Five Evidence-Based Lifestyle Habits People With Diabetes Can Use

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Several evidence-based lifestyle habits focusing on the composition, timing, and sequence of meals and on pre- and postmeal exercise can improve diabetes management. Consuming low-carbohydrate, balanced meals and eating most carbohydrates early in the day are helpful habits. Eating the protein and vegetable components of a meal first and consuming the carbohydrates 30 minutes later can moderate glucose levels. Postmeal glucose surges can be blunted without precipitating hypoglycemia with moderate exercise 30–60 minutes before the anticipated peak. Short-duration, high-intensity exercise could also be effective. Premeal exercise can improve insulin sensitivity but can also cause post-exertion glucose elevations. Moreover, high-intensity premeal exercise may precipitate delayed hypoglycemia in some people. Glycemia benefits can be enhanced by eating a light, balanced breakfast after premeal exercise.

Although decades of data show that diabetes is manageable, reversible, and preventable with the help of healthy lifestyle habits (1–3), only about 3% of adults meet most of the type 2 diabetes risk-reduction goals (4). In general, most people with diabetes are not aware of many of the lifestyle changes related to eating and exercise that they can make to improve their diabetes management.

For example, people with diabetes who understand the second-meal phenomenon, in which a previous meal leads to a moderate postmeal glucose surge after the next meal, can design meal plans that not only ensure better glucose control, but also improve satiety. This obscure, century-old finding (5) is well documented in healthy people as well as in people with type 2 diabetes (6–9). Useful changes to eating habits that can yield significant glycemic benefits include ensuring appropriate nutrient composition (1), meal timing (5–21), nutrient sequencing (22,23), and meal frequency (24).

When it comes to physical activity, most official guidelines recommend getting at least 150 minutes of moderate activity or 75 minutes of vigorous activity plus some resistance exercise two to three times per week (1). However, exercise can lead to hyperglycemia (25–35) or hypoglycemia (36–40) depending on the timing, intensity, duration, and sequence of the physical activities involved.

In this article, we describe in detail the personalized diabetes lifestyle devised and adopted by a physician-patient (author E.C., hereafter referred to as "the patient") and her endocrinologist (author C.S.). Our purpose is to shed light on some simple lifestyle changes that have the potential to yield sizable glycemic benefits for people with diabetes. Although the patient has been doing diabetes self-management for about 20 years, she started appreciating the full potential of healthy eating and getting the right exercise only after she started using continuous glucose monitoring (CGM) in July 2017, primarily as a prophylaxis for severe hypoglycemia unawareness (36–40). This article describes how people with diabetes adjust their meals (1,6–9,12–14,16–24), explains which exercises can be done safely for glycemic advantage on the basis of existing findings (25–35,41–70), and summarizes what we have observed repeatedly in the patient's CGM data. For example, we list five ways to moderate glucose levels while eating low-carbohydrate meals (75–100 g/day). These considerations are not applicable to individuals who follow a very-low-carbohydrate (<20 g/day) ketogenic diet (71,72), which can offer excellent glucose levels with or without exercise.

Background

Meals, exercise, and medications are the three major influences on glycemia. Of the three, meals and exercise offer a wide range of opportunities for individualization.

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It is exceedingly difficult to isolate the effect on glycemia of any single intervention in free-living conditions. This is because glucose levels are sensitive to numerous factors, including patient characteristics; medications; the timing, composition, and nutrient sequencing of meals; and the timing, intensity, frequency, and sequencing of exercise. This multiplicity of influences on glycemia may explain why some studies with varying designs in different populations appear to offer conflicting results (21,73,74). Consequently, it is advisable for individual patients to test these approaches themselves and design their own meal plans and exercise regimens as part of their overall diabetes self-management. Below, we describe some of the lifestyle habits involving meals and exercise the patient has practiced at various times in the course of the past 2 decades that have yielded significant glycemia benefits.

Meals-Related Considerations

Meal Composition

In the context of diabetes, it is useful to think of a meal as consisting of just two components: *1*) carbohydrates and *2*) everything else (i.e., lean protein, vegetables, fiber, and healthy fat). Carbohydrate intake plays a crucial role in shaping the glucose profile, and this fact has been extensively documented (1). Inasmuch as insulin resistance is the underlying problem, it is logical to control carbohydrate intake. Lim et al. (3) reported that, for patients with type 2 diabetes on a strict low-calorie diet (600 kcal/day), the fat content of the liver and pancreas decreased, fasting glucose normalized within 1 week, and A1C improved from 7.4 to 6.0% in 8 weeks. Hepatic fat is instrumental in increasing insulin resistance in the liver, and fat in the pancreas decreases insulin secretion. Thus, decreased calorie intake is the crucial factor that improves fasting glucose, as well as other metabolic markers.

Add lean protein, nonstarchy vegetables, dietary fiber, and healthy fat to the appropriate carbohydrate serving, and the glucose spikes get smaller and are delayed, leading to lower glycemic variability and better satiety (1). The American Diabetes Association (ADA) recommends the Mediterranean diet, the DASH (Dietary Approaches to Stop Hypertension) diet, low-carbohydrate diets, and the plate method (1).

Meal Timing

Meal timing is a more complex issue. Skipping breakfast altogether (12) and eating big suppers late (19) are not diabetes-friendly meal habits. Meal timing is crucial because glucose tolerance is generally diminished in the evening hours, for both healthy people and those with diabetes (15,16,18–21).

Breakfast plays a crucial role in metabolism for people with diabetes (12–14,16). Mekary et al. (12) showed that skipping breakfast can increase the risk for type 2 diabetes. Kahleova et al. (13) reported that eating two big meals, breakfast and lunch, offered improved hepatic fat and fasting glucose levels compared with eating six small meals in people with type 2 diabetes. Jakubowicz et al. (14) found that a high-energy breakfast and low-energy supper, combined, decrease overall daily hyperglycemia more efficiently in people with type 2 diabetes compared with a low-energy breakfast and a high-energy supper. These researchers also noticed improvements in weight and various other metabolic markers in overweight and obese women when a high-energy breakfast and a low-energy supper were used (16). Although breakfast is valuable for metabolic control, it is crucial not to increase overall daily calorie intake when adding it to avoid both weight gain and worsened glycemia (74).

The second-meal phenomenon can be a versatile component of a well-designed diabetes meal plan. Insulin sensitivity is generally high at the time of the second meal because breakfast brings about favorable hormonal changes (8). Counterregulation controls the metabolic activities of the body during the several hours of fasting through the night. Exogenous glucose is not available then, and the body uses other fuel sources, including free fatty acids, liver glycogen, and muscle glycogen (70). Breakfast switches metabolism from the counterregulatory hormones to the incretin-insulin system. Within about 30 minutes of breakfast, exogenous glucose coming from the gut becomes the major fuel for the energy needs of the body. Within 90–120 minutes, free fatty acid levels have fallen (7,8), early-phase insulin secretion has improved (9), and glycogen sparing is underway in the liver and muscles. As a result, insulin sensitivity is high during the second meal of the day (10,11).

Diurnal variation in glucose tolerance is another factor that has a bearing on meal timing. In general, glucose tolerance is worse in the evening, for both healthy people and people with diabetes (15–17). It is therefore preferable to eat fewer carbohydrates for supper but to add more to the earlier meals, and especially to the second meal. Research has further demonstrated the glycemic benefits of eating early versus eating late. The latter habit has been found to raise fasting glucose in men at risk for type 2 diabetes (19). A high-energy lunch has been found to be better than a high-energy supper (20). A high-energy breakfast has also been shown to be better than a high-energy supper (14). These results are in agreement with the study by Kahleova et al. (13) that showed that having just two meals, breakfast and lunch, helping regulate glucose levels better than having six meals per day.

Nutrient Sequencing

Research has also provided data showing the glycemia benefit of eating protein or protein and vegetables before eating the carbohydrate portion of a meal (22,23).

Meal Frequency

Most studies have found that increased meal frequency is better for minimizing both hyperglycemia and hypoglycemia, provided total calorie intake is not excessive (24) and the bulk of daily energy is not consumed in the evening. Interestingly, when two meals are consumed earlier in the day, offering lower hepatic fat and fasting glucose, some individuals get hypoglycemia (13). Meal frequency can be individualized to keep glycemic variability low (24).

Exercise-Related Considerations

Exercise is essential for physical health and to maintain optimal body composition. However, exercise can also produce untoward effects such as hyperglycemia or hypoglycemia depending on its timing, intensity, duration, and sequencing. It is therefore crucial to select the right types of exercise and perform it at the right times.

Postmeal Exercise

There is general agreement among researchers that timely postmeal exercise lowers blood glucose levels in a variety of populations (50–69). However, postmeal exercise with a high energy expenditure may cause hyperglycemia (25,26) or hypoglycemia (36,37). Studies comparing premeal walks and postmeal walks and focusing on the immediate (<24-hour) glucose response have identified timely postmeal exercise as the better option to deal with meal-related glucose surges in different populations (32–35,52–54,60,61).

On the other hand, postmeal exercise does not improve glucose tolerance for subsequent meals (56). It also does not improve fasting glucose (75); improvement in insulin sensitivity, if any, is short-lived, as demonstrated by Nygaard et al. (76) in training studies lasting 12 weeks in hyperglycemic individuals. Although long-duration, high-intensity interval exercise (HIIE) before meals is better than its postmeal counterpart for improving glycemia (49), long-duration (45 minutes) resistance exercise performed 45 minutes after meals is better than similar premeal exercise for improving glycemia and triglycerides (77). To be effective, HIIE after meals must be of short duration (78). Furthermore, with regard to exercise sequencing, resistance exercise followed by aerobic exercise is preferable to aerobic exercise followed by resistance exercise (79). The main benefit of starting postmeal exercise 30–60 minutes after meals is to blunt postmeal glucose surges (50–68). The risk of delayed hypoglycemia is minimal with moderate postmeal physical activities.

Premeal Exercise

Premeal exercise has mixed effects on blood glucose levels. Initially, there is post-exertion hyperglycemia (27–35) and then a delayed improvement in insulin sensitivity (27,41–43). Pre-breakfast exercise occurs under counterregulation, with multiple energy sources, including hepatic glucose, free fatty acids, and muscle glycogen (70). It is the extra glucose rushing into the bloodstream from the liver that causes post-exertion glucose elevations (27–35). Glycogen depletion brings on delayed insulin sensitivity improvement during glycogen repletion (27,41,42). Borer et al. (75) showed that long-duration premeal exercise improved fasting glucose in post-menopausal women. HIIE before meals has been found to be very beneficial for glycemia (49). When comparing premeal to postmeal endurance training, the former has been found to yield elevated glycogen and GLUT-4 protein levels, improved whole-body glucose tolerance, and other health benefits via molecular adaptations in healthy men (43–46).

There are, however, drawbacks to premeal exercise. A1C has not been found to improve with premeal training (7.4 vs. 7.7%), likely because of post-exertion glucose elevations (80). C-reactive protein levels also have not been found to improve (1.2–1.5 mg/L) (80). Furthermore, although no hypoglycemia occurs during the exercise activity itself (47,48), delayed hypoglycemia can be seen with premeal high-intensity exercise in patients with type 1 diabetes (38,39); this risk is higher after pre-supper exercise than after pre-breakfast exercise.

Improving Diabetes Self-Management: The Patient's Journey

Goal

In many instances, scientific evidence comes with a measure of uncertainty (21,73,74). For example, Sievert et al. (74) found that adding breakfast to the other daily meals can be counterproductive and can cause weight

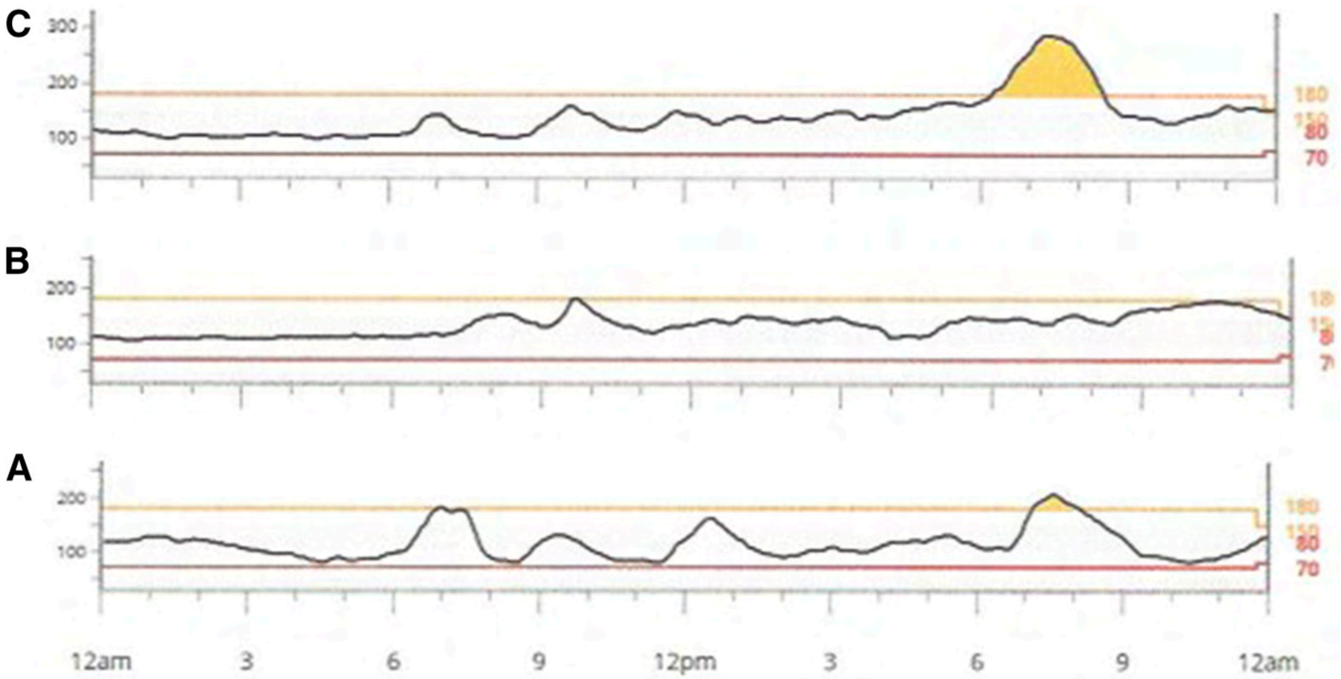

FIGURE 1 Effect of meal timing on glucose. *A*) Glucose response to four identical meals, eaten from 6:00 a.m. to 6:00 p.m, showing the second-meal phenomenon and diurnal variation in glucose tolerance. Postmeal peaks are 181, 131, 161, and 206 mg/dL; glucose tolerance was worse at breakfast and in the evening. The mean 24-hour glucose was 114 mg/dL. *B*) Glucose response to late supper at 8:00 p.m., leading to high fasting glucose (146 mg/dL) the next morning (not shown). The post-supper glucose peak was 191 mg/dL. *C*) The glucose response to a big supper at 6:00 p.m., leading to high fasting glucose (124 mg/dL) the next morning (not shown). The post-supper glucose peak was 289 mg/dL.

gain if the addition increases total calories consumed. Versteeg et al. (21) found that meal timing does not matter with regard to weight reduction by calorie restriction. Also, Solomon et al. (73) reported that postmeal exercise is most effective when the activity starts right after adults consume a liquid breakfast. Thus, before adopting these lifestyle changes, the patient felt she had to test their validity and significance for herself. Her general goal has been to improve lifestyle further by applying evidence-based lifestyle habits one at a time.

Methods

The patient's blood glucose concentrations (in mg/dL), automatically recorded every 5 minutes and stored (via Dexcom G5 or G6 CGM device) constituted the primary data source. The CGM data can be uploaded and printed using the Dexcom/Clarity app. There are two options for printing the glucose profile: daily or overlay. Fasting glucose, daily mean glucose, postprandial glucose (PPG), time in range (TIR) (81), and the entire daily glucose profile are readily accessible. Comparisons among the glycemic effects of various meals and meal plans are surprisingly straightforward. Other typical metabolic parameters such as A1C and fasting lipid profile were determined every 3–6 months through laboratory testing.

Medications included metformin 1,000 mg twice daily, glargine insulin 10 units by injection once daily, and semaglutide 0.5 mg by injection once weekly during the period involved in this account. No elective exercise was done when testing the glycemic effects of meals. The patient's meal pattern was held constant when glucose response to exercise was tested. In other words, when one variable was tested, the others were kept constant.

Results

Figures 1–4 show the patient's 24-hour glucose data in response to the interventions tested. Carb is a unit of carbohydrates; 1 carb equals 15 g carbohydrates.

Figure 1*A* shows the patient's glucose response to eating four identical meals containing 1/4 carb each during the day. The respective PPG readings were 181, 131, 161, and 206 mg/dL, reflecting the second-meal phenomenon and diurnal variation in glucose tolerance. Figure 1*B* shows the patient's glucose response to a late supper, and Figure 1*C* shows the response to a big supper, both leading

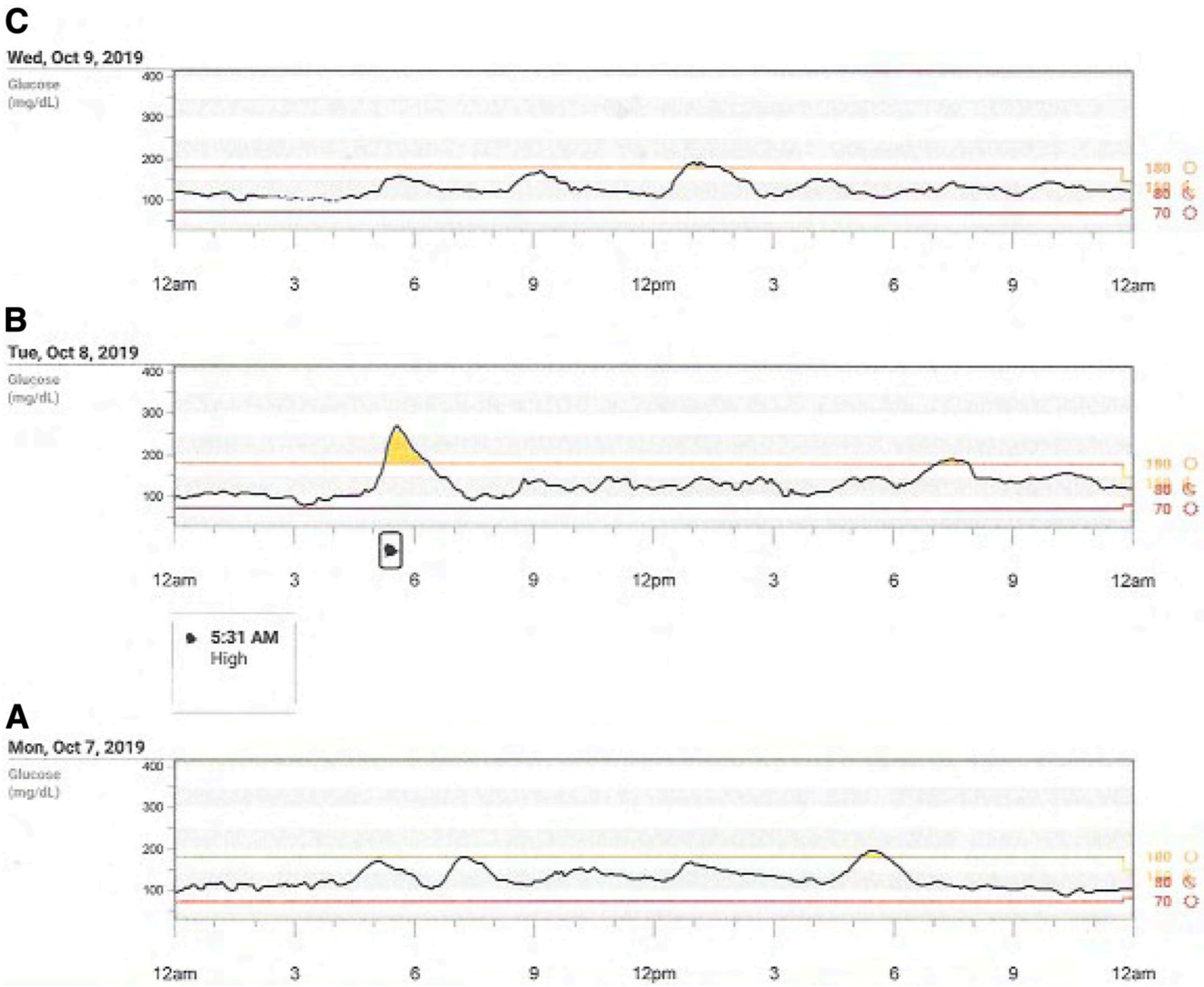

FIGURE 2 Splitting a big breakfast into one light breakfast and a big second meal. *A*) The two-meal option leads to postmeal peaks of 169 and 179 mg/dL and a mean glucose of 127 mg/dL. *B*) One big breakfast, with a postmeal glucose of 265 mg/dL and a mean glucose of 131 mg/dL. *C*) Post-supper glucose of 142 mg/dL with nutrient sequencing. *A* and *B*, without nutrient sequencing, resulted in post-supper peaks of 195 and 190 mg/dL, respectively.

to high fasting glucose levels the day after of 146 and 124 mg/dL, respectively (not shown).

Figure 2*A* and *B* show the effect on the patient's glucose levels when a big breakfast was split into a small first meal and a big second meal. PPG, TIR (81), and daily mean glucose, respectively, were 265 mg/dL, 92%, and 131 mg/dL for the big breakfast, as shown in Figure 2*B*. These same measures for the two-meal option, seen in Figure 2*A*, were 169 and 179 mg/dL (for meal 1 and meal 2, respectively), 97%, and 127 mg/dL, respectively. For the supper peaks shown in Figure 2*A* and *B*, without nutrient sequencing, PPG levels were 195 and 190 mg/dL, respectively. Figure 2*C* shows a much smaller supper peak (142 mg/dL) when nutrient sequencing was used.

Figure 3 illustrates the difference in glucose levels with premeal versus postmeal exercise. Insulin sensitivity did not improve the day after postmeal exercise (Figure 3*A*). Changes in breakfast PPG, TIR, and mean glucose from exercise day to the day after exercise were from 180 to 224 mg/dL, from 98 to 95%, and from 119 to 120 mg/dL, respectively. Insulin sensitivity improvement was clearly seen the day after premeal exercise (Figure 3*B*) with identical daily meals. The changes in breakfast PPG, TIR, and mean glucose from exercise day to the day after were from 174 to 150 mg/dL, from 97 to 99%, and from 123 to 115 mg/dL, respectively.

Figure 4 shows TIR and mean glucose improving with each intervention. When multiple interventions were

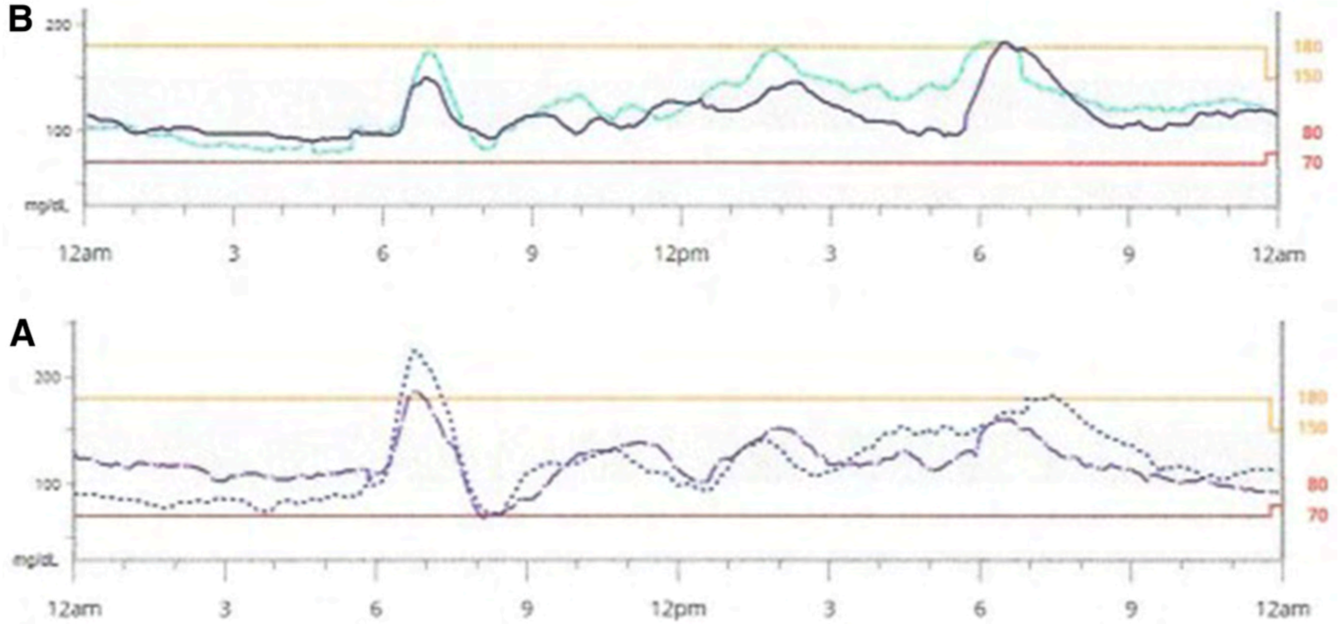

FIGURE 3 Two-day glucose responses to premeal versus postmeal walking around the breakfast meal. *A*) Dashed line: first day glucose response to a 45-minute postmeal walk starting 30 minutes after a 1 1/2-carb breakfast. Dotted line: second day glucose response after the meal alone. Post-breakfast glucose levels were 186 and 224 mg/dL, and mean glucose levels were 119 and 120 mg/dL on the first and second days, respectively. *B*) Light line: first day glucose response to a 45-minute premeal walk and 1-carb breakfast. Dark line: second day glucose response to the meal alone. Post-breakfast glucose levels were 174 and 150 mg/dL, and mean glucose levels were 123 and 115 mg/dL, on the first and second days, respectively.

applied on the same day (Figure 4*B* and *E*), the combined effects were stronger.

Discussion

Food and physical activity, respectively, are the sole source of and major sink for blood glucose in the human body. Food and physical activity also are staples of human lifestyles. Here, framed against the backdrop of available scientific evidence, are five takeaway messages useful in regulating blood glucose levels.

1. Improving Meal Composition

Carbohydrate intake plays a pivotal role in diabetes management. Excess carbohydrate intake increases liver fat, which increases insulin resistance in the liver, resulting in increased fasting glucose. Elevated fasting glucose, in turn, pushes PPG up. On the other hand, strict carbohydrate control (600 kcal/day) improves fasting glucose and A1C (3). We have observed repeatedly that when carbohydrate intake increases, fasting glucose also increases. It is imperative to determine the right level of carbohydrate intake.

ADA guidelines recommend personalizing the meal plan and keeping PPG to $<$180 mg/dL (1). A crucial aspect of personalizing the meal plan for a diabetes patient is to determine the right level of carbohydrate intake to ensure target PPG levels. It helps if patients have good insights into their own glucose tolerance for every meal.

We found a way to accomplish this in just 1 day: eat four identical meals 2–3 hours apart and see what the four glucose peaks look like (Figure 1*A*). With such a 24-hour glucose profile in mind, it should then be easy to make adjustments to the carbohydrate component of the meals. This type of analysis is best done with the help of a CGM system. Individuals without a CGM device can still get a good feel for postmeal peaks using 1-hour postmeal glucose monitoring. Indeed, before she started using CGM, the patient had been checking 1-hour postmeal glucose levels as needed and adjusting her carbohydrate intake appropriately with that method for ~16 years. As shown in Figure 1*A*, with 1 1/4-carb meals, glucose tolerance was weak at breakfast (PPG 181 mg/dL) and supper (PPG 206 mg/dL). This is why the patient's carbs have been 1, 2, 1, 1/2, and 1/2, totaling 75 g/day.

When these low-carbohydrate meals are balanced with lean protein, nonstarchy vegetables, dietary fiber, and healthy fat, the glycemic load decreases, and postmeal glucose peaks are moderate and delayed (1).

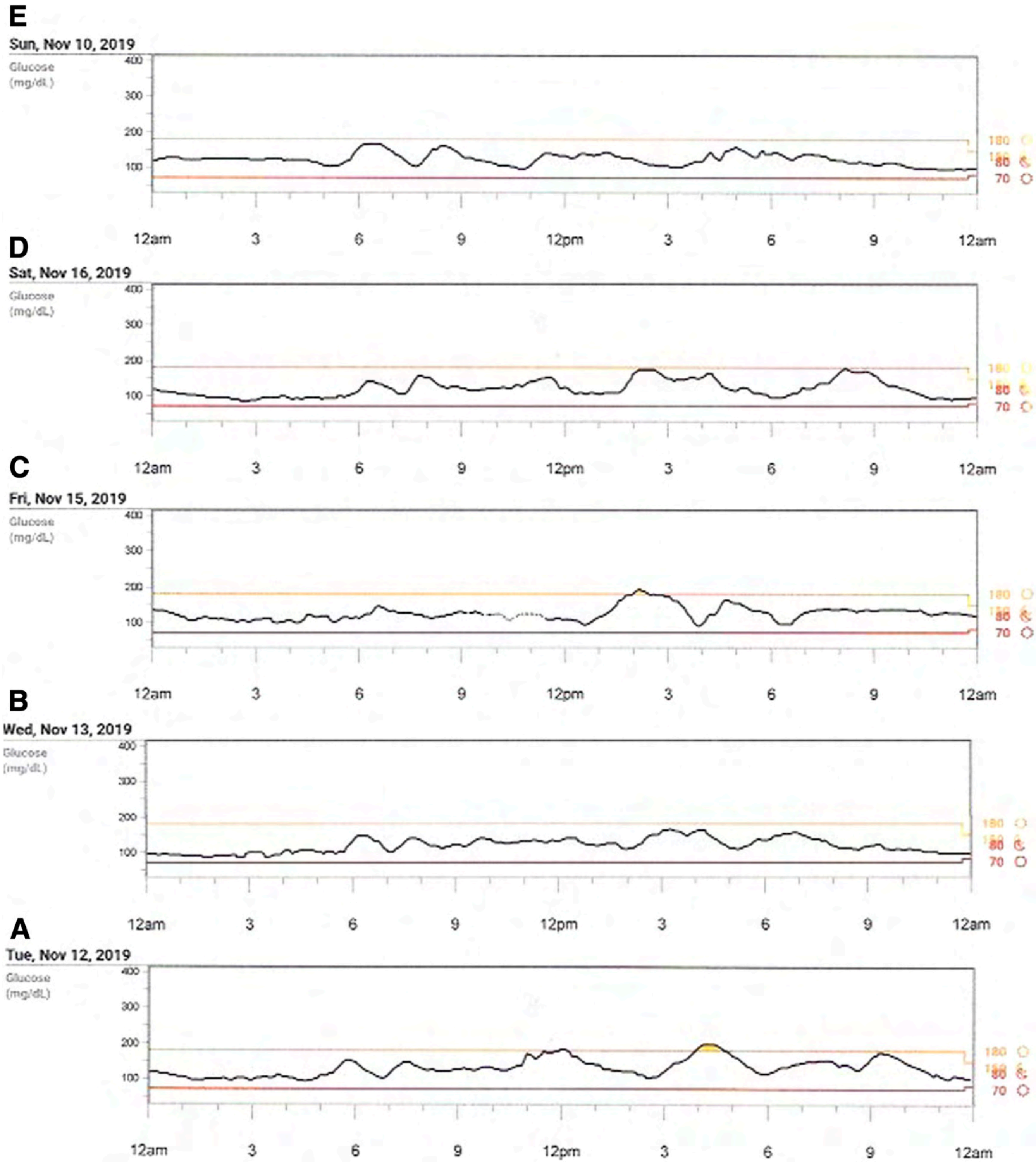

FIGURE 4 TIR and daily mean glucose for different lifestyle habits. *A*) For a low-carbohydrate (5 carbs/day) balanced meal plan, with carb servings of 1, 2, 1, 1/2, and 1/2, the TIR was 96%, and mean glucose was 130 mg/dL. *B*) For the same meal plan as in *A* but with nutrient sequencing applied for the third, fourth, and fifth meals, TIR was 100%, and mean glucose was 118 mg/dL. *C*) With postmeal exercise (12 minutes of resistance exercise + 18 minutes of walking starting 30 minutes after a breakfast of 1 carb) in a meal plan the included 5 carbs/day, the TIR was 98%, and mean glucose was 125 mg/dL. *D*) With 30 minutes of premeal walking followed by a light breakfast containing 3/4 carb and carbohydrate intake adjusted in a daily meal plan that included 5 carbs/day, the TIR was 100%, and mean glucose was 120 mg/dL. *E*) With all five lifestyle habits applied (meal composition, meal timing, nutrient sequencing at lunch, premeal exercise followed by a light breakfast, and yard work after the fourth and fifth meals of the day), the TIR was 100%, and mean glucose was 123 mg/dL.

2. Improving Meal Timing

Although breakfast is a crucial meal for people with or at risk for diabetes (12–16), it does not have to be a high-carbohydrate meal. As shown in Figure 2*A* and *B*, breakfast PPG and daily mean glucose are better when breakfast is split into two meals. This finding is in agreement with a recent study showing that a low-carbohydrate, balanced breakfast improves the glucose profile throughout the day (71,82). Also, moderating breakfast PPG using a good postmeal exercise workout helps the glucose profile for the rest of the day (57). Having small, balanced breakfasts and big second meals is a diabetes-friendly habit (Figure 2*A*).

The second meal can be the biggest meal of the day for healthy people, as well as for those with diabetes because, as illustrated in Figure 1*A*, glucose tolerance is strong at the usual time of the second meal (6–11); early-phase insulin secretion is better because of high incretin levels, free fatty acid levels are low, and hepatic glucose production and glycogen depletion are suppressed.

If glucose tolerance is worse toward the end of the day (Figure 1*A*), eating fewer carbohydrates in the evening helps. Furthermore, it is a good practice to avoid big and late suppers, as shown in Figure 1*B* and *C* (14–17,19,20).

To combat the diurnal variation in glucose tolerance seen in Figure 1*A*, the patient has been eating most of her carbohydrates earlier in the day (Figure 4*A*), when her insulin sensitivity is higher. This strategy has led to a better glucose profile, lower daily mean glucose, and lower fasting glucose levels (83). The big second meal also offers improved satiety and is in phase with the circadian rhythm (15).

3. Using Nutrient Sequencing to Moderate Postmeal Glucose Surges

The value of nutrient sequencing in moderating postmeal glucose peaks is supported by solid data in the literature (22,23). Figures 2*C* and 4*B* show the patient's actualization of these results on nutrient sequencing. Her approach has been to eat protein and vegetables first and then eat the carbohydrate portion of her meals 10–30 minutes later. However, this approach is not practical for most meals. In certain circumstances when exercising is difficult, nutrient sequencing can be valuable. For example, it is suited for an evening gathering with a buffet-style meal. Also, it may be more achievable during the supper meal for most people.

4. Blunting Glucose Peaks With Timely Postmeal Exercise

The patient has been blunting glucose surges using 30–45 minutes of walking that starts 30 minutes postmeal for more than 7 years, and her A1C has been as low as 6.0% and HDL cholesterol as high as 51 mg/dL with this practice. With the help of CGM, she has also found that short-duration high-intensity exercise is even more effective (78,84,85); either 12 minutes of resistance exercise (84,85) or 15 minutes of stair exercise (86) has worked well. The high-intensity exercise can also be followed by a 15- to 18-minute walk (79).

There are some uncertainties about when to start postmeal exercise. For most meals, starting the exercise 30–45 minutes postmeal gives good results (50,56). The post-breakfast glucose surge typically peaks at about 1 hour postmeal (87). So, starting the exercise 25–30 minutes postmeal makes sense. In a recent study in which healthy adults drink a liquid breakfast, the glucose peaks at 30 minutes postmeal (73) and the subjects had to start the exercise right after the liquid meal to minimize the glucose surge. Our experience has been that when to start the postmeal exercise depends on when the anticipated peak occurs. A partially balanced breakfast may peak at ~1 hour (87), but a well-balanced supper may give a peak as late as 2 hours postmeal. Thus, to moderate PPG, exercise may be started at 30 minutes postmeal in the former case and at 60 minutes postmeal in the latter.

With regard to hypoglycemia, moderate postmeal exercise may be safer for people taking insulin or a sulfonylurea. The patient had a seizure in 2016 while driving 3 hours after short-duration postmeal resistance exercise followed by a short walk. Hypoglycemia-prone individuals need to watch glucose levels closely, lower insulin doses as needed, and adjust meals accordingly.

5. Eating a Light, Balanced Breakfast After Premeal Exercise

One drawback of premeal exercise is post-exertion hyperglycemia (26–34), leading to poor outcomes with regard to A1C and C-reactive protein (80). On the other hand, premeal exercise is effective in increasing insulin sensitivity prospectively for the rest of the day and beyond (Figure 3*B*). Additionally, premeal exercise has salutary effects on fasting glucose (75), glycogen content, and GLUT-4 protein levels (43–46). These mixed results make the utility and efficacy of premeal exercise unclear for people with diabetes.

The patient's first experience with premeal exercise was not encouraging. In 2002, 4 years after her diagnosis of type 2 diabetes, she followed a low-carbohydrate diet (90 g/day) and did moderate premeal exercise for 1 hour every day for 4 months. Although she lost 14% of her weight, her A1C did not improve (stable at 6.4%), and her HDL cholesterol worsened (from 39 to 36 mg/dL). These outcomes were similar to those found in the study by Verboven et al. (80).

After avoiding premeal exercise for more than 15 years, daily observations in CGM data pointed the patient to a work-around for the problem of post-exertion glucose elevation; she could eat a light, balanced breakfast and keep the glucose peak modest (Figure 4*D*). The second-meal phenomenon allowed her to eat a full second meal 90 minutes later. She tried a lifestyle that alternated pre-breakfast exercise and light breakfast with post-breakfast exercise for 6 weeks. Her next laboratory test results included an A1C of 5.8%—her lowest ever—and an HDL cholesterol level of 50 mg/dL. The patient has been taking premeal walks before a light breakfast on and off for more than 1 year now. We find that a high fasting glucose can be restored to normalcy in 2–4 days by taking a long premeal walk (45–60 minutes) (75) followed by appropriate carbohydrate intake (3).

Another drawback of premeal exercise is delayed hypoglycemia after high-intensity premeal exercise in patients with type 1 diabetes (37,38). Eating three to five meals per day and doing moderate postmeal exercise may be safer for patients with increased hypoglycemia risk until more data are available.

Conclusion

The five lifestyle habits addressed here in the context of diabetes self-management relate to meal composition, meal timing, nutrient sequencing, postmeal exercise, and premeal exercise. This is not an exhaustive list. Of these five habits, the most critical one is personalized carbohydrate intake for glucose control and weight management. The others offer health benefits, including glycemic improvement. However, patients at high risk for hypoglycemia need close guidance and support from the treatment team.

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DUALITY OF INTEREST

No potential conflicts of interest relevant to this article were reported.

AUTHOR CONTRIBUTIONS

E.C. performed the literature search, designed the various diet and exercise trials, collected and interpreted data, and wrote the manuscript. C.S. was the endocrinologist caring for E.C.; devised the treatment plan; ordered medications, CGM, and laboratory tests; and extensively reviewed the manuscript. E.C. is the guarantor of this work and, as such, had full access to all the data and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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