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Systematic Review

Continuous glucose monitoring in type 2 diabetes: a systematic review of barriers and opportunities for care improvement

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Abstract

Background: Diabetes mellitus, particularly type 2 diabetes (T2DM), is a chronic disease associated with serious complications, such as heart disease, kidney failure, and blindness. Continuous glucose monitoring (CGM) systems have emerged as a more effective alternative to traditional fingerstick testing, offering patients greater control over their condition. Despite their potential benefits, several barriers to CGM sensor use persist, limiting their widespread adoption among patients with T2DM. This review explores the barriers to CGM sensor use, particularly from the patient's perspective.

Methods: A systematic literature review is conducted following PRISMA guidelines. The search focuses on studies published between January 2018 and June 2024 and is performed in two primary databases, PubMed and Scopus, selected for their relevance to T2DM research. Studies are included if they explore challenges and barriers to CGM adoption, report patient perspectives, or provide insights into the usability and accessibility of technology. The data are analyzed using deductive content analysis, applying Wilson et al.'s thematic categories as a predefined framework to systematically classify and interpret barriers to CGM adoption. This approach ensures methodological consistency and alignment with existing research on eHealth adoption challenges.

Results: The review identifies several key barriers to CGM sensor use despite the benefits, such as improved glucose control and reduced hypoglycemic events. Major challenges include the high cost of sensors, wearability issues, discomfort from adhesive materials, and concerns about the visibility of the sensors. Additionally, patients report difficulties in interpreting the large volumes of data generated by CGM systems, as well as discomfort or fear related to sensor insertion. Lack of technological support, low health literacy, and insufficient social support are also identified as factors contributing to non-adoption.

Conclusions: Policymakers and healthcare providers are encouraged to address these barriers by developing patient-centered strategies that support the adoption of CGM sensors. Successfully overcoming these challenges can further support integrating CGM sensors with the Chronic Care Model and Automated Insulin Delivery systems. As an implication, this integration has the potential to enhance glycemic control and improve patient quality of life in the management of T2DM. Furthermore, addressing these barriers may drive advancements in sensor design, improve accessibility, and minimize the environmental impact of CGM sensor use.

Keywords: CGM sensors; type 2 diabetes mellitus (T2DM); self-management; patient perspective; barriers to adoption

Introduction

Type 2 diabetes mellitus (T2DM) is a non-communicable disease (NCD), a chronic condition characterized by elevated blood glucose levels. This condition, also known as hyperglycemia, can lead to serious complications, including heart disease, stroke, kidney problems, and blindness [1, 2]. T2DM imposes a significant global financial burden on healthcare systems due to its persistent nature and the associated challenges [3–5]. Diabetes affects over 530 million people worldwide, contributing to substantial morbidity and mortality [6, 7]. As the prevalence of T2DM continues to rise globally, effective management is crucial for mitigating severe complications [8–10].

Traditional fingerstick blood glucose monitoring methods, though widely used, often fail to provide real-time insights, limiting patients to maintain optimal glycemic control [11, 12]. Instead, Continuous Glucose Monitoring (CGM) sensors, as highlighted by Adolfsson *et al.* [13], include both real-time (rtCGM) and intermittently scanned (isCGM) systems. These sensors offer a transformative solution by providing continuous, accurate glucose data, enabling patients and healthcare providers to make more informed decisions about treatment

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[11, 12]. While CGM sensors have been widely adopted among patients with type 1 diabetes, their use in T2DM has expanded in recent years [14, 15].

However, various studies suggest that the adoption of healthcare technologies, including CGM sensors, is hindered by several factors [16–18]. These include the high cost of equipment, insufficient training, lack of motivation, doubts about data accuracy, resistance to change, concerns over data governance and ethics, limited awareness, and the complexity of software systems. While previous reviews provide valuable insights into the clinical implications and practitioners' perspectives on the challenges of using and adopting CGM sensors [19, 20], they largely overlook the critical issue of patients' perspectives. Understanding these perspectives is crucial, as various challenges and constraints can significantly hinder patients' adoption of CGM technology [21]. Therefore, the expanding use of CGM sensors among T2DM patients underscores the need for research into the challenges related to their use and acceptance [22–24]. This study addresses this gap by investigating these challenges with the following research question:

> RQ: What barriers do T2DM patients encounter in adopting and effectively utilizing CGM sensors?

Methods

Design and database searching

The Systematic Literature Review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses PRISMA guidelines [25]. Two primary databases, PubMed and Scopus, are searched using a comprehensive search string [26]. Searches are limited to studies published between January 2018, when all manufacturers began commercializing CGM sensors with a MARD below 10% [27], and July 2024. The search incorporates terms such as "continuous glucose monitoring," "challenges," and "type 2 diabetes mellitus," along with synonyms of "perspective" and "lifestyle" to align with the study's focus on understanding patient opinions regarding the use of CGM sensors. A complete overview of the search string is listed in Multimedia Appendix S1.

Inclusion and exclusion criteria

Table 1 outlines the inclusion and exclusion criteria for selecting papers in this review. These criteria are applied to ensure the inclusion of only relevant and high-quality literature.

Study screening and selection process

Two researchers independently screen the eligible papers. Results are retrieved from two primary databases, Scopus ($n = 449$) and PubMed ($n = 358$), yielding a total of 817 records. After 280 duplicates and non-English papers were removed, 537 records remain. Following abstract and title screening and full-text assessment, 19 articles met the inclusion criteria (Fig. 1).

Data extraction, analysis, and synthesis of the literature

The content analysis technique allows for systematic, replicable interpretation of textual data across various contexts [28]. This method is particularly well-suited for systematic literature reviews, as it enables the structured classification of findings while uncovering patterns and relationships within the data [29, 30]. Among content analysis methods, this study employs deductive content analysis, where predefined categories derived from prior research serve as a framework for organizing and interpreting findings [28]. Following this approach, the analysis is conducted using Wilson's thematic categorization of barriers as a guiding structure [31]. These categories, synthesized from multiple studies on eHealth adoption, provide a structured lens for identifying barriers related to CGM sensor adoption.

Data from each article are organized into a table, which includes the authors and year of publication, reported barriers and challenges, research country, study type, analysis method, sample size, patient age, sensor type and model, calibration requirements, sensor lifespan, sensor positioning on the patient's body, and cost. The complete characteristics and findings of the included papers are outlined in Multimedia Appendix S2.

Theoretical framework

The selected papers are analyzed using Wilson *et al.*'s [31] thematic categories, which synthesize findings from multiple studies on barriers to eHealth adoption. These categories serve as a predefined framework for organizing and interpreting data, aligning with the deductive content analysis approach described earlier. Wilson *et al.* apply the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) as an analytical framework to interpret their findings and examine key influences on technology acceptance. In this paper, UTAUT2 will be used in the discussion section to contextualize the findings within the broader technology adoption literature. Specifically, this paper will examine how UTAUT2 constructs relate to the barriers identified through the lens of Wilson *et al.*'s thematic categories. This approach enables a more nuanced interpretation of the factors influencing CGM sensor adoption and long-term adherence.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
(i) Only articles published in peer-reviewed academic journals.	(i) Articles published in languages other than English.
(ii) Research outputs utilizing quantitative, qualitative, or mixed-method approaches.	(ii) Articles consisting of grey literature, reviews, study protocols, or conceptual papers.
(iii) Articles exploring challenges and barriers patients encounter during and after using CGM sensors.	(iii) Research notes, lecture notes, editorials, conference proceedings, expert opinions, Ph.D. dissertations, and abstracts.
(iv) Studies exclusively focused on patients with Type 2 diabetes.	(iv) Studies primarily focused on patients with Type 1 or gestational diabetes.
(v) Studies where the number of Type 2 diabetes (T2DM) patients is greater than or equal to those with Type 1 diabetes (T1DM).	(v) Studies addressing challenges faced by clinicians or healthcare providers rather than patients.

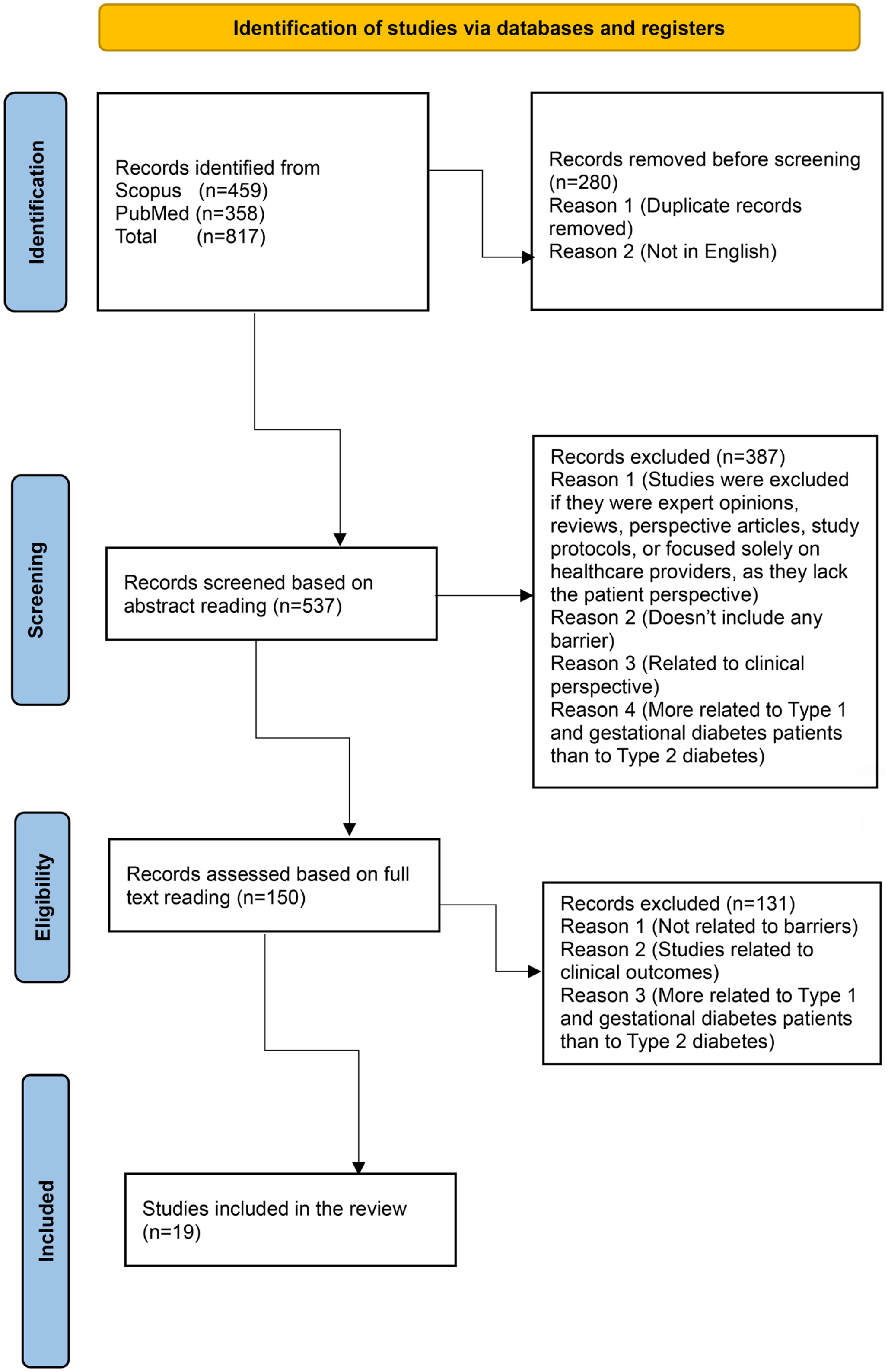

Figure 1 PRISMA 2020 flowchart of the search and selection procedure of studies.

The five thematic categories identified by Wilson *et al.* [31] capture major socio-technical influences on eHealth adoption:

- Individual factors: user attributes such as cognitive abilities, experience, and motivation that influence their ability and willingness to adopt and use eHealth technologies, such as CGM sensors.
- Technological factors: the characteristics of the technology that influence adoption, ease of use, and continued usage, such as usability, functionality, and accessibility of the technology.

- Relational factors: social and interpersonal dynamics that influence technology adoption, such as the impact of social and technical support systems.
- Organizational factors: healthcare institutions and regulatory structures that affect adoption, such as privacy concerns.
- Environmental factors: external influences beyond the individual or healthcare system that impact adoption, such as policy, economic, and infrastructural influences.

Each factor is further divided into categories and specific barriers, ensuring a structured and contextually relevant analysis.

Results

Geographical scope

Based on the geographical classification of the selected articles, it is evident that a large proportion of research on CGM sensors has been conducted in developed countries: twelve studies (57.14%) are from America; four studies (19.05%) from Europe; three papers from Oceania (14%); and two papers from Asia-Pacific (10%). Research from developing countries is notably lacking, with studies highlighting that financial barriers, such as the high cost of devices and the absence of social support, significantly hinder technology adoption in these regions [32, 33].

Characteristics of the included papers

The selected papers employ various research methodologies and are categorized into two groups. The qualitative studies include mixed-method feasibility studies, semi-structured interviews, single-center studies, and pilot studies. The quantitative analyses include multi-center trials, retrospective cohort studies, prospective studies, pilot interventional studies, randomized controlled trials, and clinical trials (see the table in Multimedia Appendix S2). These studies explore the nuances of patients' barriers to CGM adoption and use through in-depth semi-structured or structured interviews and questionnaire-based survey analysis.

Findings

The 19 selected papers include a variety of CGM sensors from different manufacturers, highlighting diverse models and technologies available in the market. Among them, seven studies use rtCGM sensors, eight use isCGM sensors, four use both, and two do not specify the sensor model.

Three different rtCGM sensor models are used:

(i) Medtronic Guardian iPro2 sensors [34, 35]: MARD of 9.1%, 6-day lifespan, requiring calibration. Positioned on the abdomen or upper arm, they alert an hour before glucose emergencies. These are professional blinded systems, with only physicians or caregivers able to monitor the data.

(ii) Dexcom G4 platinum [36]: MARD of 13%, 7-day lifespan, requiring calibration. They can be worn on the abdomen or upper arm, providing alerts and alarms for glucose fluctuations.

(iii) Dexcom G6 sensors [37–44]: MARD of 9%, 10-day lifespan, no calibration required. Like the G4, it can be worn on the abdomen or upper arm, providing alerts and alarms for glucose changes.

The only isCGM model is Freestyle Libre sensors by Abbott Laboratories [37–39, 42, 43, 45–50]: MARD of 11.4%, 14-day lifespan, no calibration needed. Positioned on the upper arm, it does not provide emergency glucose alerts.

Table 2 categorizes the barriers faced by T2DM patients based on Wilson's thematic categories [31]. The following sections will provide details on each of the categories.

Individual

Intrinsic

Several studies highlight intrinsic barriers linked to patients' personal experiences with sensors, as well as the emotional factors that impact their use. Many patients, particularly older individuals, fear the insertion of real-time sensors [36] and feel anxious about the force required, fearing they may break the sensors due to a lack of confidence [34]. They also struggle with interpreting large volumes of sensor data [36]. On the other hand, younger patients experience stigma due to the visibility of CGM sensors on their arms, leading to unwanted attention, negative emotions, and reluctance to use the sensors [38, 43]. Discomfort is another significant barrier, as some patients report irritation from the adhesive on rtCGM sensors [36]. In contrast, others experience significant pain at the sensor insertion sites [49].

Extrinsic

External barriers hindering patients' use of sensors include lower education levels [34] or inadequate eHealth literacy [38], making it difficult to understand and use digital technologies. Additionally, many patients were unaware of the availability of sensors, which further impeded their adoption [43].

Technological

Functional

Functional barriers are related to design, performance, usability, and interface features, all of which contribute to the complexity and reliability issues of the sensor. Sensor detachment and accidental dislodgement are the most frequently reported barriers in the reviewed studies. As highlighted by five studies, these issues are often linked to daily activities and movements, which can cause the sensors to fall off [35]. Some sensors detach prematurely during activities like changing clothing or removing a bra [40, 46]. Sensors can also get caught on clothes or pressed against surfaces throughout the day [43, 47].

Exercising poses challenges, as patients find it difficult to keep sensors attached during physical activity [41], with concerns about sensors shifting during work or movement [36]. Bumping into objects or wearing/removing a backpack also dislodges sensors [39]. Lying down is another concern, as sensors can catch on bedding or clothing and be pulled off [43]. Adhesion issues are reported in two studies, where poor adhesiveness causes sensors to fall off, requiring extra efforts to secure them [37, 40]. Additionally, some sensors are not fully waterproof, limiting patients to showers and preventing them from swimming or submerging the sensors in water deeper than one meter [34, 41].

Eight papers report severe skin infections and other issues from sensor insertion, including bleeding, bruising, redness, rashes, edema, itching, pain, erythema, induration, and skin

Table 2. Overview of the findings.

No. of factors	Factors	Category	Barriers/challenges	Paper ID
1	Individual	Intrinsic	Fear of insertion	[34, 36]
			Unwanted attention/negative emotions/sensor's visibility	[38, 43]
			Discomfort	[36, 49,50]
			Lack of confidence	[36]
		Extrinsic	Difficult to use for low-educated people	[34]
			Lack of knowledge of sensors	[43, 50]
			Lack of eHealth information/digital literacy/technical difficulty	[38, 50]
2	Technological	Functional	Wearability issues	[38, 41,42, 51]
			Skin issues	[37, 40, 44,45, 47–49, 51]
			Activity-related sensor displacement	[35,36, 40–42, 44, 47,48, 51]
			Adhesive issues	[37, 40, 50]
			Sensor's visibility	[39, 44]
			Plastic wastage using a sensor	[40]
			Calibration requirements	[36]
			Malfunctioning	[37, 39,40]
			Accuracy issues	[42]
		Content	Disturbing alarms	[38, 50]
			Poor accessibility for visually impaired individuals	[40]
			All users cannot interpret information	[47]
		Availability	High cost of CGM sensors/no insurance coverage	[36, 39,40, 42,43, 46,47, 51,52]
			No technology is available for socioeconomic reasons	[47]
3	Relational	Technological support	Training sensors	[46]
		Social support	Lack of family/community/social support	[36, 47]
			HCP involvement is needed/lack of HCP involvement	[47]
4	Environmental	Location		
5	Organizational	Privacy	Privacy concerns	[38, 50]
		Data sharing		
		Trust	No trust in data	[36]

trauma [37, 40, 44, 45, 47–49, 51]. Wearability issues are also highlighted, with patients struggling to attach sensors and maintain correct positioning [41, 42, 51]. Some express concerns about disconnection or inaccurate readings due to their movements [38]. Additionally, material waste from the sensors is cited as a barrier to use [40].

Three studies report malfunctioning as a barrier to CGM sensor use, including sensor connectivity issues, failure after insertion or during the warm-up period, complete non-functionality, and difficulty downloading or accessing sensor apps [37, 39, 40]. Patients using Dexcom G4 sensors find calibration challenging due to the need for finger-pricking [36], and some express concerns about the sensor's lower accuracy than finger-pricking [42]. Patients using Dexcom G4 sensors find calibration challenging due to finger-pricking [36], with some concerned about the sensor's lower accuracy compared to finger-pricking [42].

Content

Content-related barriers complicate the user experience, causing confusion or disrupting effective technology use. Reported issues include disturbing alarms [38], difficulty understanding sensor data [47], and poor accessibility on mobile devices for visually impaired patients [40].

Availability

Eight studies highlight barriers related to the availability and affordability of CGM sensors. A significant barrier is their high cost, making them unaffordable even for motivated patients [36, 39, 40, 42, 46, 47, 51, 52]. Patients hope government funding can improve accessibility and benefit more people [47]. Currently, the lack of insurance coverage prevents many patients from using them [43].

Relational

Technological support

One study reports that a lack of technological support, including training, troubleshooting, assistance, and guidance, hinders the effective use of CGM sensors for patients with limited tech knowledge [46].

Social support

Two studies mention challenges in social support, such as the lack of emotional, informational, and practical assistance, which hinders sensor adoption. Patients lack community and family support and face negative societal perceptions [36, 47]. Additionally, patients note that general practitioners' familiarity with new technologies could improve support [47].

Organizational

Privacy

One study highlights that youth are concerned about the privacy and security of sensor data, emphasizing the need for robust organizational policies [38].

Trust

Challenges related to the reliability and credibility of sensors significantly affect their adoption. One study notes that patients lack trust in sensor data, expressing concerns about its accuracy [36].

Discussion

Statement of principal findings

Day-to-day diabetes care is primarily managed by patients and their families; hence, making reliable self-management tools is essential for everyone involved in the treatment [5, 8]. Implementing new eHealth technologies for chronic diseases like diabetes presents challenges for both home use and clinical integration [52, 53]. Commercialized CGM sensors offer real-time insights into blood glucose levels, potentially preventing complications [54, 55].

This systematic review aimed to identify patient-reported barriers to CGM sensor use, classified according to Wilson's thematic categories [31]. The most prominent barriers are sensor performance, user emotions, community engagement, and financial constraints. To further interpret these findings, we apply key constructs of the UTAUT2 model within the broader technology adoption context, examining how barriers identified through Wilson *et al.*'s thematic categories align with established technology acceptance factors. This approach provides a structured lens to explore the relationship between CGM sensor adoption barriers and user acceptance dynamics, offering insights into potential strategies for improving long-term adherence and patient engagement. For instance, a lack of healthcare provider involvement often leads to inadequate training and reduced confidence [56], while low digital literacy contributes to difficulties in interpreting data [57]. Similarly, high sensor costs of sensors contribute to socioeconomic barriers, limiting access to CGM technology for certain patient populations [58]. Notably, addressing one barrier may help mitigate related issues, ultimately enhancing the overall effectiveness of CGM sensors for patients. This aligns better with the broader literature, which indicates that overcoming specific barriers can have a cascading effect on enhancing patient outcomes and device adoption.

Interpretation within the context of the broader literature

Enhancing CGM adoption through patient-centered design

Given the interconnected nature of these barriers, especially those related to sensor functionality, a patient-centered approach is crucial in sensor design. The review findings highlight key issues such as discomfort, poor adhesiveness, and wearability problems, which impact patients' quality of life and motivation to adopt the technology [40, 47, 51]. These barriers align with the effort expectancy and performance expectancy constructs of the UTAUT2 model, as the perceived ease of use plays a vital role in adopting new health technologies. Current sensors often fail to meet user needs and behaviors [59], emphasizing the necessity for user-friendly, patient-centered designs that prioritize comfort, reliability, and seamless integration into their daily lives. To encourage successful adoption, it is crucial to focus on usability usefulness and consider real-world factors while designing new technologies so that they can enhance user experience [60, 61].

Overcoming barriers through technological advancements

Ongoing advancements in CGM technology, such as the Dexcom G6 and Freestyle Libre, have addressed several usability issues by eliminating calibration requirements, reducing technical problems, and improving accuracy [62]. However, users of older models continue to face barriers, including high costs, routine disruptions, and resistance to change [63]. These barriers highlight the importance of facilitating conditions in the UTAUT2 framework, which emphasizes the need for a reliable and supportive technological infrastructure. Continuous innovation is essential to enhance the long-term adoption of these sensors, streamline functionality, and improve accessibility for all patients [64]. Ensuring the successful adoption of e-health technologies requires continuous technological advancements that align with advancing user needs and expectations [65].

Adapting CGM sensors for different age groups

Barriers to the adoption of CGM technology differ among patient age groups. Younger patients are more concerned with sensor visibility and its impact on appearance [14, 39], while older patients prioritize technical support, reliability, and ease of use [34, 36, 66]. UTAUT2's construct of social influence suggests that perceptions of adopting health technology are affected by peer and community acceptance. Likewise, CGM sensor adoption can vary depending on the support patients receive from their families and social networks [50]. Tailored approaches are needed, with discrete designs for younger patients and simple interfaces for older ones that can help promote long-term usage.

Financial burden of CGM sensors

The high cost of sensors, including both initial and recurring expenses for replacements, remains a significant barrier for CGM patients [46, 67]. This financial burden is particularly challenging for the underserved population [68, 69]. Using the UTAUT2 framework, the construct of price value suggests that the financial burden on patients significantly affects their perception of eHealth technology's affordability and influences their willingness to integrate it into their daily lives. To address this, healthcare providers and insurance companies should collaborate on cost-effective solutions that can help improve affordability [70].

Strengths and limitations

This systematic review is the first to broadly examine the barriers to adopting and using CGM sensors by T2DM patients. Wilson's thematic categories [31] identified key challenges in the review, including costs, wearability, adhesive issues, and sensor visibility. These findings have significant policy and practical implications, offering valuable insights for healthcare providers and policymakers to improve diabetes management and patient care.

However, it has some limitations. Language constraints may have excluded studies published in languages other than English, potentially overlooking cross-cultural behaviors and patient experiences. Additionally, limiting the search to Scopus and PubMed may have missed relevant literature indexed in other databases.

Implications for policy, practice, and research

This review provides valuable insights for CGM sensor manufacturers and policymakers. By addressing the identified barriers, managers can focus on overcoming these challenges through interventions and design improvements, promoting broader patient adoption and minimizing sensor-related complications. Additionally, integrating CGM sensors with healthcare systems like the Chronic Care Model (CCM) systems can enhance monitoring and treatment strategies.

The CCM, developed in the USA by E.H. Wagner [71], is an evidence-based framework that emphasizes proactive, planned, patient-centered care support and long-term treatment approaches for chronically ill patients, including those with T2DM. The CCM offers substantial benefits due to its different support and tracking methods. This model streamlines the healthcare system and enhances primary care by improving ongoing care, on-time communication, scheduling, and fostering interactions between patients and healthcare providers [72–74]. CGM sensor plays a crucial role in CCM in clinical practice by providing real-time glucose data. Integrating CGM sensors within CCM supports evidence-based diabetes management, empowering patients to engage in active self-management.

In clinical practice, CGM sensors can be crucial for implementing the CCM, providing real-time blood glucose data that significantly improve patient outcomes and quality of life. Integrating CGM sensors into the CCM framework can support evidence-based diabetes management, allowing patients to effectively manage their condition and empowering them to act as self-managers. This capability enables patients to make timely decisions about their meals, control their activities, and plan treatment accordingly [75]. Furthermore, the CCM helps healthcare providers track patient progress and identify patterns for personalized treatment plans, ultimately improving patient outcomes [74]. Additionally, integrating CGM sensors with Automated Insulin Delivery (AID) systems further strengthens the CCM by offering a seamless approach to glucose monitoring and insulin delivery [76].

AID systems represent significant progress in diabetes management by combining CGM sensors with insulin pumps to automate insulin delivery based on real-time glucose data [77–79]. This reduces the need for manual injections, stabilizes blood sugar levels, and minimizes hypo- and hyperglycemia risks, improving patient outcomes [76, 80, 81]. However, Using CGM sensors and insulin pumps simultaneously may cause discomfort for some patients, as devices on both sides of the body can feel like excess gears [82]. Despite this, AID systems have been shown to effectively increase time within the target glucose range and reduce hypoglycemic events [83].

Conclusion

This systematic review highlights the benefits of CGM sensors, including improved glycemic control, reduced hypoglycemic events, and enhanced quality of life [55, 81]. These sensors provide real-time data that enable informed decision-making in diabetes care [84]. However, barriers such as high costs, design flaws, technological limitations, and patient-related factors hinder access. Policymakers and healthcare providers must address these barriers to enhance patient engagement and care. Additionally, future efforts should focus on reducing the environmental impact of CGM sensors, mainly plastic waste [40], by using sustainable materials and implementing proper waste management [85].

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Author contributions

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Supplementary data

Supplementary data is available at *IJQHC* online.

Conflict of interest

No known conflict of interest.

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Data availability

The data underlying this article are available in the article and in its online supplementary material.

Ethics and other permissions

No permissions were required for this work, as it is based solely on publicly available literature.

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