth in diabetes self-care.

2. MATERIALS AND METHODS

2.1 Data sources and search strategy

The selection of specific databases was driven by their comprehensive coverage and relevance to healthcare and technological research. PubMed was chosen for its extensive repository of biomedical literature, Sage Publications and Taylor & Francis for their robust collections of peer-reviewed journals in healthcare and social sciences, ProQuest for its wide-ranging dissertations and theses, and ScienceDirect for its vast array of scientific and technical research articles. This diverse selection ensured that the relevant literature was broadly incorporated across different domains.

The search terms were devised to capture a comprehensive range of studies related to diabetes management using mHealth and gamification. Terms such as "diabetes," "mHealth," "mobile health app," "patient education," and "self-management" were used. Boolean operators (AND, OR) were applied to interlink these terms, broadening the search to include various combinations and ensuring the inclusion of relevant studies. This strategy encompassed all pertinent literature, from broad conceptual studies to specific intervention assessments.

2.2 Eligibility criteria

The decision-making process for the inclusion and exclusion criteria was guided by the objective of synthesizing comprehensive and relevant insights from existing literature.

The inclusion criteria for the study are as follows:

a) Types of studies: Systematic reviews and review articles were included to comprehensively synthesize existing research. Additionally, pilot studies and longitudinal research were conducted to identify emerging trends and insights into novel applications of gamification and mHealth.
b) Publication date: Studies published between 2019 and 2023 were included to capture recent technological developments in the field.
c) Language: Only studies published in English were included to ensure a clear understanding and interpretation of the content.
d) Accessibility: Studies available in full text, either through databases or interlibrary loans, were included to allow thorough analysis.

The exclusion criteria for this study are as follows:

a) Types of articles: Original research articles, editorials, commentaries, and letters were excluded to maintain a focus on synthesized evidence.
b) Publication date: Studies published before 2019 were excluded to ensure that the review reflects the latest trends and research findings.

This approach ensured a focused and relevant set of studies for the review, providing a thorough understanding of the impact of gamification and mHealth interventions on diabetes self-care.

2.3 Data extraction

Data extraction was performed using a rigorous and systematic procedure based on a standardized form designed for this review. The key information documented from each study included the objectives, methodology, main findings, and conclusions. To ensure accuracy and reliability, each study was reviewed in detail, and any uncertainties were addressed through further analysis. This meticulous approach ensured the integrity and reliability of the extracted data.

2.4 Quality assessment

The quality assessment of the included systematic reviews was performed using a measurement tool to assess systematic reviews (AMSTAR). AMSTAR's criteria evaluate critical methodological elements, such as the extent of the literature search, the scientific rigor of the included studies, and the appropriateness of the methods used for data synthesis. Each review was independently assessed by two reviewers, and any disagreement was resolved through discussion or consultation with a third reviewer. This thorough quality assessment ensured that the review was based on methodologically sound and high-quality scientific evidence.

3. RESULTS AND DISCUSSION

This study systematically addresses the burgeoning impact and efficacy of mHealth interventions and gamification in diabetes self-management, placing the findings within the context of advancing healthcare technology. Findings from seminal studies (Brady et al., 2023; El-Gayar et al., 2021; Kruse et al., 2023; Wei et al., 2023) collectively signal a significant shift toward improved patient engagement and enhanced clinical outcomes. The narrative seeks to integrate these findings, examining the complexities inherent in their application and proposing future research directions grounded in substantial evidence. An analysis of the limitations and consideration of the wider implications of these studies aimed to provide a comprehensive perspective on the

current landscape of mHealth in diabetes management and to delineate informed strategies for its continued development and widespread adoption.

The advent of mHealth interventions has heralded a significant advancement in diabetes self-care, highlighting a potential paradigm shift in patient engagement and management strategies. This review synthesizes evidence from recent studies, highlighting the multifaceted nature of mHealth applications and the breadth of their impact on diabetes management. This discussion contextualizes these findings within the broader framework of healthcare technology, patient-centered care, and the chronic nature of diabetes management.

The systematic search and data extraction for this mini-review followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. Adherence to these guidelines was crucial for preserving
the integrity of the review process. The structure PRISMA framework facilitated an exhaustive and impartial search across multiple academic databases, guiding the identification, screening, and selection of relevant literature. This rigorous method enabled an in-depth assessment of the research on this topic. The results from each database search varied according to the number of articles retrieved and their relevance and suitability for inclusion in this study. While search results varied by database, this comprehensive process ensured the inclusion of a diverse range of high-quality studies that strictly aligned with PRISMA standards.

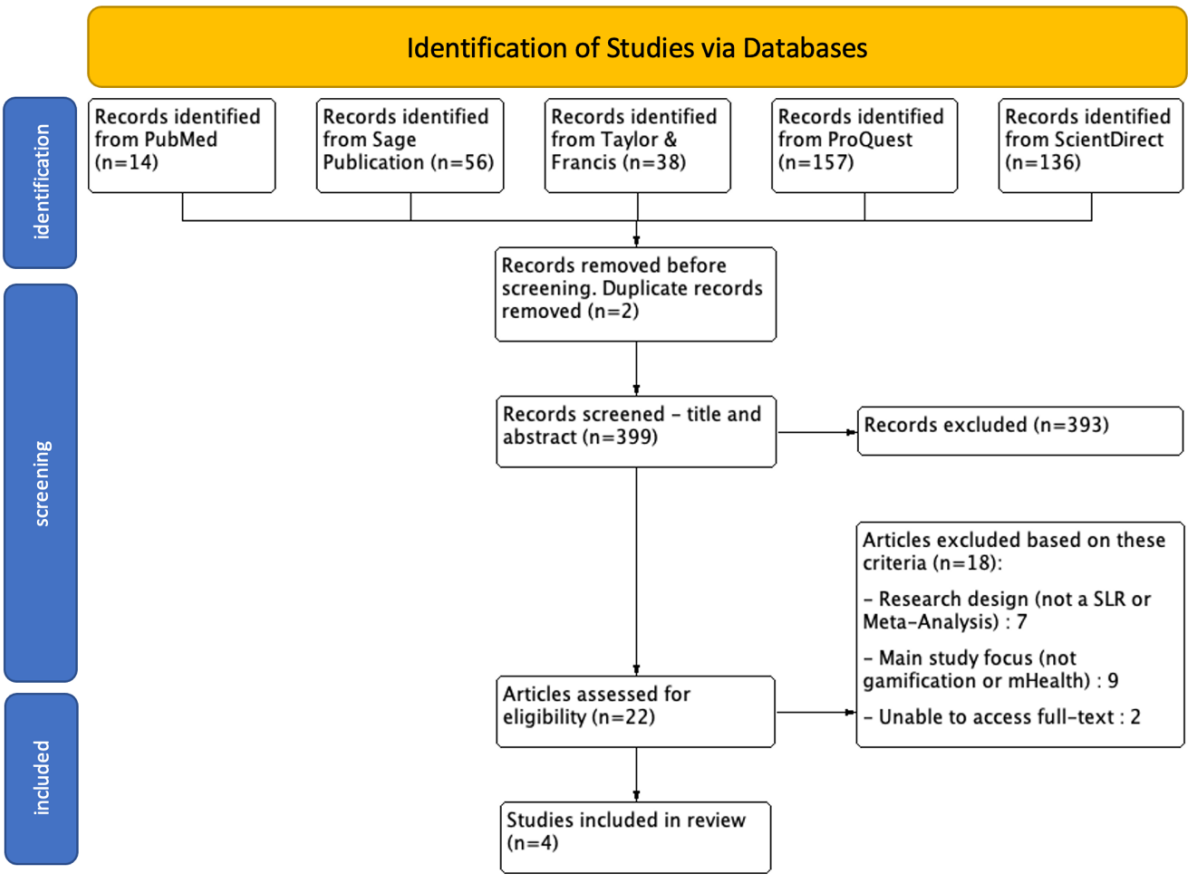

Figure 1. Flow diagram for study inclusion

The systematic search for this review, conducted across multiple databases, yielded varying results regarding the number of articles found and their eligibility for inclusion. A search of the PubMed database identified 14 articles (Figure 1). However, none of these articles met the review's stringent eligibility criteria, underscoring the review's specific inclusion parameters and the focused nature of the PubMed database with the subject matter of the study. In comparison, a search within the Sage Publications database yielded a much higher number of articles, totaling 56. Of these, four articles were found to align with the review's criteria, indicating a more pronounced congruence between the content of Sage Publications and this review's thematic and methodological framework.

The Taylor & Francis database search identified 38 articles. Despite the large number of studies, only one article met the eligibility requirements for inclusion. This result emphasizes the expansive scope of the Taylor & Francis database but indicates a relatively lower volume of literature directly relevant to the review's objectives. A similar pattern emerged in the ProQuest database, where 157 articles were identified, but none qualified for inclusion. This indicates a divergence in the focal points of the ProQuest database relative to the specific criteria delineated for this review. The ScienceDirect database

produced the highest number of articles, totaling 136. Within this extensive collection, three articles were deemed eligible for inclusion, demonstrating the broad reach of ScienceDirect and its relevance to the review topic.

The data search and extraction processes encountered various challenges. Two articles were identified as duplicates in different databases. These duplicates were meticulously excluded from the final analysis to maintain the content's uniqueness and integrity. Additionally, two articles that initially appeared relevant and met the eligibility criteria were inaccessible, likely caused by subscription constraints or nonfunctional links, thus hindering a thorough evaluation. Ultimately, only four studies were included in the review, reflecting the thoroughness of the selection process and the focus of the research topic.

3.1 Study design of the selected studies

The integration of mHealth apps into diabetes care represents a revolutionary shift in patient self-management strategies. As shown in Table 1, the systematic investigation by Brady et al. (2023) explored the efficacy of gamification and informational resources in ameliorating self-care behaviors and glycemic control among individuals with Type 2 diabetes (Brady et al., 2023). This comprehensive review, including randomized controlled trials and quasi-experimental studies, provides an extensive overview of the current trends, emphasizing the importance of engaging and interactive platforms in diabetes self-management. In parallel, El-Gayar et al. (2021) made a significant contribution to this field with their meta-analysis, which scrutinized the efficacy of mHealth applications in the realm of diabetes management, with a particular focus on behavior change techniques (BCTs) (El-Gayar et al., 2021). These techniques are fundamental to patient self-management education. The deliberate inclusion of randomized controlled trials in the analysis provides a solid foundation for evaluating the influence of mHealth interventions on glycemic control. This evaluation is crucial because it facilitates a deeper understanding among healthcare professionals and patients regarding the utility of mHealth as an adjunctive resource in the ongoing management of diabetes.

Kruse et al. (2023) adopted a focused lens in their systematic review by investigating the effectiveness of mHealth interventions specifically within the demographics of adults over the age of 50. Given that this population segment often contends with distinctive challenges in diabetes management, such as multiple comorbidities and polypharmacy, the review's emphasis on contemporary literature indicates the rapid evolution of mHealth technologies, suggesting a pivotal role for these technologies in customizing educational and management approaches to the unique needs of the older adult population. Moreover, Wei et al. (2023) presented an all-encompassing research synthesis that combined systematic review and meta-analysis methodologies. Their focus on the efficacy of mHealth interventions for gestational diabetes mellitus (GDM) underscores the empowering capacity of mHealth for pregnant individuals to manage their condition. Drawing upon randomized controlled trial data, this study provides invaluable perspectives on integrating mHealth into GDM management, enabling expectant mothers to assume an active and informed role in their prenatal health and the health of their future offspring.

The analysis of this review has been extended to provide a more comprehensive discussion of demographic representation (as shown in Table 1). This review details how gamification and mHealth interventions perform across different age groups, socioeconomic backgrounds, and cultural contexts. This expanded focus allows for a richer understanding of the applicability and effectiveness of these interventions in diverse populations, highlighting potential disparities and areas for targeted improvement.

3.2 Research methodology of the selected studies

The advancement of healthcare research is contingent upon the design and execution of study methodologies, particularly when examining the efficacy of mHealth interventions for diabetes management. The systematic review by Brady et al. (2023) is a paradigm of such research, employing a rigorously structured methodology for selecting and evaluating pertinent studies. Their commitment to stringent inclusion criteria, comprehensive data extraction processes, and robust assessment of study quality exemplifies the thoroughness of their investigation. This assiduous combination of findings from diverse studies enables researchers to present well-informed conclusions regarding the effectiveness of gamification in diabetes self-management, thus making significant contributions to the domain. Another study by El-Gayar et al. (2021) maintained this standard of methodological integrity by adhering to the PRISMA guidelines, reflecting an ethos of rigorous and transparent research practices. Their methodical search of respected databases, such as PubMed/Medline and Web of Science, indicates dedication to the breadth and quality of their research. The selection of studies featuring adult participants diagnosed with Type 1 or 2 diabetes, in which interventions are primarily app-based and include well-documented BCTs, represents a focused and methodical approach to their meta-analytic examination.

Kruse et al. (2023) further advanced this methodological rigor by following the Kruse Protocol along with the PRISMA guidelines. Their selective review, which encompasses only the most relevant research published in the preceding 2.5 years, demonstrates a concentrated and contemporary literature review. This method ensures that conclusions are pertinent and directly applicable to modern clinical practice. Finally, a comprehensive review by Wei et al. (2023) delivered a comprehensive and systematic approach to their review and meta-analysis, specifically targeting mHealth interventions for GDM. Their methodology is characterized by a disciplined search and selection process and a detailed review of studies that adhere to established research protocols. The insights derived from their work provide a detailed perspective on the impact of mHealth interventions on GDM management, empowering expectant mothers to proactively engage in their health management and the health of their unborn children.

Table 1. Demographic information summary of selected studies

Author	Study design	Methodology	Intervention details	Patient demographics
Brady et al. (2023)	This systematic review focuses on gathering and analyzing research studies that investigate the use of gaming or gamification to improve self-care behaviors and glycemic outcomes in adults with Type 2 diabetes. It includes both randomized controlled trials and quasi-experimental studies to provide a comprehensive overview of the field.	The methodology involves a structured approach to selecting and evaluating relevant studies. Criteria for inclusion, data extraction processes, and methods for assessing the quality of the studies are part of this process. The review synthesizes findings across different studies to draw conclusions about the effectiveness of gamification in diabetes management.	The interventions examined were various forms of gaming or gamification, including online environments, virtual systems, video games, and smartphone technology, aimed at improving diabetes self-management behaviors such as diet, exercise, medication adherence, blood glucose monitoring, and coping.	The review included studies with adult participants diagnosed with Type 2 diabetes. It focused on a diverse range of patient backgrounds, although specific demographic details like age range, gender distribution, or ethnic backgrounds of participants across the studies were not uniformly detailed.
El-Gayar et al. (2021)	This meta-analysis focused on the efficacy of mHealth applications in managing diabetes, particularly assessing behavior change techniques (BCTs). It included randomized controlled trials (RCTs) examining the impact of these interventions on glycemic control.	The study adhered to PRISMA guidelines, systematically searching databases like PubMed/Medline and Web of Science. It included studies with adult participants diagnosed with Type 1 or Type 2 diabetes, where interventions were primarily app-based and had well-documented BCTs.	The interventions were diverse, encompassing a range of mHealth apps that included features like self-monitoring, feedback mechanisms, goal setting, and other BCTs. Some interventions also integrated behavior change theories like the Transtheoretical Model and Social Cognitive Theory.	The analysis included studies with a total of 1920 diabetes patients, with varying study durations and encompassing different age groups and diabetes types. The mean age of participants and specific demographic distribution varied across the studies.
Kruse et al. (2023)	This systematic review aimed to evaluate the effectiveness of mHealth interventions in managing diabetes in adults over 50 years old, based on recent literature.	Employing a structured approach, the review followed the Kruse Protocol and PRISMA guidelines, selectively including relevant research published in the last 2.5 years.	The review identified various mHealth interventions such as apps, SMS-based services, and telemedicine, assessing their impact on diabetes self-management.	The focus was on older adults (over 50 years), with studies spanning multiple countries, reflecting a diverse demographic in terms of age, gender, and ethnicity.
Wei et al. (2023)	This document presents a systematic review and meta-analysis focused on evaluating the effectiveness of mHealth interventions for managing gestational diabetes mellitus (GDM) in pregnant women. The study consolidates data from various randomized controlled trials to provide a comprehensive analysis of the topic.	The methodology includes a rigorous literature search and selection process following established guidelines. The review incorporates studies that specifically examine mHealth interventions for GDM, assessing their impact on various outcomes related to diabetes management in pregnancy.	The interventions examined in the review are diverse mHealth strategies. These include mobile apps, text messaging services, and other digital tools designed to assist in the management of GDM. The review analyzes how these interventions contribute to managing blood glucose levels and other diabetes-related outcomes in pregnant women.	The demographic focus is on pregnant women diagnosed with GDM. The review includes studies with participants from different geographical regions, providing a broad perspective on the global application of mHealth interventions for GDM.

3.3 Intervention models of the selected studies

The field of diabetes management is being markedly transformed by the introduction of diverse mHealth interventions designed to augment patient self-care. Brady et al. (2023) examined an array of mHealth strategies, which are instrumental in this transformation. The strategies range from engaging gaming experiences in virtual environments to the practical utility of smartphone applications. Such interventions target essential self-management behaviors, including diet regulation, consistent exercise, medication adherence, diligent blood glucose monitoring, and the development of effective coping strategies. The integration of gamification into diabetes management is a highlight of this research, demonstrating the potential to significantly boost patient engagement and adherence, which is instrumental in enhancing health outcomes for individuals with diabetes.

El-Gayar et al. (2021) extended these insights by evaluating various mHealth applications equipped with features that facilitate self-monitoring, provide feedback, assist with goal setting, and incorporate BCTs. Their

extensive review examined interventions anchored in reputable behavioral change theories, such as the transtheoretical model and social cognitive theory. The implementation of these theoretical models is crucial because they augment the capacity of mHealth interventions to promote substantial behavioral modification, thus highlighting the comprehensive potential of mHealth in the effective management of diabetes. Another study by Kruse et al. (2023) contributes to the discourse by analyzing a suite of mHealth interventions that embrace a broad spectrum of technologies, including smartphone applications, SMS-based services, and telemedicine. Their evaluation of the effects of these varied services on diabetes self-management provided substantive evidence supporting the adaptability and efficacy of mHealth solutions. This evidence is invaluable to healthcare practitioners who are keen to integrate sophisticated digital health strategies into their therapeutic repertoire.

In the specific field of GDM, Wei et al. (2023) examined mHealth strategies that involve mobile apps, text messaging services, and other technological tools tailored to manage high blood glucose levels effectively. The goal of these interventions is to equip expectant individuals with the tools they need to competently monitor and control their condition, which can yield improved perinatal outcomes. The comprehensive nature of these mHealth interventions emphasizes the capability of digital health technologies to meet the distinctive requirements of diverse patient demographics.

3.4 Patient demographics of selected studies

Understanding patient demographics is essential for evaluating the impact of mHealth interventions on diabetes management. The review by Brady et al. (2023) included various studies with adult participants diagnosed with Type 2 diabetes, highlighting the heterogeneity among patient backgrounds. While the review considers a broad spectrum of demographic characteristics, such as age, gender, and ethnic background, the review acknowledges that the level of detail regarding these demographics varies significantly across studies. This observation underscores the necessity for a standardized approach in demographic reporting, which is crucial for comprehensively establishing how different populations engage with and benefit from mHealth interventions. El-Gayar et al. (2021) further delved into demographic specifics in their analysis, which assessed studies involving a total of 1,920 patients with diabetes. The scope of their review is broad, covering various study durations, age groups, and diabetes types. The variance in the mean age of the participants and demographic distribution across studies indicates the wide-ranging applicability of mHealth solutions. However, it also highlights the inconsistency in research focus, accentuating the significance of demographic considerations in influencing the interpretation and generalizability of research outcomes.

Kruse et al. (2023) focused on a particular demographic—older adults over 50. Their research includes studies from multiple countries and captures various demographic factors such as age, gender, and ethnicity. By focusing on older adults who are likely to encounter comorbidities and require more complex care, this review sheds light on how mHealth interventions can be specifically tailored to address the needs of this growing population segment. Finally, Wei et al. (2023) conducted a demographic exploration of pregnant women managing GDM. Their review compiled research on patients from diverse geographical regions, offering an extensive view of the international application of mHealth interventions for GDM. This examination emphasizes the versatility of mHealth technologies in adapting to different regional healthcare contexts and the potential to customize these interventions to various patient populations while considering cultural and regional healthcare nuances.

3.5 Measured outcomes of the selected studies

The evaluation of mHealth interventions in diabetes care requires the selection and assessment of appropriate outcome measures. Brady et al. (2023) conducted a thorough review of the gamut of self-care behaviors recommended by the ADA standards of medical care in diabetes. These behaviors, including physical activity, diet, medication adherence, coping strategies, and self-efficacy, are pivotal in managing the condition effectively. The principal measure of glycemic control is the change in hemoglobin A1c (HbA1c) levels, an established marker of glucose management over time, reflecting the sustained impact of interventions on patient health. Meanwhile, El-Gayar et al. (2021) broadened the perspective on diabetes management by incorporating both primary and secondary outcomes into their reviewed studies. The primary outcomes are essential glycemic control indicators, such as HbA1c levels, providing direct insight into the immediate effects of mHealth. The secondary outcomes, including weight management, blood pressure regulation, and enhancement of diabetes-related knowledge and self-care practices, offer a wider perspective on the comprehensive benefits of mHealth interventions on patients' overall health and self-management capabilities.

Kruse et al. (2023) embraced a holistic perspective in the measurement of health outcomes, encompassing a suite of variables critical to all-encompassing diabetes care. The selection of outcomes, which span weight loss, body mass index change, dietary and exercise regimen improvement, HbA1c levels, disease awareness, blood pressure, cholesterol management, medication adherence, and foot care, underscores the complexity of diabetes as a condition that necessitates a multipronged management approach. Focusing on the unique characteristics of GDM, Wei et al. (2023) identified key health indicators pertinent to this condition. The authors emphasize the importance of monitoring fasting and postprandial blood glucose levels, HbA1c, and maternal and neonatal health outcomes. Furthermore, their examination of self-management behaviors in regulating blood glucose is particularly relevant for GDM, where detailed glucose monitoring is essential to avert pregnancy-related complications and safeguard the health of the mother and child. Figure 2 presents the number of studies measuring specific outcomes.

3.6 Results and effectiveness of the selected studies

The incorporation of mHealth applications into diabetes care represents a significant advancement in medical research focused on patient outcomes. Brady et al. (2023) offered compelling evidence on the effectiveness of gamification in mHealth, demonstrating its potential to significantly lower HbA1c levels, a key indicator of glycemic control. The reviewed studies go beyond

physiological measures, documenting improvements in physical activity, self-efficacy, and overall quality of life. This multifaceted impact suggests that gamification in diabetes management could revolutionize patient care by offering a more integrative and engaging approach to health and self-management.

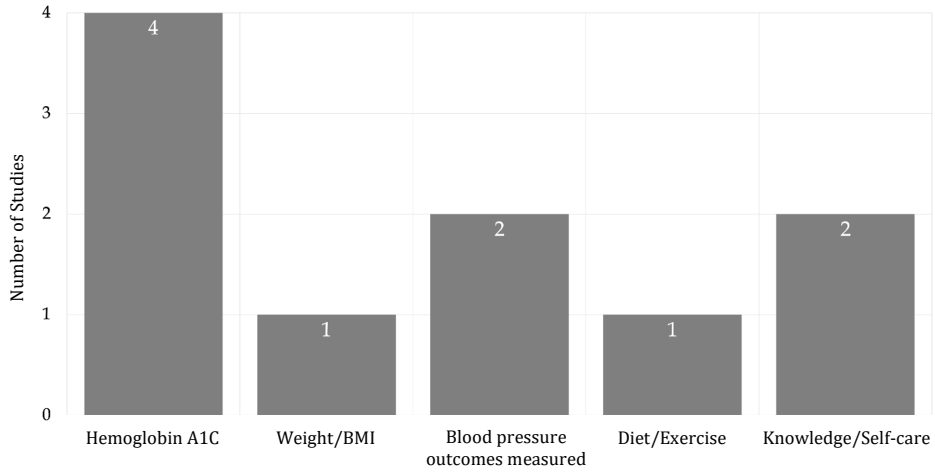

Figure 2. Number of studies measuring specific outcomes

El-Gayar et al. (2021) further validated the effectiveness of mHealth interventions through a comprehensive analysis that revealed substantial reductions in HbA1c levels. Their findings are not limited to primary outcomes; significant enhancements in secondary outcomes, such as weight management, blood pressure regulation, and diabetes-specific educational advancements, were also noted. The statistical methodologies employed to determine these effects provide a robust foundation for the argument that mHealth applications are viable supplements to conventional diabetes management methods.

Kruse et al. (2023) amplify this narrative by synthesizing data from diverse studies, thereby illustrating the comprehensive efficacy of mHealth interventions. These interventions have been shown to positively influence health behaviors and promote self-care in patients. Notably, when mHealth is synergized with SMS and telemedicine coaching, the outcomes are particularly striking, suggesting a cumulative effect that augments patient education and self-management capabilities, ultimately fostering improved health outcomes. In the particular context of GDM, Wei et al. (2023) demonstrated that mHealth interventions play a critical role in significantly enhancing glycemic control and positively affecting maternal and neonatal health outcomes. These interventions also strengthen self-management behaviors that are crucial for high-quality diabetes care during pregnancy. The statistical significance of these findings underscores the pivotal role of mHealth applications in managing GDM, emphasizing their utility in promoting superior health practices among expectant mothers.

The integration of technological and behavioral change theories, such as Fogg's behavior and the transtheoretical models, underpins the effectiveness of gamification and mHealth interventions. These theories explain how motivation, ability, and triggers can drive behavioral change, making self-care practices more engaging and sustainable. Gamification, through elements such as rewards, points, and challenges leverage intrinsic and extrinsic motivation to encourage consistent self-care behaviors. The transtheoretical model's stages of change help tailor interventions to individual readiness, promoting gradual and sustained behavioral modification. Furthermore, the success of mHealth apps lies in their ability to provide real-time feedback, personalized reminders, and educational resources. These features enhance the user's ability to manage their condition effectively, which aligns with the principles of Fogg's behavior model by making desired behaviors easier to perform. The combination of these technological and behavioral strategies creates a supportive environment that empowers patients to take control of their health, resulting in improved clinical outcomes and quality of life.

However, the challenges associated with the adoption and adherence to mHealth solutions persist. The user interface design plays a crucial role in ensuring that such applications are user-friendly and accessible to individuals with varying levels of technological proficiency. A well-designed interface can significantly reduce the learning curve and increase user engagement. The ease of use is another critical factor; complicated or cumbersome applications are less likely to be adopted and consistently used by patients. Personalized feedback mechanisms are essential for maintaining user engagement and motivation. These mechanisms should provide actionable insights and adapt to the individual needs and preferences of users, thereby enhancing the overall user experience and effectiveness of the intervention.

Addressing these challenges is vital for maximizing the impact of gamification and mHealth in diabetes management. By focusing on user-centric design principles, simplifying the user experience, and delivering personalized feedback, developers and healthcare providers can improve the adoption and sustained use of these digital health tools. By delving into these underlying theories, the effectiveness of gamification and mHealth interventions in diabetes management can be better understood and optimized, ensuring that these tools are designed and implemented in ways that maximize their impact on patient health behaviors and outcomes.

3.7 Study limitations for each selected study

The burgeoning field of mHealth interventions for diabetes management offers promising advancements but is accompanied by significant limitations that merit careful consideration to ensure the accurate interpretation and application of research findings. In the systematic review by Brady et al. (2023), a notable limitation was the incomplete coverage of self-care behaviors within the reviewed studies, which led to a potentially partial representation of patient self-management capabilities. Furthermore, heterogeneity in the study designs and the varying quality of the interventions challenge the conclusions' universality. The limited number of studies also poses constraints on the robustness and generalizability of the findings, potentially skewing perceptions of the efficacy of gamification elements in diabetes management.

The research presented by El-Gayar et al. (2021) has similar limitations. Variations in sample sizes, study durations, and the nature of interventions may introduce potential inconsistencies in outcomes. The uneven monitoring and adherence to the interventions by the participants added another layer of complexity, thereby affecting the uniformity of the results. Additionally, the possibility of publication bias—where studies demonstrating positive outcomes are more likely to be published than those with nonsignificant or negative results—could present a skewed view of mHealth intervention effectiveness. These collective concerns underscore the generalizability of the results, suggesting that the findings may not represent a broader population of patients with diabetes or other real-world conditions.

Kruse et al. (2023) identified further limitations in their review, including a pronounced selection bias caused by convenience sampling and the consequent sample bias, which may lead to overrepresenting certain demographic groups. Such biases can significantly impact the applicability of the results because the real-world effectiveness of mHealth interventions may vary across different populations. An overrepresentation of a particular gender or race in the reviewed studies narrows the scope of the findings, limiting their transferability to a diverse patient base. Similarly, Wei et al. (2023) acknowledged the limitations of their studies, particularly publication bias and the specialized nature of GDM research. The increased scrutiny of safety and efficacy in GDM interventions necessitates a rigorous and balanced research approach.

The convergence of digital technology frameworks with behavioral change theories, e.g., Fogg's Behavior Model and the Transtheoretical Model, offers a comprehensive lens for explaining how motivation, ability, and cues can shape and sustain user engagement in gamified and mHealth interventions. However, challenges in adoption and adherence remain significant. Factors such as user interface design, ease of use, and personalized feedback mechanisms are critical for improving patient engagement. Addressing these challenges is essential to maximize the impact of these interventions.

3.8 Future research recommendations for selected studies

The evolution of mHealth research in the context of diabetes care provides a profound understanding of the potential trajectory of this innovative field. Brady et al. (2023) emphasized the critical importance of future research to widen the scope of self-care behaviors under investigation and to adopt more robust and standardized study methodologies, incorporating larger and more diverse participant groups. This rigorous approach is pivotal for reinforcing the evidence base, particularly regarding the influence of gamification on diabetes management. Furthermore, they underscore the necessity for longitudinal studies that examine the enduring impacts of mHealth interventions on patient engagement and the management of diabetes to fully capitalize on their potential benefits.

El-Gayar et al. (2021) highlighted the need for an intensified focus on mHealth domains that are either under-researched or demonstrate promise but lack extensive study. They recommend that subsequent research endeavors bridge existing gaps by lengthening follow-up durations, broadening participant demographics, and implementing more rigorous study frameworks. Such a methodical and strategic approach is critical for acquiring an enriched understanding of mHealth interventions and their effectiveness in improving outcomes related to diabetes care.

Kruse et al. (2023) encouraged future research initiatives to actively seek methodologies that minimize sampling biases by employing more randomized and representative sample collections. The study also highlighted the significance of exploring the enduring viability of mHealth interventions, including their economic impact on healthcare expenditures and identifying technological barriers that may impede user engagement and adherence to mHealth programs. Addressing these challenges is essential for creating sustainable, economically viable mHealth solutions with broad accessibility. A study by Wei et al. (2023) stresses the importance of future studies that implement standardized interventions and consistently assess long-term outcomes. They called for research that extends beyond immediate clinical measures to explore the comprehensive influence of mHealth practices. Such investigations are essential to illuminate how mHealth tools can impact clinical parameters, such as glycemic control, and overall health and well-being. Table 2 summarizes the outcomes, results, effectiveness, limitations, and future research recommendations of the selected studies.

Future research should explore collaborations with key stakeholders, including healthcare providers, patient advocacy groups, and technology companies, to facilitate the implementation and adoption of mHealth interventions in real-world. These collaborations can help bridge the gap between technological innovation and practical application, ensuring that interventions are user-friendly, accessible, and aligned with patients' needs. In addition, stakeholders can enhance the sustainability and scalability of these interventions.

Collaborations with healthcare providers are crucial for integrating mHealth solutions into existing clinical workflows and ensuring that they complement traditional care methods. Healthcare professionals can offer valuable insights into patient needs and preferences to help tailor mHealth tools to be more effective and user-friendly. Furthermore, patient advocacy groups can provide a voice for end-users, ensuring that their concerns and suggestions are considered in the development and implementation process. This participatory approach can improve patient satisfaction and adherence to mHealth interventions.

Table 2. Summary of the study's outcomes, results, limitations, and recommendations

Author	Outcomes measured	Results and effectiveness	Limitations	Future research recommendations
Brady et al. (2023)	The review takes into account various self-care behaviors based on the Association of Diabetes Care and Education Specialists framework, such as physical activity, healthy coping, and self-efficacy. Glycemic outcomes are primarily measured by changes in Hemoglobin A1C levels.	The results indicate that the majority of the studies showed a reduction in A1C, suggesting a positive effect of gamification on glycemic control. Moreover, improvements in physical activity and self-efficacy were also reported, underscoring the potential of gamification to enhance quality of life and diabetes self-management.	Despite these promising findings, the review notes that not all self-care behaviors were addressed, and the diversity of the study designs and interventions makes it challenging to generalize the results. The high variability in study quality and the limited number of studies also pose constraints on the conclusiveness of the findings.	The review suggests the need for further research that encompasses a wider range of self-care behaviors, more rigorous and standardized study designs, and larger sample sizes to reinforce the evidence base. Additionally, exploring the long-term impact of gamification on diabetes management and patient engagement is recommended to fully understand its potential benefits.
Kruse et al. (2023)	The studies collectively measured various health outcomes such as weight loss, body mass index reductions, diet and exercise improvements, HbA1C levels, disease awareness, blood pressure, cholesterol levels, medication adherence, and foot care. These outcomes are critical indicators of successful diabetes management and patient self-care.	The aggregated results demonstrated positive effects on several health factors, with mHealth interventions showing promise in changing behavior and encouraging self-care. Notably, interventions that combined mHealth SMS with telemedicine coaching were particularly effective, suggesting a synergistic effect that enhances patient education and behavior change, leading to improved health outcomes.	The review noted several limitations, including a high prevalence of selection bias due to convenience sampling and the potential influence of sample bias due to majority representation of one gender or race in certain studies. These biases can affect both the external and internal validity of the findings.	Future research should aim to mitigate the identified biases by employing more randomized and representative sampling methods. Additionally, there is a need to explore the long-term sustainability of mHealth interventions and their impact on healthcare costs, as well as the technological barriers that may affect patient engagement and adherence to mHealth programs.
Wei et al. (2023)	The study focused on key health indicators, including fasting and postprandial blood glucose levels, HbA1c, and maternal and neonatal/fetal complications. It also examined self-management behavior in managing blood glucose.	The meta-analysis demonstrated that mHealth interventions significantly improved glycemic control and reduced complications. These interventions also positively influenced self-management behaviors, indicating their efficacy in managing gestational diabetes.	The study acknowledges certain limitations, such as potential biases in the selected trials and the heterogeneity of the interventions. These factors might impact the generalizability of the results.	The study suggests further research with more standardized interventions and a focus on long-term outcomes. It also recommends exploring the impact of mHealth on a broader range of health behaviors and outcomes.

Partnerships with technology companies can drive innovation and provide the technical expertise required to develop robust, scalable, and secure mHealth applications. Collaborations can also facilitate the continuous improvement of mHealth tools through regular updates and the incorporation of new features based on user feedback and technological advancements. Additionally, technology companies can assist in addressing the digital divide by developing solutions accessible to individuals with varying levels of technological proficiency and ensuring that mHealth tools are available across different platforms and devices. By fostering these collaborations, future research can ensure that mHealth interventions are not only scientifically validated but also practically feasible and widely adopted. This approach can lead to the development of comprehensive and user-centered mHealth solutions that effectively support diabetes self-management and improve patient outcomes.

3.9 Quality assessment of each study

This systematic review conducted a thorough quality assessment of the included studies using the AMSTAR criteria, providing an in-depth evaluation of each study's methodological rigor and adherence to established best practices in systematic reviews (Table 3). Brady et al. (2023) demonstrated notable adherence to the AMSTAR criteria, achieving a global rating of 8 out of a possible 11. This study satisfactorily met several criteria, including the presence of an "a priori" design, execution of duplicate study selection and data extraction, performance of a comprehensive literature search, detailed reporting of the characteristics of the included

studies, appropriate use of the scientific quality of included studies in formulating conclusions, effective combination of study findings, and clear statement of any conflicts of interest. Nonetheless, it failed to provide a list of included and excluded studies, assess the risk of publication bias, and use the publication status as an inclusion criterion. These shortcomings indicate a robust methodological approach with potential areas for enhancement, particularly in improving transparency and addressing bias.

El-Gayar et al. (2021) demonstrated high methodological quality, as evidenced by a global rating of 10 out of 11. The study met most of the AMSTAR criteria, including an "a priori" design, duplicate study selection and data extraction, a comprehensive literature search, inclusion of the status of publication as a criterion, provision of lists of included and excluded studies, thorough documentation of the characteristics and scientific quality of the included studies, appropriate use of scientific quality in deriving conclusions, and employment of suitable methods for amalgamating study findings. The study's assessment of the risk of publication bias was also noteworthy. The only area in which it did not fully comply was the declaration of conflicts of interest. This high rating reflects the study's comprehensive systematic review, thereby setting a benchmark in the field.

Table 3. The results of AMSTAR analysis of selected studies

Included studies	AMSTAR criteria											Global rating
	1	2	3	4	5	6	7	8	9	10	11	
Brady et al. (2023)	1	1	1	0	0	1	0	1	1	1	1	8
El-Gayar et al. (2021)	1	1	1	1	1	1	1	1	1	1	0	10
Kruse et al. (2023)	1	1	1	1	1	1	1	1	1	1	1	11
Wei et al. (2023)	1	1	1	1	1	1	1	1	1	0	1	10

Note: (1) an 'a priori' design provided; (2) there duplicate study selection and data extraction; (3) a comprehensive literature search performed; (4) the status of publication (i.e. grey literature) used as an inclusion criterion; (5) a list of studies (included and excluded) provided; (6) the characteristics of the included studies provided; (7) the scientific quality of the included studies assessed and documented; (8) the scientific quality of the included studies used appropriately in formulating conclusions; (9) the methods used to combine the findings of studies appropriate; (10) the likelihood of publication bias assessed; (11) the conflict of interest stated.

Kruse et al. (2023) obtained an exemplary global rating of 11 out of 11, indicating full compliance with the AMSTAR criteria. This study proficiently met all the criteria evaluated, including an "a priori" design, duplication in study selection and data extraction, a comprehensive literature search, incorporation of publication status as an inclusion criterion, provision of comprehensive lists of included and excluded studies, detailed documentation of the characteristics and scientific quality of included studies, appropriate application of scientific quality in conclusions, and effective methods for synthesizing study findings. Additionally, the study thoroughly assessed the risk of publication bias and transparently declared any conflicts of interest. This perfect score underscores the study's methodologically robust and transparent approach, significantly bolstering the credibility of its findings and conclusions.

Wei et al. (2023) also exhibited high methodological quality, with a global rating of 10 out of 11. This study adhered to numerous AMSTAR criteria, including the establishment of an "a priori" design, duplication in study selection and data extraction, comprehensive literature search, use of publication status as an inclusion criterion, provision of detailed lists of included and excluded studies, reporting of the characteristics and scientific quality of included studies, appropriate use of scientific quality in formulating conclusions, and proper methodologies for combining study findings. It also transparently stated the conflicts of interest. The study's sole limitation was that it did not assess the likelihood of publication bias, indicating a rigorous approach to conduct a systematic review with a minor gap in addressing potential biases.

3.10 Comparison with other studies

The exploration of gamification within mHealth apps by Brady et al. (2023) indicates an emerging trend that taps into behavioral science to enhance patient engagement. This trend is consistent with findings from previous studies, which suggest that heightened patient engagement is associated with improved health outcomes, particularly in the management of chronic diseases (Aboumatar et al., 2022; Law et al., 2023; Marzban et al., 2022). The efficacy of gamification in improving glycemic control and other self-care behaviors was demonstrated. This underscores the need for innovative approaches that can maintain patient interest and adherence over time (Fabbrizio et al., 2023). Meanwhile, the contributions of El-Gayar et al. (2021) augment this understanding by highlighting the effectiveness of mHealth interventions through robust data analysis, revealing significant improvements in HbA1c levels and other diabetes management parameters. This effectiveness is echoed in a growing body of literature that indicates that mHealth interventions can lead to better diabetes control, especially when BCTs are integrated into the design of these interventions (Mair et al., 2023; Singh et al., 2023; Zheng et al., 2023). Nonetheless, the variability in study designs and the potential for publication bias identified in their meta-analysis necessitate a more standardized and transparent approach to research in this domain.

Kruse et al. (2023) emphasized the necessity of addressing biases and researching the long-term sustainability of mHealth interventions. The economic implications of mHealth, particularly its cost-effectiveness, emerge as a critical factor for the widespread adoption of healthcare innovations. Furthermore, understanding and addressing technological barriers is crucial for ensuring the effective integration of mHealth tools into patients' lives and the healthcare system (Zakerabasali et al., 2021). In the context of GDM, Wei et al. (2023) underscored the significance of mHealth interventions tailored to specific patient groups. The distinct needs of pregnant women with GDM necessitate interventions that are clinically effective, safe, and attuned to the subtleties of prenatal care (Tsironikos et al., 2023). The observed positive impact on

maternal and neonatal outcomes suggests that mHealth plays a significant role in this specialized field of diabetes care (Edo et al., 2023; Stoumpos et al., 2023; Swain et al., 2024).

Future research recommendations from each study should chart a course toward more comprehensive and patient-centric mHealth solutions. There is a definitive call for future studies to build on the current findings by engaging larger, more diverse populations and employing extended follow-up periods to assess the long-term effects of these interventions. Moreover, implementing standardized intervention protocols and emphasizing economic analysis will be pivotal for elucidating the broader implications of mHealth in diabetes management. The integration of these findings into a wider body of literature highlights the need for a multidisciplinary approach to mHealth research. Collaborative efforts among healthcare professionals, behavioral scientists, and technology experts are vital for devising effective interventions that resonate with users. Additionally, incorporating patient feedback into the development process is fundamental to ensure that mHealth tools meet the actual needs of individuals with diabetes.

The practical implications of the findings of this study for healthcare providers, patients, and policymakers are significant. Gamification and mHealth can be integrated into existing healthcare frameworks to enhance patient engagement and diabetes self-management. Healthcare providers should consider incorporating these technologies into their practices to support patients more effectively. Policymakers must facilitate the adoption of these interventions through supportive policies and funding. Ethical considerations, such as data privacy, informed consent, and addressing the digital divide, must also be addressed to ensure equitable access and implementation.

The ethical implications of gamification and mHealth interventions include concerns regarding data privacy, informed consent, and the digital divide. Ensuring that patient data are securely managed and used ethically is paramount. Patients must be fully informed about how their data will be used and must provide explicit consent. Additionally, addressing the digital divide is important for preventing disparities in access to such technologies. Policymakers and healthcare providers must work together to ensure that these interventions are accessible to all patients, regardless of socioeconomic status or technological proficiency.

3.11 Strengths and limitations

This review on the efficacy of mHealth and gamification within diabetes self-care represents a substantial contribution to the field, offering a detailed examination of current practices and potential pathways for future research. The wide-ranging exploration of mHealth strategies is one of the strengths of this review, extending from innovative gamification to traditional app-based interventions. The methodological diversity, including randomized controlled trials and quasi-experimental studies, significantly bolsters the review's credibility and underscores the complex nature of mHealth interventions.

A particular merit of this review is its comprehensive demographic analysis. This review scrutinizes studies across various age brackets and conditions, including older adults and pregnant individuals with gestational diabetes, thus recognizing the unique challenges within the diabetes community. This broad approach yields a nuanced understanding that is imperative when crafting customized management plans that reflect the diverse needs of individuals with diabetes. Moreover, the review's in-depth evaluation of the intervention models is a key strength. By delving into the theoretical foundations of BCTs and their practical deployment within mHealth applications, this study provides a holistic view of intervention mechanics and their potential to drive meaningful behavior change. This is especially pertinent considering the shift toward patient-centric care models and the integral role of self-management in chronic disease treatment. Nonetheless, the review is not without limitations. The variability in the study design and intervention types present challenges in generalizing the findings. Although this diversity offers a broad survey of the domain, it complicates data synthesis for formulating definitive conclusions regarding the effectiveness of mHealth interventions.

Publication bias poses another significant limitation that potentially distorts the representation of mHealth's efficacy by favoring studies with positive outcomes over those with null or negative results. Additionally, the relatively narrow scope of studies in certain areas may not capture the full spectrum of patient outcomes and experiences associated with mHealth interventions. Additionally, the review indicates a selection bias caused by convenience sampling and the potential overrepresentation of certain demographics, which may restrict the generalizability of the findings and their applicability to the wider diabetes population.

3.12 Suggestions for future research

Research on mHealth interventions has revealed several critical paths for future exploration that promise to deepen our understanding and enhance the practical application of these digital tools. Drawing from the insights of Brady et al. (2023), El-Gayar et al. (2021), Kruse et al. (2023), and Wei et al. (2023), it is evident that future studies must strive to bridge the identified gaps and confront the methodological challenges highlighted.

Future investigations should extend the scope of self-care behaviors examined within mHealth interventions. It is imperative to evaluate not only the direct effects on glycemic control but also the repercussions of mHealth on lifestyle alterations, mental health, and the trajectory of diabetes over time. A broadened investigation into these self-care behaviors will facilitate a holistic appraisal of the efficacy of mHealth interventions and their pivotal role in fostering enduring health practices. Moreover, there is an unmistakable need for adopting more robust and standardized research designs. The ensuing studies should recruit larger cohorts to enhance the statistical robustness and extrapolation of the findings. It is crucial that these cohorts encapsulate a spectrum of demographic variables, including diverse age brackets, socioeconomic status, and ethnic diversities, to accurately mirror the expansive diabetes-affected population.

Longitudinal research is warranted to determine the protracted consequences of mHealth interventions on diabetes management and patient engagement. Such studies should seek extended observation periods to monitor enduring outcomes and patient behavior evolution over time. These longitudinal insights will also

yield valuable information on the economic ramifications of mHealth, potentially elucidating cost efficiencies related to decreased hospitalization rates and optimized disease management.

To circumvent the potential for bias, future studies should rigorously implement randomized controlled trials with randomization to guarantee the representativeness of the study participants. The use of stratified sampling strategies can ensure equitable representation of diverse subgroups within the diabetes community. Furthermore, integrating qualitative methodologies could capture nuanced patient experiences and identify obstacles to adopting and adhering to mHealth interventions. Additionally, there is a distinct need to examine the impact of mHealth in specific cohorts, such as those with gestational diabetes and the elderly, who may grapple with distinct challenges in diabetes care. Research concentrated on these groups should consider their specific needs and limitations to customize mHealth interventions appropriately.

Future research efforts should rigorously investigate the technological barriers that hinder the use and effectiveness of mHealth apps. This involves a thorough evaluation of the digital literacy requirements of mHealth resources and a comprehensive assessment of the infrastructure necessary for their widespread implementation. Understanding these factors is crucial for ensuring that mHealth solutions are effective in controlled environments and broadly accessible and usable in diverse real-world settings. By addressing these technological challenges, future studies can optimize the design and delivery of mHealth interventions, thereby enhancing their impact on public health.

4. CONCLUSION

This review underscores the potential of gamification and mHealth interventions in enhancing diabetes self-care by integrating technological and behavioral change theories. Addressing challenges in user interface design, ease of use, and personalized feedback is crucial for improving adoption and adherence. Collaborations with healthcare providers, patient advocacy groups, and technology companies can facilitate the effective implementation of mHealth solutions. These interventions can significantly improve patient engagement, glycemic control, and overall quality of life. Policymakers should support the widespread adoption of these technologies to maximize their impact on patient outcomes and healthcare delivery.

ACKNOWLEDGMENTS

The author extends heartfelt appreciation to the School of Pharmacy, Faculty of Medicine and Health Sciences, Universitas Muhammadiyah Yogyakarta, for their invaluable support and significant contributions to this research. The author also thanks the 1984-EL Research Team, including Mahsa Amaliasita, M. M., Gendhis AI, and Latief Perdana, for their dedicated collaboration and insightful contributions, which have greatly enriched this review. Their expertise and unwavering commitment were vital to successfully supporting this work.

REFERENCES

Aboumatar, H., Pitts, S., Sharma, R., Das, A., Smith, B. M., Day, J., Holzhauer, K., Yang, S., Bass, E. B., & Bennett, W. L. (2022). Patient engagement strategies for adults with chronic conditions: An evidence map. *Systematic Reviews*, *11*(1), Article 39. https://doi.org/10.1186/s13643-021-01873-5

Alaslawi, H., Berrou, I., Al Hamid, A., Alhuwail, D., & Aslanpour, Z. (2022). Diabetes self-management apps: Systematic review of adoption determinants and future research agenda. *JMIR Diabetes*, *7*(3), Article e28153. https://doi.org/10.2196/28153

American Diabetes Association. (2021). 2. Classification and diagnosis of diabetes: Standards of medical care in diabetes—2021. *Diabetes Care*, *44*(Suppl. 1), S15–S33. https://doi.org/10.2337/dc21-S002

Amjad, A., Kordel, P., & Fernandes, G. (2023). A review on innovation in healthcare sector (Telehealth) through artificial intelligence. *Sustainability*, *15*(8), Article 6655. https://doi.org/10.3390/su15086655

Avilés-Santa, M. L., Monroig-Rivera, A., Soto-Soto, A., & Lindberg, N. M. (2020). Current state of diabetes mellitus prevalence, awareness, treatment, and control in Latin America: Challenges and innovative solutions to improve health outcomes across the continent. *Current Diabetes Reports*, *20*(11), Article 62. https://doi.org/10.1007/s11892-020-01341-9

Benis, A., Tamburis, O., Chronaki, C., & Moen, A. (2021). One digital health: A unified framework for future health ecosystems. *Journal of Medical Internet Research*, *23*(2), Article e22189. https://doi.org/10.2196/22189

Brady, V. J., Mathew Joseph, N., & Ju, H.-H. (2023). Impact of gaming (gamification) on diabetes self-care behaviors and glycemic outcomes among adults with type 2 diabetes. *The Science of Diabetes Self-Management and Care*, *49*(6), 493–511. https://doi.org/10.1177/26350106231208153

Cascella, M., Cascella, A., Monaco, F., & Shariff, M. N. (2023). Envisioning gamification in anesthesia, pain management, and critical care: Basic principles, integration of artificial intelligence, and simulation strategies. *Journal of Anesthesia, Analgesia and Critical Care*, *3*(1), Article 33. https://doi.org/10.1186/s44158-023-00118-2

Choudhury, A. A., & Devi Rajeswari, V. (2021). Gestational diabetes mellitus—A metabolic and reproductive disorder. *Biomedicine & Pharmacotherapy*, *143*, Article 112183. https://doi.org/10.1016/j.biopha.2021.112183

Damaševičius, R., Maskeliūnas, R., & Blažauskas, T. (2023). Serious games and gamification in healthcare: A meta-review. *Information*, *14*(2), Article 105. https://doi.org/10.3390/info14020105

Doupis, J., Festas, G., Tsilivigos, C., Efthymiou, V., & Kokkinos, A. (2020). Smartphone-based technology in diabetes management. *Diabetes Therapy*, *11*(3), 607–619. https://doi.org/10.1007/s13300-020-00768-3

Edo, O. C., Ang, D., Etu, E.-E., Tenebe, I., Edo, S., & Diekola, O. A. (2023). Why do healthcare workers adopt digital health technologies—A cross-sectional study integrating the TAM and UTAUT model in a developing economy. *International Journal of Information Management Data Insights*, *3*(2), Article 100186. https://doi.org/10.1016/j.jjimei.2023.100186

El-Gayar, O., Ofori, M., & Nawar, N. (2021). On the efficacy of behavior change techniques in mHealth for self-management of diabetes: A meta-analysis. *Journal of Biomedical Informatics*, *119*, Article 103839. https://doi.org/10.1016/j.jbi.2021.103839

Fabbrizio, A., Fucarino, A., Cantoia, M., De Giorgio, A., Garrido, N. D., Iuliano, E., Reis, V. M., Sausa, M., Vilaça-Alves, J., Zimatore, G., Baldari, C., & Macaluso, F. (2023). Smart devices for health and wellness applied to tele-exercise: An overview of new trends and technologies such as IoT and AI. *Healthcare*, *11*(12), Article 1805. https://doi.org/10.3390/healthcare11121805

Galicia-Garcia, U., Benito-Vicente, A., Jebari, S., Larrea-Sebal, A., Siddiqi, H., Uribe, K. B., Ostolaza, H., & Martín, C. (2020). Pathophysiology of type 2 diabetes mellitus. *International Journal of Molecular Sciences*, *21*(17), Article 6275. https://doi.org/10.3390/ijms21176275

Ghozali, M. T. (2024). Assessment of knowledge, perception, and readiness for telepharmacy-assisted pharmaceutical services among young pharmacists in rural Indonesia. *Exploratory Research in Clinical and Social Pharmacy*, *16*, Article 100513. https://doi.org/10.1016/j.rcsop.2024.100513

Klonoff, D. C., Zhang, J. Y., Shang, T., Mehta, C., & Kerr, D. (2021). Pharmacoadherence: An opportunity for digital health to inform the third dimension of pharmacotherapy for diabetes. *Journal of Diabetes Science and Technology*, *15*(1), 177–183. https://doi.org/10.1177/1932296820973185

Koumpouros, Y. (2022). User-centric design methodology for mHealth apps: The PainApp paradigm for chronic pain. *Technologies*, *10*(1), Article 25. https://doi.org/10.3390/technologies10010025

Kruse, C. S., Mileski, M., Heinemann, K., Huynh, H., Leafblad, A., & Moreno, E. (2023). Analyzing the effectiveness of mHealth to manage diabetes mellitus among adults over 50: A systematic literature review. *Journal of Multidisciplinary Healthcare*, *16*, 101–117. https://doi.org/10.2147/JMDH.S392693

Law, B., Chhatwal, P. K., Licskai, C., Scurr, T., & Sibbald, S. L. (2023). Patient engagement in interprofessional team-based chronic disease management: A qualitative description of a Canadian program. *Patient Education and Counseling*, *114*, Article 107836. https://doi.org/10.1016/j.pec.2023.107836

León-Hernández, R., Rodríguez-Pérez, A. C., Pérez-González, Y. M., de Córdova, M. I. P., de León-Escobedo, R., Gómez-Gutiérrez, T., & Toledano-Toledano, F. (2023). Psychosocial factors associated with self-management in patients with diabetes. *Healthcare*, *11*(9), Article 1284. https://doi.org/10.3390/healthcare11091284

Mair, J. L., Salamanca-Sanabria, A., Augsburger, M., Frese, B. F., Abend, S., Jakob, R., Kowatsch, T., & Haug, S. (2023). Effective behavior change techniques in digital health interventions for the prevention or management of noncommunicable diseases: An umbrella review. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine*, *57*(10), 817–835. https://doi.org/10.1093/abm/kaad041

Marzban, S., Najafi, M., Agolli, A., & Ashrafi, E. (2022). Impact of patient engagement on healthcare quality: A scoping review. *Journal of Patient Experience*, *9*, 1–12. https://doi.org/10.1177/23743735221125439

Schmidt-Kraepelin, M., Toussaint, P. A., Thiebes, S., Hamari, J., & Sunyaev, A. (2020). Archetypes of gamification: Analysis of mHealth apps. *JMIR mHealth and uHealth*, *8*(10), Article e19280. https://doi.org/10.2196/19280

Singh, J., Sillerud, B., & Singh, A. (2023). Artificial intelligence, chatbots and ChatGPT in healthcare—narrative review of historical evolution, current application, and change management approach to increase adoption. *Journal of Medical Artificial Intelligence*, *6*, Article 30. https://doi.org/10.21037/jmai-23-92

Sittig, S., Wang, J., Iyengar, S., Myneni, S., & Franklin, A. (2020). Incorporating behavioral trigger messages into a mobile health app for chronic disease management: Randomized clinical feasibility trial in diabetes. *JMIR mHealth and uHealth*, *8*(3), Article e15927. https://doi.org/10.2196/15927

Stoumpos, A. I., Kitsios, F., & Talias, M. A. (2023). Digital transformation in healthcare: Technology acceptance and its applications. *International Journal of Environmental Research and Public Health*, *20*(4), Article 3407. https://doi.org/10.3390/ijerph20043407

Swain, S., Muduli, K., Kumar, A., & Luthra, S. (2024). Analysis of barriers of mHealth adoption in the context of sustainable operational practices in health care supply chains. *International Journal of Industrial Engineering and Operations Management*, *6*(2), 85–116. https://doi.org/10.1108/IJIEOM-12-2022-0067

Tran, S., Smith, L., & Carter, S. (2024). Understanding patient perspectives on the use of gamification and incentives in mHealth apps to improve medication adherence: Qualitative study. *JMIR mHealth and uHealth*, *12*, Article e50851. https://doi.org/10.2196/50851

Tsironikos, G. I., Potamianos, P., Zakynthinos, G. E., Tsolaki, V., Tatsioni, A., & Bargiota, A. (2023). Effectiveness of lifestyle interventions during pregnancy on preventing gestational diabetes mellitus in high-risk women: A systematic review and meta-analyses of published RCTs. *Journal of Clinical Medicine*, *12*(22), Article 7038. https://doi.org/10.3390/jcm12227038

van Gaalen, A. E. J., Brouwer, J., Schönrock-Adema, J., Bouwkamp-Timmer, T., Jaarsma, A. D. C., & Georgiadis, J. R. (2021). Gamification of health professions education: A systematic review. *Advances in Health Sciences Education*, *26*(2), 683–711. https://doi.org/10.1007/s10459-020-10000-3

Wei, H. X., Yang, Y. L., Luo, T. Y., & Chen, W. Q. (2023). Effectiveness of mobile health interventions for pregnant women with gestational diabetes mellitus: A systematic review and meta-analysis. *Journal of Obstetrics and Gynaecology*, *43*(2), Article 2245906. https://doi.org/10.1080/01443615.2023.2245906

Yoon, S., Kwan, Y. H., Phang, J. K., Tan, W. B., & Low, L. L. (2022). Personal goals, barriers to self-management and desired mHealth application features to improve self-care in multi-ethnic Asian patients with type 2 diabetes: A qualitative study. *International Journal of Environmental Research and Public Health*, *19*(22), Article 15415. https://doi.org/10.3390/ijerph192215415

Zakerabasali, S., Ayyoubzadeh, S. M., Baniasadi, T., Yazdani, A., & Abhari, S. (2021). Mobile health technology and healthcare providers: Systemic barriers to adoption.

Healthcare Informatics Research, *27*(4), 267–278. https://doi.org/10.4258/hir.2021.27.4.267

Zheng, S., Edney, S. M., Goh, C. H., Tai, B. C., Mair, J. L., Castro, O., Salamanca-Sanabria, A., Kowatsch, T., van Dam, R. M., & Müller-Riemenschneider, F. (2023). Effectiveness of holistic mobile health interventions on diet, and physical, and mental health outcomes: A systematic review and meta-analysis. *eClinicalMedicine*, *66*, Article 102309. https://doi.org/10.1016/j.eclinm.2023.102309