Systematic Review Article

The Accuracy, Effectiveness, and Psychosocial Benefits of Continuous Glucose Monitors as Compared to Traditional Fingerstick Blood Glucose Monitoring in Type 1 Diabetic Populations: A Systematic Review

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ABSTRACT

Type 1 diabetes (T1D) management relies on accurate and consistent glucose monitoring. While self-monitoring of blood glucose (SMBG) has long been the standard for type 1 diabetes (T1D) care, continuous glucose monitoring (CGM) technologies have gained prominence due to their ability to provide real-time glucose trends. This systematic review's objective is to analyze seventeen studies (2015-2025) to evaluate clinical and psychosocial outcomes of CGM versus SMBG in T1D, with attention to device type, accuracy constraints (exercise, medication interference), and user factors. Previous research has demonstrated the effectiveness of CGM in lowering hemoglobin A1c (HbA1c) levels and improving glycemic control, but few have reviewed holistically comparing variations in study design, response variables, and type influence outcomes. This study addresses that gap by analyzing key response variables (HbA1c, time in range, hypoglycemia, and glycemic variability), CGM accuracy metrics, study design features, and patient-reported outcomes such as behavioral changes and quality of life. The findings show that CGM use typically increased time in range by 5-10 percentage points and reduced time below range by 2-7 percentage points. HbA1c levels ranged from no change to about -0.5% over 12-16 weeks. In children with elevated HbA1c using isCGM 2.0, time below range fell by 6.4 percentage points over 12 weeks without an HbA1c change; these time below range benefits and higher testing frequency were sustained to 24 weeks after crossover to isCGM in both arms. Psychosocially, early CGM after diagnosis was widely endorsed by parents for reduced worry, better sleep, and remote monitoring benefits. Primary limitations in this review include heterogeneity in device types, populations, durations, and co-interventions. These results highlight the clinical value of CGM in improving both physiological and psychosocial outcomes. Differences in CGM technology, calibration needs, and adherence also impacted outcomes. These results reinforce the clinical value of CGMs while highlighting the need for standardized protocols and broader inclusion across demographic groups to optimize diabetes care.

Keywords: Type 1 Diabetes; CGMs; Hypoglycemia; SMBG; Glycemia; HbA1c; Glucose Monitoring; Diabetes

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INTRODUCTION

Type 1 diabetes is an autoimmune disease that leads to pancreatic beta cell loss and insulin deficiency, requiring life-long monitoring of glucose and insulin therapy. Traditionally, fingerstick blood glucose

monitoring has been the main method of observing glucose levels, often several times daily. However, CGM systems such as the Freestyle Libre and Dexcom have recently become available alternatives that may give more detailed insight into glycemic variability and can also potentially lead to improved HbA1c levels (1).

While CGMs are promoted to give more continuous feedback, how well the results approximate laboratory HbA1c measurements and how well they reflect the day-to-day variation of glycemia compared with standard fingersticks is unknown. In short, their comparability to fingerstick methods is not yet well understood (1). Questions also remain about (i) the magnitude and consistency of HbA1c change, (ii) accuracy constraints under dynamic conditions (e.g., exercise) and potential drug interference, and (iii) user and system factors (e.g., motivational stage, early versus delayed initiation, and insurance coverage) that affect efficiency of CGMs. This makes it difficult for clinicians to determine whether CGMs truly optimize clinical outcomes in this population or whether fingerstick methods are sufficient.

This review aims to answer the following question: Do CGMs (versus SMBGs) more accurately and comprehensively capture glycemic control and variability and translate into improved HbA1c and psychosocial outcomes across T1D populations, and under what device and user conditions? The hypothesis is that CGMs, with their frequency of data collection and trend identification, are more accurate in monitoring glycemic control. Acknowledgement of these distinctions can aid in device recommendations, individualize diabetes care plans, and improve glycemic control and quality of life in individuals with T1D.

METHODS AND MATERIALS

A systematic review (PRISMA-guided, Figure 2) of clinical trials (2015–2025) comparing CGM use with SMBG or alternate CGM strategies in people with T1D was conducted. The review includes randomized and prospective studies reporting HbA1c and/or CGM metrics (time in range, time below range, time above range, coefficient of variation), device accuracy or interference testing, and patient-reported outcomes. Pediatric (including very young children), adolescent/young adult, adult, and pregnancy cohorts were eligible, and geography was unrestricted. Studies that were exclusively qualitative were included when they addressed early initiation and caregiver experience. Data were abstracted into a standardized template (population, device, duration, comparators, outcomes, adverse events), and synthesized narratively due to heterogeneity in device generation, follow-up, and co-interventions (e.g., behavioral training). Risk bias was assessed using the Cochrane tool for risk bias (Figure 1). Ten studies were randomized clinical trials, two were diagnostic test accuracy studies, four were cohort/analytical cross-sectional studies, and one was a qualitative study. Key studies informing pediatric glycemia and psychosocial outcomes included a 12-week Libre 2 RCT and its 12-week extension (children, elevated HbA1c), an exercise-accuracy study (Dexcom G4/G5), a very-young 52-week trial with and without behavioral intervention, an early-CGM qualitative study, and a motivational-stage analysis.

RESULTS

How were the studies designed?

A more detailed description and comparison of study designs is included in this section. The response variable tested, such as HbA1c, time in range, or hypoglycemia frequency, directly influences how clinical effectiveness is measured and compared across studies. Similarly, the control group and study design, including whether trials used parallel groups, crossover methods, or delayed intervention arms, affect internal validity and the strength of comparative conclusions. Finally, the inclusion criteria used in each study determine the characteristics of the population under investigation, influencing both the relevance of results to specific subgroups, such as children or pregnant women, and the generalizability of the review's findings.

Response Variable Tested

Most papers focused on glycemic outcomes as a response variable to the CGMs and other treatments (Figure 3), with nine out of the seventeen studies primarily exploring glycemia and HbA1c outcomes (1-9). Additionally, CGM accuracy was also measured, with Laffel *et al*., Zaharieva *et al*., and Thabit *et al*. testing the accuracy of various continuous glucose monitoring systems (10-12). Participant use of CGM features, behavioral outcomes, and CGM adherence were recorded in Messer *et al*., while Lawson *et al*. focused solely on CGM adherence (13, 14). Elbalshy *et al*. and Tanenbaum *et al*. observed parents' experiences with their children's CGM use (15, 16). Lastly, the interference effect of acetaminophen on CGM readings was measured by Calhoun *et al*. (17).

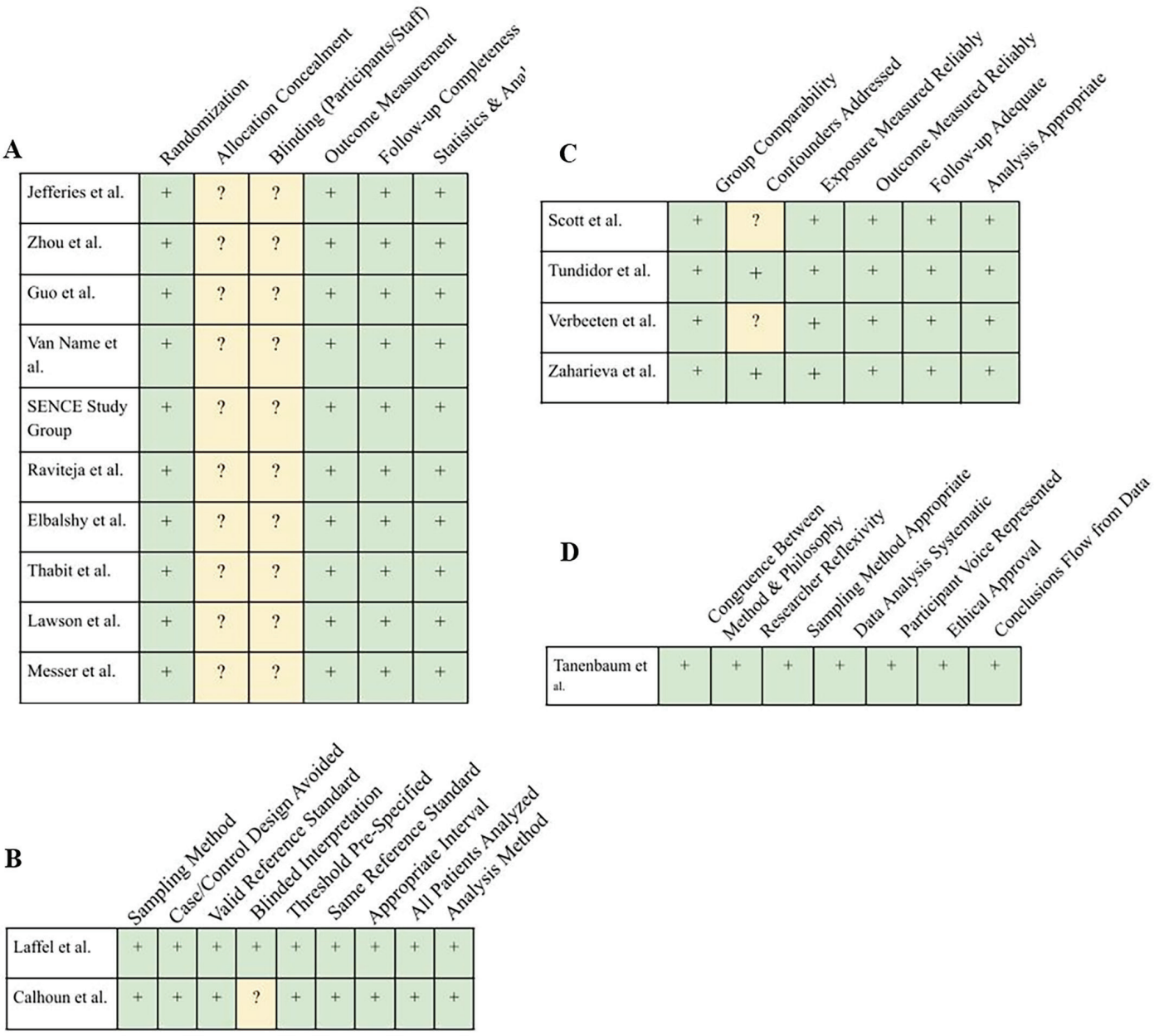

Figure 1. Cochrane tool for risk bias, analyzed using JBI's critical appraisal tool for the assessment of risk of bias for randomized controlled trials (RCTs) (Table A), for diagnostic test accuracy studies (Table B), for cohort/analytical cross-sectional studies (Table C), and qualitative studies (Table D). Each of the seventeen studies included in this systematic review has low-to-moderate levels of risk of bias.

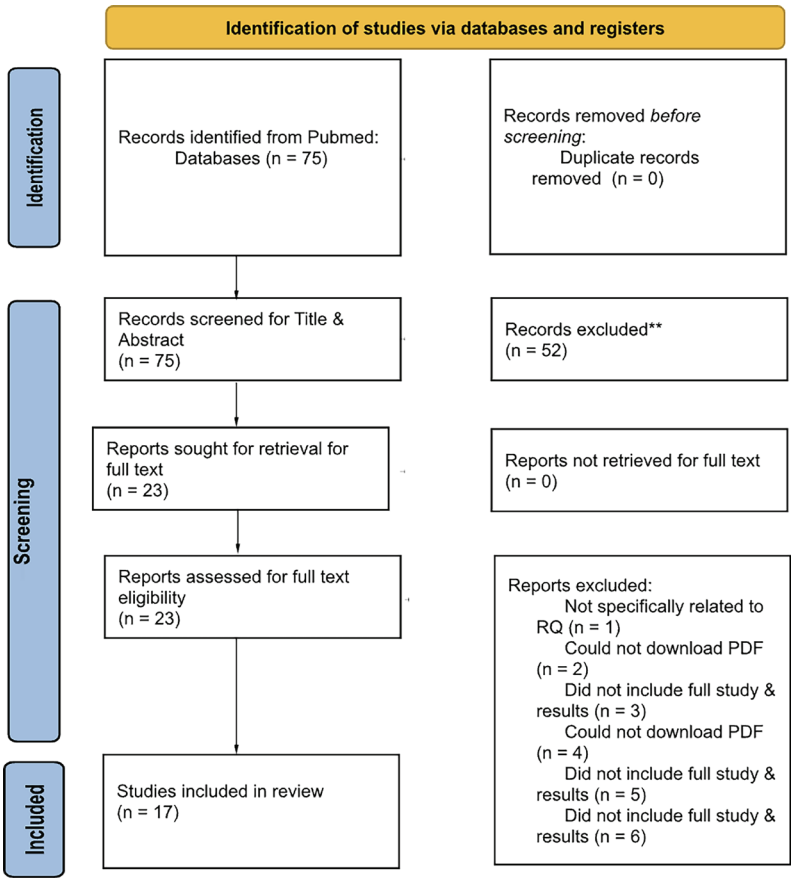

Figure 2. PRISMA flow chart for data extraction. Records identified, screened, excluded with reasons, full texts assessed, and number of final studies included.

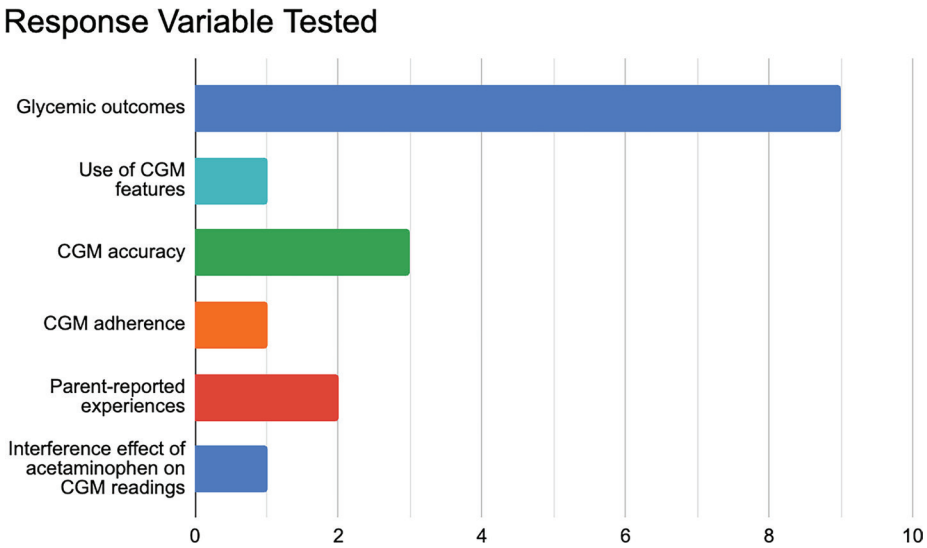

Figure 3. Response variable tested in studies reviewed. The majority of studies (n=9) focused on glycemic outcomes such as HbA1c, time in range, and hypoglycemia frequency as primary response variables. Other studies examined CGM accuracy (n=3), parent-reported experiences (n=2), use of CGM features (n=1), CGM adherence (n=1), and interference effects of acetaminophen on CGM readings (n=1).

Duration of Study

Laffel *et al*. involved an average of 10.5 days of sensor wear per participant, with a 12-hour grace period, totaling around 11 days overall (Figure 4) (10). Calhoun *et al*. used a single 8-hour clinic session on day 4 or 5 of CGM wear, with around 5 days of home calibration and wear beforehand (17). Raviteja *et al*. used CGM for 3-5 days per participant across multiple visits (9). Thabit *et al*. analyzed CGM performance in day-and-night closed-loop trials over 4 weeks in adults and 3 weeks in adolescents, totaling 2,002 CGM days (12). Conversely, many trials were conducted over a period ranging from a few weeks to 6 months, often evaluating device efficiency or adherence. Zhou *et al*. was a 24-week study, comprising a 12-week random clinical trial followed by a 12-week extension phase (1). Jefferies *et al*.'s and Guo *et al*.'s studies each lasted 12 weeks, while Elbalshy *et al*.'s spanned 17 weeks, including a 1-week run-in, two 6-week intervention periods, and a 4-week washout (2, 3, 15). SENCE Study Group observed CGM use over a 6-month duration (7). Similarly, Thabit *et al*. ran over 4 weeks in adults and 3 weeks in adolescents, with additional closed-loop testing phases and washouts (12). Moreover, several studies used longer durations to evaluate CGM adherence and glycemic outcomes. Messer *et al*. and Van Name *et al*. were 52-week trials composed of a 26-week random clinical trial and a 26-week extension (13, 4). Verbeeten *et al*. followed participants for 12 months total, comparing simultaneous and delayed CGM initiation arms over 6-month periods (5). Tanenbaum *et al*. included parental interviews about children with type 1 diabetes for an average duration of 10.35 ± 3.89 months (16). Lawson *et al*.'s study totaled 12 months, with CGM adherence tracked over 6 months after CGM initiation (14). Finally, two studies focused on gestational glucose control and tracked outcomes across pregnancy stages. Tundidor *et al*. gathered CGM and HbA1c data at three key timepoints: first trimester, 24 weeks, and 34 weeks, with outcomes followed through delivery (6). Scott *et al*. had a similar structure, collecting CGM data at baseline, 24, and 34 weeks, for a total of approximately 20 weeks of pregnancy monitoring (8). Overall, study durations ranged from single-day metabolic trials to year-long random clinical trials with extensions, with 12-26 week studies being most common (Figure 4). Short-term trials tended to observe acute glucose responses and device calibration data, while longer-term studies focused on behavior change, HbA1c outcomes, and adherence patterns over time.

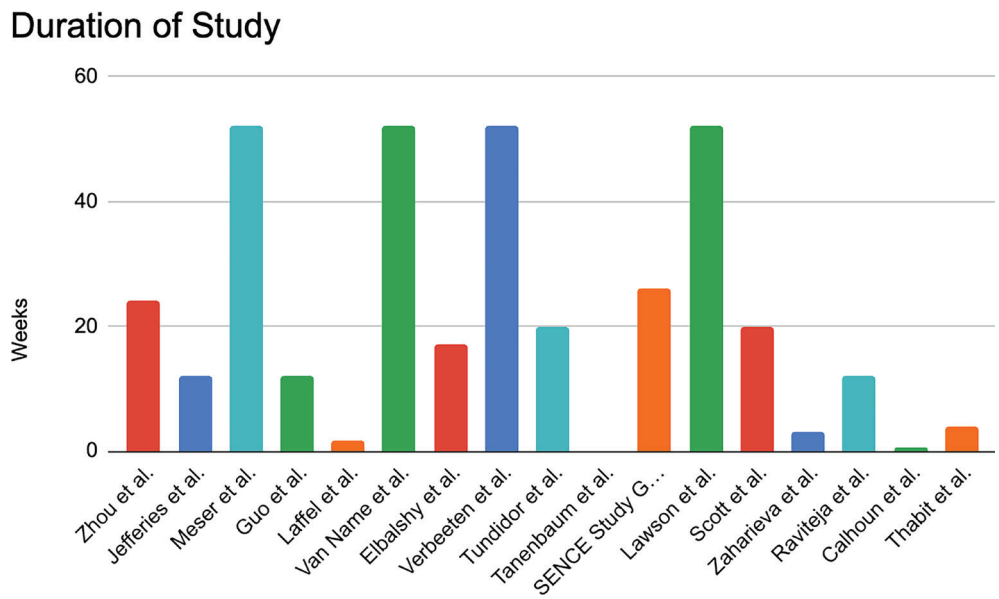

Figure 4. Duration of studies reviewed. The duration of the studies varied substantially, ranging from single-day sessions to one-year trials, reflecting the diverse goals and populations studied. Several studies employed short-duration CGM protocols focused on immediate glucose response or device testing. The most common durations were 12–26 weeks, typically used to evaluate CGM efficacy and adherence. Longer studies focused on long-term behavioral outcomes and sustained glycemic effects, while shorter protocols assessed device calibration and technical performance.

Control Group

Control group methodologies varied across the studies. A common control model involved the use of fingerstick SMBG in participants. Zhou *et al*. used SMBG for 12 weeks before the individuals crossed over to the isCGM (1). Jefferies *et al*. and the SENCE Study Group also used SMBG/fingerstick methods as the control group (2, 7). In Messer *et al*. and Van Name *et al*., participants in the BGM-CGM arm used SMBG exclusively for 26 weeks before switching to CGM, while the CGM-CGM group continued CGM throughout (13, 4). Guo *et al*. included a blinded isCGM group using the FreeStyle Libre Pro for monitoring (3). In Scott *et al*., women in the control group performed more than 7 SMBG tests/day and wore masked CGMs only for evaluation periods (8). Raviteja *et al*. compared CGM and p-CGM intervention against an SMBG-only control group (9). Some trials incorporated masked CGM for data collection but maintained SMBG for clinical decision-making, such as Tundidor *et al*. and Scott *et al* (6, 8). In Verbeeten *et al*., a delayed CGM initiation arm served as the comparison group, with participants beginning CGM six months after insulin pump therapy initiation (5). This allowed comparison of early versus delayed CGM implementation across matched timelines. This was also the case in Lawson *et al*., which involved a delayed group where CGM use was initiated 6 months after starting an insulin pump (14). Elbalshy *et al*. continued participants on standard FreeStyle Libre isCGM and routine care in the control group, while the intervention group received additional features or feedback on their treatment (15). In Zaharieva *et al*., each participant served as their own control group across three basal rate conditions (11). Thabit *et al*. compared closed-loop insulin therapy to open-loop pump therapy within subjects (12). Lastly, two studies were single-arm trials without independent control groups, with Laffel *et al*. focused solely on CGM sensor performance and Calhoun *et al*. examining CGM versus YSI reference data within each subject (10, 17). Tanenbaum *et al*. was a qualitative study interviewing parents' experiences with their children's CGM use (16).

Inclusion Criteria

Inclusion criteria across the studies varied according to age, diabetes, duration, glycemic control, prior technology use, and physiological condition. Nine studies included children or adolescents as primary participants. Zhou *et al*. and Jefferies *et al*. enrolled children aged 4-13 years with T1D and HbA1c levels between 7.5% and 12.2%, T1D duration more than 6 months, insulin dose more than 0.5 U/kg/day, and no CGM use in the previous 3 months (1, 2). Laffel *et al*. included children and adolescents aged 2 to 17 years with T1D, based on protocol compliance (10). Van Name *et al*. focused on 2 to 8-year-olds diagnosed with T1D for 3 or more months, with insulin dosage more than 0.3 U/kg/day, and HbA1c between 7.0% and 10.0% (4). Elbalshy *et al*. enrolled children aged 2-13 years already using isCGM, excluding those with psychiatric conditions or severe complications (15). Verbeeten *et al*. involved children aged 5-18 years with more than a year of T1D and starting insulin injection at study entry, while the SENCE Study Group included children aged 2 to 8 years with T1D, HbA1c levels 7.0% to <10.0%, with more than 200 hours of masked CGM and more than 3 fingersticks/day (5, 7). Raviteja *et al*. enrolled 2-10-year-olds diagnosed with T1D ≥6 months, using basal-bolus insulin with more than 3 SMBG checks/day (9). Messer *et al*. targeted adolescents and young adults aged 14 to <25 years with more than one year of T1D, HbA1c levels less than 10%, and no CGM use in the past 3 months. Participants were also required to speak English and use a smartphone (13). Lawson *et al*. focused on type 1 diabetes patients aged 5-18 without prior use of insulin pumps or CGM technology, HbA1c levels below 10%, and regular BG monitoring and clinic attendance required (14).

Several studies also focused on adult participants with established type 1 diabetes, with Guo *et al*. including adults aged more than 18 years with a T1D diagnosis, on insulin therapy, and without CGM use in the previous 3 months, Zaharieva *et al*. including adults aged 17-65 years, on insulin pump therapy for at least a month, and with HbA1c levels less than 9.9%, Calhoun *et al*. enrolling adults diagnosed with either T1D or T2D and be able to refrain from acetaminophen use during the study, and Thabit *et al*. including type 1 diabetes insulin pump users for more than 3 months, including both adults and adolescents recruited from clinical sites in Europe (3, 11, 17, 12). Two studies specifically targeted pregnant individuals with T1D: Tundidor *et al*. enrolled pregnant women with T1D and HbA1c levels less than 10% at enrollment, and Scott *et al*. included women aged 18-40 years with T1D duration more than a year, singleton pregnancy less than 14 weeks of gestation, and HbA1c between 6.5%-10%, with participants needing to be on intensive insulin therapy via pump or multiple daily injections (6, 8). A last study focused on parental experiences rather than the clinical

criteria of child participants. Tanenbaum *et al*. included parents of youth who had started CGM within 30 days of T1D diagnosis and had more than 6 months of diabetes duration. The children participated in a larger early-CGM clinical trial (16). Inclusion criteria across the seventeen studies were designed to capture a wide spectrum of the T1D population. Most studies required HbA1c levels between 6.5% and 12.2%, excluded prior CGM use, and focused on children, adolescents, or pregnant women, depending on study goals. Many studies also consistently required participants to be on intensive insulin treatments and adhere to testing or technology protocols.

What were the clinical outcomes of the studies analyzed?

In clinical research on type 1 diabetes, clinical outcomes are essential for evaluating the effectiveness of interventions such as CGMs. The response variable in clinical trials represents the main outcome measured to evaluate the intervention's effect. In studies involving CGM, response variables include metrics like HbA1c levels, time in target glucose range, or glycemic variability. The choice of response variable depends on the study's aim, which may be to assess metabolic control, user experience, or device accuracy. HbA1c reflects the average blood glucose concentration over the past 2 to 3 months and assesses long-term glycemic control. Lowering HbA1c is strongly associated with a reduced risk of diabetes-related complications (18). However, because HbA1c does not capture glycemic variability or hypoglycemia, it is often combined with CGM-derived metrics in contemporary trials.

Hypoglycemia, normally defined as blood glucose <70 mg/dL, poses immediate risks such as seizures, unconsciousness, and even death. For children and adolescents with T1D, frequent hypoglycemia also contributes to fear of low blood sugar, impacting daily life and diabetes management (4). Therefore, studies often report time below range (TBR) or episodes of severe hypoglycemia to evaluate device safety and effectiveness. Glycemic variability refers to fluctuations in blood glucose levels throughout the day, which can occur despite stable HbA1c. CGM technologies allow tracking of these changes through metrics like the coefficient of variation (CV) or standard deviation (SD) of glucose values. The time in range (TIR) metric, typically defined as the percentage of time spent between 70–180 mg/dL, provides another measure of glucose control. Time above range (TAR) and time below range (TBR) record hyperglycemia and hypoglycemia, respectively.

HbA1c Outcomes

In this review, HbA1c outcomes, hypoglycemia, TIR, TAR, and TBR were analyzed. Overall, no statistically significant differences were found in the HbA1c levels before and after the interventional treatment. However, one study noted a significant decrease in HbA1c levels (HbA1c decreased by 0.5% in the unblinded group and 0.4% in the blinded group) (3).

Hypoglycemic Outcomes

With respect to hypoglycemia outcomes, most studies indicated a significant decrease in hypoglycemic episodes after continued use of CGM. The most striking result was in Jefferies *et al*., where time below 70 mg/dL was reduced by 6.4%, which, when statistically analyzed, had a p-value of less than 0.001 (2). In terms of glycemic variability, most papers reported statistically significantly lower coefficients of variation (CVs). Zhou *et al*. noted that the CV decreased from 46.1% to 41.4% in the isCGM group, improving modestly (1). Guo *et al*. observed the CV decreasing by 2.4% (3). Additionally, Elbalshy *et al*. noted a similar outcome, with the CV being significantly lower in the experimental group (38.8%) as compared to the control group (42.6%) (15). In very young children consistently using CGMs, hypoglycemia fell and stayed low (≈3–4%→≈2%), but HbA1c and TIR were unchanged, highlighting persistent daytime hyperglycemia (4).

Timing of Glycemic Variability

Regarding time in range, time below range, and time above range metrics, a majority of the papers demonstrated decreased TBR/TAR as well as increased TIR. Interestingly, one study reported a statistically significant decrease in TBR in unblinded groups, with the percentage decreasing from 5.3% to 3.4%, but an insignificant decrease in TBR in blinded groups, with the percentage decreasing from 5.5% to 4.7%. A similar outcome was seen with TAR (3).

How do the types and accuracy of technology used vary in the studies analyzed?

CGMs are an essential technology in diabetes research and care. Noting the brands of CGMs used in studies is important for interpreting study outcomes. Different CGM brands (e.g. Dexcom, Abbott FreeStyle Libre, Medtronic Guardian) may

influence device performance, user satisfaction, and general comparability of results because of variation in calibration requirements and data collection frequency.

CGM accuracy is central in assessing device reliability and comparing results to those of traditional fingerstick monitoring methods. The most common metric used to evaluate CGM accuracy is the Mean Absolute Relative Difference (MARD), which compares CGM glucose readings to a standard such as capillary blood glucose or laboratory values. MARD represents the average of the absolute differences between CGM and reference values, expressed as a percentage of the reference value. Lower MARD values, usually under 10%, indicate better accuracy (19). This is crucial in clinical care because high-accuracy CGMs enable safer insulin dosage decisions, better glucose trend interpretation, and generally lead to improved clinical outcomes.

Additionally, device malfunction reporting is essential for evaluating the reliability of CGMs in daily usage. Malfunctions such as sensor adhesion failures, calibration errors, or irritation can reduce user satisfaction and trust in the device, impact data quality, and limit the effectiveness of CGM intervention (20). Reporting of adverse device events is crucial for assessing feasibility and patient burden in long-term CGM use.

Finally, CGM data collection frequency directly impacts the interpretation of study results. Most CGMs sample glucose every 5 minutes (around 288 readings/day), which provides a wide database of glucose levels that can be used to more accurately assess glycemic variability in patients. Moreover, TIR data can be tracked more effectively with more frequent readings. In the studies analyzed, collection protocols vary, which can affect study results.

Brands of CGM Used (Figure 5)

Accuracy of CGMs

Seven studies had no mention of MARD data or did not directly measure CGM accuracy in patients (1, 2, 5, 6, 7, 13, 14). Three studies provided qualitative accuracy statements that affirmed the accuracy of the CGMs, with Elbalshy *et al.* stating that accuracy was supported via daily calibrations and 67% of caregivers trusted the device readings, Scott *et al.* noting that the CGM was described as accurate for interstitial glucose, and Van Name *et al.* observing that the CGM device was known for improved accuracy (15, 8, 4). Finally, the remaining seven studies had specific MARD values that indicated the accuracy of the CGMs. Laffel *et al.* mentioned a MARD of 9.0% in the abdomen insertion group and 8.1% in the arm insertion group, whereas Zaharieva *et al.* observed a MARD during exercise of 13%, during a meal of 8%, and overall 11% (10,11). Raviteja *et al.* measured using MAD, or Mean Absolute Difference, which was less than 28% in 80% of subjects (9). Calhoun *et al.* noted a pre-dose MARD of 6.7% and a post-dose number of 8.0% (17). Lastly, Thabit *et al.* observed an overall MARD of 14.2% (12).

Device Malfunctions

Device malfunctions were variably reported across the studies. In several trials (1, 3, 4, 6, 8, 11, 14), device malfunction data were not available or not reported. Minor or no significant malfunctions were reported in multiple studies (9, 12, 13), with some noting issues such as the need for recalibration due to over-reading (12). In contrast, Jefferies *et al.* documented a low sensor failure rate (less than 1%) but reported a participant

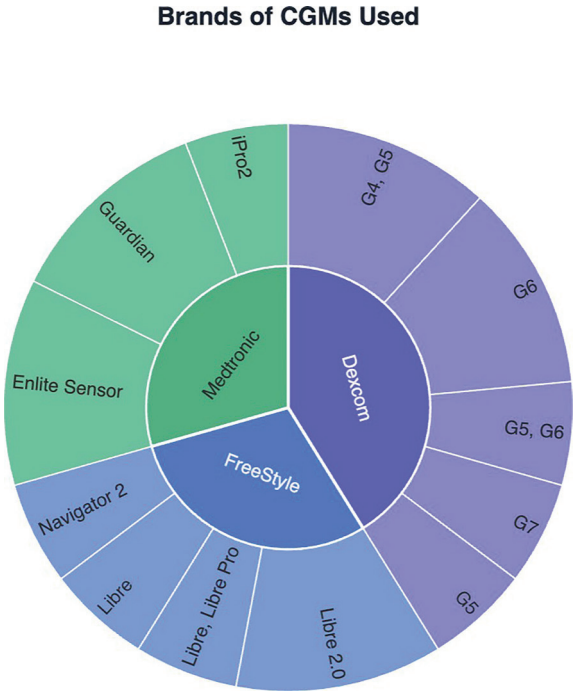

Figure 5. The brands of CGMs used in the studies. Seven studies out of the seventeen analyzed mentioned using Dexcom devices for glucose monitoring, with two G4 devices, four G5 devices, three G6 devices, and one G7 device used across the studies. Multiple papers used several versions of Dexcoms (4, 11, 13). Five used Freestyle Libre/FreeStyle Navigator devices, and five used Medtronic brand CGMs.

withdrawal after repeated sensor adhesion issues (2). Laffel *et al*. presented multiple device failures, with three participants experiencing failures of arm and abdomen sensors and eight reporting mild-to-moderate device-related events, including pain and irritation (10). Similarly, Tanenbaum *et al*. observed issues such as signal loss and adhesive problems (16). Some studies described more frequent complications, with Elbalshy *et al*. reporting connectivity issues in over 70% of users and the SENCE Study Group documenting 81 device-related issues, including two instances where sensor tips remained under the skin, though both resolved without outside intervention (15, 7). Technical data collection errors were seen in Verbeeten *et al*., though device malfunctions were not systematically assessed (5). Additionally, Raviteja *et al*. reported two sensor insertion failures, three early removals, and minor redness and irritation (9). Calhoun *et al*. excluded data from four participants due to sensor failure or accidental restarts (17). Overall, while most studies reported minimal device malfunction, a few noted issues impacting sensor performance, connectivity, or participant comfort.

Collection Frequency

Seven papers used CGMs with a collection frequency of around 5-minute intervals or 288 readings per day (8, 9, 10, 11, 12, 15, 16). Thabit *et al*., in particular, reported a total of over 48,000 hours of CGM data, with ~90% sensor wear time. Thabit *et al*. assessed accuracy through continuous sampling linked to MAD and correlation metrics (12). On the other hand, other studies emphasized frequent daily use, though not strictly continuous. For example, Zhou *et al*. observed an increase in scanning frequency from 4.7 to 9.2/day in the intervention group and from 3.2 to 10.7/day in the control/isCGM group (1). Similarly, Jefferies *et al*. reported 10.7 daily glucose checks in the interventional group (interstitial and SMBG), which represents a 6.77/day increase compared to the control group (2). Messer *et al*. tracked weekly adherence to CGM use and found that over 70% of participants used CGM more than 5 days a week by week 52 (13). Guo *et al*. and Van Name *et al*. collected data over two-week and four-week intervals, respectively, while the SENCE Study Group reported that around 90% of participants used CGM more than 6 days a week (3, 4, 7).

Three studies used intermittent or episode-dependent CGM protocols. Verbeeten *et al*. collected data weekly through CareLink, mainly focusing on adherence during the sixth 28-day period post-initiation (5). Tundidor *et al*. involved three 6-day CGM sessions timed to stages of pregnancy (early, mid, late gestation), while Calhoun *et al*. used intensive 10-15-minute sampling over a 6-hour testing window (6, 17).

Collectively, the studies demonstrate wide variability in CGM use patterns across clinical contexts.

How did users react to sustained CGM use?

Measuring user satisfaction, quality of life (QoL), and behavioral changes is essential when analyzing these studies, as these factors directly influence CGM adherence, use, and clinical effectiveness. High satisfaction and improved QoL are associated with more consistent CGM use, better self-management, and reduced diabetes-related stress, as well as indicating the effectiveness of CGMs. Evaluating behavioral changes or outcomes provides insight into how CGMs affect the livelihood of individuals managing type 1 diabetes. Incorporating these patient-centered outcomes is important for a comprehensive understanding of CGM efficacy.

User Satisfaction and QoL

User satisfaction and QoL outcomes varied across studies, with a majority reporting positive experiences and improved satisfaction with CGM use. Several studies noted participants and caregivers describing CGMs as "life-changing," contributing to significantly reduced stress and anxiety, and improving physical functioning for both children and parents (1, 7, 10, 13, 15, 16). Messer *et al*., using the Glucose Monitoring Satisfaction Survey (GMSS), showed a significant increase in user satisfaction, while Laffel *et al*. found that over 80% of users rated the sensor as easy to insert, with 74.5% reporting it was more comfortable than previous CGMs (13, 10). Additional studies stated that high adherence and sustained use of CGMs (88-92%) indicated improved user satisfaction as well as reduced diabetes burden (4, 7).

On the other hand, some studies observed no significant changes in psychosocial outcomes or did not directly assess satisfaction or QoL. For example, Jefferies *et al*., measuring PedsQL and administering a Hypoglycemia Fear Survey, found no significant differences in quality of life between the control group and interventional (CGM) group (2). Some did not measure user satisfaction (5, 6, 8, 9, 11, 12, 17), while others relied on observational feedback rather than specific QoL assessment tools (4).

Guo *et al*. and Raviteja *et al*., on the other hand, noted mixed to potentially negative experiences, reporting reduced hypoglycemic confidence, increased fearful behaviors, or parental concerns. However, Guo *et al*. found that these observations were not statistically significant after adjustment (3, 9).

Behavioral Changes

As for general behavioral changes, several papers noted an increase in glucose checking frequency as well as increased confidence in avoiding hypoglycemia and improved diabetes management skills (1, 2, 13, 16). Psychosocial responses to CGM use varied significantly by population, reflecting differences in life stage, caregiver involvement, and technological context. Children and their parents consistently reported the strongest emotional and quality-of-life gains. Real-time glucose feedback and remote monitoring alleviated fear of hypoglycemia, improved sleep, and enhanced caregivers' sense of safety (15, 16). Among adolescents and young adults, CGM use fostered greater independence, confidence in diabetes self-management, and higher treatment satisfaction, yet some users described frustration with calibration demands or social visibility of devices (7, 13). In pregnant women, CGM contributed to reassurance and tighter self-monitoring, even when HbA1c improvements were modest, which highlights emotional and behavioral benefits (6, 8).

Overall, while QoL data collection was varied among the 17 studies, evidence suggests that CGM use is generally associated with high satisfaction, perceived comfort, and, in many cases, improved QoL, especially when used consistently or in family-centered contexts (1, 7, 13, 10, 15, 16).

DISCUSSION

CGM technologies have significantly transformed diabetes management over the past decade, especially for patients with type 1 diabetes. Compared to traditional SMBG or fingerstick monitoring methods, CGMs offer real-time, continuous insight into glycemic trends and variability. This systematic review synthesized data from seventeen studies that varied in design, population, duration, and outcome metrics to evaluate the comparative impact of CGM versus SMBG on clinical and user-reported outcomes. Overall, most studies reported improved TIR, decreased TBR, and reduced hypoglycemic episodes with CGM use. Some papers also reported improvements in HbA1c levels, while others found no statistically significant HbA1c reduction. Device performance, user satisfaction, and frequency of CGM usage were also consistently reported as high across most studies. Most control groups used SMBG exclusively, while experimental groups varied between blinded and unblinded CGM use. Inclusion criteria were generally consistent across trials, often excluding prior CGM use and requiring HbA1c levels within a moderate range pre-trial.

One notable finding is the variation in response to CGM use across different populations. For example, Jefferies *et al*. and Zhou *et al*. reported significant increases in glucose checking frequency and improved glycemic outcomes in pediatric populations (2, 1). Meanwhile, studies focusing on pregnant women (6, 8) or very young children (4, 10) showed that CGMs could be used successfully but highlighted challenges such as adhesive issues or fear of hypoglycemia in participants. Interestingly, while most studies reported improvements in user satisfaction and QoL, Jefferies *et al*. found no statistically significant psychological benefit from using a CGM (2). These mixed results may stem from differing survey techniques or cultural differences and expectations. Compared to prior studies, this review supports the idea that CGM improves glycemic control more effectively than SMBG alone but reveals differences in psychosocial and behavioral outcomes associated with the use of CGMs. In addition, the prevalence of crossover designs and delayed intervention arms allowed researchers to compare CGM initiation timing, which adds insight into clinical intervention planning.

Another noteworthy finding is that HbA1c improvement was highly inconsistent. This inconsistency across studies stems from a combination of technological, behavioral, and methodological factors. Short-term and observational trials often lacked sufficient duration to capture HbA1c changes, which reflect average glycemia over 8–12 weeks. In several pediatric studies using intermittently scanned CGM, hypoglycemia and TBR markedly decreased while HbA1c remained unchanged, which suggests that users focused on preventing lows rather than correcting hyperglycemia. In contrast, real-time CGM (rtCGM) and professional CGM interventions with continuous feedback demonstrated clearer HbA1c declines of ~0.4–0.6%, particularly in children with higher baseline HbA1c or when CGM data guided insulin adjustments by clinicians (9). Device feature differences further explain variability: systems lacking predictive alerts or remote monitoring (e.g., early isCGM

models) produced behavioral reassurance without necessarily modifying insulin dosing patterns, whereas alert-equipped rtCGMs facilitated more proactive corrections. Adherence and data usage were equally critical. For example, long-term trials such as SENCE showed >90% wear time and sustained hypoglycemia reduction, yet HbA1c plateaued, implying that sensor use alone cannot overcome factors like meal dosing errors, missed insulin boluses, or caregiver fatigue (7). Population-specific factors also contributed, with pregnant users achieving better neonatal outcomes and reduced glycemic excursions despite modest HbA1c change, while adolescents and adults sometimes reported alarm fatigue or psychological burden that blunted behavioral adaptation (6, 8). Overall, the mixed HbA1c findings highlight that CGM efficacy depends less on continuous data acquisition and more on how those data are interpreted, acted upon, and supported by education, device features, and user engagement.

These findings emphasize that clinical implementation of CGM should pair technological initiation with teaching patients how to interpret trends, how to manage alarm fatigue, respond appropriately to sensor data, and incorporate CGM insights into meal dosing and exercise planning. Ongoing psychosocial screening for diabetes distress, burnout, and caregiver fatigue should become a standard part of CGM follow-up visits, especially for families managing pediatric diabetes.

At a policy level, the consistent reductions in hypoglycemia, improved confidence, and caregiver well-being demonstrated across age groups provide compelling evidence to expand insurance coverage and early-access programs to CGMs. Early adoption, especially within the first months of diagnosis, has been shown to improve parental coping and long-term device adherence, but cost and coverage barriers remain a major determinant of continued use. Equitable CGM access should therefore be viewed as a public health investment that mitigates psychological burden, enhances self-management capacity, and supports family resilience in T1D care.

Despite this study's reach, this review also highlighted several limitations. Many studies lacked uniformity in response variable definitions, CGM brands, calibration protocols, and adherence tracking. Device accuracy metrics, such as MARD or MAD, were not reported consistently across studies, making comparisons challenging. In several cases, sample sizes were small or limited to single-arm trials without matched controls (10, 16), and a few relied solely on short-term CGM use or single-day clinic visits. Furthermore, user satisfaction and behavioral metrics were sometimes evaluated qualitatively or omitted entirely, which weakens conclusions about the long-term psychosocial benefits of CGM use. Finally, while pediatric and adolescent populations were well represented within the studies evaluated, fewer papers addressed adults or older patients, limiting the population to which the results can be generalized.

Further work would benefit from consistently collecting MARD or equivalent accuracy data and more consistently including behavioral and psychosocial outcomes. Randomized trials with longer durations and broader populations, including adults and minority populations, are needed to improve the generalizability of the results. Importantly, research should be conducted to investigate not only glycemic efficacy but also cost-effectiveness and long-term adherence to CGM use. Overall, this review affirms that CGM technologies often enhance clinical outcomes in T1D management, particularly by reducing hypoglycemia levels and improving TIR. With further optimization and widespread access, CGMs may become the standard of care for all individuals with type 1 diabetes.

CONCLUSION

This systematic review highlights the growing body of evidence supporting the clinical and psychosocial benefits of continuous glucose monitoring (CGM) over self-monitoring of blood glucose (SMBG) in individuals with type 1 diabetes. Across seventeen studies, CGM use was consistently associated with improved TIR, reduced hypoglycemia levels, and increased user satisfaction, although HbA1c outcomes were more variable. Notably, CGMs demonstrated high accuracy and were generally well tolerated across a range of pediatric, adolescent, adult, and pregnant populations. Despite some limitations in age range, the results support the integration of CGM as a more effective and user-friendly technology for diabetes management. As CGM technologies continue to advance, future research should focus on expanding access to CGMs and further assessing long-term health outcomes to ensure adoption of CGM into routine diabetes care.

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CONFLICT OF INTERESTS

The author declares that there are no conflicts of interest regarding the publication of this article.

REFERENCES

1. Zhou Y, Wheeler BJ, Boucsein A, Styles SE, *et al*. Use of Freestyle Libre 2.0 in children with type 1 diabetes mellitus and elevated HbA1c: Extension phase results after a 12-week randomized controlled trial. *Diabetic Medicine*. 2025; 42 (5): e15494. https://doi.org/10.1111/dme.15494
2. Jefferies C, Bouscein A, Styles SE, Chamberlain B, *et al*. Effects of 12-Week Freestyle Libre 2.0 in Children with Type 1 Diabetes and Elevated HbA1c: A Multicenter Randomized Controlled Trial. *Diabetes Technology & Therapeutics*. 2023 Dec 1; 25 (12): 827-35. https://doi.org/10.1089/dia.2023.0292
3. Guo L, Li Y, Zhang M, Xiao X, *et al*. Efficacy of unblinded and blinded intermittently scanned continuous glucose monitoring for glycemic control in adults with type 1 diabetes. *Frontiers in Endocrinology*. 2023 Feb 22; 14. https://doi.org/10.3389/fendo.2023.1110845
4. Van Name MA, Kanapka LG, DiMeglio LA, Miller KM, *et al*. Long-term Continuous Glucose Monitor Use in Very Young Children With Type 1 Diabetes: One-Year Results From the SENCE Study. *Journal of Diabetes Science and Technology*. 2022 Mar 26; 193229682210846. https://doi.org/10.1177/19322968221084667
5. Verbeeten KC, Chan J, Sourial N, Courtney JM, *et al*. Motivational Stage at Continuous Glucose Monitoring (CGM) Initiation in Pediatric Type 1 Diabetes Is Associated With Current Glycemic Control but Does Not Predict Future CGM Adherence or Glycemic Control. *Canadian Journal of Diabetes*. 2021 Jul; 45 (5): 466-472.e4. https://doi.org/10.1016/j.jcjd.2021.04.004
6. Tundidor D, Meek CL, Yamamoto J, Martínez-Bru C, *et al*. Continuous Glucose Monitoring Time-in-Range and HbA1c Targets in Pregnant Women with Type 1 Diabetes. *Diabetes Technology & Therapeutics*. 2021 Oct 1; 23 (10): 710-4.
7. Miller K; Strategies to Enhance New CGM Use in Early Childhood (SENCE) Study Group. A Randomized Clinical Trial Assessing Continuous Glucose Monitoring (CGM) Use With Standardized Education With or Without a Family Behavioral Intervention Compared With Fingerstick Blood Glucose Monitoring in Very Young Children With Type 1 Diabetes. *Diabetes Care*. 2020 Dec 17; 44 (2): 464-72.
8. Scott EM, Feig DS, Murphy HR, Law GR; CONCEPTT Collaborative Group. Continuous Glucose Monitoring in Pregnancy: Importance of Analyzing Temporal Profiles to Understand Clinical Outcomes. *Diabetes Care*. 2020 Mar 24; 43 (6): 1178-84.
9. Raviteja KV, Kumar R, Dayal D, Sachdeva N. Clinical efficacy of Professional Continuous Glucose Monitoring in improving glycemic control among children with Type 1 Diabetes Mellitus: An Open-label Randomized Control Trial. *Scientific Reports*. 2019 Apr 16; 9 (1). https://doi.org/10.1038/s41598-019-42555-6
10. Laffel LM, Bailey TS, Christiansen MP, Reid JL, Beck SE. Accuracy of a Seventh-Generation Continuous Glucose Monitoring System in Children and Adolescents With Type 1 Diabetes. *Journal of Diabetes Science and Technology*. 2022 Apr 25; 193229682210918. https://doi.org/10.1177/19322968221091816
11. Zaharieva DP, Turksoy K, McGaugh SM, Pooni R, *et al*. Lag Time Remains with Newer Real-Time Continuous Glucose Monitoring Technology During Aerobic Exercise in Adults Living with Type 1 Diabetes. *Diabetes Technology & Therapeutics*. 2019 Jun; 21 (6): 313-21. https://doi.org/10.1089/dia.2018.0364
12. Thabit H, Leelarathna L, Wilinska ME, Elleri D, *et al*. Accuracy of Continuous Glucose Monitoring During Three Closed-Loop Home Studies Under Free-Living Conditions. *Diabetes Technology & Therapeutics [Internet]*. 2015 Nov; 17 (11): 801-7. https://doi.org/10.1089/dia.2015.0062
13. Messer LH, Bauza C, Miller KM, Clements MA, *et al*. Adolescent- and Young Adult-Reported Outcomes and Use of Continuous Glucose Monitoring Features: A Report from the CITY Trial. *Pediatric diabetes*. 2023 Sep 15; 2023: 1-10. https://doi.org/10.1155/2023/6906023
14. Lawson ML, Verbeeten KC, Courtney JM, Bradley BJ, *et al*. Timing of CGM initiation in pediatric diabetes: The CGM TIME Trial. *Pediatric Diabetes*. 2020 Nov 4;
15. Elbalshy MM, Styles S, Haszard JJ, Galland BC, *et al*. The effect of do-it-yourself real-time continuous glucose monitoring on psychological and glycemic variables in children with type 1 diabetes: A randomized crossover trial. *Pediatric Diabetes*. 2022 Mar 13; 23 (4): 480-8. https://doi.org/10.1111/pedi.13331
16. Tanenbaum ML, Zaharieva DP, Addala A, Ngo J, *et al*. "I was ready for it at the beginning": Parent experiences with early introduction of continuous

glucose monitoring following their child's Type 1 diabetes diagnosis. *Diabetic Medicine*. 2021 Apr 21; 38 (8). https://doi.org/10.1111/dme.14567

17. Calhoun P, Johnson TK, Hughes J, Price D, Balo AK. Resistance to Acetaminophen Interference in a Novel Continuous Glucose Monitoring System. *Journal of Diabetes Science and Technology*. 2018 Jan 16; 12 (2): 393-6. https://doi.org/10.1177/1932296818755797
18. Nathan DM. The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications Study at 30 Years: Overview. *Diabetes Care.* 2013 Dec 19; 37 (1): 9-16. https://doi.org/10.2337/dc13-2112
19. Heinemann L, Schoemaker M, Schmelzeisen-Redecker G, Hinzmann R, *et al*. Benefits and Limitations of MARD as a Performance Parameter for Continuous Glucose Monitoring in the Interstitial Space. *Journal of Diabetes Science and Technology.* 2019 Jun 19; 14 (1): 135-50. https://doi.org/10.1177/1932296819855670
20. Shaw JLV, Bannuru RR, Beach L, ElSayed NA, *et al*. Consensus Considerations and Good Practice Points for Use of Continuous Glucose Monitoring Systems in Hospital Settings. *Diabetes Care*. 2024 Oct 25; 47 (12). https://doi.org/10.2337/dci24-0073