ISSN 2472-1972

Approach to Using Trend Arrows in the FreeStyle Libre Flash Glucose Monitoring Systems in Adults

Yogish C. Kudva,[1] Andrew J. Ahmann,[2] Richard M. Bergenstal,[3] James R. Gavin III,[4] Davida F. Kruger,[5] L. Kurt Midyett,[6] Eden Miller,[7] and Dennis R. Harris[8]

[1]Division of Endocrinology and Metabolism, Department of Internal Medicine, Mayo Clinic, Rochester, Minnesota 55905; [2]Division of Endocrinology, Diabetes, and Clinical Nutrition, Oregon Health and Science University, Portland, Oregon 97239; [3]International Diabetes Center, Park Nicollet Health Services, Minneapolis, Minnesota 55416; [4]Emory University School of Medicine, Atlanta, Georgia 30322; [5]Division of Endocrinology, Diabetes, and Bone and Mineral Disorders, Henry Ford Health System, Detroit, Michigan 48202; [6]St. Luke's Hospital, Kansas City, Missouri 64111; [7]High Lakes Health Care, St. Charles Hospital, Bend, Oregon 97702; and [8]Endocrine Society, Washington, District of Columbia 20036

ORCiD numbers: 0000-0003-0285-6622 (Y. C. Kudva); 0000-0002-4544-5404 (A. J. Ahmann); 0000-0002-9050-5584 (R. M. Bergenstal); 0000-0003-4901-8781 (J. R. Gavin III); 0000-0002-3188-8132 (D. F. Kruger); 0000-0002-8262-5818 (D. R. Harris).

The use of personal continuous glucose monitoring (CGM) has expanded dramatically among individuals with diabetes. CGM systems provide retrospective data, as well as the current glucose value and trend arrow data, which indicate the direction and velocity of changing glucose. In 2017, Aleppo and colleagues developed a simplified approach for adults with diabetes to safely adjust rapid-acting insulin doses using trend arrow information in the Dexcom G5 CGM system. Since then, the FreeStyle Libre and FreeStyle Libre 14-day CGM systems have become available in the United States; however, guidance on using trend arrow data that take the unique features of these systems into consideration is lacking. Specifically, the FreeStyle Libre systems do not have automatic alarms, which impact how the system and trend arrow data are used. The Endocrine Society convened an expert panel to address this gap and develop an approach to adjusting rapid-acting insulin doses for adults using trend arrows in the FreeStyle Libre systems. We based our approach on previous work and expanded upon engagement and scanning recommendations, and we incorporated pre-exercise planning specific to these systems. Our approach provides insulin dose adjustments as discrete insulin units based on an individual's insulin sensitivity and directionality of the trend arrow. We focus on the needs of patients treated with multiple daily injections because these individuals currently make up a greater proportion of individuals on intensive insulin therapy. Our recommendations are intended to provide a safe, practical approach to using trend arrows in the FreeStyle Libre systems.

Freeform/Key Words: continuous glucose monitoring, flash glucose monitoring, trend arrows, scanning, diabetes, diabetes technology

Use of personal continuous glucose monitoring (CGM) has expanded dramatically over the past decade and is recommended as the gold standard of care for individuals with diabetes treated with intensive insulin therapy [1–3].

Abbreviations: CGM, continuous glucose monitoring; CSII, continuous subcutaneous insulin infusion; MDI, multiple daily injection; T1D, type 1 diabetes; T2D, type 2 diabetes.

Received 12 September 2018
Accepted 23 October 2018
First Published Online 14 November 2018

CGM provides information that can be critical for safe and effective diabetes management. Unlike fingerstick monitoring, which measures glucose at a single point in time, CGM displays the immediate glucose value within the context of both prior glucose data and, importantly, the direction and velocity of changing glucose using trend arrows. Real-time information allows patients to react immediately to mitigate or prevent acute glycemic events. Retrospective review of CGM data in combination with standardized data management tools such as the ambulatory glucose profile [4, 5] help clinicians and patients fine-tune management strategies.

One of the newest CGM systems available in the United States is the FreeStyle Libre flash glucose monitoring system (FreeStyle Libre system; Abbott Diabetes Care, Alameda, CA), often referred to as flash CGM or intermittently scanned CGM. The system received US Food and Drug Administration clearance in September 2017 for nonadjunctive use in adults (age 18 years and older) with diabetes. The FreeStyle Libre 14-day flash glucose monitoring system (FreeStyle Libre 14-day system; Abbott Diabetes Care) was more recently approved by the US Food and Drug Administration with the same indications but with a longer wear time and shorter warm-up period that is comparable to systems available in Europe (Table 1). The nonadjunctive indication allows patients to calculate insulin doses based on current sensor value using individual insulin dosing parameters, target glucose concentration, and trend arrow information.

Large randomized controlled trials demonstrated that use of the FreeStyle Libre system resulted in significant reductions in hypoglycemia, increased time in target range, reduced glycemic variability, and greater patient satisfaction compared with fingerstick monitoring [6, 7]. These benefits were seen in well-controlled type 1 diabetes (T1D) [6] as well as suboptimally controlled type 2 diabetes (T2D) treated with intensive insulin therapy [7]. Studies also showed high device utilization, suggesting that the FreeStyle Libre system may enhance patient engagement [6, 7]. Smaller observational and prospective studies have also shown improvements in both A1c and a reduction in hypoglycemic events [8–10].

Although research provides compelling evidence of the benefits of the FreeStyle Libre system, there is sparse guidance for what actions individuals should take based on the trend arrow data. The purpose of this article is to provide safe, practical guidance on the use of trend arrow data in the FreeStyle Libre and FreeStyle Libre 14-day systems—collectively called the FreeStyle Libre systems unless denoted otherwise—in the United States for clinicians and their patients on intensive, rapid-acting insulin therapy. Current sensor warm-up and wear time in US-approved systems has been an iterative process that has resulted in closer alignment between systems approved in the United States and beyond. Our hope is that this better alignment of systems will improve access and utility, but we note differences outside the United States in patient indications (systems are available to children as young as 4 years of age and to women during pregnancy) as well as interface options (systems may use the mobile LibreLink application on a compatible smart device to scan the sensor). We focus on the US-approved systems, recognizing the differences in patient indications and interface options in the FreeStyle Libre systems available outside the United States.

Our approach is based on the recently published guidance by Aleppo *et al.* [11], which focused on a different CGM system (Dexcom, San Diego, CA). We have modified our approach to account for these differences. Specifically, we address that the FreeStyle Libre systems do not have automatic alarms or double up and double down trend arrows, which are present in the Dexcom systems. We developed our approach to be applicable to any patient with diabetes treated by intensive insulin therapy who is using continuous subcutaneous insulin infusion (CSII) or multiple daily injections (MDIs). However, we focus on the needs of patients treated with MDIs because these individuals currently make up a greater proportion of T1D and T2D populations on intensive insulin therapy. Additionally, our approach is based on the anticipated changes in individuals using rapid-acting insulin analogs for prandial and correction insulin doses. Our approach is not intended for individuals using more recently available ultra–rapid-acting insulins, which have reduced insulin action times and may affect rate of glucose change differently. We also incorporate our clinical experiences, our personal

Table 1. Overview of Features in the FreeStyle Libre Systems Approved in the United States

This overview is representative of the FreeStyle Libre systems approved in the United States at time of publication.* The FreeStyle Libre system is approved in the European Union (EU) as of September 2014 and in the United States as of November 2017. The FreeStyle Libre 14 day system is approved in the United States as of July 2018. EU and US systems have differences in patient indication and interface options. Refer to the table for features of US approved systems only.

Minimum use age:	≥18 years
Sensor placement:	Back of arm; placement is not approved for other sites
Sensor warm-up period:	▶ FreeStyle Libre system: 12 hours after insertion before able to retrieve glucose data ▶ FreeStyle Libre 14 day system: 1 hour after insertion before able to retrieve glucose data
Sensor wear time:	▶ FreeStyle Libre system: 10 days ▶ FreeStyle Libre 14 day system: 14 days
Calibration:	Factory calibrated; does not require daily calibration
Insulin dosing:	Individuals are able to use sensor glucose reading for treatment decisions without confirmatory fingerstick monitoring. Under the following conditions, sensor glucose readings may not be accurate, and you should conduct a fingerstick: ▶ If inaccurate reading is suspected ▶ If experiencing symptoms that may be due to low or high blood glucose ▶ If experiencing symptoms that do not match sensor glucose readings ▶ During times of rapidly changing glucose of more than 2 mg/dL per minute (i.e., straight up or down trend arrow) ▶ When the sensor glucose reading does not include a current glucose number or trend arrow ▶ To confirm hypoglycemia or impending hypoglycemia as reported by the sensor ▶ When "Check Blood Glucose" symbol appears in the reader ▶ During the first 12 hours of wearing a FreeStyle Libre 14 day Sensor
Cautions and Contraindications:	▶ The system is not approved for use in pregnant women or persons on dialysis and has not been evaluated in these populations. ▶ The system has not been evaluated for use in patients with hypoglycemia unawareness and will not automatically alert to current or impending hypoglycemic event without scanning the sensor. The system will not automatically notify the user when experiencing hypoglycemia or hyperglycemia unless the sensor is scanned.
Potential Interferents:	▶ Salicylic acid (used in aspirin and other pain relievers) at doses ≥650 mg may cause falsely lower glucose values ▶ Ascorbic acid (vitamin C) at doses ≥500 mg may cause falsely higher readings. ▶ At lower doses, salicylic acid and ascorbic acid are known to have minimal effect on sensor glucose readings in the FreeStyle Libre systems.

* For full indications for use and safety information, seek out product information from the manufacturer.

experiences as people living with diabetes and using CGM, and guidance from other diabetes specialists.

1. FreeStyle Libre Flash Glucose Monitoring System

A. System Overview

The FreeStyle Libre systems use two components: a disposable sensor that is inserted into the user's upper arm and a separate handheld touchscreen reader device used to scan and retrieve CGM glucose readings. Following sensor insertion, the FreeStyle Libre 10-day system has a 12-hour warm-up period until the reader is able to retrieve sensor glucose readings. The system is factory calibrated, which eliminates the need for daily calibration during the 10-day wear time (Table 1). Similarly, the FreeStyle Libre 14-day system is factory calibrated, but it has a 1-hour warm-up period and 14-day wear time.

When the reader is swiped close to the sensor in either system, the sensor glucose data are transmitted to the reader. The reader displays the current glucose concentration and the most recent 8 hours of sensor glucose readings, as well as trend arrow data when present. When >8 hours occur between scans, only the last 8 hours of data are reported. Importantly, the system lacks automatic alarms. Therefore, patients must be actively engaged in scanning because they will not receive automatic alarms in the event of hypoglycemia or hyperglycemia, as is the case with other CGM systems.

B. Trend Arrows

The system measures glucose concentrations every minute and, when scanned, transmits the current glucose reading and historical glucose readings in 15-minute increments to the reader. The trend arrows are calculated from glucose readings with an emphasis on the most recent 15 minutes. The directionality of trend arrows allows individuals to anticipate future glucose concentrations. This additional information can be used proactively to adjust therapy and prevent hypoglycemia or hyperglycemia. For individuals on intensive insulin therapy, upward trend arrows indicate rising glucose concentrations and may suggest a need for additional rapid-acting insulin. Downward trend arrows indicate falling glucose concentrations and may suggest a need for less rapid-acting insulin or carbohydrate ingestion to avoid hypoglycemia. Flat arrows indicate that glucose concentrations are changing very slowly and that therapy adjustments are probably not needed if in the target range. Figure 1 provides an example of how these trend arrows appear in the FreeStyle Libre system and the anticipated glucose change they represent.

C. Scanning Frequency

Although, there are no "hard and fast" rules for scanning frequency, large clinical studies have shown that the glycemic benefits of the FreeStyle Libre system use were achieved at mean scanning frequencies ranging from 8 times per day in patients with T2D [7] to 15 times per day in patients with T1D [6]. However, scanning at any frequency has been associated with clinical benefit, and an analysis of real-world data from 50,831 users revealed a mean of 16.3 scans per day, suggesting that this scanning frequency is reasonable among most users [12]. The

FreeStyle Libre System Trend Arrows

Reader	Glucose Direction	Change in Glucose
↑	Rising quickly	**Glucose is rising quickly** Increasing >2 mg/dL/min or >60 mg/dL in 30 minutes
↗	Rising	**Glucose is rising** Increasing 1–2 mg/dL/min or 30–60 mg/dL in 30 minutes
→	Changing slowly	**Glucose is changing slowly** Not increasing/decreasing >1 mg/dL/min
↘	Falling	**Glucose is falling** Decreasing 1–2 mg/dL/min or 30–60 mg/dL in 30 minutes
↓	Falling quickly	**Glucose is falling quickly** Decreasing >2 mg/dL/min or >60 mg/dL in 30 minutes
No arrow present indicates that the system cannot calculate the velocity and direction of the glucose change.		

Figure 1. Trend arrows in the FreeStyle Libre systems. The FreeStyle Libre systems present trend arrow data as icons on the reader. Trend arrows indicate rates of glucose change (mg/dL per min) and can be described as the anticipated glucose change. Notably, the flat arrow does not indicate no change in sensor glucose readings. The flat arrow indicates steady glucose values with a change of <1 mg/dL per min. For individuals using the FreeStyle Libre systems, more frequent scanning may be warranted to monitor for hypoglycemia when a flat arrow is present and sensor glucose is near the low end of the target range. In general, anticipated glucose may be less accurate when trying to predict changes over extended periods of time (*e.g.*, beyond 20 to 30 min) due to the many factors that may influence glucose concentrations. Conversion: mg/dL × 0.0555 = mmol/L.

Table 2. Scanning Recommendations for Optimal Diabetes Management Using the FreeStyle Libre Systems

Prior studies have demonstrated greater glucose control benefits were associated with increasing frequency of daily scans using the FreeStyle Libre systems. However, we emphasize that patient engagement with the sensor is paramount to clinical success and that scanning frequency may vary substantially between patients. We offer suggested daily scanning approaches that represent an ideal scenario of patient engagement with the FreeStyle Libre systems.

ROUTINE SCANNING		
Scenario	**Recommendation**	**Explanation**
Morning	Scan upon waking	Scanning upon waking facilitates a more complete stream of continuous sensor glucose readings and a retrospective review of the prior night's glucose trends. A gap in data may be present if an individual sleeps longer than 8 hours. Individuals are able to begin the day with appropriate adjustments, if needed, to improve time in glucose range.
Pre-meal	Scan prior to meals	Scanning prior to meals allows individuals to use current sensor glucose readings and trend arrow data as part of insulin dose calculation. Current sensor glucose reading and trend arrow data also help to evaluate timing of insulin injection prior to a meal.
Post-meal	Scan 2 hours after mealtime	Glucose concentrations often change dramatically following mealtime. Scanning 2 hours following a meal enables evaluation of mealtime treatment decisions and determination if corrective action is needed. Refer to Figure 3 for more detailed post-meal guidance.
Bedtime	Scan prior to sleep	Bedtime scanning enables evaluation of current sensor glucose and trend arrow data to determine if corrective action is needed to prevent nocturnal hypoglycemia or hyperglycemia. Individuals who wake during the night are encouraged to scan to assess their current glycemic status and to maintain a continuous stream of sensor glucose data.
SCANNING TO ASSESS GLUCOSE CONTROL		
Scenario	**Recommendation**	**Explanation**
Continuous Data	Scan every 8 hours	The FreeStyle Libre systems display the current glucose concentration and the most recent eight hours of sensor glucose readings. Scanning at least every 8 hours maintains a continuous data stream of sensor glucose readings, which may benefit retrospective analysis. Depending on the individual's sleeping patterns, this may require a nighttime scan.
Meal Analysis	Scan hourly for first 4 hours following a meal	Scan every hour for the first 4 hours following a meal to evaluate the effect of treatment decisions and rate of glucose change following a meal. Scanning hourly may help evaluate insulin dose timing, impact of meal composition, and insulin to carbohydrate ratio (ICR).
Post-correction scanning	**Hyperglycemia** Scan hourly for up to 4 hours following corrective action	Scan at least every hour following a corrective insulin bolus to treat hyperglycemia to follow trend arrow directionality, ensure target glucose is achieved, and prevent hypoglycemia.
	Hypoglycemia Scan every 15 minutes, following corrective action until steady target glucose is achieved	The trend arrows are calculated from glucose readings with an emphasis on the most recent 15 minutes. Following a corrective action to treat hypoglycemia, scan every 15 minutes to verify that trend arrow directionality reflects the corrective action, determine if additional action is needed, and protect against severe hypoglycemia and/or over-treatment leading to hyperglycemia.

(Continued)

Table 2. Scanning Recommendations for Optimal Diabetes Management Using the FreeStyle Libre Systems (Continued)

Prior studies have demonstrated greater glucose control benefits were associated with increasing frequency of daily scans using the FreeStyle Libre systems. However, we emphasize that patient engagement with the sensor is paramount to clinical success and that scanning frequency may vary substantially between patients. We offer suggested daily scanning approaches that represent an ideal scenario of patient engagement with the FreeStyle Libre systems.

SCANNING IN SPECIAL CIRCUMSTANCES		
Scenario	**Recommendation**	**Explanation**
Sick Day	Scan every 2 hours	More frequent scanning in conjunction with fingerstick monitoring may be needed during illness when sensor glucose readings may not accurately reflect blood glucose values due to the increased potential for rapidly changing glucose and high doses of ascorbic acid (vitamin C) and/or salicylic acid (used in some pain relievers such as aspirin).
Elderly/Frail patients	Scan at least every 4 hours to prevent hypoglycemia during waking day and at bedtime	Ideally, elderly and/or frail patients should scan more frequently due to increased risk for hypoglycemia.
Exercise	Scan before exercise and every 15-30 minutes during exercise Scan immediately following exercise Scan 6-8 hours following exercise	Pre-exercise monitoring will determine whether exercise will be safe, and/or if any corrective actions are needed. Frequent monitoring during exercise is important especially with extended-duration activities. Attention to scanning is needed several hours following exercise due to risk of delayed hypoglycemia with prolonged aerobic exercise.

recommendations for scanning frequency presented in Table 2 are based on our clinical judgment and personal experiences using the FreeStyle Libre system in a clinical setting.

2. Approach to Using Trend Arrows in the FreeStyle Libre Systems to Adjust Insulin Doses

In 2017, Aleppo *et al.* [11] published recommendations for using trend arrows with the Dexcom G5 CGM system in adults. Those recommendations were based on review of four previously published methods to adjust insulin doses using trend arrows: the DirecNet Applied Treatment Algorithm [13], the Scheiner method [14], Pettus and Edelman method [15], and the Klonoff and Kerr equation [16]. We have modified those recommendations to accommodate the features and functionalities of the FreeStyle Libre systems.

Our approach may be applied to any patient with diabetes treated by intensive insulin therapy. Our recommendations are applicable to both CSII and MDI therapy; however, we focus mainly on trend arrow use with patients treated with MDIs, who comprise more than half of the T1D population [17] and a growing number of patients with T2D [18].

Recognizing that many patients treated with MDIs may be unfamiliar with CGM use, we have endeavored to make our method as simple and intuitive as possible. Because adjusting insulin dose using trend arrows adds a layer of complexity, we recommend patients wait until they are comfortable with the general application of CGM data and learn how their body responds to various meals (quantity/composition) and physical activity before adjusting insulin dose using trend arrows. Safe and effective use of the FreeStyle Libre systems requires that patients have a basic understanding of how to use their current glucose value, target glucose value, food intake (if any), and insulin dosing parameters to calculate their

insulin doses. Importantly, the approach relies on the accurate determination of insulin-to-carbohydrate ratio and correction factors as insulin dose parameters.

A. Mealtime Insulin Calculation

Figure 2 outlines our method for adjusting insulin doses at meal time and at least 4 hours after a meal, using trend arrows. The method utilizes a simple approach to insulin dose calculation: Total premeal insulin dose = food ± correction ± arrow adjustment. Patients would calculate their rapid-acting insulin dose for food and correction, and then add or subtract insulin based on the trend arrow.

The insulin dose adjustment recommendations are based on typical insulin sensitivity ranges for adult patients as determined by Aleppo *et al.* [11]. Similarly, we offer an insulin dose adjustment in insulin units for each insulin sensitivity range. In this manner, insulin adjustments can be simply added to or subtracted from standard calculations. The adjustments also take into consideration the limitations of 0.5-U increment minimums for individuals treated with MDI with significant insulin sensitivity. Although 0.5-U increment insulin pens are generally reserved for use in highly insulin-sensitive patients, it is not uncommon for adults with T1D to also be insulin sensitive, and use of 0.5-U increment insulin pens can be a practical tool for diabetes management [19]. Alternatively, adult patients using 1.0-U increments can round the total insulin dose, including food, correction, and adjustment, to the closest full unit.

Because the previous approach determined by Aleppo *et al.* focused on the Dexcom G5 system, which includes double up and double down trend arrows that correspond to >3 mg/dL per minute rate of glucose change, we modified our guidance to accommodate the FreeStyle Libre systems, which do not have double up or double down trend arrows. Specifically, we retained the same adjustment value as Aleppo *et al.* for the single up and single down trend arrows rather than increase the suggested insulin dose adjustment to account for a lack of double up and double down trend arrows. We think this is a safe approach to using trend arrows in the FreeStyle Libre systems, which lack automatic alarms. Based on clinical experience and a study by Kovatchev *et al.* [20], we also think that the time spent at >3 mg/dL per minute is relatively infrequent in the absence of food intake or exercise, for which we offer specific guidance. In this manner, we think our suggested approach provides a safe starting point for individuals seeking to use trend arrows in the FreeStyle Libre systems to reduce glycemic variability. It is important to differentiate MDIs from CSII when using trend arrows; for instance, CSII users may need to adjust insulin dose more conservatively when they are using temporary basal rates to address trend arrows following mealtime. Table 3 presents sample scenarios that demonstrate how the approach can be used.

Our approach to adjusting insulin dose is not intended to replace standard care in the event of a missed insulin dose for meals. In this case, it is standard practice to calculate the insulin dose based on the carbohydrate ingested, CGM value, and CGM trend arrow at the time of the meal. Adjusting insulin doses using trend arrows should also be avoided in cases of underestimating carbohydrate intake from a previous meal (*i.e.*, miscalculations) and overcorrecting for hypoglycemia with fast-acting carbohydrate. At these times, the trend arrows can play an important role as indications to patients of a missed dose or a miscalculation. For other unplanned situations, more specific strategies for the use of trend arrows should be established between patients and their health care providers.

B. Postmeal Monitoring (2 to 4 Hours After Meal)

We also include an approach to postmeal monitoring and treatment in adults based on the guidelines used in the REPLACE-BG trial, which suggested a method to minimize hypoglycemia and hyperglycemia during the 4 hours following a meal [21]. Figure 3 outlines the approach that can be used by both patients treated with MDIs and patients treated with insulin pumps.

As a general rule, we recommend caution when adjusting insulin dose using trend arrows during the 4 hours following a meal due to the many variables (*e.g.*, meal composition, total calories, physical activity/exercise, insulin on board) that affect rate of glucose change during this time. Notably, our

Insulin Dose Adjustments Using the FreeStyle Libre System Trend Arrows in Adults: Pre-meal and Corrections ≥4 Hours Post-meal

Insulin Dose Adjustments

FreeStyle Libre Trend Arrows	Correction Factor* (CF)			
	<25	25–<50	50–<75	≥75
↑	+3.5 units	+2.5 units	+1.5 units	+1.0 units
↗	+2.5 units	+1.5 units	+1.0 units	+0.5 units
→	No adjustment	No adjustment	No adjustment	No adjustment
↘	-2.5 units	-1.5 units	-1.0 units	-0.5 units
↓	-3.5 units	-2.5 units	-1.5 units	-1.0 units

Insulin dose adjustments using trend arrows do not replace standard calculations using ICR and CF. Adjustments are increases or decreases of rapid-acting insulin in addition to calculations using ICR and CF. Adjustments using trend arrows are an additional step to standard care.

*Correction factor (CF) is in mg/dL and indicates glucose lowering per unit of rapid-acting insulin.

Considerations

Mealtime is ideal to begin applying insulin dose adjustments using trend arrows. For the 4 hours following a meal, refer to *Figure 3* for an approach to minimize hypo- and hyperglycemia during this timeframe.

For rapidly rising sensor glucose (UP arrow; ↑) at pre-meal, consider administering insulin 15–30 minutes before eating.

For rapidly falling sensor glucose (DOWN arrow; ↓):
- Pre-meal: consider administering insulin closer to the meal
- Near or lower than 150 mg/dL: consider holding pre-meal insulin dose until glucose trends have stabilized

For frail or older adults, start conservatively to reduce hypoglycemia risk:
- Upward arrows: reduce dose increase by at least 50% (e.g., +1.0 units may become +0.5 units or no insulin increase)
- Downward arrows: increase dose reduction by least 50% (e.g., -1.0 units may become -1.5 or -2.0 units)

When rounding of insulin dose is needed:
- Calculate total insulin dose using insulin dosing parameters for food intake (if any), correction, and trend arrow adjustment
- Round to the nearest whole number or half unit as appropriate
- If at a midpoint (i.e., 0.5 units) and needing to round to a whole number:
  - Round up when flat or upward arrow is present
  - Round down when downward arrow is present

Figure 2. Insulin dose adjustments for adults using trend arrows in the FreeStyle Libre systems. Our recommended approach to adjusting insulin dose using trend arrow data in the FreeStyle Libre systems assumes that the patient has insulin-requiring diabetes, is using rapid-acting insulin for meals and correction, and is using insulin-to-carbohydrate ratio (ICR) and correction factors (CFs) that have been optimized as much as possible. The approach is based on anticipated glucose change and typical insulin sensitivity ranges in adults. The approach utilizes a simple approach to insulin dose calculation: Total insulin dose = food ± correction ± arrow adjustment. It provides adjustments in terms of insulin units over the range of insulin sensitivities to minimize additional calculations. It is generally recommended to start adjusting conservatively and at mealtime to understand how the recommendations impact individual glucose responses. Adjusting the insulin dose using trend arrows does not replace but, rather, adds to standard calculations using ICR and CFs. Importantly, a single arrow up may require additional corrections due to unknown velocity of glucose increase (*e.g.*, >2 mg/dL). The CF (in mg/dL) indicates glucose lowering per unit of rapid-acting insulin. Conversion: mg/dL × 0.0555 = mmol/L.

approach assumes the use of rapid-acting insulin. More recently available ultra–rapid-acting insulins may also affect rate of glucose change during this time. Individuals using ultra–rapid-acting insulin should take caution when considering our postmeal approach. Importantly, patients should be cautioned to wait at least 2 hours after a meal-time bolus before taking any corrective action (*e.g.*, standard corrections based on correction factor or insulin dose adjustments using trend arrows).

Table 3. Illustrative Examples of Using Trend Arrows in the FreeStyle Libre Systems

Case scenarios assume patients have insulin-requiring diabetes and are using a FreeStyle Libre system. Case scenarios assume ICR and CF values have been accurately determined by the patient's healthcare team and that the patient is administering rapid-acting insulin for boluses and corrections.

SCENARIOS OF GLUCOSE RATE OF CHANGE									
A	**Upward Trend Arrow:** A 44-year-old man with T1D on CSII therapy is about to eat a meal with 45 g of carbohydrate. His sensor glucose value is 164 mg/dL and an angle up trend arrow is present. Based on the parameters below, he determines 4.5 units are needed for his meal and 1.1 units for correction. An additional 1.5 units is suggested to account for the angle up trend arrow.								
	Sensor	**Arrow**	**Target**	**Carb**	**Values**	**Insulin Dose Adjustment**			
	164 mg/dL	↗	120 mg/dL	45 g	CF–40 ICR–1:10	**Food**	**Correction**	**Trend Arrow**	**Total Dose**
						4.5 units	1.1 units	+1.5 units	7.1 units
B	**Downward Trend Arrow:** A 59-year-old woman with T2D on MDI therapy scans her sensor before leaving a late day of work and sees a glucose value of 194 mg/dL and a straight down trend arrow. It has been 6 hours since her last meal. Fingerstick confirms the sensor glucose value. Based on the parameters below, she determines 3.7 units would be needed to correct for the high glucose; however, based on the anticipated falling glucose, she is suggested to subtract 3.5 units. Because she is on MDI therapy, she will take no insulin and continue to scan periodically.								
	Sensor	**Arrow**	**Target**	**Carb**	**Values**	**Insulin Dose Adjustment**			
	194 mg/dL	↓	120 mg/dL	0 g	CF–20 ICR–1:7	**Food**	**Correction**	**Trend Arrow**	**Total Dose**
						0 units	3.7 units	–3.5 units	0 units
POST-MEAL MONITORING AND TREATMENT									
C	**Post-meal:** A 29-year-old man with T1D on CSII therapy scans his sensor 2 hours after eating dinner to see a glucose value of 150 mg/dL and flat trend arrow. Although the glucose value is above target, he follows post-meal suggestions (*Figure 3*) and does not take additional insulin. This will prevent insulin stacking. Importantly, a flat trend arrow does not indicate zero change; a flat trend arrow represents <1 mg/dL/min rate of glucose change (i.e., ±30 mg/dL in 30 minutes). He will rescan in 1 hour to continue monitoring.								
	Sensor	**Arrow**	**Target**	**Carb**	**Values**	**Insulin Dose Adjustment**			
	150 mg/dL	→	120 mg/dL	0 g	CF–35 ICR–1:12	**Food**	**Correction**	**Trend Arrow**	**Total Dose**
						0 units	0 units	NA	0 units
PRE-EXERCISE PLANNING FOR AEROBIC EXERCISE									
D	**Pre-exercise:** A 50-year-old man with T2D on MDI therapy is planning to walk 3 miles within 1 hour very soon; the time is 4:00 pm. He scans his sensor in preparation and sees a glucose value of 128 mg/dL and a flat trend arrow. This person is likely to experience falling glucose during his planned exercise. As a precaution to avoid hypoglycemia, he ingests 15 g of fast-acting carbohydrate before beginning his walk. He will rescan after 30 minutes at a minimum to continue monitoring and ensure safe exercise.								
	Sensor	**Arrow**	**Target**	**Carb**	**Values**	**Insulin Dose Adjustment**			
	128 mg/dL	→	120 mg/dL	15 g	CF–30 ICR–1:9	**Food**	**Correction**	**Trend Arrow**	**Total Dose**
						0 units	0 units	0 units	0 units
E	**Pre-exercise:** A 23-year-old woman with T1D on CSII therapy is preparing to run 3 miles as a training for an upcoming race. She scans her sensor in preparation and sees a glucose value of 220 mg/dL and an angle down trend arrow. This person is likely to experience falling glucose during her planned exercise. Additionally, her angle down trend arrow indicates falling glucose. However, her current glucose is well above target range. She will start her planned run without taking a corrective insulin dose or fast-acting carbohydrate. Instead, she will continue monitoring by rescanning every 30 minutes at a minimum to prevent hypoglycemia.								
	Sensor	**Arrow**	**Target**	**Carb**	**Values**	**Insulin Dose Adjustment**			
	220 mg/dL	↘	120 mg/dL	0 g	CF–70 ICR–1:25	**Food**	**Correction**	**Trend Arrow**	**Total Dose**
						0 units	0 units	0 units	0 units

(Continued)

Table 3. Illustrative Examples of Using Trend Arrows in the FreeStyle Libre Systems (Continued)

Case scenarios assume patients have insulin-requiring diabetes and are using a FreeStyle Libre system. Case scenarios assume ICR and CF values have been accurately determined by the patient's healthcare team and that the patient is administering rapid-acting insulin for boluses and corrections.

FRAIL INDIVIDUAL

F

Frail individual: A 75-year-old man with T1D on CSII therapy is scanning his sensor before eating his evening meal that contains 50 g of carbohydrate. The current sensor glucose is 185 mg/dL and straight up trend arrow is present. Fingerstick confirms the sensor glucose value. Based on the parameters below, he determines 2.5 units would be needed to account for his meal and 1.0 unit needed as a correction. This person is quite insulin sensitive and at greater risk for hypoglycemia considering his age. The suggested insulin dose adjustment is for the trend arrow is to add 1.5 units. However, out of an abundance of caution to prevent hypoglycemia, he reduces the insulin dose adjustment to +0.75 units. He takes a total insulin dose of 4.25 units.

Sensor	Arrow	Target	Carb	Values	Insulin Dose Adjustment			
					Food	Correction	Trend Arrow	Total Dose
185 mg/dL	↑	120 mg/dL	50 g	CF–65 ICR–1:20	2.5 units	1.0 unit	0.75 unit	4.25 units

SICK DAY MANAGEMENT

G

Sick day management: A 35-year-old woman with T1D on MDI therapy has stayed home from work because of a viral illness. She ingested a vitamin drink with 1 g vitamin C (ascorbic acid) and took 625 mg of acetaminophen about 1 hour prior. She scans her sensor in preparation for lunch, which has 60 g carbohydrate. Her sensor shows a glucose value of 243 mg/dL and a straight up trend arrow. Notably, the FreeStyle Libre systems are susceptible to falsely high readings with vitamin C (ascorbic acid) doses >500 mg readings; however, the systems are not susceptible to interference by acetaminophen. Confirmatory fingerstick shows an actual glucose value of 170 mg/dL. Based on the parameters below, she determines 4.0 units are needed for her meal and 1.0 unit for correction. Due to the vitamin C interference, she will not adjust her insulin dose based on the trend arrow and will instead continue to monitor by fingerstick while taking the vitamin C drink. She will take 5.0 units of insulin at this time.

Sensor	Arrow	Target	Carb	Values	Insulin Dose Adjustment			
					Food	Correction	Trend Arrow	Total Dose
243 mg/dL	↑	120 mg/dL	60 g	CF–50 ICR–1:15	4.0 units	1.0 unit	NA	5.0 units

Abbreviations: CF, correction factor in mg/dL indicates glucose lowering per unit of rapid-acting insulin; CSII, continuous subcutaneous insulin infusion; ICR, insulin-to-carbohydrate ratio; MDI, multiple daily injection; T1D, type 1 diabetes; T2D, type 2 diabetes. Conversion: mg/dL × 0.0555 = mmol/L.

3. Engaging Your Patients

Optimal use of the FreeStyle Libre systems requires that patients and clinicians become actively engaged with utilizing CGM data in both real-time decision-making and retrospective analysis. Real-time decision-making refers to patients actively using their CGM data to make insulin dosing decisions to achieve desired glycemic control and prevent or mitigate acute glycemic events. Retrospective analysis refers to review of historical CGM data to identify glucose patterns that may indicate a need for therapy adjustment and/or changes in behaviors.

A. Real-Time Decision-Making

The FreeStyle Libre systems require patients to make a conscious effort to obtain glucose data with periodic scanning. As such, patients need guidance regarding when and how often to scan based on their current glucose and trend arrows (see Table 2). However, monitoring is not managing. Patients also need guidance about what they should do with the information they obtain and, importantly, they need to be empowered to make changes when needed. These measures will enhance patients' confidence in the device and their ability to avoid acute glycemic events and effectively manage their diabetes.

B. Retrospective Analysis

Use of retrospective CGM data by patients and clinicians is equally important. Patients can use built-in reader reports (*e.g.*, Glucose Pattern Summary or Weekly Summary) and detailed information downloaded via the LibreView software to see the effects of their current activities (*e.g.*,

Post-meal Scanning and Treatment Decisions for MDI and CSII-Treated Patients Using the FreeStyle Libre Systems

During the 4 hours following mealtime bolus, individuals needing corrective action should rely on current sensor glucose and predetermined ICR and CF values. Avoid taking additional bolus insulin doses within the first 2 hours to prevent insulin stacking.

2–4 hr Post-meal Glucose Concentration

>250 mg/dL

FreeStyle Libre Trend Arrows	Action
↑	Take corrective action using bolus insulin dose based on CF. Re-scan in 1 hour. If up arrow persists after additional hour: • Confirm with fingerstick • Change infusion site (if using an insulin pump) • Take additional corrective insulin dose based on CF
↗	Take corrective action using bolus insulin dose based on CF. Re-scan in 1 hour. Avoid additional correction doses for 2 hours.
→	No action needed. Rescan in 1 hour.
↘	No action needed. Rescan in 1 hour.
↓	No action needed. Rescan in 1 hour.

181–250 mg/dL

↑	Consider corrective action using bolus insulin dose based on CF. Re-scan in 1 hour. Avoid additional correction doses for 2 hours.
↗	Consider corrective action using bolus insulin dose based on CF. Re-scan in 1 hour. Avoid additional correction doses for 2 hours.
→	No action needed. Rescan in 1 hour.
↘	No action needed. Rescan in 30 minutes.
↓	No action needed. Rescan in 30 minutes.

70–180 mg/dL

↑	No action needed. Rescan in 1 hour.
↗	No action needed. Rescan in 1 hour.
→	No action needed. Rescan in 1 hour.
↘	Ingest 15 g fast-acting carbohydrate. Re-scan in 15–30 min. If sensor glucose ≤70 mg/dL with downward arrow at 30 min, confirm with fingerstick and ingest additional 15 g fast-acting carbohydrate.
↓	Ingest 15 g fast-acting carbohydrate. Re-scan in 15–30 min. If sensor glucose ≤70 mg/dL with downward arrow at 30 min, confirm with fingerstick and ingest additional 15 g fast-acting carbohydrate.

Corrective action is necessary for sensor glucose readings at or below 70 mg/dL when downward arrows are present. Following corrective action, rescanning is needed to ensure the sensor glucose reading is trending toward an acceptable range.

Considerations

- Flat arrows indicate that glucose concentrations are changing very slowly at a rate of less than 1 mg/dL/min. For individuals using the FreeStyle Libre systems, more frequent scanning may be warranted to monitor for hypoglycemia when a flat arrow is present and sensor glucose is near the low-end of target range.
- CSII-treated individuals should use established CF with the pump bolus calculator, which will account for insulin-on-board.
- MDI-treated individuals that are not using a bolus calculator that takes insulin-on-board into consideration are generally recommended to administer 50% of the calculated insulin dose during this timeframe to avoid hypoglycemia.
- Confirmatory fingerstick is indicated:
  - During times of rapidly changing glucose of more than 2 mg/dL/min (i.e., straight up or down arrow)
  - To confirm hypoglycemia or impending hypoglycemia as reported by the sensor

Figure 3. Monitoring and treatment decisions using trend arrows in the FreeStyle Libre systems 2 to 4 h following mealtime bolus. Several variables impact glycemia following

mealtime bolus. During the 4 h following mealtime bolus, individuals needing corrective active should rely on current sensor glucose and predetermined CF and ICR values. Importantly, the approach relies on the accurate determination and use of insulin-to-carbohydrate ratio (ICR) and correction factors (CFs) as insulin dose parameters. Individuals should not rely on insulin dose adjustments using trend arrow data during this time. The following is based on the protocol used in the REPLACE-BG study [21] and has been modified to account for the unique features of the FreeStyle Libre system and includes observed trend arrows for the FreeStyle Libre systems. In general, individuals should avoid taking corrective action by bolus insulin dose within the first 2 h after eating. Insulin stacking is a primary concern during this time. Beyond 4 h, it is assumed that most, if not all, carbohydrate has entered the system and that there is no active bolus insulin on board. In this case, the authors recommend using the trend arrows for dose adjustment (Fig. 2). The CF (in mg/dL) indicates glucose lowering per unit of rapid-acting insulin. Conversion: mg/dL × 0.0555 = mmol/L.

insulin dosing, exercise, meal amounts/composition) and adjust their behaviors accordingly. Importantly, patients should be encouraged to use retrospective analysis to evaluate glucose variability, the reasons behind glycemic excursions, and whether they are spending more time in target range without hypoglycemia. Each clinician and patient will have to individualize the type of data they look at to personalize their therapy and/or behavioral measures.

Reflection is also valuable to evaluate an individual's use of trend arrow adjustments, scanning frequency, and level of patient engagement. When patients make frequent adjustments for trend arrow data and/or hyperglycemia and hypoglycemia events, it may be an indication that their current treatment plan or insulin parameters are inaccurate and need modification. It may also indicate the need for further education in insulin management and/or diabetes self-management behaviors.

4. Special Considerations When Using the FreeStyle Libre Systems

Insulin dosing decisions during special circumstances are complex and multifactorial and may be impacted by food intake, physical activity, and stressors among other factors. These areas are of great concern and our suggestions should serve as a starting point for future discussion on how our suggested approach may apply. In particular, bedtime insulin dose decisions and potential nocturnal hypoglycemia are common concerns impacted by several factors, particularly when patients engage in intensive physical activity during the day. Our approach to insulin dose adjustments may be considered at bedtime; however, patients should use caution when adding insulin to calculated correction insulin doses at that time. Additional guidance during other special circumstances is provided.

A. Sick Day Management and Medication Considerations

During illness, there is increased risk of glucose instability that can lead to severe hypoglycemia, hyperglycemia, and diabetic ketoacidosis. Use of the FreeStyle Libre systems likely offers some benefit in patients with acute illness, but special precautions must be considered. Based on our clinical experience, we recommend more frequent scanning and suggest that individuals consider insulin correction every 2 to 3 hours with appropriate ketone monitoring during illness. Additionally, patients should consider using fingerstick monitoring for treatment decisions when glucose is >250 mg/dL and ketones (blood or urine) are present and when glucose is <70 mg/dL or symptoms of hypoglycemia are present.

A confirmatory fingerstick may be required when high doses of salicylic acid and/or ascorbic acid are used, which is more likely to occur during sick days. Salicylic acid (used in aspirin and other pain relievers) at doses ≥650 mg may cause falsely lower glucose values, and ascorbic acid (vitamin C) at doses ≥500 mg may cause falsely higher readings. At lower doses, salicylic acid and ascorbic acid are known to have minimal effect on sensor glucose readings in the FreeStyle Libre systems.

B. Young Adults

In the United States, the FreeStyle Libre systems are approved for all adults ≥18 years of age; however, there are distinct differences between younger and older adults that should be considered when initiating CGM in patients within these age groups. As reported by Miller *et al.* [22], achieving adequate glucose control among younger adults with T1D remains problematic. Moreover, early CGM studies with older CGM devices found that CGM adherence among patients <21 years of age was suboptimal [23].

The FreeStyle Libre systems' ease of use, scanning reminders, low-profile sensor, and absence of alarms offer distinct advantages for younger adult patients. Nevertheless, finding ways to motivate patients and sustain their engagement with CGM is paramount when initiating CGM use in younger adults. It is important that clinicians have frank discussions with their younger adult patients to identify and resolve barriers to sustained use. It is also important that patients receive adequate training in using their CGM data to make appropriate adjustments, when needed. Guidance about when to scan and how to use trend arrows in treatment decisions is essential. Based on clinical experience, clinicians should de-emphasize "the numbers" and emphasize "staying flat within the lines," with a focus on minimizing glycemic variability. This will facilitate more positive, supportive discussions with patients that focus on achieving desired glycemic control.

C. Elderly and Frail Adults

Elderly patients with diabetes are at a notably higher risk for severe hypoglycemia and its ramifications due to age, duration of diabetes, and greater prevalence of hypoglycemia unawareness [24–28]. The increased risk is compounded by cognitive and physical impairments and other comorbidities. Hence, it is important to start conservatively when using our approach to adjust insulin doses using trend arrows.

In the older and frail diabetes populations, there is a tendency to relax A1c targets; however, this clinical decision needs to be individualized based on recent epidemiologic data. For example, severe hypoglycemia is common in T1D and to a lesser extent in adults with T2D with both higher and lower A1c levels, although the relationship between A1c goal setting and frequency of severe hypoglycemia in those individuals is less clear [29, 30]. Also, as discussed earlier, use of the FreeStyle Libre system reduces hypoglycemia and hyperglycemia in both well-controlled T1D [6] and poorly controlled insulin-treated patients with T2D [7], whereas frequent fingerstick monitoring does not protect against severe hypoglycemia [28].

In short, rather than relax glycemic goals, we may instead strive to optimize the medications and self-management tools that are now available to create a stable glucose profile. However, we recognize that there is a learning curve challenge with newer technology for older patients and emphasize the value in ongoing patient education.

D. Exercise/Physical Activity

Glycemic responses to exercise and physical activity are complex and can be influenced by multiple factors: type of diabetes; fitness level, timing/dose of last bolus; timing/content of last meal; current glucose concentration; rate of changing glucose at start of exercise/activity; rate of insulin infusion (insulin pump basal rate); insulin on board; and type, intensity, and duration of exercise/activity [31]. Information about the impact of various types of exercise on glycemia is presented in Table 4.

A suggested guide to using the trend arrow data prior to and during exercise in the FreeStyle Libre systems is presented in Fig. 4. Our guide is not intended to be comprehensive, and we recognize that numerous factors can influence glycemia prior to, during, and up to 8 hours or longer following exercise [31]. We strive to highlight the unique features of the FreeStyle Libre systems to provide a starting point to individualize an exercise strategy for individuals performing moderate aerobic exercise.

Table 4. Impact of Exercise on Glycemia

Prior studies have demonstrated greater glucose control benefits were associated with increasing frequency of daily scans using the FreeStyle Libre system. However, we emphasize that patient engagement with the sensor is paramount to clinical success and that scanning frequency may vary substantially between patients. We offer suggested daily scanning approaches that represent an ideal scenario of patient engagement with the FreeStyle Libre systems.

TYPE OF EXERCISE	EXAMPLES	IMPACT ON GLYCEMIA
Aerobic	Running, swimming, cycling	Often lowers glucose concentrations (via increased glucose uptake and insulin sensitivity) during exercise/activity but may lead to acute and delayed hypoglycemia, which can last up to 24 hours; the risk for nocturnal hypoglycemia is particularly high following afternoon exercise/activity.
Anaerobic	Sprinting, resistance training, weight lifting	May cause glucose concentrations to rise during exercise/activity; however, exercise/activity-induced hypoglycemia may last for hours after the end of the activity.
Mixed	Combination of aerobic and anaerobic activities, tennis, soccer, squash	Can have variable effects on glucose concentrations, during and after the event.

It is important to consider the potential impact of emerging exercise trends (e.g., hot yoga) on glycemic control. However, data regarding this issue are sparse.

Avoiding hypoglycemia is the primary goal for glycemic control during and after exercise. Despite metabolic differences between T1D and T2D in terms of insulin requirements, the following general principles apply to all patients treated with intensive insulin therapy. First, it is important to plan ahead whenever possible, anticipating both type and duration of the exercise. We recommend waiting >2 hours after a meal-time bolus, as basal insulin becomes the dominant insulin. Patients may also consider adjusting basal rates (insulin pump users). Patients may also want to lower their bolus dose if the exercise/activity will occur <2 hours following the meal. Importantly, patients should be cautioned against "insulin stacking" in response to anaerobic activity; rising glucose may prompt patients to over-correct. Frequent scanning is needed after exercise because of the increased risk of delayed hypoglycemia in the 6–8 hours following prolonged aerobic activity. Clinicians should collaborate with high-performance athletes and patients who often engage in extended duration (>150 min) exercise to develop individualized strategies for safe exercise. Figure 4 presents some pre-exercise/activity recommendations based on current glucose concentrations and rate of change arrows. For detailed reviews on exercise strategies for patients with diabetes, we recommend consulting recent publications (31–33).

E. Environmental Factors

There are no indications that environmental factors, such as extreme temperature, altitude, or humidity, impact CGM accuracy, but they do affect fingerstick monitoring values [34]. Certain medications may impact reliability of data stream as indicated above in the sick day management section.

5. Discussion

A large proportion of individuals with diabetes treated with intensive insulin therapy are not achieving their glycemic goals [22, 35] and hypoglycemia remains a key obstacle to effective diabetes management [36]. Today's CGM devices, such as the FreeStyle Libre systems, can help patients overcome obstacles and improve quality of life [6, 7, 12, 37]. However, monitoring glucose is only the first step in optimizing care; patients need to know how to use their glucose data, including trend arrow information, to make informed decisions.

Our recommendations are intended to provide a safe, practical approach to using the FreeStyle Libre systems, in general, and trend arrows, in particular. Our goal is to provide guidance that facilitates individualized recommendations for trend arrow use and data assessment. Our approach focuses on typical insulin sensitivity ranges used in adults and

Pre-Exercise Planning for Aerobic and Mixed Exercise Using Trend Arrows in the FreeStyle Libre Systems

Pre-Exercise Glucose Concentration			
<100 mg/dL	100–180 mg/dL	181–250 mg/dL	>250 mg/dL
DO NOT Exercise *Ingest carbohydrate and/or wait until >100 mg/dL*	**Exercise Carefully** *Rescan every 30 minutes to avoid hypoglycemia*	**Exercise** *Rescan every 30 minutes to avoid hypoglycemia*	**DO NOT Exercise** *Correct and/or wait until ≤250 mg/dL*
↑ Wait until >100 mg/dL	↑ Rescan in 30 min	↑ Rescan in 30 min	↑ Correct to ≤180 mg/dL
↗ Wait until >100 mg/dL	↗ Rescan in 30 min	↗ Rescan in 30 min	↗ Correct to ≤180 mg/dL
→ Ingest 15 g carbohydrate	→ Consider ingesting 15 g carbohydrate*	→ Rescan in 30 min	→ Correct to ≤180 mg/dL
↘ Ingest 15 g carbohydrate	↘ Consider ingesting 15 g carbohydrate*	↘ Rescan in 30 min	↘ Wait until ≤250 mg/dL
↓ Ingest 30 g carbohydrate	↓ Consider ingesting 30 g carbohydrate*	↓ Consider ingesting 15 g carbohydrate	↓ Wait until ≤250 mg/dL

Considerations

- Hypoglycemia is a primary concern for individuals with diabetes during aerobic and mixed exercise, which typically causes glucose concentrations to fall. It is strongly recommended that indviduals plan ahead as much as possible prior to exercise and consider both the type and duration of exercise when planning. Individiuals are advised to wait 2 hours after a bolus dose to begin exercise to minimize rapid glucose changes. Individuals with the ability to adjust basal insulin delivery should discuss adjustment strategies with their healthcare provider.
- Patients engaged in anaerobic exercise should consider ingesting less carbohydrate during exercise and refrain from insulin stacking if glucose concentrations rise.
- Vigilant scanning after exercise is needed to avoid delayed hypoglycemia (6-8 hours following exercise).
- Strategies for extended duration (>150 min) exercise and/or high-performance athletics should be developed collaboratively with the healthcare provider.
- Consider ketone testing for readings >250 mg/dL with upward trend arrows.

*Aerobic exercise-related hypoglycemia is a serious concern. When in the lower end of normal glucose range, ingest fast-acting carbohydrate prior to starting exercise.

Figure 4. Approach for pre-exercise/activity planning based on current glucose concentration and trend arrow direction. The following recommendations are based on the consensus statement by Riddell *et al.* [31] and our own clinical experience. Our pre-exercise planning approach takes the unique features of the FreeStyle Libre systems approved in the United States into consideration including the scanning requirement and trend arrow information. In addition to the suggested planning steps, individuals should be aware of how they respond to different types and/or durations of exercise and plan accordingly in advance of activities as best as possible. In general, frequent scanning is recommended for individuals using the FreeStyle Libre systems during exercise.

provides a range of adjustments in discrete insulin units. We believe this simplified approach reduces numeracy requirements and the number of calculations, which will help patients improve glucose control and increase glucose time in range without hypoglycemia, while promoting clinical discussion.

CGM has the potential to transform diabetes management. With this approach as a starting point, we hope to address the needs of clinicians and the growing number of patients using CGM seeking an approach to safely reduce glycemic variability using trend arrow data. We also hope to see this approach applied in practice to derive empirically based information for all currently available and emerging glucose monitoring devices.

Acknowledgments

We thank Irl B. Hirsch for his contributions as an editorial advisor, the Endocrine Society for convening and facilitating the writing group, and Christopher G. Parkin for editorial support in developing this manuscript.

Financial Support: This work was supported by an unrestricted educational grant to the Endocrine Society from Abbott Diabetes Care Inc., Alameda, California.

Author Contributions: Y.C.K. led the writing group as chair and facilitated development and group consensus of the methods proposed. All authors contributed equally in manuscript review, discussion of the results and implications, and comments on the manuscript at all stages.

Correspondence: Yogish C. Kudva, MBBS, Department of Internal Medicine, Division of Endocrinology and Metabolism, Mayo Clinic, Rochester, 200 1st Street South West, Rochester, Minnesota 55905. E-mail kudva.yogish@mayo.edu.

Disclosure Summary: Y.C.K. has received research support from Dexcom, Roche Diabetes Care, and Tandem Diabetes. A.J.A.'s institution has received research support from Dexcom and Medtronic, and he has consulted for Dexcom. R.M.B. has received research support, consulted, and/or has been on the scientific advisory boards for Abbott Diabetes Care, Dexcom, Eli Lilly, Johnson & Johnson, Medtronic, Novo Nordisk, Onduo, Roche, Sanofi, and United Healthcare. R.M.B.'s employer, nonprofit HealthPartners Institute, contracts for his services and no personal income goes to R.M.B. J.R.G. III has served on advisory boards and/or speaker bureaus for Abbott Diabetes Care. D.F.K. has served on advisory boards and speaker bureaus for Abbott Diabetes Care and Dexcom; her institution has received research support from Abbott Diabetes Care and Dexcom; and she owns stock in Dexcom. L.K.M. has served on scientific advisory boards for Abbott Diabetes Care, and his institution has received research support from Abbott Diabetes Care. E.M. has served on advisory boards and/or speaker bureaus for Abbott Diabetes Care. D.R.H. has nothing to disclose.

References and Notes

1. Fonseca VA, Grunberger G, Anhalt H, Bailey TS, Blevins T, Garg SK, Handelsman Y, Hirsch IB, Orzeck EA, Roberts VL, Tamborlane W; Consensus Conference Writing Committee. Continuous glucose monitoring: a consensus conference of the American Association of Clinical Endocrinologists and American College of Endocrinology. *Endocr Pract*. 2016;**22**(8):1008–1021.
2. American Diabetes Association. 6. Glycemic targets: standards of medical care in diabetes—2018. *Diabetes Care*. 2018;**41**(Suppl 1):S55–S64.
3. Peters AL, Ahmann AJ, Battelino T, Evert A, Hirsch IB, Murad MH, Winter WE, Wolpert H. Diabetes technology—continuous subcutaneous insulin infusion therapy and continuous glucose monitoring in adults: an Endocrine Society clinical practice guideline. *J Clin Endocrinol Metab*. 2016;**101**(11): 3922–3937.
4. Bergenstal RM, Ahmann AJ, Bailey T, Beck RW, Bissen J, Buckingham B, Deeb L, Dolin RH, Garg SK, Goland R, Hirsch IB, Klonoff DC, Kruger DF, Matfin G, Mazze RS, Olson BA, Parkin C, Peters A, Powers MA, Rodriguez H, Southerland P, Strock ES, Tamborlane W, Wesley DM. Recommendations for standardizing glucose reporting and analysis to optimize clinical decision making in diabetes: the Ambulatory Glucose Profile (AGP). *Diabetes Technol Ther*. 2013;**15**(3):198–211.
5. International Diabetes Center. Ambulatory glucose profile: AGP reports. Available at: www.agpreport.org/agp/agpreports. Accessed 22 April 2018.
6. Bolinder J, Antuna R, Geelhoed-Duijvestijn P, Kröger J, Weitgasser R. Novel glucose-sensing technology and hypoglycaemia in type 1 diabetes: a multicentre, non-masked, randomised controlled trial. *Lancet*. 2016;**388**(10057):2254–2263.
7. Haak T, Hanaire H, Ajjan R, Hermanns N, Riveline JP, Rayman G. Flash glucose-sensing technology as a replacement for blood glucose monitoring for the management of insulin-treated type 2 diabetes: a multicenter, open-label randomized controlled trial. *Diabetes Ther*. 2017;**8**(1):55–73.
8. Ish-Shalom M, Wainstein J, Raz I, Mosenzon O. Improvement in glucose control in difficult-to-control patients with diabetes using a novel flash glucose monitoring device. *J Diabetes Sci Technol*. 2016;**10**(6): 1412–1413.
9. McKnight JA, Gibb FW. Flash glucose monitoring is associated with improved glycaemic control but use is largely limited to more affluent people in a UK diabetes centre. *Diabet Med*. 2017;**34**(5):732.
10. Dover AR, Stimson RH, Zammitt NN, Gibb FW. Flash glucose monitoring improves outcomes in a type 1 diabetes clinic. *J Diabetes Sci Technol*. 2017;**11**(2):442–443.
11. Aleppo G, Laffel LM, Ahmann AJ, Hirsch IB, Kruger DF, Peters A, Weinstock RS, Harris DR. A practical approach to using trend arrows on the Dexcom G5 CGM system for the management of adults with diabetes. *J Endocr Soc*. 2017;**1**(12):1445–1460.
12. Dunn TC, Xu Y, Hayter G, Ajjan RA. Real-world flash glucose monitoring patterns and associations between self-monitoring frequency and glycaemic measures: a European analysis of over 60 million glucose tests. *Diabetes Res Clin Pract*. 2018;**137**:37–46.

13. Buckingham B, Xing D, Weinzimer S, Fiallo-Scharer R, Kollman C, Mauras N, Tsalikian E, Tamborlane W, Wysocki T, Ruedy K, Beck R; Diabetes Research In Children Network (DirecNet) Study Group. Use of the DirecNet applied treatment algorithm (DATA) for diabetes management with a real-time continuous glucose monitor (the FreeStyle Navigator). *Pediatr Diabetes*. 2008;**9**(2):142–147.
14. Scheiner G. Practical CGM: Improving Patient Outcomes through Continuous Glucose Monitoring. 4th ed. Alexandria, VA: American Diabetes Association; 2015.
15. Pettus J, Edelman SV. Recommendations for using real-time continuous glucose monitoring (rtCGM) data for insulin adjustments in type 1 diabetes. *J Diabetes Sci Technol*. 2017;**11**(1):138–147.
16. Klonoff DC, Kerr D. A simplified approach using rate of change arrows to adjust insulin with real-time continuous glucose monitoring. *J Diabetes Sci Technol*. 2017;**11**(6):1063–1069.
17. Grunberger G, Abelseth JM, Bailey TS, Bode BW, Handelsman Y, Hellman R, Jovanovič L, Lane WS, Raskin P, Tamborlane WV, Rothermel C. Consensus statement by the American Association of Clinical Endocrinologists/American College of Endocrinology insulin pump management task force. *Endocr Pract*. 2014;**20**(5):463–489.
18. McGill JB, Ahmann A. Continuous glucose monitoring with multiple daily insulin treatment: outcome studies. *Diabetes Technol Ther*. 2017;**19**(S3):S3–S12.
19. Klonoff DC, Nayberg I, Stauder U, Oualali H, Domenger C. Half-unit insulin pens: disease management in patients with diabetes who are sensitive to insulin. *J Diabetes Sci Technol*. 2017;**11**(3): 623–630.
20. Kovatchev BP, Clarke WL, Breton M, Brayman K, McCall A. Quantifying temporal glucose variability in diabetes via continuous glucose monitoring: mathematical methods and clinical application. *Diabetes Technol Ther*. 2005;**7**(6):849–862.
21. Aleppo G, Ruedy KJ, Riddlesworth TD, Kruger DF, Peters AL, Hirsch I, Bergenstal RM, Toschi E, Ahmann AJ, Shah VN, Rickels MR, Bode BW, Philis-Tsimikas A, Pop-Busui R, Rodriguez H, Eyth E, Bhargava A, Kollman C, Beck RW; REPLACE-BG Study Group. REPLACE-BG: a randomized trial comparing continuous glucose monitoring with and without routine blood glucose monitoring in adults with well-controlled type 1 diabetes. *Diabetes Care*. 2017;**40**(4):538–545.
22. Miller KM, Foster NC, Beck RW, Bergenstal RM, DuBose SN, DiMeglio LA, Maahs DM, Tamborlane WV; T1D Exchange Clinic Network. Current state of type 1 diabetes treatment in the U.S.: updated data from the T1D Exchange clinic registry. *Diabetes Care*. 2015;**38**(6):971–978.
23. Tamborlane WV, Beck RW, Bode BW, Buckingham B, Chase HP, Clemons R, Fiallo-Scharer R, Fox LA, Gilliam LK, Hirsch IB, Huang ES, Kollman C, Kowalski AJ, Laffel L, Lawrence JM, Lee J, Mauras N, O'Grady M, Ruedy KJ, Tansey M, Tsalikian E, Weinzimer S, Wilson DM, Wolpert H, Wysocki T, Xing D; Juvenile Diabetes Research Foundation Continuous Glucose Monitoring Study Group. Continuous glucose monitoring and intensive treatment of type 1 diabetes. *N Engl J Med*. 2008;**359**(14):1464–1476.
24. Weinstock RS, DuBose SN, Bergenstal RM, Chaytor NS, Peterson C, Olson BA, Munshi MN, Perrin AJ, Miller KM, Beck RW, Liljenquist DR, Aleppo G, Buse JB, Kruger D, Bhargava A, Goland RS, Edelen RC, Pratley RE, Peters AL, Rodriguez H, Ahmann AJ, Lock JP, Garg SK, Rickels MR, Hirsch IB; T1D Exchange Severe Hypoglycemia in Older Adults With Type 1 Diabetes Study Group. Risk factors associated with severe hypoglycemia in older adults with type 1 diabetes. *Diabetes Care*. 2016;**39**(4): 603–610.
25. Bremer JP, Jauch-Chara K, Hallschmid M, Schmid S, Schultes B. Hypoglycemia unawareness in older compared with middle-aged patients with type 2 diabetes. *Diabetes Care*. 2009;**32**(8):1513–1517.
26. Punthakee Z, Miller ME, Launer LJ, Williamson JD, Lazar RM, Cukierman-Yaffee T, Seaquist ER, Ismail-Beigi F, Sullivan MD, Lovato LC, Bergenstal RM, Gerstein HC; ACCORD Group of Investigators; ACCORD-MIND Investigators. Poor cognitive function and risk of severe hypoglycemia in type 2 diabetes: post hoc epidemiologic analysis of the ACCORD trial. *Diabetes Care*. 2012;**35**(4): 787–793.
27. Giorda CB, Ozzello A, Gentile S, Aglialoro A, Chiambretti A, Baccetti F, Gentile FM, Lucisano G, Nicolucci A, Rossi MC; HYPOS-1 Study Group of AMD. Incidence and risk factors for severe and symptomatic hypoglycemia in type 1 diabetes. Results of the HYPOS-1 study. *Acta Diabetol*. 2015; **52**(5):845–853.
28. Cariou B, Fontaine P, Eschwege E, Lièvre M, Gouet D, Huet D, Madani S, Lavigne S, Charbonnel B. Frequency and predictors of confirmed hypoglycaemia in type 1 and insulin-treated type 2 diabetes mellitus patients in a real-life setting: results from the DIALOG study. *Diabetes Metab*. 2015;**41**(2): 116–125.
29. Weinstock RS, Xing D, Maahs DM, Michels A, Rickels MR, Peters AL, Bergenstal RM, Harris B, Dubose SN, Miller KM, Beck RW; T1D Exchange Clinic Network. Severe hypoglycemia and diabetic

ketoacidosis in adults with type 1 diabetes: results from the T1D Exchange clinic registry. *J Clin Endocrinol Metab*. 2013;**98**(8):3411–3419.

30. Lipska KJ, Warton EM, Huang ES, Moffet HH, Inzucchi SE, Krumholz HM, Karter AJ. HbA_{1c} and risk of severe hypoglycemia in type 2 diabetes: the Diabetes and Aging Study. *Diabetes Care*. 2013;**36**(11): 3535–3542.
31. Riddell MC, Gallen IW, Smart CE, Taplin CE, Adolfsson P, Lumb AN, Kowalski A, Rabasa-Lhoret R, McCrimmon RJ, Hume C, Annan F, Fournier PA, Graham C, Bode B, Galassetti P, Jones TW, Millán IS, Heise T, Peters AL, Petz A, Laffel LM. Exercise management in type 1 diabetes: a consensus statement. *Lancet Diabetes Endocrinol*. 2017;**5**(5):377–390.
32. Bally L, Laimer M, Stettler C. Exercise-associated glucose metabolism in individuals with type 1 diabetes mellitus. *Curr Opin Clin Nutr Metab Care*. 2015;**18**(4):428–433.
33. Rabasa-Lhoret R, Bourque J, Ducros F, Chiasson JL. Guidelines for premeal insulin dose reduction for postprandial exercise of different intensities and durations in type 1 diabetic subjects treated intensively with a basal-bolus insulin regimen (ultralente-lispro). *Diabetes Care*. 2001;**24**(4):625–630.
34. Erbach M, Freckmann G, Hinzmann R, Kulzer B, Ziegler R, Heinemann L, Schnell O. Interferences and limitations in blood glucose self-testing: an overview of the current knowledge. *J Diabetes Sci Technol*. 2016;**10**(5):1161–1168.
35. Carls G, Huynh J, Tuttle E, Yee J, Edelman SV. Achievement of glycated hemoglobin goals in the US remains unchanged through 2014. *Diabetes Ther*. 2017;**8**(4):863–873.
36. Cryer PE. Hypoglycemia: still the limiting factor in the glycemic management of diabetes. *Endocr Pract*. 2008;**14**(6):750–756.
37. Al Hayek AA, Robert AA, Al Dawish MA. Evaluation of FreeStyle Libre flash glucose monitoring system on glycemic control, health-related quality of life, and fear of hypoglycemia in patients with type 1 diabetes. *Clin Med Insights Endocrinol Diabetes*. 2017;**10**:1179551417746957.