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REVIEW ARTICLE

Use of continuous glucose monitors in low- and middle-income countries: A scoping review

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Abstract

Aims: The use of continuous glucose monitors (CGMs) has been shown to have positive impact on diabetes management for people with type 1 diabetes (T1DM), type 2 diabetes (T2DM) and gestational diabetes (GDM) in high-income countries. However, as useful as CGMs are, the experience in low- and middle-income countries (LMICs) is limited and has not been summarized.

Methods: A scoping review of the scientific literature was conducted. Medline, Embase, Global Health and Scopus were used to seek original research conducted in LMICs. The search results were screened by two reviewers independently. We included studies assessing health outcomes following the use of CGMs at the individual level (e.g. glycaemic control or complications) and at the health system level (e.g. barriers, facilitators and cost-effectiveness) in English, Portuguese, Spanish and French. Results were summarized narratively.

Results: From 4772 records found in database search, 27 reports were included; most of them from China ($n = 7$), Colombia ($n = 5$) and India ($n = 4$). Thirteen reports studied T1DM, five T2DM, seven both T1DM and T2DM and two GDM. Seven reports presented results of experimental studies (five randomized trials and two quasi-experimental); two on cost-effective analysis and the remaining 18 were observational. Studies showed that CGMs improved surrogate glycaemic outcomes (HbA_{1c} reduction), hard endpoints (lower hospitalization rates and diabetes complications) and patient-oriented outcomes (quality of life). However, several caveats were identified: mostly observational studies, few participants in trials, short follow-up and focused on surrogate outcomes.

Conclusions: The scoping review identified that studies about CGMs in LMICs have several limitations. Stronger study designs, appropriate sample sizes and the inclusion of patient-important outcomes should be considered to inform the evidence about CGMs for the management of people with diabetes in LMICs.

KEYWORDS

diabetes, glycaemic control, health technologies, scoping review

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1 | INTRODUCTION

Diabetes, including type 1 (T1DM), type 2 (T2DM), as well as gestational diabetes (GDM), has a high prevalence worldwide, disproportionally affecting low- and middle-income countries (LMICs).[1] Diabetes is a major risk factor for impaired health outcomes,[2] such as lower-extremity amputations,[3] kidney failure[4] and cardiovascular diseases.[5] However, diabetes can be effectively managed, and the impaired health outcomes prevented or delayed.

For effective diabetes management there are several pharmacological interventions,[6] yet they may require careful supervision in some cases. Insulin plays a key role in diabetes management, being the only treatment for T1DM and can be prescribed for T2DM when glycaemic control is not achieved with oral drugs. Nevertheless, the doses of insulin need careful titration due to the effect of food consumption and physical activity in the glucose levels. For accurate insulin dose titration, frequent blood glucose self-testing is needed, which demands a person with diabetes to perform several daily blood glucose tests via finger-prick, using a portable glucose meter and test strips (also referred to as self-monitoring of blood glucose, or SMBG). Taking several blood tests throughout the day may be troublesome, inconvenient and painful.[7] Nowadays, continuous glucose monitors (CGMs) offer a solution to measure glycaemic levels without any (or very little) action needed from the person with diabetes[8]: CGMs currently available are minimally invasive, attached to a person's skin and have a thin needle that is inserted into the interstitial fluid, providing automatic glucose measurements every few minutes. Not only do CGMs eliminate (or reduce) the need for fingerstick glucose testing, but they also provide the user with more data points on their glycaemic profile throughout day and night.

Empirical evidence suggests using CGMs improves glycaemic control,[9,10] and reduces the risk of complications in comparison to people with diabetes who do not use CGMs.[11,12] As useful as CGMs are, they are not available in many LMICs and even in countries where CGMs are marketed, especially in high-income countries, there may be inequalities in accessing them.[13] It is therefore unknown whether the conclusions of research conducted in high-income countries or in populations with privileged access to CGMs, apply to people with diabetes in LMICs or those facing significant barriers to access CGMs. Similarly, the experiences of using CGMs, barriers and facilitators of using CGMs and other scientific gaps in LMICs, need in-depth exploration to share experiences between countries and benchmarking.

This scoping review aimed to understand what the current knowledge about CGMs is in LMICs, including their effect on health outcomes (e.g. quality of life, diabetes complications), surrogates (e.g. glycated haemoglobin [HbA_{1c}], time in range or glycaemic variability) and implementation strategies (e.g. barriers and facilitators). This will provide evidence for researchers, funders and public health officers on what has been studied about CGMs in LMICs and what needs further research.

What is already known?

The use of continuous glucose monitors has a positive impact on diabetes management for people with type 1 diabetes, type 2 diabetes and gestational diabetes. However, information comes from high-income countries, instead of low- and middle-income countries.

What this study has found?

We identified that studies about using continuous glucose monitors in low- and middle-income countries have several caveats. Stronger study designs, appropriate sample size and the inclusion of patient-important outcomes should be considered to inform evidence for appropriate diabetes management.

What are the implications of the study?

The empirical evidence about the use of continuous glucose monitors in low- and middle-income countries is limited in terms of quantity and scope, precluding the formulation of context-specific and evidence-based policies and recommendations.

2 | METHODS

2.1 | Study design and protocol

A scoping review was conducted, and the PRISMA checklist for Scoping Reviews was followed for reporting (Table S1).[14] A protocol, including the search strategy, was developed by the authors, and approved by the funder who provided input on the scope of the search strategy. The protocol can be accessed upon reasonable request from the corresponding author.

2.2 | Eligibility criteria

We included original studies reporting outcomes following the use of CGMs by people with T1DM, T2DM or GDM.

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Outcomes included those at the individual level (e.g. surrogates such as HbA_{1c} change or glycaemic control; or direct health outcomes, such as incidence of complications, or quality of life); those at the health system level (e.g. implementation experiences or cost-effectiveness); as well as those at the provider level (e.g. physicians' or patients' experience using CGMs). The original reports were either observational (e.g. cohort studies) or experimental (e.g. clinical trials), and could have followed a quantitative or qualitative approach. We included studies conducted in the community (e.g. population-based) and studies conducted in a healthcare facility (e.g. inpatients or emergency care). Manuscripts in English, Spanish, Portuguese and French language were evaluated.

We excluded original studies conducted in high-income countries as well as those reporting on the validation or reliability of a CGM (e.g. accuracy comparison between two CGMs). No year restrictions were applied to the search strategy.

2.3 | Information sources and search

On July 7 2022, we conducted a bibliographic search on OVID, including Medline, Embase and Global Health, and Scopus. The full search strategy for each search engine is available in Table S2.

2.4 | Selection of sources of evidence

Search results were downloaded and duplicated records were excluded in EndNote, and then exported to Rayyan, an online application for blind screening of scientific publications.[15] Titles and abstracts were screened by the two authors independently (RMC-L and AB-O), and discrepancies were solved by consensus between them. Reports selected from the screening phase were read in detail by two reviewers independently (RMC-L and AB-O) to verify whether they met the selection criteria; discrepancies were solved by consensus between them.

2.5 | Data items

The authors developed an extraction form in Microsoft Excel. This form collected information about the original reports (e.g. publication date); about the study (e.g. study design and inclusion criteria); about the study population (e.g. sample size and mean age) and about the study outcome measures as well as results. One author (AB-O) conducted the data extraction, and another author (RMC-L) verified a random sample of 50% of all selected documents. Discrepancies were solved by consensus.

2.6 | Synthesis of results

We did not conduct a critical appraisal of the selected documents. The results are presented qualitatively in a narrative fashion.

2.7 | Ethics statement

Ethical approval was not considered mandatory given; this study summarizes existing information from manuscripts, that is, a scoping review was conducted.

3 | RESULTS

3.1 | Selection of sources of evidence

We identified 4772 records obtained through database search (2980 from OVID and 1492 from Scopus) and, after removing duplicates, 3489 were evaluated in the screening phase. Forty-nine records were studied in detail and 27 studies were included in the scoping review (Figure 1).

3.2 | Characteristics of sources of evidence

China contributed with seven studies,[16–22] Colombia with five,[23–27] India with four,[28–31] Brazil[32–34] and Turkey[35–37] with three each, and Argentina,[38] Bosnia and Herzegovina,[39] Georgia,[40] Malaysia[41] and Mexico,[42] with one study each (Table 1). Only one report was published in 2002,[32] and the number of reports per year increased steadily, reaching eight reports in 2021,[17–19,22,26,31,40,42] and five reports up to July 2022.[20,30,34,36,38]

Overall, seven reports presented results of experimental studies (five randomized trials and two quasi-experimental [pre-post])[16,17,19,22,27,41,42]; two reports focused on cost-effective analysis[23,37] and the remaining 18 were observational in nature. The number of participants in the studies varied between 20 and 5072, whereas follow-up time ranged from 14 days to 18 months.

3.3 | Results of individual sources of evidence

Thirteen reports studied T1DM, one of them working with paediatric endocrinology fellows and attending physicians. Five reports were about T2DM. Seven reports included both T1DM and T2DM. Finally, two reports studied women with GDM.

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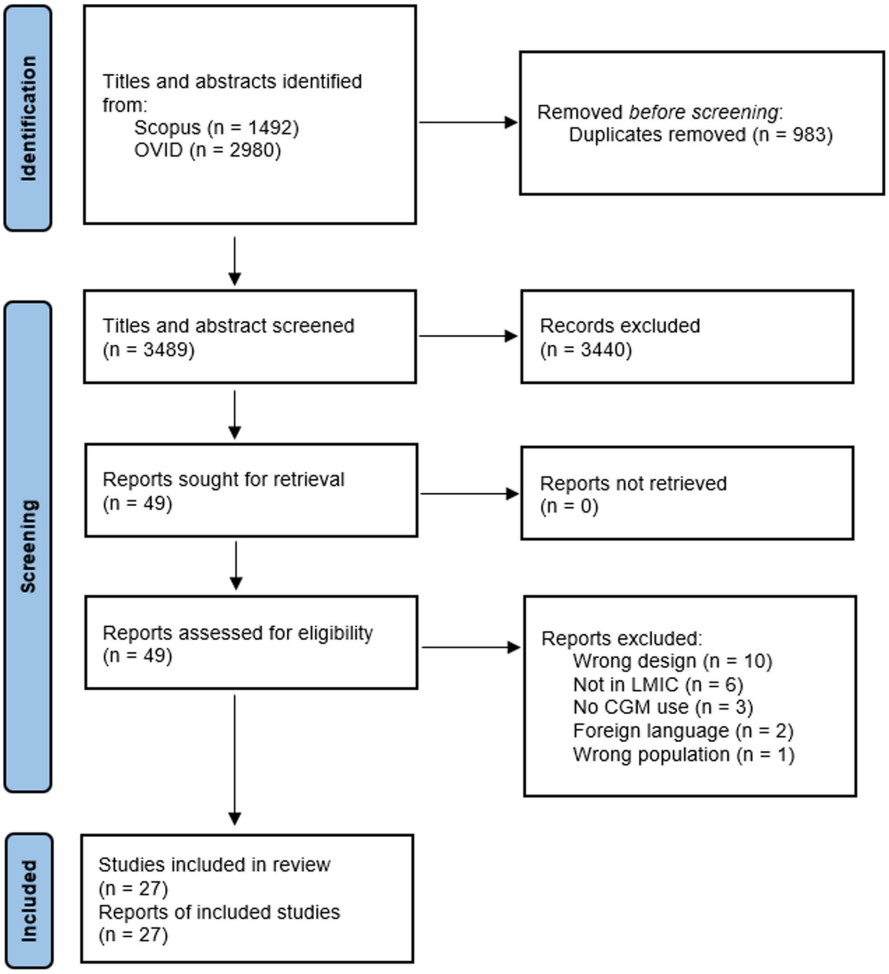


FIGURE 1 Flow diagram for scoping review selection.

Four studies focused only on children or adolescents,[19,35,39,40] though two of them included the parents as well.[35,40] The most common CGM devices used in the studies were from Medtronic ($n = 10$) and Abbott ($n = 7$).

3.3.1 | The effect of CGMs on diabetes management and outcomes

In 14 reports, the primary aim was to assess the effect of CGMs on diabetes management, surrogates or health outcomes (Table S3). Of these reports, four were experimental (three clinical trials and one pre-post study), and 10 were observational. In the four experimental studies, one trial focused on T1DM,[22] one on T2DM,[17] and one on GDM,[41] whereas the pre-post report focused on T2DM.[42] In the three trials, changes in surrogates (e.g. HbA_{1c}) were used to assess the effectiveness of CGMs and all of them concluded that the use of CGMs reduced HbA_{1c} levels. Besides, two of the trials also concluded that CGMs improved both quality of life and self-management.[17,22] The trial focusing on GDM did not find evidence CGMs improved foetal outcomes, yet found that these devices improved glycaemic control.[41] The pre-post study focusing on T2DM showed a reduction in HbA_{1c} levels after 3 months.[42] The 10 observational studies focused on glycaemic surrogates, and five reported significant reductions in the frequency of hypo- and hyper-glycaemia events, as well as less glucose variability.[20,21,30,31,34] One observational study also included the assessments of health outcomes and reported that hypo- and hyper-glycaemia profiles were negatively associated with diabetes complications after controlling for potential confounders.[31]

3.3.2 | CGM benefits in combination with other treatments and devices

13 reports aimed to describe CGM benefits in combination with other devices or treatments. Two reports focused on cost-effective analysis: one of them comparing insulin pump therapy in combination with a CGM versus multiple daily injections (MDI) and the use of SMBG,[23] and the other report compared sensor-augmented pump therapy (SAP) versus continuous subcutaneous insulin infusion (CSII) with both groups using CGMs.[37] Both studies showed an increase in quality-adjusted life years (QALYs) and a delay of the onset of diabetes-related complications.

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TABLE 1 Characteristics of the study included in the review.

First author	Publication year	Study country	Study design	Diabetes type	Study aim
Studies assessing the effect of CGMs on diabetes management and outcomes					
Maia[33]	2008	Brazil	Observational: Retrospective cohort	T1DM	To assess accuracy and short- and long-term efficacy (complications and glycaemic control) of a CGM device used by 3, 4 and 5 days.
Yu[21]	2014	China	Observational: Prospective cohort	GDM	To determine whether a CGM system could be used to improve pregnancy outcomes of patients with GDM.
Mohan[29]	2016	India	Observational: Prospective cohort	T2DM	To evidence that a CGM device enable healthcare professionals treating patients with T2DM to improve glycaemic control.
Anjana[28]	2017	India	Observational: Matched case–control study	T1DM T2DM	To assess the efficacy of CGM-based ambulatory glucose profile in improving glycaemic control in patients with uncontrolled T1DM and T2DM.
Eren[35]	2017	Turkey	Observational: Cross-sectional study	T1DM	To study the data about the use of flash glucose monitoring and the experience, satisfaction and concerns of the families.
Paramasivam[41]	2018	Malaysia	Experimental: Randomized controlled trial	GDM	To prospectively evaluate the therapeutic effect of retrospective CGM use in women with insulin-treated GDM.
Guo[17]	2021	China	Experimental: Randomized controlled trial	T2DM	To assess the feasibility and to compare the effectiveness of a 4-week mHealth intervention (network platform, implantable glucose sensor, a mobile app and general practitioner support) to usual health management for T2DM patients.
Kheladze[40]	2021	Georgia	Observational: Qualitative descriptive study	T1DM	To elucidate Georgian parents' experiences of their daily lives when a child in their family uses a flash glucose monitoring device.
Rivera-Avila[42]	2021	Mexico	Experimental: Pre-post study	T2DM	To evaluate the effects of professional CGM as an adjuvant educational tool for improving glycaemic control in patients with T2DM.
Varghese[31]	2021	India	Observational: Cross-sectional study	T2DM	To identify profiles of T2DM from CGM data using ambulatory glucose profile indicators and examine the association with prevalent complications.
Zhang[22]	2021	China	Experimental: Randomized controlled trial	T1DM	To investigate whether the use of flash glucose monitoring could be an effective method for achieving A1c improvement and reducing glycaemic variability during T1DM maintenance.

(Continues)

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TABLE 1 (Continued)

First author	Publication year	Study country	Study design	Diabetes type	Study aim
Sabharwal[30]	2022	India	Observational: Retrospective cohort	T1DM T2DM	To analyse association of glycaemic variability and time in range assessed by CGM with diabetes microvascular complications.
Tannus[34]	2022	Brazil	Observational: Cross-sectional study	T1DM	To determine the relationship between glycaemic variability, assessed by blinded CGM measurements, and cardiovascular autonomic neuropathy in T1DM.
Yin[20]	2022	China	Observational: Retrospective study	T1DM T2DM	To evaluate the relationship between CGM-derived time in range and the rate of major amputation.
Studies assessing CGMs benefits in combination with other treatments and devices					
Hissa[32]	2002	Brazil	Observational: Prospective cohort	T1DM	To improve metabolic control (A1c < 7%) with use of CSII and insulin lispro in patients previously treated with MDI or conventional insulin therapy.
Gomez[24]	2017	Colombia	Observational: Prospective cohort	T1DM	To describe the long-term results of the sensor-augmented insulin pump and low-glucose suspend feature (SAP-LGS) therapy.
Ramirez-Rincon[27]	2016	Colombia	Experimental: Pre-post study	T1DM T2DM	To describe the results after 1 year of CSII-rtCGM in diabetic patients, which was started in a specialized centre in Medellin, Colombia.
Gomez[23]	2016	Colombia	Observational: Cost-effective analysis	T1DM	To evaluate the clinical and economic impact of the insulin pump integrated in the CGM system compared to MDI.
Gu[16]	2017	China	Experimental: Randomized controlled trial	T2DM	To compare the efficacy and safety of sensor-augmented insulin pump (SAP) and MDI (with blinded CGM) in hospitalized insulin-requiring patients in terms of time required to reach glycaemic targets.
Bukara-Radujkovic[39]	2018	Bosnia and Herzegovina	Observational: Prospective cohort	T1DM	To broaden research employment of a relatively novel device (iPro2) for measuring glucose control.
Roze[37]	2019	Turkey	Observational: Cost-effective analysis	T1DM	To investigate the cost-effectiveness of sensor-augmented insulin pump versus CSII from the public payer perspective in two different populations of T1DM patients.
Guzman[25]	2020	Colombia	Observational: Retrospective cohort	T1DM T2DM	To evaluate the factors that could be related to hypoglycaemic events when using insulin pump therapy compared to using CGM.

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TABLE 1 (Continued)

First author	Publication year	Study country	Study design	Diabetes type	Study aim
Morros-Gonzalez[26]	2021	Colombia	Observational: Retrospective cohort	T1DM T2DM	To evaluate the safety and efficacy of sensor-augmented pump + low-glucose suspend feature (SAPLGS) therapy in elderly patients with T1DM and T2DM.
Shen[18]	2021	China	Observational: Retrospective cohort	T2DM	To analyse the glycaemic profiles of patients with diabetes with confirmed COVID-19 using intermittently scanned CGM and to determine the association of glycaemic metrics with adverse outcomes of COVID-19.
Xu[19]	2021	China	Experimental: Randomized controlled trial	T1DM	To clarify the effect of the WeChat intervention combined with flash glucose monitoring on glycaemic control, hypoglycaemia incidence and life quality.
Mutlu[36]	2022	Turkey	Observational: Cross-sectional study	T1DM	To evaluate attitudes, experiences and self-efficacy of paediatric endocrinology fellows and attending physicians about technology in T1DM patients.
Proietti[38]	2022	Argentina	Observational: Prospective cohort	T1DM	To assess the efficacy of an hybrid closed-loop system in T1DM patients over a prolonged period who were naïve to the system and received virtual training.

One trial showed that reaching glycaemic target levels required 2.6 fewer days when using SAP (with a CGM) compared to MDI (using SMBG).[16] A pre-post study reported that CSII plus real-time CGM reduced HbA_{1c}, hospital admissions and hypoglycaemia rates after 12 months.[27] Lastly, one trial utilized a flash CGM in combination with WeChat, an interactive management group application, showing that CGM use was associated with a decline in HbA_{1c} levels and improvement in self-monitoring and quality of life compared to SMBG.[19]

Out of the eight observational studies assessing CGMs in combination with other treatment devices, five of them showed improvement in HbA_{1c} levels, two of them assessed and reported reduction of hospitalizations,[25,26] whereas one study reported that higher glycaemic variability in people with diabetes and COVID-19 was associated with a poor outcome as well as with a prolonged hospitalization.[18]

Finally, some studies reported enablers and barriers related to using CGMs. Two studies reported that CGMs were easy and comfortable to wear with subsequent better glycaemia management[24,29]; however, one of them reported some patients' concerns due to differences between SMBG measurements and CGM results, no compatibility with insulin pumps, and the lack of alarm for hypo- and hyper-glycaemia events.[24] One study reported improvement in quality of life for both parents and children after children started using CGMs, and the device was considered of great help for decision-making, especially when children did physical activity.[40] Finally, a study assessing knowledge about technology in diabetes among T1DM endocrinology fellows and attending physicians,[36] reported that 35% acquired knowledge from the institution where they had received training, 16% acquired knowledge from their patients and 30% acquired knowledge from technology company representatives. Moreover, 33% of the fellows and attending physicians thought their knowledge was adequate.

4 | DISCUSSION

4.1 | Summary of evidence

In general, both experimental and observational studies conducted in LMICs, show that CGMs improve surrogate glycaemic outcomes (e.g. HbA_{1c} reduction), hard endpoints (e.g. lower hospitalization rates and diabetes complications) and patient-oriented outcomes (e.g. quality of life). While this is consistent with evidence from high-income countries, our findings from LMICs had several caveats (e.g. mostly observational, few participants in trials, studies with short follow-up,

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the use of surrogate outcomes, etc.) that ought to be addressed while boosting the availability and use of CGMs in LMICs. Finally, qualitative studies reported better glycaemia management and helping in the decision-making process.

Previous evidence on CGMs showed better outcomes, especially in glycaemic management and reduction of hypoglycaemic events. For example, a recent systematic review of 22 randomized controlled trials in people with T1DM found effects in glycaemic control but they did not find influence of the CGMs on the number of severe hypoglycaemia or diabetic ketoacidosis events,[9] perhaps due to the small number of participants in the included studies. In addition, another systematic review in T1DM subjects with 15 trials (10 RCTs and 5 crossover design trials) reported an effect in decreasing the incidence of severe hypoglycaemia (risk ratio 0.52, 95% CI 0.35–0.77).[10] Our current scoping review and the previous systematic reviews should be used to design studies that considered long-term patient-oriented outcomes and proper sample sizes to have stronger evidence related to CGMs from LMICs. Besides, it is important to consider other outcomes such as emotional distress and sleep disruption, that have been previously described in qualitative studies using CGMs or other devices for their diabetes management,[43,44] with the subsequent effect in the quality of life of people with diabetes.

4.2 | Strengths and limitations of the scoping review

We conducted a comprehensive search in four global and well-known libraries, conducted by two researchers independently. Because this is a scoping review, we did not target a specific question, nor did we report results for a specific outcome. We aimed to map, compile and synthetize available evidence about CGMs in LMICs, especially focused on relevant health outcomes. Future work can leverage our results to conduct systematic reviews and meta-analyses about specific questions. Nevertheless, a great variability in terms of study design, studied population, follow-up periods and outcomes, was found, highlighting the need of stronger studies, with better methodology, from LMICs at this point.

4.3 | Strengths and limitations of the reports included in the summary

Although diverse research teams have gone through great efforts to conduct studies using CGMs in LMICs, there were some limitations worth signalling to be improved in future work. First, most of the research was observational and descriptive (e.g. cohort or cross-sectional studies). More compelling evidence to foster the use of CGMs in LMICs, should come from experimental designs, which provide stronger evidence on a causal relationship between CGM and positive outcomes. Second, the outcomes most often addressed were glycaemic control surrogates such as HbA_{1c} or glucose variability; thus, future research in LMICs should also include hard endpoints such as diabetes-related complications, incident cardiovascular diseases, and all-cause and cause-specific mortality that will require longer follow-up periods and/or bigger sample sizes. Moreover, the epidemiological profile of LMICs also includes infectious diseases and future work should address different outcomes such as community-acquired infections or tuberculosis when using CGMs. Third, the few clinical trials (i.e. studies in which the researcher provided the participants with an intervention or a new device outside their usual care) we identified had a small sample size and had short follow-up (<6 months). Future trials should try to include more participants to enhance diversity, reduce statistical uncertainty and quantify smaller differences or more outcomes. Similarly, future clinical trials should follow-up participants for longer periods, enough to quantify less frequent or different health outcomes such as amputations or retinopathy. Fourth, most studies were conducted in China, Colombia and India (almost 60% of all reports) and also, most of the studies were conducted in upper-middle-income countries. There are many more LMICs, and researchers as well as funders should try to conduct studies in new sites where there may be strong and reasonable scientific justifications. Fifth, several studies included children or adolescents, particularly those focusing exclusively on T1DM; arguably, T1DM is more prevalent in this age range. Future work should also target adult individuals, but also elderly (e.g. above 65 years old) as increasing life expectancy means that more older people are living with diabetes. Furthermore, the elderly population may have several diseases (i.e. multimorbidity), and whether CGM use influences their diabetes control alongside that of other co-morbidities is unknown, yet it could reveal information for preventive strategies.

5 | CONCLUSIONS

Consistent with evidence from high-income countries, CGMs seem to be associated with favourable outcomes from different aspects (i.e. from the patient's or health system perspectives) in LMICs. Nonetheless, the empirical evidence from LMICs is limited in terms of quantity and scope, precluding the formulation of context-specific and evidence-based policies and recommendations about

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CGMs in LMICs. Research limitations and gaps highlighted in this review need to be recognized by funders for increased investment in evidence generation of CGM use in LMICs to improve equitable access to these technologies for people living with diabetes.

FUNDING INFORMATION

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CONFLICT OF INTEREST STATEMENT

ES and BV declare that they are employed by FIND, the global alliance for diagnostics.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study. This is a scoping review of the scientific literature. All data are available within this article.

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Additional supporting information can be found online in the Supporting Information section at the end of this article.

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