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Adherence to Glycemic Monitoring in Diabetes

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Abstract

Glucose monitoring either by self-monitoring of blood glucose (SMBG) or continuous glucose monitoring (CGM) plays an important role in diabetes management and in reducing risk for diabetes-related complications. However, despite evidence supporting the role of glucose monitoring in better patient health outcomes, studies also reveal relatively poor adherence rates to SMBG and CGM use and numerous patient-reported barriers. Fortunately, some promising intervention strategies have been identified that promote at least short-term improvements in patients' adherence to SMBG. These include education, problem solving, contingency management, goal setting, cognitive behavioral therapy, and motivational interviewing. Specific to CGM, interventions to promote greater use among patients are currently under way, yet one pilot study provides data suggesting better maintenance of CGM use in patients showing greater readiness for behavior change. The purpose of this review is to summarize the literature specific to glucose monitoring in patients with diabetes focusing specifically on current adherence rates, barriers to monitoring, and promising intervention strategies that may be ready to deploy now in the clinic setting to promote greater patient adherence to glucose monitoring. Yet, to continue to help patients with diabetes adhere to glucose monitoring, future research is needed to identify the treatment strategies and the intervention schedules that most likely lead to long-term maintenance of optimal glycemic monitoring levels.

Keywords

continuous glucose monitoring, measurement, self-monitoring of blood glucose, adherence, intervention

Glucose monitoring, or the act of regularly checking the concentration of glucose in the blood or interstitial space, is an important component of modern diabetes treatment.[1-3] Glucose monitoring allows patients to recognize and correct for dangerous blood glucose levels, appropriately calculate and administer mealtime insulin boluses, and get feedback on their body's response to carbohydrate intake, insulin or medication use, and physical activity.[1-3] In addition, glucose monitoring provides diabetes care teams with critical information needed to treat a patient in an emergency and to adjust a patient's routine diabetes therapy.[1-3] The effective management of type 1 diabetes (T1DM) and type 2 diabetes (T2DM) both rely on patients' completion of glucose monitoring and use of these data to correct for abnormal glycemic levels.[1-3] Unfortunately, there is evidence that patients with diabetes do not always complete glucose monitoring as frequently as prescribed.[4-10] Multiple barriers may exist to effective blood glucose monitoring.[10-13] However, there are also a few promising behavioral interventions which have specifically targeted blood glucose monitoring, particularly in patients with T1DM.[14-19] While many of these studies present only preliminary results, some of the strategies incorporated in these interventions may be immediately deployable in a clinic setting and should be considered for future intervention trials. The purpose of this review is to summarize the literature specific to glucose monitoring in patients with diabetes focusing specifically on current adherence rates, barriers to monitoring, and promising intervention strategies. Presently, patients with diabetes can monitor glucose levels via self-monitoring blood glucose (SMBG) meters and real-time continuous glucose monitoring (CGM). However, the guidelines and literature supporting the use of these technologies are different. Therefore, this review will separately discuss SMBG and CGM for patients with diabetes.

SMBG

Recommendations for the timing and frequency of SMBG can vary based on diabetes diagnosis and on each patient's health needs and goals. For example, current American Diabetes Association Practice Guidelines recommend

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patients using insulin perform glucose checks with meals, before and after exercise, before bedtime, prior to critical tasks, such as driving, and in situations where an abnormal glucose level is suspected, resulting typically in between 4 to 10 checks per day.[1,2] However, for patients who are not prescribed insulin or medications that either impact glucose absorption (viz, alpha-glucosidase inhibitors) or insulin production (ie, sulfonylurea), less frequent monitoring may be safe due to a decreased risk of glycemic variability.[2] Because SMBG guidelines can be individually based, adherence to guidelines is difficult to assess. Still, in 1 large international study, SMBG adherence rates were reported to be as low as 44% for adults with T1DM and 24% for adults with T2DM.[4] Several studies show close agreement with these low estimates of adherence,[5-7] suggesting that for many adults, SMBG adherence is suboptimal. In youths, studies show rates of SMBG adherence ranging from 31% to 69%,[8,9] similarly suggesting suboptimal adherence levels.

Suboptimal adherence to SMBG is potentially problematic because research has demonstrated a correlation between lower glycated hemoglobin (HbA1c) levels and more frequent SMBG across patients with both T1DM and T2DM.[7,20-24] However, despite the evidence supporting the role of glucose monitoring in better patient health outcomes, patient-reported barriers to SMBG are common, span psychological (ie, frustration, distress, fear), social (ie, workplace barriers, peer relations), and financial (ie, cost of supplies) concerns,[12,13,25] and likely contribute to adherence problems. As such, clinical research has worked toward developing interventions that help to minimize barriers and improve patients' adherence to SMBG. Presently, there are several studies that support the efficacy of self-management interventions to improve patients' short-term adherence to SMBG. Self-management interventions are programs that typically combine patient education, behavioral strategies, and psychological support with a goal to improve patient self-care.[26] Common behavioral strategies used in these interventions include problem solving, contingency management, and goal setting. Problem solving is a behavioral strategy that teaches patients a stepwise plan to identify new or more adaptive strategies to address a problem. This strategy can be particularly helpful in situations where patients have previously identified a less adaptive strategy and are having difficulty recognizing alternative strategies to solve their problem. Contingency management is a feedback paradigm in which the patient receives positive feedback in the form of a tangible incentive (ie, money) or verbal praise for performing a desired behavior and either punishment (ie, paying back money) or no feedback (ie, withdraw of praise) for performing an undesirable behavior. Contingency management can be an effective strategy for teaching a new behavior or to maintain a previously learned behavior. Goal setting is a stepwise approach to define a realistic treatment target (ie, increasing SMBG checking) and outline a plan to reach that target. Used independently, goal setting can help patients to set a behavior goal, monitor their progress in meeting that goal, and provide feedback to help with short-term motivation. As a component of contingency management, goal setting helps to define when to deliver positive feedback or a punishment. By contrast, common psychological treatments used in these interventions include cognitive-behavioral therapy (CBT),[26,27] which can address patients' feelings of helplessness or despair and motivational interviewing (MI),[26,28] which can help to reduce patients' ambivalence for behavior change. To further illustrate these treatment strategies, Table 1 provides a rationale, description, and example of how these strategy could be applied to promote better adherence to SMBG, while a summary of the results of recent studies that have used some of these strategies are described next.

Tan et al[18] tested a brief education plus CBT intervention for adults with T2DM. Eighty-two adults were randomized to either the treatment or control group. After 12 weeks of treatment, adults receiving the treatment increased their frequency of performing SMBG from 0.56 times per week to 2.88 times per week ($P < .001$), while adults in the control group experienced no change in SMBG frequency. More recently, a positive change in frequency of SMBG was found for an intervention combining CBT and goal setting.[16] This randomized controlled trial recruited 87 adults with T2DM and adherence was measured based on the percentage of SMBG checks performed given the number of checks recommended. At posttreatment, adults assigned to the treatment group completed 79% of SMBG checks compared to 49% of checks completed by adults in the control group ($p = 0.04$), demonstrating a positive treatment impact. Focusing on patients with T1DM, there is evidence that a recent internet-based intervention combining education, goal setting, and peer mentoring can improve patients' adherence.[19] Participants were 57 adults with T1DM and HbA1c levels ≥ 8.0% who were randomized to receive the intervention or education only. After 12 weeks, adults receiving the intervention completed more SMBG checks per day than adults receiving education only (1.41 more versus 0.30 more).[19] In youths with T1DM, 2 recent interventions have used education plus contingency management to improve SMBG in adolescents.[14,15] In the first trial,[14] a mobile app, *bant*, was pilot tested in 20 adolescents (mean age = 14.9 ± 1.3 years). Adolescents using *bant* received education and practiced goal setting specific to SMBG. They also received incentives for performing SMBG checks. Adolescents used *bant* for 12 weeks. At posttreatment, researchers found a 50% increase in the frequency of SMBG checks (2.4 checks/day to 3.6 checks/day) compared to baseline.[14] In the second trial,[15] adolescents received cash incentives to perform at least 4 SMBG checks per day, but could lose the money if they performed less than 4 SMBG checks per day. Using an A-B-A reversal design with a baseline condition lasting for 5 days (A), the incentive program lasting for 5 days (B), and a return to baseline period lasting for 5 days (A), the researchers

Table 1. Descriptions and Examples of Intervention Strategies That Have Been Used to Improve Adherence to SMBG.

Strategy	Rationale	Description/steps	Examples specific to SMBG	
Problem solving[26,44]	Problem solving can help patients to identify new or more adaptive strategies to reduce the impact of these barriers	1. Name the problem or identify the barrier	An adolescent who is not carrying her SMBG meter with her when she leaves her house.	
		2. Generate possible strategies to address the problem/barrier	1. Problem: cannot perform SMBG while away from home	
		3. Evaluate all strategies and select the best one	2. Possible strategies:[a]	3-4. Evaluate/pick best strategy
		4. Implement the strategy identified in step 3	Continue to leave meter at home	Poor; not checking
		5. Monitor and evaluate the outcomes; if unsuccessful repeat steps 2-4	Carry meter/supplies in the car	OK; can check when at the car, but not other times
			Buy a new bag to carry meter/supplies	OK; get a new bag, but still have to carry it
			Buy a smaller meter; carry it and limited supplies to perform 1-2 checks when away from home; never leave home	OK; can more easily check; may not be noticeable in pocket; only can perform 1-2 checks **(strategy selected)**; poor; not practical
			5. Monitoring/evaluate: Decided to buy and carry smaller meter/supplies; after 2-3 weeks, see a 25% increase in SMBG performed away from home	
Contingency management[45]	Adherence to glucose monitoring is a behavior and behaviors that are reinforced are likely to occur more frequently	1. Identify the target behavior	A youth who is not performing SMBG	
		2. Identify the reinforcers (seeking reinforcers that have value to the patient and are practical for the setting)	1. Target behavior: increasing SMBG frequency per day	
		3. Determine monitoring schedule and delivery schedule for the reinforcers; some things to consider:	2. Identify reinforcers: gaming time; money	
		a. Identify behaviors that occur (or should occur) often to provide more opportunities to earn reinforcers)	3. Plan: youth can earn 10 minutes of gaming time for each SMBG performed per day up to 60 minutes; youth will lose 10 minutes of gaming time for each SMBG not performed at lunch or dinner; parent-youth will review meter memory after dinner and award gaming time	
		b. Consider reinforcing successive approximations, or incremental improvements (ie, reinforcing each SMBG check)	4. Fade: youth can earn up to 20 minutes of gaming time when at least 4 SMBG performed per day; additional gaming time now contingent on performance of another behavior	
		c. Deliver reinforcers immediately; best for learning		
		d. Reinforcers delivered immediately with each behavior repetition is best for learning; reinforcers delivered randomly after behaviors is best for maintenance		
		4. Fade reinforcers once the new behavior pattern is established		

(continued)

Table 1. (continued)

Strategy	Rationale	Description/steps	Examples specific to SMBG
Goal setting[26]	Setting goals related to glycemic monitoring defines the behavior's objective, provides a plan for measuring success, provides a vision for long-term maintenance or behavior change, and helps with short-term motivation	1. Define a specific goal 2. Determine how to measure goal progress/attainment 3. Determine if goal is achievable a. Seek feedback and discuss potential barriers to the behavior 4. Set a realistic goal a. Based on identified barriers, does the goal need to be modified? b. Are there solutions to reduce the impact of barriers and are these realistic? 5. Determine a schedule for monitoring goal attainment/revision	An adult patient who wants to increase the frequency of postprandial SMBG 1. Define specific goal: perform SMBG 2 hours after lunch and dinner each day 2. Plan to measure goal: each Sunday night will count/record the number of days the goal was achieved 3. Is goal achievable? Hard to check after lunch if afternoon meetings 4. Modify goal: perform SMBG 2 hours after dinner each night and after lunch if no meetings 5. Schedule for monitoring/revision: monitor weekly on Sunday nights; try goal for 1 month and the reevaluate
Cognitive-behavioral therapy[26,27]	Feelings of helplessness and hopelessness can impact behavior.	Activating event: event or interpretation of the event Beliefs about the event Consequences: feelings and behavior after CBT helps patients to identify maladaptive beliefs and consequences related to an activating event	An adult patient who finds performing SMBG distressing Activating event: SMBG is stressful and only shows me how poorly I'm doing in managing my glucose Beliefs: my BG levels are unchangeable Consequences: I feel bad about myself after performing SMBG, so I don't do it Example of possible reframing: Event reframed: SMBG shows me how the insulin is working in my body Beliefs reframed: a lot of the time I can change my BG levels, but sometimes my BG level doesn't change like I want it to Consequences reframed: SMBG is a tool, and I'm learning not to take it personally
Motivational interviewing[26,28]	Failure to perform SMBG may negatively impact the pursuit of other goals	Five general principles: Build empathy with reflective listening Help patient to explore discrepancies between their desired outcome and current behaviors Avoid confrontation If the patient shows resistance to change, try reflective listening, remain nonjudgmental, and encourage the patient to keep talking Help patient to build self-efficacy around behavior change	An adolescent patient who is not performing SMBG before or during sports practice Build empathy through reflective listening (example: "So on the one hand, SMBG would help you know if you need to eat more carbs during practice and help your game, but if you're low, you'd miss some practice treating the low and less practice time hurts your game.") Help patient to explore discrepancies between their desired outcome and current behaviors (example: "Suppose you do need to treat a low, what is the worst thing that could happen?"; "What would be different if you did perform SMBG before each practice?") Avoid confrontation/ Try reflective listening if the patient shows resistance to change (example: "It sounds like you can see the problem here and getting in the practice time is really important to you."; "We've talked about the potential benefits of performing SMBG before and during practice, but maybe right now there's too much on the line for you to change this behavior.") Help patient to build self-efficacy around behavior change (example: "There is no simple answer, but in thinking this through and coming up with a way to perform SMBG more frequently during practice you've showed a lot of determination.")

[a]At this stage of problem solving, all strategies including ones that are clearly suboptimal or impossible should be included. During the evaluation phase, time can be spent helping to identify the specific reasons why these strategies are suboptimal or impossible.

found an increase in frequency of SMBG checks during the intervention phase for all participants (mean 1.7 checks/day in the baseline period to 5.7 checks/day in the intervention period). In addition, they found a carryover effect during the return to baseline period, with youths averaging 3.1 checks/day, thus suggesting at least short-term improvement in SMBG frequency is possible with a low-technology, contingency management based intervention.[15] Finally, combining contingency management with MI, a pilot study of 17 adolescents (mean age = 14.8 ± 1.5) found youths who received the treatment increased their SMBG frequency by 2.2 checks/day at posttreatment.[17] Youths also increased the mean number of days per week with at least 6 SMBG checks from 1.35 to 5.40 days/week. Interestingly, although contingency management and MI were ultimately combined, the first 2 ½ weeks of treatment just involved MI and even without incentives, youths nearly doubled the number of SMBG checks performed per day from week 1 to week 2, suggesting some impact from MI only.

In summary, the literature suggests self-management interventions can lead to at least short-term improvements in patients' frequency of SMBG. These interventions typically combined education, behavioral strategies, and psychological support. Some of these strategies (eg, problem solving, contingency management, goal setting) may be readily deployable in a clinic setting or in future research with minimal training. Future research is needed examining the long-term influence of self-management interventions on maintaining optimal adherence to SMBG.

Real-Time CGM

CGM technology has been available for about 15 years, but its use in daily care is not yet widespread. Based on data from the T1 Diabetes Exchange, approximately 9% of participants in the exchange (n = 1613) reported using CGM in their daily care, with adult patients (at least 26 years old) reporting the highest adoption rate (21% or 999 users).[10] CGM can help patients to achieve better glycemic control by improving the identification of abnormal glycemic levels and/or alerting patients to potentially harmful trends in glycemia (viz, rapidly falling or rising glucose levels).[1,3] In addition, results from a survey of current and former CGM users suggest that CGM use is associated with patient perceptions of greater control over diabetes and perceptions of more hypoglycemia safety.[29] Current recommendations for CGM do not provide specific guidelines for the timing or frequency of use.[1,3] Yet, multiple studies demonstrate improvements in patients' glycemic control if CGM is worn consistently.[30-36] In the landmark Juvenile Diabetes Research Foundation (JDRF) randomized clinical trial evaluating the efficacy of real-time CGM, researchers found significant improvement in HbA1c for adults only (mean difference −0.53%).[33] However, this difference may have been attributable to CGM frequency of use, as this was also highest among adults (83% reported use at least 6 days/week versus 30% of users between 15-25 years and 50% of users between 8 and 14 years old).[33] Since the JDRF trial multiple other trials have reported a negative correlation between CGM frequency of use and glycemic control in patients in good glycemic control (defined as HbA1c < 7.0%),[32,37] patients in poor glycemic control (HbA1c ≥ 8.0%[36]), patients pairing CGM and pump use,[35] and youths.[34] Similarly, in routine care, data from the T1 Diabetes Exchange suggest a lower mean HbA1c between CGM users versus nonusers for children (8.3% vs 8.6%, $P < .001$) and adults (7.7% vs 7.9%, $P < .001$), the 2 groups that reported the highest rates of CGM use (≥6 day per week, 55% of children and 60% of adults).[10] In contrast, there was no difference in HbA1c between CGM users versus nonusers for adolescents (9.0% vs 9.0%) and young adults (8.4% vs 8.5%), the 2 groups that reported the lowest rates of CGM use (≥6 days per week, 45% of adolescents and 37% of young adults).[10]

While multiple studies suggest that greater CGM use is related to lower HbA1c levels, several other trials show declining use of CGM over time. In a study recruiting 30 youths with T1DM, average CGM use decreased from 149 hours/week during the first month of the study to 134 hours/week during month 3 of the study.[38] Likewise, among children 4-9 years old,[39] researchers found a decline in use of CGM over time, with only 41% of children using CGM at least 6 days/week after about 6 months of continuous use, while another study conducted in children less than 4 years old,[40] found only 45% of children using CGM at least 6 days/week after 6 months of continuous use. Results from the JDRF-CGM showed the least decline in CGM use over time in adults (median use in adults declined from 7.0 days/week in the first month of the study to 6.5 days/week by the 6th month). However, greater declines were observed in adolescents (6.3 to 3.3 days/week) and children (6.8 to 3.7 days/week) in this trial.[31]

Although CGM has the potential to provide a more comprehensive report of a patient's glycemic levels than SMBG alone, studies have identified several common patient-reported barriers to CGM use, including pain associated with the sensor, problems with sensor insertion, problems with the sensor adhesive strip, problems with the sensor working properly, nuisance alarms, concern about the device accuracy, CGM interference with daily activities and sports, and skin reactions due to the sensor adhesive.[10,11] Cost of CGM supplies has also been identified as a barrier to use.[11,41] Indeed, cost may be a formidable barrier in countries with limited insurance reimbursement for CGM. However, a recent study tested the impact of cost on CGM frequency of use in Israel, where CGM is covered by their national health insurance program.[41] Eighty-three youths who had self-selected to start CGM based on physician recommendation participated. While cost was not a barrier, over 12 months, the investigators still tracked declining use among youths. Specifically, at 3 months, 71 youths (86%) were using CGM at least 75% of the time while at 12 months, only 32 youths were using CGM at least 75% of the time.[41] These data suggest that other patient characteristics may have a greater influence on CGM use than cost. For example, although not specifically predictive of frequency of use, other studies have found relations between better outcomes using CGM and patient-report of greater motivation for glycemic control, better coping resources, a better understanding of how to use CGM data, and greater family support, suggesting the opposites of all of these could be additional barriers to use.[11,42]

Interventions targeting more frequent CGM use are few. There is 1 trial (NCT01472159) currently under way in the United States that is investigating the impact of a CBT+MI focused intervention on increasing CGM use among adolescents. This proposed intervention approach has a high potential to be successful. MI, with its focus on strengthening the patient's own commitment to change, may provide adolescents with greater motivation and personal incentive to use CGM consistently to achieve goals both directly (ie, lower HbA1c, reduced glycemic variability) and indirectly (ie, improved academic or sports performance, reduced stress) related to their diabetes control. Similarly, CBT can teach adolescents new cognitive (ie, reframing negative thoughts) and behavioral (ie, problem solving, alternative coping responses) strategies to minimize barriers to CGM use. There is 1 published intervention that piloted simultaneous versus delayed initiation of CGM with continuous subcutaneous insulin infusion (CSII) in youths with T1DM.[43] The researchers hypothesized that patients would be more likely to adhere to using CGM consistently if the technology was introduced at the same time as CSII because patients would (1) see CGM as an integral part of optimal CSII management and (2) experience an easier time adopting CGM because they were already demonstrating a greater readiness for behavior change. Forty-one youths were randomly assigned to receive CGM plus CSII simultaneously or CSII with delayed CGM start. For youths receiving CGM plus CSII simultaneously, 75% of youths used CGM >60% of the time during the 4-month study compared to 14% of youths in the delayed start group, suggesting greater adoption of CGM may be possible if introduced simultaneously with CSII. However, researchers still noted an overall decline in CGM use over time (mean use > 65% of the time during weeks 1-14 vs 36% of the time at the end of the study), suggesting additional strategies may be needed to help patients to maintain a higher rate of CGM use over the long term.[43]

Research demonstrates that CGM has the potential to improve patients' HbA1c levels when used consistently.[30-36] However, several other studies report patients struggling with long-term adherence to this technology and problems with barriers to CGM use.[10,11] Intervention trials designed to target greater CGM use are now under way, and their results may provide greater insight into strategies to deploy within the clinic setting to improve patient's adherence to CGM. In addition, future research is needed to determine strategies that lead to greater long-term maintenance of CGM use among patients.

Conclusion

Many patients with diabetes struggle to adhere to recommendations for glycemic monitoring,[4-10] despite extensive evidence consistently demonstrating better HbA1c levels among patients who perform more SMBG checks per day[20-23] and/or use CGM greater than 60% of the time.[10,24] Strategies that appear to lead to at least short-term improvements in SMBG include education, problem solving, contingency management, goal setting, CBT, and MI. In contrast, less is currently known about how to improve CGM use among patients, but there is some initial efficacy suggesting better CGM adoption among patients showing greater readiness for behavior change. Overall, future research is needed examining strategies that lead to long-term maintenance of optimal glycemic monitoring in patients with diabetes. However, in the clinic setting, it may be possible to achieve at least short-term improvements now with greater adoption of problem solving, contingency management, and goal setting strategies within routine diabetes care.

Abbreviations

CBT, cognitive behavioral therapy; CGM, continuous glucose monitoring; CSII, continuous subcutaneous insulin infusion; HbA1c, glycated hemoglobin; JDRF, Juvenile Diabetes Research Foundation; MI, motivational interviewing; SMBG, self-monitoring blood glucose; T1DM, type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus.

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