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REVIEW

Identification of Continuous Glucose Monitoring Self-Management Structured Education Programs for People with Type 1 Diabetes Mellitus: A Mixed Methodology Systematic Review

Eirini Pizirtzidou[1], Chrysovalantis Karagkounis[1], Thalia Bellali[1,2], Niki Katsiki[3,4], Kyriakos Kazakos[1], Emir Muzurović[5,6], Evgenia Minasidou[1]

[1]Faculty of Nursing, International Hellenic University of Thessaloniki, Thessaloniki, Greece; [2]Faculty of Health Sciences, European University Cyprus, Nicosia, Cyprus; [3]School of Medicine, European University Cyprus, Nicosia, Cyprus; [4]Department of Nutritional Sciences and Dietetics, International Hellenic University, Thessaloniki, Greece; [5]Department of Internal Medicine, Endocrinology Section, Clinical Center of Montenegro, Podgorica, Montenegro; [6]Faculty of Medicine, University of Montenegro, Podgorica, Montenegro

Correspondence: Eirini Pizirtzidou, Department of Nursing, International Hellenic University of Thessaloniki, Alexandria Panepistimioupoli, Sindos, Post office Box 141, Thessaloniki, 57400, Greece, Email eirinipizi@hotmail.gr

Background: The use and innovation of continuous glucose monitoring systems (CGMs) offer a wealth of information regarding glycemic variability on a day-to-day basis, providing the opportunity to assess the broader picture of glycemic control compared with the static data from Blood Glucose Monitors. Diabetes self-management structured education (DSMSE) is the cornerstone of successful diabetes management. Educational programs on CGMs self-management, structured following National Institute for Health and Care Excellence (NICE) guidelines, have shown remarkable outcomes in glycemic management, technology acceptance and adherence, user satisfaction, and the reduction of diabetes-related distress.

Purpose: Our study aims to gather information on all available structured educational programs for CGM self-management in people with type one diabetes and analyze their characteristics.

Methods: The study is a mixed-method systematic review (PROSPERO registration number CRD42024579331). We searched the following databases (Cochrane Library, CINAHL, PubMed, and PsycINFO) from inception to May 7, 2024.

Results: We included nine studies documenting nine structured educational programs on CGM self-management. These studies, published between 2019 and 2023, targeted adults, adolescents, and pediatric populations with type one diabetes using real-time CGM (rt-CGM) or intermittent scanning CGM (isCGM). Overall, 7/9 programs (ie, the CGM Academy, both versions, Spectrum, Flash, IDEAL, Share-plus, and ABC/is-CGM) met all the criteria for structured educational programs.

Conclusion: Taking into consideration any limitation due to study heterogeneity, programs such as Spectrum and CGM Academy serve as comprehensive models, for CGM self-management education, as they meet all the NICE UK structured education criteria, and offer the most robust, holistic, and evidence-based curricula. They incorporate the most effective approaches, methods, and materials based on literature and utilize rt-CGM technology, which broader clinical evidence suggests is superior to isCGM in improving Time in Range and reducing hypoglycemia. The CGM Academy is particularly suited for pediatric and young adult populations, whereas Spectrum targets all populations (pediatric and adult) regardless of the rt-CGM manufacturer.

Keywords: continuous glucose monitoring systems, diabetes self-management, glycemic control, educational programs

Introduction

In recent decades, diabetes management and self-monitoring of glycemic control have shifted from a conventional one-size-fits-all approach to a more patient-centered strategy. Such strategy has proved more effective in improving outcomes across all aspects of this chronic disease.[1] Advances in diabetes technology have highlighted the limitations of blood glucose monitoring (BGM), as it provides a static measurement that fails to capture the full picture of glycemic

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variability, leading to the loss of valuable information. Additionally, the burden of using BGM- such as painful finger pricks and the inconvenience of performing multiple blood glucose tests to inform insulin dosing decisions- can lead to poor adherence to the care plan.[2]

Continuous Glucose Monitors (CGMs), which measure glucose concentrations in the interstitial fluid (a different body compartment than blood) overcome the limitations of Hba1c (Glycosylated hemoglobin) and BGM systems. Such systems capture day-to-day glycemic excursions, trends, and periods of hypoglycemia unawareness or hyperglycemia. CGMs measure glucose continuously, allowing for daily, weekly, or monthly analysis. This real-time monitoring includes glucose trend arrows and alerts. The data generated by CGMs are summarized and analyzed in an Ambulatory Glucose Profile (AGP) report. In 2023, an expert consensus panel standardized CGM-derived metrics in a report endorsed by diabetes scientific societies worldwide.[3]

The GOLD trial demonstrated a 0.7% reduction in HbA1c (from 8.6% to 7.9%) in individuals with type one diabetes on multiple daily insulin injections using CGM.[4] However, in another study,[5] where the real-time CGM (rt-CGM) use was combined with structured, individualized education, Hba1c reduction was 1.3%, and the Time in Range (TIR) increased 15.3% (3 hours and 42 minutes per day). Therefore, achieving optimal clinical outcomes and therapeutic goals with CGMs requires that people with diabetes, along with their supportive environment, be trained to interpret and analyze the displayed data in order to make safe therapeutic decisions.[6]

The 2017 Advanced Technologies & Treatments for Diabetes (ATTD) Consensus Guidelines recommend that all CGM users receive education on analyzing and responding to CGM data.[5] Similarly, the 2018 French position statement emphasizes that CGM training should be structured and contain problem-solving and decision-making skills.[7] According to the 2020 guidelines from the Association of Diabetes Care and Educational Specialists (ADCES), CGM education should focus on empowering individuals with diabetes through self-management and problem-solving principles.[8] Such education can enhance acceptance of technology, improve user satisfaction, increase knowledge of the system, and foster a sense of safety for the person with diabetes. The curriculum for a CGM education program should include the following key points: selection of the insertion site, sensor insertion technique, connecting the transmitter to the receiver/application, understanding the difference between subcutaneous glucose and blood glucose, interpreting CGM data and trends, calibration (if required) including timing, frequency, and importance of accurate meter/fingerstick technique. It should also cover setting up and managing alerts (high, low, and predictive), troubleshooting site adhesiveness, coping strategies, problem-solving for individual behavioral issues that can improve management, recognizing substances that may interfere with CGM operation, education on avoiding overcorrection of high glucose, data sharing, and understanding CGM reports including the AGP and TIR. Through structured education, individuals with diabetes can discuss realistic expectations for the technology, understand its features and limitations, and optimize its use to maximize the benefits.[5] Although several guidelines have established the clinical benefits of CGM technology, there remains a significant gap in the systematic characterization of the standardized educational frameworks that support its use. The American Diabetes Association Standards of Care 2024 and 2026 recommend diabetes self-management education and support (DSMES) as an integral part of therapy, but these frameworks remain broad and are not specifically tailored to CGM use, particularly in relation to data interpretation and behavioral decision-making. Existing literature often overlooks the specific pedagogical structures and detailed curricula required for effective CGM integration.[5,9–11] This review uniquely addresses this gap by systematically identifying and evaluating structured CGM-specific educational programs against established quality criteria (NICE), providing a comprehensive roadmap for clinicians to select or design evidence-based training models.

In this mixed-methods review and in absence of a similar piece of work in recent literature, we aim to summarize all available structured educational programs on self-management of CGM systems and analyze their characteristics. Although structured education programs for CGM self-management exist, no such program exists currently in Greece or several other countries. Thus, this review could serve as a guide for the future development, adoption, and implementation of a structured educational program with the goal of optimizing glycemic control, enhancing technology acceptance and satisfaction, and improving overall diabetes management. Additionally, emerging approaches such as continuous glucose monitoring (CGM)-based dynamic markers and machine learning models could further enhance screening and tracking of disease progression.[12,13]

Research Question

To achieve better clinical outcomes, what structured educational programs have been developed and implemented to support self-management of CGM systems in people with type one diabetes?

Methods

Design

The mixed-method systematic review aims to derive results by combining different methodological approaches that address one or more formulated research questions. This review includes qualitative, quantitative analysis, and mixed-methodology studies. After data collection and analysis, this approach was chosen to provide a comprehensive understanding of the subject area.[14,15] The integration of findings followed a convergent design, where quantitative results regarding clinical outcomes were synthesized narratively alongside qualitative data on program curricula. This approach aligns with the Medical Research Council (MRC) guidance for evaluating complex health interventions, which recognizes that educational and behavioral programs involve multiple interacting components that are best captured through a mixed-method synthesis. To this end, the primary objective of this review is to identify and critically appraise the structural and pedagogical characteristics of CGM-specific educational curricula against established quality standards. A secondary objective is to descriptively present the clinical outcomes reported by these programs to provide a comprehensive overview of their implementation.

Search Strategy

The search process and reporting followed the guidelines outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Group,[16] which two independent reviewers searched (Figure 1). Although systematic reviews were part of the initial eligibility criteria to maximize the scope of the search, none were included in the final synthesis as they did not meet the specific inclusion criteria regarding the detailed analysis of CGM-specific educational curricula. Relevant reviews identified during the search were instead used for manual reference chaining to ensure the inclusion of all available primary studies. Studies were included if they met the criteria defined by the PICO acronym (Patient problem or Population, Intervention, Comparison, and Outcome).[17] Specifically, the review included references that satisfied the requirements for population type, indicators, comparison, outcome measures, time, setting and study characteristics (PICOTSS) (Table 1).

Individuals with type 2 diabetes were excluded from this review to minimize clinical heterogeneity, as CGM self-management education in type 1 diabetes requires distinct pedagogical approaches focused on intensive insulin adjustment and proactive hypoglycemia prevention, which differ fundamentally from the management strategies typically employed in type 2 diabetes populations.

We systematically reviewed four databases- the Cochrane Library, CINAHL, PubMed, and PsycINFO-for studies that met the eligibility criteria. The databases were searched from inception to May 7, 2024. This timeframe was selected to focus on studies reflecting the modern era of CGM technology, characterized by the introduction of factory-calibrated systems and the standardization of CGM-derived metrics, such as Time in Range, following the 2017 international consensus. Full search strings are presented in Table S1 (PubMed), and Table S2 (PsycINFO), Table S3 (Ebsco host, CINAHL), Table S4 (Cochrane Library) in supplementary material. We selected these four databases because they index all major nursing, diabetes care, and diabetes technology journals. The selection of these four databases was strategically designed to capture a multidisciplinary spectrum of evidence across biomedical (PubMed), nursing (CINAHL), psychological (PsycINFO), and evidence-synthesis (Cochrane Library) domains. To complement this search and ensure maximum coverage, we performed manual cross-referencing of the bibliographies of all retrieved papers and relevant systematic reviews to identify any additional studies that might have been indexed in other multidisciplinary databases such as Scopus or Web of Science. The development of the search strategy involved close collaboration with all co-authors. “Continuous Glucose Monitoring” [Mesh], “Education” [MeSH], and “Diabetes Mellitus, Type 1” [MeSH] were some of the keywords and Medical Subject Headings (MeSH terms) combined with Boolean operators AND or OR. The following search filters were applied: “Randomized clinical trials”, “Clinical trials”, “Review”, “Systematic review”,

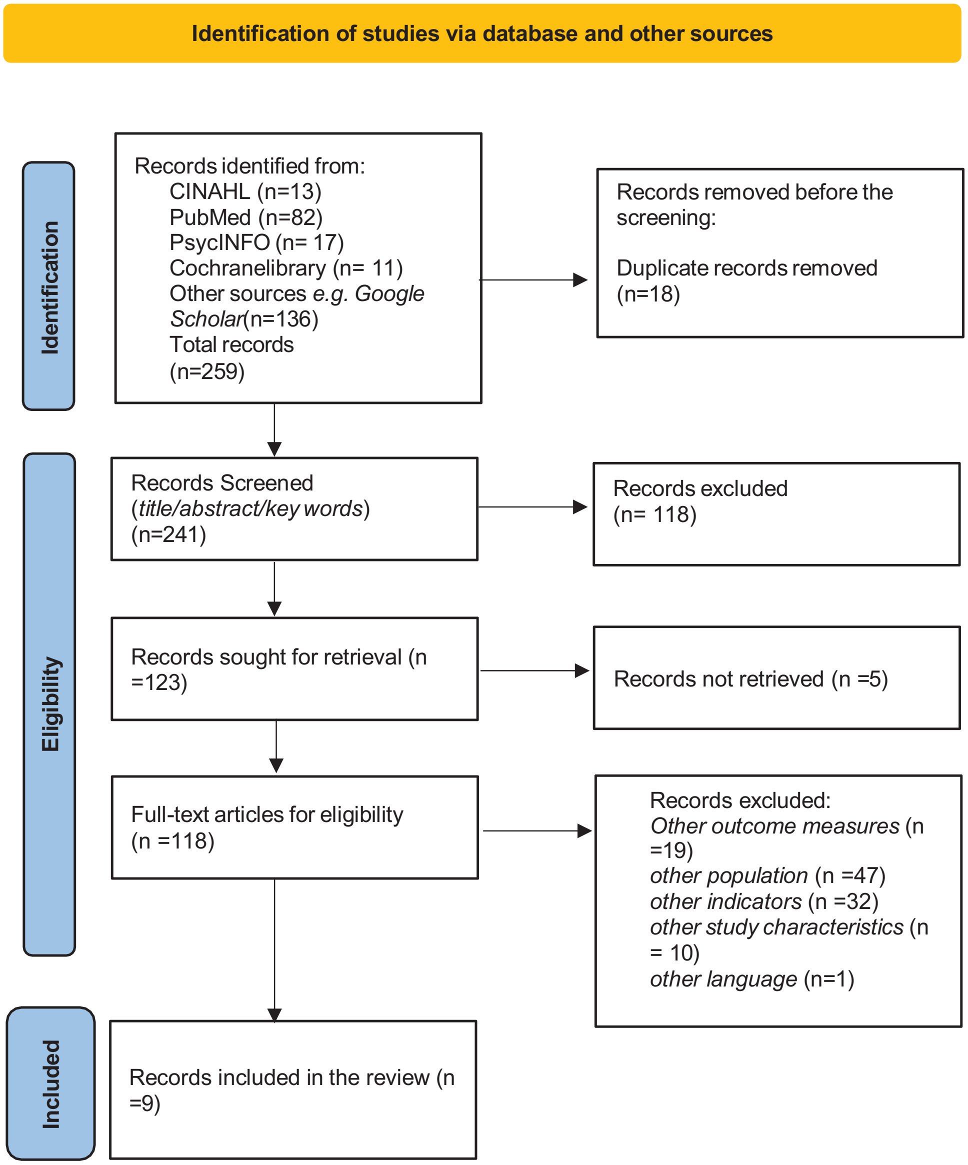

Figure 1 Prisma Flowchart outlining the selection process, eligibility and data extraction.

"Reviews or Meta-analysis", "Age: no limit", "English or Modern Greek", "Published between May 2016 and May 2024", "Humans", and "Full Text". References were managed using the EndNote online software. Subsequently, literature addressing the research question was identified, and relevant texts were selected.

Table 1 Selection Criteria for Inclusion and Exclusion of Studies

	Inclusion Criteria	**Exclusion Criteria**
Population/Participants	People with type 1 diabetes of all ages	People with type 2 diabetes, healthcare professionals, carers
Indicator	Structured education on continuous glucose monitoring use	Education without specific structure on continuous glucose monitoring use, other type of education on diabetes (eg exercise, adherence to treatment plan)

(*Continued*)

Table 1 (Continued).

	Inclusion Criteria	Exclusion Criteria
Comparison	Structured education programs on continuous glucose monitoring self-management	
Outcome measures	Continuous Glucose monitoring	
Time	Published between 2016–2024	
Setting	All settings	
Study Characteristics	Quantitative and Qualitative, primary studies, Systematic reviews and meta-analyses	Systematic review protocol, grey literature
Language of publication	Abstract in English, full text in English or Modern Greek	

Study Selection and Quality Appraisal

Two members of the review team independently conducted a critical appraisal of the studies using the Mixed Methodology Assessment Tool (MMAT) version 2018 Tables S5–S7 in supplementary material.[18] The MMAT is a tool designed for the appraisal stage of systematic mixed studies reviews, ie, reviews that include qualitative, quantitative and mixed methods studies. It allows assessing the methodological quality of five categories of studies: qualitative research, randomized controlled trials, non-randomized studies, quantitative descriptive studies, and mixed methods studies. In accordance with the MMAT development team's recommendations, no overall quality percentage or composite score was calculated for the included studies. This approach ensures transparency and avoids the potential bias of oversimplifying complex methodological strengths and weaknesses into a single numerical value. In cases where discrepancies arose in the critical appraisal outcomes, resolution was achieved through discussion or, if necessary, involvement of additional reviewers for further appraisal.

Data Extraction and Synthesis

The characteristics of the included studies and educational programs were gathered before the synthesis process. Data related to the characteristics of the educational programs were extracted from the reported data of the included studies. One reviewer conducted the data extraction, and three other reviewers performed a quality check to ensure the overall accuracy of the educational programs. A narrative synthesis was employed, following a qualitative assessment of the clinical and methodological heterogeneity of the included studies, to elucidate and condense the principal findings and characteristics of the included studies and the identified educational programs. The alignment of the identified educational programs with the NICE criteria for structured diabetes education was assessed through a rigorous, non-subjective process. Two reviewers independently evaluated each program's curriculum against the six explicit benchmarks defined by NICE (having a philosophy, a written curriculum, trained educators, being quality-assured, being audited, and delivered by a multidisciplinary team) using a standardized binary (yes/no) checklist. Any discrepancies in the categorization were resolved through consensus among the research team to ensure methodological consistency and objectivity.

Results

Selected Studies

Following the application of initial limiters and filters, 259 records were obtained from searches across all four databases and other sources. Among these, 18 duplicates were identified and removed before the screening process. The remaining 241 records were screened for inclusion based on titles, abstracts, and keywords. Subsequently, 118 records were identified as relevant and selected for retrieval and full-text examination. After a thorough review of the full texts, 109 records were excluded for the following reasons: absence of a structured educational curriculum (n=32), inclusion of

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Type 2 diabetes populations (n=47), records being study protocols or conference abstracts (n=10), other language (n=1), and lack of focus on CGM self-management metrics (n=19). The remaining 9 studies were ultimately included in the final synthesis (Figure 1).

Characteristics of the Included Studies

Three randomized control trials, one randomized crossover study, three prospective studies (one prospective cohort and one prospective multicenter study), one qualitative descriptive study, one secondary observational sub-study of the ABC Flash trial were included (Table 2). The studies were published between 2019 and 2023, with most of them published in 2021. One study was published in Journal of clinical nursing, one in Clinical Care and Technology and the remaining seven studies were published in diabetes-related journals such as Diabetes Research and Clinical Practice, Pediatric Diabetes, Diabetic Medicine, Journal of Medical Internet Research Diabetes, and Practical Diabetes.[4,19–26]

Characteristics of Educational Programs

The detailed characteristics of the identified educational programs are presented in Table 3. Nine structured educational programs were identified, all of which target individuals with type one diabetes on Multiple Daily Insulin (MDI) regime, Continuous Subcutaneous Insulin Infusion (CSII), or both, using either rt-CGM or intermittent scanning CGM (isCGM) otherwise called flash technology. The studies describing these educational programs were published between 2019 and 2023, originating from Europe (specifically the United Kingdom (UK), Denmark, and Germany) and non-European countries (United States of America (USA), Korea, and Japan). Examples include The CGM Academy, Spectrum, Flash, and Automated Bolus Calculator (ABC) combined with isCGM from Europe, and IDEAL CGM, ISCHIA, SHARE plus, and Korean Structured Individualizing Education from non-European countries. The target populations included adults, adolescents, and pediatrics.

The programs were delivered face-to-face and virtually/web-based (eg, The CGM Academy, IDEAL CGM) using various methods such as workbooks, apps, videos, scenarios, and online platforms. The CGMs used included rt-CGM systems (The CGM Academy, Spectrum, IDEAL CGM, Korean structured individualizing education, Share-plus), such as Dexcom G5, G6 and intermittent glucose monitoring systems such as Freestyle Libre (Flash, ABC combined with isCGM, ISCHIA group). The total duration of the programs varied from 4.5 to 10 hours.

The programs were classified as structured based on six criteria from the National Institute for Health and Care Excellence (NICE) in United Kingdom (UK)[27] Table 4: be evidence-based and tailored to individual's needs, have specific aims and learning objectives, and support the individual, their family members, and carers in developing attitudes, beliefs, knowledge, and skills for diabetes self-management, have a structured curriculum that is theory-driven, evidence-based, resource-effective, includes supporting materials, and is documented, be quality is assured and reviewed by trained, competent, independent assessors who ensure consistency by meaning it against established criteria, have outcomes that are regularly audited, be delivered by trained educators who understand educational theory appropriate to the age and needs of the individual and are trained and competent to deliver the program content and principles. While each program demonstrated positive outcomes in its respective study context, the lack of standardized reporting across studies precludes a direct comparative ranking of their clinical efficacy.

Discussion

In this mixed-methodology review, we included nine studies documenting nine structured educational programs on CGM self-management. In clinical practice, people with diabetes who use a CGM system often receive technical guidance and education on sensor placement, activation, and the data upload process from the company's representative, a trained Healthcare Professional (HCP), or via video tutorials. However, this technical education does not always follow a specific evidence-based curriculum or structure, as it focuses solely on supporting the person in the technical aspects of sensor use. While clinical improvements were observed across most included studies, the emphasis of this discussion is placed on curriculum quality and alignment with NICE criteria, which constitutes the primary focus of our analysis.

Table 2 Characteristics of the Included Studies

Authors, Year, Journal	Study Design and Aim	Population	Duration of Educational Intervention and Intensity	Primary Outcomes
Hermanns et al (2019); Diabetes Research and Clinical Practice[21]	Randomized clinical trial Aim: We have developed and evaluated a structured education and treatment program, termed FLASH, to assist Flash System Glucose Monitor (FSGM) users to understand and use the available glycemic information for optimization of their diabetes treatment	N=216 Adults 16–75 years old	6 weeks It consists of 4 educational sessions, lasting 90 min each.	• **Hba1c improvement**: During the intervention phase, HbA1c was reduced by 0.33 percentage points in the FLASH group and by 0.14 percentage points in the control group. • **Hba1c improvement maintenance at follow-up**: At 6-month follow-up glycemic outcomes as measured by HbA1c improved in both the FLASH group (−0.28%, 95% CI 0.16 to 0.40%) and in the control group (0.11%, 95% CI 0.00 to 0.22%).
Smith et al (2021); Journal of Medical Internet Research Diabetes[24]	Randomized Control Trial Aim: a pilot feasibility study testing a theory-driven, web-based intervention designed to provide extended training and follow-up support to adolescents and young adults newly implementing CGM and to describe CGM adherence, glycemic control, and CGM-specific psychosocial measures before and after the intervention.	N=8 to adolescents and young adults 15–24 years old	6 weeks	• **CGM Satisfaction improvement**: Within the intervention group, median CGM satisfaction scale scores improved from 3.7 at baseline (range 1.3–4.7) to 3.9 at follow-up (range 3.6–4.3). • **Hba1c improvement**: Four participants within the intervention group saw an improvement in HbA1c levels, ranging from 0.1% to 2.5%.
Pemberton et al (2021); Pediatric Diabetes[23]	Prospective cohort study Aim: Create and evaluate the effectiveness of a structured education program in children and young people (CYP) with type 1 diabetes using continuous glucose monitoring (CGM).	N=50 pediatric patients children and young adults	2 months, 5 sessions. Session 1 30 minutes, Session 2 180 minutes, Session 3 120 minutes, Session 4 120 min, Session 5 120 min.	• **Time Below Range (TBR) improvement**: The percentage of readings for TBR2 dropped from 3.2% to 0.4% a reduction of 2.8% [95% CI (2.4, 3.2), p<0.001], TBR dropped from 10.4% to 2.1%, a reduction of 8.3% [95% CI (6.8, 9.8), p<0.001] • **Time Above Range (TAR) improvement**: TAR dropped from 42.2% to 40.3%, a non-significant reduction of 1.9% [95% CI (−2.4, −6.3), p =0.377] and TAR2 dropped from 14.1% to 7.3%, a reduction of 6.8% [95% CI (5.6, 8.0), p<0.001]. • **HbA1c Reduction**: HbA1c dropped from a mean of 7.4 to 7.1% (57.6 to 53.8 mmol/mol), a reduction of 0.3% (3.8 mmol/mol) [95% CI (1.9, 5.7 mmol/mol), p<0.001]. • **Time in Range (TIR) improvement**: TiR increased significantly from 47.4% to 57.0%, an increase of 9.6% [95% CI (6.2, 13.1) p<0.001].

(*Continued*)

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Table 2 (Continued).

Authors, Year, Journal	Study Design and Aim	Population	Duration of Educational Intervention and Intensity	Primary Outcomes
Schluter et al (2021); Diabetic Medicine[22]	Prospective multicenter study Aim: The "CGM-TRAIN study" evaluated the efficacy and acceptance of SPECTRUM and real-time continuous glucose monitoring (rt-CGM) systems among adults with insulin therapy.	N=120 adults	6 modules 2 months duration 90 minutes each	• **CGM Knowledge improvement and maintenance**: The rt-CGM-specific knowledge (scale 0–40) increased by 43% from 21.2 ± 7.6 before the training modules to 30.4 ± 4.5 right after last module at visit 2 ($p < 0.001$). This level of knowledge persisted until visit 3 (29.4 ± 4.5; 39% increase from visit 1). • **Increased satisfaction with the program**: The overall rating for satisfaction was positive with 1.4 ± 0.5 points (1–3; n = 110) (scale: 1 = high satisfaction to 6 = low satisfaction). • **Increased acceptance and satisfaction with rt-CGM**: Acceptance of rt-CGM was high directly after training at visit 2 with 6.3 ± 0.6 (4.1–7.0; n = 110) and remained stable until visit 3 (6.3 ± 0.7; 2.5–7.0; n = 108). At visit 2, satisfaction with rt-CGM was high with 4.2 ± 0.5 (2.0–5.0; n = 110) (scale: 1 = low satisfaction to 5 = high satisfaction). • **Hba1c improvement**: HbA1c levels decreased from 61 ± 14 mmol/mol (7.7 ± 1.3%) (ranging from 28 mmol/mol [4.7%] to 132 mmol/mol [14.2%]) at visit 0 to 60 ± 14 mmol/mol (7.6 ± 1.3%) (ranging from 32 mmol/mol [5.1%] to 146 mmol/mol [15.5%]) at visit 3 ($p = 0.04$).
Yoo et al (2022); Diabetes Research and Clinical Practice[5]	Randomized controlled trial Aim: to evaluate the efficacy of structured individualized education combined with rt-CGM on glycemic outcomes in adults with type 1 diabetes.	N=47 adults with poorly controlled type 1 diabetes 18–70 years old on MDI	3-month study 3 sessions of education 30–120 minutes duration	• **TIR Improvement**: Education group had a higher TIR than the control group (63.4% vs. 44.5%) at week 12, with a 15.3% difference ($p < 0.001$). • **HbA1c Reduction**: HbA1c levels decreased by 0.5% (5.5 mmol/mol) more in the intervention group compared to the control group at week 12 ($p < 0.001$). • **Extension Period Results**: TIR increased significantly by 8.9% (2.2 to 15.6, $p = 0.01$) in the educated control group during the extension period.

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ISCHIA Study Group Murata et al (2022); Diabetes Research and Clinical Practice[19]	Randomized cross over study Aim: to compare intermittent-scanning continuous glucose monitoring (isCGM) device with structured education (Intervention) to self-monitoring of blood glucose (SMBG) (Control) in the reduction of time below range.	N=104 Adults 20–74 years old	Intervention period 84 days	• **TBR improvement**: The primary endpoint was the decrease in the time below range (TBR; <70 mg/dL).
Pemberton et al (2022); Clinical Care and Technology[20]	Prospective study Aim: 1 Compare the clinical and cost effectiveness of teaching Dynamic Glucose Management (DynamicGM) strategies by the established Face-to-Face CGM Academy with VIRTUAL delivery using flipped learning. 2. Combine Face-to-Face and VIRTUAL data to ascertain the most effective DynamicGM strategies predicting TiR at 6 months and create a user-friendly infographic incorporating these strategies.	N=100	5 sessions 2 months duration	• **Diabetes specific measurements**: The mean difference in HbA1c, TIR and episodes of severe hypoglycemia between VIRTUAL and Face-to-face groups were 1.16 ($p = 0.47$), 0.76 ($p = 0.78$) and 0.06 ($p = 0.61$) respectively. • **Cost effectiveness**: Delivery cost per 50 Children and Young Patients with Diabetes for VIRTUAL and Face-to-Face were $5752 and $7020, respectively. • **TIR strongest predictors**: The strongest predictors of TIR (n = 100) were short bursts of exercise (10–40 min) to lower hyperglycemia ($p < 0.001$), using trend arrow adjustment tools ($p < 0.001$) and adjusting pre-meal bolus timing based on trend arrows ($p < 0.01$).
Allen et al (2023); Journal of Clinical Nursing[25]	Qualitative Descriptive study Aim: To examine the perceptions of the SHARE plus intervention and its effects on communication, collaboration, and involvement in day-to- day diabetes management in older adults with type 1 diabetes (T1D) and their care partners.	N=10 Older adults and their partners ≥65 years old	12 week intervention	• **Improved communication and collaboration between dyads**: The SHARE plus intervention improved dyadic quality of diabetes-related communication and increased collaboration, especially around when and how to intervene with diabetes management. • **Improvement of knowledge and supporting mechanisms**: The SHARE plus intervention increased diabetes knowledge across the dyads; improving confidence and helping partners understand how to navigate symptoms and behaviors and when to intervene.
Raimond et al (2023); Practical Diabetes[26]	Secondary observational sub-study of the ABC Flash trial Aim: to describe the educational program and user's guide for decision support for persons with type 1 diabetes who commence carbohydrate counting with automated bolus calculator (ABC) and flash (intermittently scanned) glucose monitoring (is-CGM) and to evaluate the impact of the program and the combined interventions on patient-reported outcome parameters	N=35 adults with T1DM on MDI 22–71 years old	7 topics, 4.5 hours in total	• **Treatment satisfaction improvement and diabetes related burden**: Implementation of the educational program and initiating combined intervention with carbohydrate counting with ABC and is-CGM improve treatment satisfaction and different psychosocial areas among persons with type 1 diabetes. Decreased diabetes-related burden on quality of life with regards to work and sex life. • **Hba1c improvement**: 6mmol/mol decrease in HbA1c

Notes: Outcomes are presented exactly as reported in the original studies to maintain data accuracy; therefore, units and reporting formats may vary across programs.

Table 3 The Detailed Characteristics of the Identified Educational Programs

Education Program/ Training Program	Year & Country of Development	Delivered By	Target Group/ Population	Group Teaching/ Individualized Teaching	Method of Delivery	Type of CGM Used	Duration of Program	Program Curriculum	Evaluation
The CGM Academy Face to Face (FtF)	2020, United Kingdom (UK)	Diabetes nurse or dietitian and CGM Coordinator (clinical support worker)	Children and Young People (CYP) on Continuous Subcutaneous Insulin Infusion (CSII) or Multiple Daily injections (MDI)	Group teaching	FtF using an interactive workbook which incorporates problem-based learning scenarios to demonstrate learning and a companion digital workbook with videos of real-life Dynamic Glucose Management was created.	Dexcom G6	10 hours, Duration in weeks 2 months	5 Teaching sessions 1. Awareness session to prepare the CYP and family for CGM. 2. and 3 focus on preventing hypoglycemia and sessions 4 and 5 teach more advanced DynamicGM strategies to increase TiR. 6. A clinical review to assess ongoing funding for CGM.	Efficacy and cost implications
The CGM Academy (Virtual)	2022, UK	Diabetes Educator	Children and Young Adults	Group teaching	Virtually flipped learning where educational material was provided beforehand for self-learning and the sessions with diabetes staff were used to deepen understanding >30 videos Virtual workbook	Dexcom G6	10 hours	3 teaching sessions Pre-program work (180 minutes). Session 1 (60 minutes): Start CGM device, recap session 1, homework for session 2. Session 2 (90 minutes): AGP review and DynamicGM preventing post-meal spikes, meal-time insulin guide and exercise management, homework for session 3. Session 3 (90 minutes): AGP review and advanced DynamicGM – exercise to lower highs between meals, superbolus, bolus timing based on value and trend arrow, homework for clinical review	Efficacy and cost-effectiveness of the virtual program (VIRTUAL) compared to the original face to face program (FtF)

Spectrum	2020, Germany	The group of authors was composed of diabetologists, certified diabetes educators and scientists	Three age-adjusted versions: for adults, parents of younger children and adolescents with type 1 diabetes on MDI	Group teaching	FtF specific sets of slides for adults (introductory session + 6 training modules), for parents with younger children and adolescents (introductory session + 5 training modules for each version). The slides are digitally available on a memory stick. A SPECTRUM folder printed form	Various rt-CGM excluding is-CGM	9 hours, 2 months	SPECTRUM consists of one introductory module followed by six training modules. Each module lasts approximately 90 min.	Efficacy and acceptance of the program and of rt-CGMs
IDEAL CGM	2021, United Stated of America (USA)	Platform web-based/Mobile phone based and Health Care Professionals (HCP)	Patients 15–24 years old with type 1 diabetes new to CGM	Group teaching	Web-based intervention	Dexcom G5	7 modules, Median time spent within the web-based platform was 32 minutes (range 0–138 minutes) 6 weeks period	Introduction, Expectation and Goal setting, Treatment decisions –the basics, CGM Alarms, CGM Placement and adhesion, Uploading and sharing, Interpreting Data-Advanced treatment decision	Adherence to CGM, changes in glycemic control, psychosocial measures, and knowledge levels in the intervention and enhanced standard care groups
FLASH	2019, Germany	Diabetologist and employing at least one certified diabetes educator	Participants 16–75 years old on MDI and CSII	Group teaching	FtF, written material and worksheets and encouraged to test the contents of each lesson on their own and to discuss their experiences in the group setting.	FreeStyle Libre	Over 6 weeks, 4 education sessions, 90 min each	1. Information about and motivation for using flash glucose monitoring. 2. Recognition of glucose patterns. 3. Therapy adjustments based on pattern recognition and AGP.4. Review of therapy adjustments.	The impact of the program on HbA1c as a primary outcome for Flash sensor-based glucose monitoring (FSGM) users and on a broad set of glycemic, psychosocial and behavioral outcomes

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Table 3 (Continued).

Education Program/ Training Program	Year & Country of Development	Delivered By	Target Group/ Population	Group Teaching/ Individualized Teaching	Method of Delivery	Type of CGM Used	Duration of Program	Program Curriculum	Evaluation
Structured Education from ISCHIA Study Group	2022, Japan	Members of ISCHIA study Group, HCPs	Adults 20–74 years old on MDI	Group Teaching	F2F in outpatient setting using education material	First Generation Freestyle Libre	84 days intervention period, no hourly duration mentioned	1. Sensor settings 2. Interpreting the sensor glucose level 3. Effective use of Freestyle Libre 4. To prevent hypoglycemia	Effects of isCGM device with structured education regarding the trend arrow and scanning frequency on the prevention of hypoglycemia compared to Self-Monitoring Blood Glucose (SMBG).
Structured individualizing education	2022, Korea	Diabetes experienced Nurse and Dietitian	Adults 18–70 years old	Individualized	Education sessions were delivered through in-person or by phone call	Dexcom G5	3 sessions 30 to 120 min per visit	Baseline: How to use CGM and interpret AGP results • How to calculate total daily insulin dose, initiate and adjust basal insulin • How to check and adjust insulin-to-carbohydrate ratio and correction factor • How to calculate prandial insulin dose using detailed carbohydrate counting and correction dose • Using trend arrows to avoid glycemic variability • How to solve unwanted glucose patterns • Using the AGP report to modify behavior or therapeutic decisions	The efficacy of structured individualized education combined with real-time continuous glucose monitoring (rt-CGM) on glycemic outcomes in adults with type 1 diabetes.

Share plus	2023, USA	Research Team	Older Adults with their care partners on MDI and CSII	Group teaching	Telehealth mobile app for data- sharing	Dexcom G6	190-minute education session	1. Training in communication strategies, 2. Problem-solving strategies, 3. Development of an action plan	The perceptions of the SHARE plus intervention and its effects on communication, collaboration, and involvement in day-to-day diabetes management in older adults with ype 1 diabetes (T1D) and their care partners.
The educational program on initiating the combination of ABC and isCGM, specifically for the Automated Bolus Calculator (ABC) Flash trial.	2023, Denmark	Diabetes Specialist Nurse and Dietitian	Adults	Group teaching	F2F with telephone follow up individual consultations	Freestyle Libre	4.5 hours 26 week period including follow ups 1hr, 30mins, 30–60mins, 30 mins, 30–60 mins.	1. Theoretical and practical training in carbohydrate counting, 2. Bolus calculation and the ABC, 3. Introduction to isCGM use, 4. How to incorporate glucose trend arrows to adjust the ABC settings	The impact of the educational program and effect on the quality of life, treatment satisfaction, diabetes-related distress, and psychosocial self-efficacy among participants in the combined ABC and isCGM arm from the ABC Flash trial.

Notes: Program duration is reported exactly as documented in the original studies (either in hours, weeks, or sessions) to ensure accuracy and avoid potential errors through unauthorized conversions.

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Table 4 Classification of the Educational Programs Based on the UK NICE Structured Education Criteria

Educational Program	Evidence-Based Curriculum	Specific Aims and Learning Objectives	Supports the Adoption of Behaviors/Attitudes/ Beliefs/Knowledge/Skills to Self-Management	Structured Curriculum Resource Effective with Written Material	Quality Assured	Audited Outcomes	Delivered by Trained Educator
The CGM Academy	✓	✓	✓	✓	✓	✓	✓
The CGM Academy virtual setting	✓	✓	✓	✓	✓	✓	✓
Spectrum	✓	✓	✓	✓	✓	✓	✓
IDEAL CGM	✓	✓	✓	✓	✓	✓	✓
FLASH	✓	✓	✓	✓	✓	✓	✓
Share plus	✓	✓	✓	✓	✓	✓	✓
ISCHIA	•	✓	✓	•	•	✓	✓
ABC/isCGM	✓	✓	✓	✓	✓	✓	✓
Korean structured individualizing education	✓	✓	✓	•	✓	✓	✓

Notes: • = Educational Program does not fulfill this characteristic. ✓ = Educational Program fullfills this characteristic.

Structured education, as endorsed by the Diabetes UK framework, is categorized as Level 3 diabetes education. According to NICE 2023,[27] people with type one diabetes should be offered a structured educational program to promote self-management. NICE defines structured education as:

> A planned and graded program that is comprehensive in scope, flexible in content, responsive to an individual's clinical and psychological needs and adaptable to his or her educational and cultural background.

A CGM-structured education curriculum should cover various topics, such as CGM type, physical placement, site issues, alerts/alarms, data transmission, sensor lag, glucose reports, calibration, data sharing, arrow interpretation and dose adjustments. For an educational program to be classified as structured, it should comply with NICE's structured education characteristics as presented in Table 3. A structured education program can reduce the self-care burden, ensure realistic expectations are met, promote the achievement of glycemic targets, and improve quality of life.[28,29] According to ADCES,[8] diabetes care and education specialists play a vital role not only in the delivery and support of the program but also in offering expert advice on technology integration and its continuity in daily life. Although many programs are labelled and described as structured, they do not always meet all the necessary requirements.

Education Format and Educational Material

Regarding the delivery format of the programs in this review, some were delivered virtually (DynamicGM in a Virtual setting, IDEAL CGM), while the rest were conducted face-to-face. According to literature, blended educational programs, which are delivered both in-person and through digital means, are more effective for people with type one diabetes.[30] The selection of the materials used to deliver education plays an important role in comprehension, consolidation, and acceptance of the new information.[31]

The use of infographics in the virtual version of the DynamicGM program assisted the participants in consolidating the key points of the dynamic glucose management strategies, as these strategies were the strongest predictors TIR.

Infographics in a teaching process promote health literacy by simplifying complex concepts, enhancing comprehension, and improving retention.[32] The IDEAL CGM training program utilized a web-based training intervention via mobile phone or desktop, allowing participants to watch educational videos on different modules, engage in supervised by HCP peer discussions, and evaluate their knowledge through quizzes.

According to ISPAD Guidelines 2022,[31] web-based educational platforms and peer-led learning are of utmost importance for better understanding, engagement, and comprehension of the educational content, ultimately leading to improved diabetes management. The Share plus program utilized telehealth, while the ABC/isCGM program combined a bolus calculator application with isCGM upload to a remote monitoring platform. Telemedicine and remote CGM monitoring contribute to safe therapy adjustments based on glucose profiles, reduce the burden of in-person visits (eg, time of work, transportation, waiting), facilitate collaboration between HCPs and people with diabetes in evaluating data and developing care plans, and enable more efficient time management and resource allocation.[33]

The Flash education program led to more frequent evaluation of trend arrows and glycemic variability more frequent daily adjustments based on the data uploaded to the cloud. This demonstrates that CGM education ensures more effective use of technology and promotes self-management behaviors.

Peer-Led Education and Learning

Selecting the most effective educational method is crucial for promoting diabetes self-management and self-care. Peer-led learning is one such method, and it was associated with increased satisfaction in the IDEAL CGM program. The Flash educational program is also based on peer learning, as participants are encouraged to exchange their experiences. A peer is defined as a person with the same condition who can motivate others in the same social group.

According to a randomized clinical trial[34] comparing the effectiveness of peer-led education with HCP-led education, peer-led education improved adherence to self-care behaviors. The Dose Adjustment for Normal Eating (DAFNE) structured education program,[35] endorsed by NICE in the UK, also promotes peer learning. The concept of the expert patient in promoting empowerment and self-efficacy among people with chronic conditions, specifically diabetes, was first introduced in 2002 by the Department of Health, National Health Service (NHS).[36]

Real-Time CGM versus Intermittent-Scanning CGM/Flash Technology

In the structured educational programs included in our review, participants used various CGM devices from different pharmaceutical companies, including both isCGM and rt-CGM. According to ALERTT1 trial,[37] which compared isCGM with rt-CGM, switching from isCGM to rt-CGM lead to an improvement in TiR after 6 months of treatment. Additionally, the HART CGM study showed that switching from isCGM to rt-CGM can reduce the time spent below the target range <70mg/dl), thus decreasing hypoglycemia. Hence, rt-CGMs are superior to isCGM, providing greater benefits and better glycemic management.[38,39] While the structured education programs reviewed here do not all perform head-to-head comparisons between the two technologies, the clinical benefits of rt-CGM (eg, alerts and alarms) provide a more robust framework for proactive self-management education. When rt-CGM is offered in combination with self-management education, it becomes a valuable technological tool, particularly for people with hypoglycemia unawareness and severe recurrent hypoglycemic episodes. This is due to rt-CGM's features, such as low and high alarms and predictive alerts for glucose projection, which isCGM systems lack.

In the ISCHIA study, although there was a significant reduction in the time spent below the target range (21.9%) in the group that received structured education, there was no reduction in the emotional burden of diabetes or the fear of hypoglycemia. This may be because the study used a first-generation Libre sensor, which lacked the hypo/hyperglycemia alerts and alarms, as rt-CGM was unavailable in Japan then. Participants were also encouraged to perform adjunctive measurements using a Self-Monitoring of Blood Glucose (SMBG) system and to scan sensors frequently. Alerts and alarms in rt-CGM systems are crucial as they allow users to take therapeutic actions, thereby preventing hypoglycemic episodes and enabling appropriate treatment decisions. However, while alarms and alerts are highly beneficial, proper use and setup are essential to meet individual needs and prevent alarm fatigue.[40,41]

Group Teaching vs Individualized Education

Although NICE[28] recommends in its quality standards that all adults with type one diabetes should be offered structured self-management group education, there is no one-size-fits-all approach. According to the literature, both group and individualized teaching methods are beneficial. Group diabetes self-management teaching is cost-effective compared to individualized. It requires a facilitator with high expertise, not only in diabetes and diabetes technology but also in managing group dynamics. In group teaching, there is a lot of interaction among participants from the same social group, sharing common experiences, challenges, and goals, which leads to greater empowerment and positive self-management behavior change.

Before conducting group teaching, individual needs and the group's culture and homogeneity should be assessed. Group size is crucial (not more than 8 participants), as larger groups make it difficult to individualize the teaching needed.[42–44] Most of the educational programs included in this review are based on a group teaching approach. In contrast, one program, the Korean individualized education program, was conducted either in person or by phone, based on the participant's understanding.

Psychological and Behavioral Variables

Diabetes can cause many distressful experiences in daily life, directly affecting the quality of life and mental and emotional health of the person. Addressing psychological, behavioral, and emotional variables is of utmost importance, as any imbalance in these areas can lead to worsening diabetes control, elevating Hba1c levels, and poor adherence to care plan.[44] The Flash and ABC/is-CGM program addresses various psychological and behavioral aspects of living with diabetes, including diabetes distress, satisfaction with glucose monitoring, depressive symptoms, diabetes empowerment, self-efficacy, treatment satisfaction, hypoglycemia worry, hypoglycemia awareness, and the use of CGM features.

According to the literature, diabetes distress has gained significant attention because it is directly linked to diabetes management and can manifest in various forms, such as feelings of powerlessness, fear of hypoglycemia, burnout, and frustration with the healthcare team.[45] The prevalence of diabetes distress is high (42–77%) among people with type one diabetes.[46] Research identifies seven significant sources of diabetes distress in people with type one diabetes, including feelings of powerlessness and helplessness over diabetes control, social distress (such as fear of diabetes stigma), the role of family or care partners in diabetes management and their level of involvement, eating distress related to the impact of food on glucose levels, physician distress from insufficient or unsatisfactory support from the healthcare team, and hypoglycemia distress, particularly related to early identification of the symptoms, especially at night or while driving.

In the ISCHIA program, diabetes distress levels did not reduce, likely because the isCGM used did not have alarms and alerts, which heightened fear of hypoglycemia.[46] The Share-plus program focused on improving communication between people with diabetes (PWD) and their care partners (CP), using rt-CGM to foster better communication, collaboration, and management of disagreements.

Self-Efficacy and Educational Programs

Self-efficacy is the perception of a person's ability to perform tasks and achieve goals through the implementation of specific behaviors.[47] Individual goal-setting and decision-making processes are common approaches in most of the educational programs included in this review. These strategies help improve self-efficacy by overcoming emotional and motivational obstacles and negative attitudes toward the effective use of diabetes technology, which can hinter CGM acceptance and glycemic control. The ABC/isCGM program also addresses the psychological and emotional burdens of diabetes self-management for participants, focusing on improving quality of life in areas such as work, sex life, psychological self-efficacy, and treatment satisfaction.

The Spectrum program evaluates the participants' satisfaction levels and acceptance of technology based on two core factors influencing acceptance: perceived usefulness and perceived ease of use, both of which are influenced by various other variables.[48] The IDEAL CGM program measures the satisfaction and acceptability of the program, as well as CGM self-efficacy and adherence.

Situational Awareness and Proactive Engagement

In diabetes self-management, very often, there is a discrepancy between intention and behavior. Based on the Two Mind Theory (TMT),[49] a specific cognitive process is involved in decision-making based on the intuitive and narrative system. The intuitive system determines the final behavior automatically without conscious contemplation of the positive or negative outcomes. In contrast, the narrative system involves processing the past and planning of future behaviors. When a stimulus arrives, the intuitive system responds with an automatic behavior, then the behavior and the repercussions are processed in the narrative system, where there is an analysis of the current behavior in conjunction with the past attitudes and beliefs.

Educational programs on diabetes self-management should recruit techniques approaching both the intuitive system by tricking it with environmental cues and training it with positive feedback or negative outcomes, and the narrative system by planning future behaviors and by delaying instant response, giving the time to contemplate the outcomes of the behavior. Situational awareness (SA)[50] is a term used to describe the person's ability to appraise, comprehend and efficaciously reply to a situation, processes that belong to the intuitive system. According to the literature, SA is a strong predictor of TIR, including proactive management and regular feedback.

Educational programs should include proactive rather than reactive glucose management, exploiting the full potential of rt-CGM features with the predictive, high and low glucose alarm. In DynamicGM program, the 7 Dynamic strategies promote proactive glucose management based on the glucose value and the trend arrow. The Spectrum program also promotes proactive management skills through the discussion of management of real-life scenarios based on glucose value, diagram and trend arrow. It should be noted that this review did not perform a formal comparative evaluation or meta-analysis to rank the programs. The identification of certain programs as more "comprehensive" is based on the qualitative alignment of their curriculum with established clinical guidelines and the incorporation of advanced CGM features.

Strengths and Limitations

To our knowledge, this study is the first mixed-method review conducted on CGM educational programs used to promote CGM self-management. In our review we conducted a critical appraisal, classifying the educational programs based on specific quality standards aiming to identify the most appropriate ones for clinical practice implementation.

We employed an extensive search strategy to identify all potentially pertinent studies, searching databases such as Cochrane Library, CINAHL, PubMed, and PsycINFO. We also excluded unpublished findings or studies from the grey literature, potentially introducing publication bias. While publication bias may influence reported clinical outcomes, our evaluation primarily relied on the NICE qualitative criteria for structured diabetes education. These criteria emphasize structural and pedagogical rigor, providing a robust framework that is less susceptible to the biases typically associated with quantitative outcome reporting. Nevertheless, it's worth mentioning that the methodological quality of grey literature is generally lower compared to that of published studies.[50,51] Despite our thorough and extensive literature search, our study only incorporated English language studies.

The quality of the validation studies was independently evaluated by two reviewers, with any discrepancies resolved by a third reviewer. However, some limitations affect our findings. Firstly, although our search strategy aimed to encompass all relevant literature, it's plausible that some papers may have eluded inclusion due to the nature of this topic. Secondly, diabetes-related clinical performance of the educational programs (ie diabetes-specific clinical outcomes) was not analyzed and compared in our study. This decision stemmed from the fact that assessing the effectiveness of the educational programs was not one of the main objectives of our study, compounded by the heterogeneity of programs within the literature included. However, both aspects (program's structure, approach and clinical performance) are essential for evaluating the appropriateness of an educational program in clinical practice. Furthermore, some of the included studies featured small sample sizes (eg, N=8 to N=10), which limits the generalizability of their clinical results and precludes the calculation of formal effect sizes. Consequently, these studies were synthesized qualitatively, with a primary focus on the feasibility of the interventions and the structural alignment of their curricula with established guidelines (NICE) rather than their statistical power. This approach allowed for a comprehensive mapping of existing educational models regardless of the trial size.

Conclusions

Technology has the potential to ease the burden of diabetes self-care, but if its use does not align with a person's realistic expectations, abilities, and culture context, it will not be successful. Structured education is the key to achieving technology acceptance, continuity, and integration. Based on this mixed methodology review and the CGM educational programs identified, we conclude that the programs meeting the structured education guidelines- those with the most robust and holistic structure and curriculum- are the most effective. These programs address all adult and pediatric populations and incorporate the most effective approaches, methods, and materials. They include group teaching with peer-led learning, address behavioral change and psychological aspects, promote problem-solving, proactive management and decision-making processes, and utilize rt-CGMs, the literature identifies as superior to isCGM, due to its incorporation of alarms and alerts. Additionally, these programs assess participants' learning and understanding.

Educational programs on rt-CGM that have specific aims and objectives, are theory- based, include evidence-based curricula, incorporate problem-solving and behavior change strategies, focus on achieving time in range, reducing time below and above range, educate on exercise management, and use trend arrows in insulin decision-making, are more effective. These programs also empower people with type one diabetes to review and assess CGM-derived data and make necessary adjustments to improve glycemic control. Taking all of this into consideration, we conclude that the CGM Academy program, both in face-to-face and virtual format, is more suitable for pediatric and young adult populations, while the Spectrum program is appropriate for both pediatric and adult populations regardless of rt-CGM manufacturer. In conclusion, further effort is needed to implement current or new standardized structured educational programs accompanied with high-quality controlled studies with proven clinical benefits, in larger populations and incorporate them into diabetes technology national framework for better clinical outcomes through safe and effective use of technology advancement and benefits.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author, [EP], upon reasonable request. Additional material for this article is available in the online supplementary materials.

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