The "Ups" and "Downs" of a Bike Race in Type 1 Diabetes: Dramatic Differences in Strategies and Blood Glucose Responses from the Paris to Ancaster Spring Classic

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Running title: Athletic competition in type 1 diabetes

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Word Count (excluding abstract):
Abstract: 224
Main text: 2411
Tables and Figures: 2 tables, 2 figures

Abstract

Objective: Recommendations for insulin adjustments and carbohydrate intake exist for individuals with type 1 diabetes undertaking moderate exercise. Very few guidelines exist for athletes with type 1 diabetes competing in higher intensity and/or longer duration events. This observational study reports the strategies adopted by 6 habitually active men with type 1 diabetes (HbA_{1c} = 8.3±2.0%) undertaking a relatively intense endurance cycling event.

Methods: Participants wore continuous glucose monitoring (CGM) sensors for 24 hours before competition, while racing and overnight post-race. They were asked to eat their regular meals and snacks, and make their usual insulin adjustments before, during and after competition. All food intake and insulin adjustments were recorded in detail.

Results: Participants used a variety of adjustments for exercise. Four of 6 participants decreased their insulin dosage, and all participants consumed carbohydrate during the race (mean= 87±57g). In spite of these strategies, three of the six participants experienced mild to moderate hypoglycemia (not requiring assistance) during the event. Hyperglycemia was seen in all participants three hours post-exercise. There were no incidents of nocturnal hypoglycemia.

Conclusions: Individuals with type 1 diabetes can compete in intensive long-distance athletic events using a variety of nutritional and insulin adjustment strategies. In addition to finely tuned insulin adjustments and increased carbohydrate intake, vigilance will always be required to maintain some semblance of glycemic control during extended duration events.

Key words: blood glucose control, insulin adjustment, hypoglycemia, diabetes

INTRODUCTION

Physical activity is a common challenge to blood glucose control in individuals with type 1 diabetes. Moderate aerobic exercise is known to cause rapid declines in blood glucose (1), thereby increasing the risk of hypoglycemia both during and after exercise. Meanwhile, short periods of high intensity activity have been associated with increases in blood glucose concentration in early recovery with the potential for hyperglycemia both during and after activity (2-4). Some recent studies have attempted to duplicate the physical stresses of intense field sports by examining how short, high intensity bouts of exercise affect blood glucose levels when combined with moderate aerobic activity (5-7). Unfortunately, controlled laboratory conditions likely fail to truly reflect the physical and psychological stresses of competition, leaving athletes with type 1 diabetes with little information on how to manage blood glucose levels for competitive events where exercise intensity and duration will be variable in nature.

Several organizations offer guidelines related to managing blood glucose during exercise for individuals with type 1 diabetes (8, 9). Recommendations include decreasing insulin dosage, increasing carbohydrate intake, or using a combination of both of these strategies (8, 9). Unfortunately, most of these guidelines assume that individuals will be performing moderate exercise for a relatively short time (30 to 60 minutes) and at a fairly constant intensity. In actuality, many team (e.g. basketball, volleyball, soccer, etc.) and individual sports (e.g. cycling, running, cross-country skiing, etc.) involve both training sessions and competitions of extended duration (>90 minutes) where periods of high intensity work may be interspersed with slightly less intense activity. Finding the right balance of insulin reductions and increased carbohydrate intake is essential for preventing both hypo and hyperglycemia, both of which can influence sport performance. Having too much insulin or insufficient carbohydrate intake prior to/during exercise often results in hypoglycemia (10), which can lead to decreases in performance at best (11), or to serious medical problems requiring medical assistance (12) at worst. Conversely, hyperglycemia can result from withholding insulin, consuming excess carbohydrate (13) or from intense activities above the anaerobic threshold (14). Prolonged hyperglycemia can lead to the production of ketones, which can subsequently cause dehydration (15), thereby increasing the risk of muscle cramp and heat stress during intense activity (16).

As a great deal of inter- and intra- individual variability exists in terms of the hormonal responses to various types and intensities of training and competition, it is difficult for general insulin adjustment and carbohydrate supplementation recommendations to be made. In these situations, athletes must often adopt a trial-and-error approach in devising a strategy appropriate for the duration and intensity of exercise they are about to undertake, based on past experience of their blood glucose responses to similar activities. Very few of these strategies have been documented in the literature, leaving novice athletes with type 1 diabetes with very few resources at their disposal. This observational study follows six athletes, varying from recreational to elite in their competitive experiences, during a long-distance on- and off-road cycling race, in order to document how different insulin and carbohydrate strategies influence blood glucose outcomes during competition.

METHODS

This study was approved by the York University Human Participants Review Committee. Six male athletes with type 1 diabetes participated in the 2013 Paris to Ancaster Bicycle Race (Ontario, Canada) in order to take part in this observational study. All participants were habitually active in endurance-based sports. Four participants took part in regular cycling or triathlon competition, with two of these participating at an elite level. Participants ranged in age (36.3 ± 9.3 years, range = 24-46 years) and diabetes duration (15.7 ± 11.8 years, range = 2-31 years). All participants had moderate to excellent blood glucose control (Table 1). Two of the participants were using multiple daily insulin injections (MDI), three were using continuous subcutaneous insulin infusion (CSII), and one participant used a combination of both MDI and CSII. For comparison purposes, one non-diabetic athlete agreed to be monitored during competition. Subjects were provided with instruction on the experimental procedures and provided informed consent in agreement with York University ethics policies.

On the day before the race, participants were provided with continuous glucose monitoring (CGM) sensors. Data was recorded by a separate CGM device for individuals using MDI, while participants using CSII recorded the CGM data on their insulin pumps. Participants were asked to take at least four capillary glucose readings each day of sensor wear, during periods of relative glycemic stability, for CGM calibration purposes. The athletes did not perform any exercise or consume any alcohol in the 24 hours prior to the race. While participants were asked to follow their regular pre-race routines with respect to insulin dosage and food intake, they were also asked to record their food intake before, during, and after competition on race day with as much detail as possible. On the day following the race, CGM data and capillary glucose values for participants were uploaded using a website associated with the CGM devices.

OBSERVATIONS

The event took place the morning of Sunday, April 15th, 2013. The course consisted mixed terrain including asphalt, dirt or gravel roads, as well as off-road single and double-track trails involving a substantial amount of deep mud (i.e. cyclo-cross style racing). Four participants and the non-diabetic control participant completed the ~70 km route from Paris, Ontario to Ancaster, Ontario while the other two participants took part in the ~40 km route from St. George, Ontario to Ancaster, Ontario. All participants completed the event successfully, with completion time for the participants ranging from 176 minutes to 244 minutes for the 70 km route, and from 123 to 135 minutes for the 40 km route.

Insulin adjustments and carbohydrate intake

Details of each participant’s insulin adjustments and carbohydrate intake both before and during the race can be found in Table 1. CGM tracings for the race, 12-hours post-race and overnight post-race for all six participants with diabetes, along with the control participant without diabetes can be found in Figure 1. Two (one MDI, one CSII) out of the six participants did not make any adjustments to insulin dosage and chose instead to rely solely on “extra” carbohydrate intake (i.e. Ex carbs, without insulin administration) during the race to prevent hypoglycemia. The other two participants using a long-acting insulin injection decreased their evening injection by 20% and 33% respectively on the evening before the race and consumed Ex carbs. Of the three remaining participants using CSII, two decreased their basal insulin infusion rate approximately one hour prior to the race, while one chose to suspend the basal insulin infusion completely at the start of the race. All three also used a modified Ex carb approach, which takes into account reductions in insulin administration (17). The different insulin adjustment strategies and the resulting blood glucose outcomes of all participants, along with the CGM glucose profiles can be found in Figure 2.

As mentioned above, all participants consumed additional carbohydrate both before and during competition. Pre-race carbohydrate intake varied from 33 to 120 grams (Table 1), while carbohydrate intake during the race varied greatly from as little as 7 grams in one participant who struggled with severe hyperglycemia during the race, to 165 grams in another participant who struggled with hypoglycemia. Four out of the six participants with diabetes consumed over 100 grams of carbohydrate during the event, in line with the 30 to 60 grams of carbohydrate per hour that are generally recommended for athletes during endurance events (18).

Blood glucose levels

Interstitial glucose levels as measured by CGM show that two participants (Participants 4 and 5 in both Figure 1 and Figure 2) experienced mild to moderate hypoglycemia during the event. While interstitial glucose levels for participant 6 were measured between 6 and 12 mmol/l during the race, the participant performed a capillary glucose test with a handheld meter after 60 minutes due to feeling unwell and found that his glucose levels had dropped below 3 mmol/l. Conversely, participant 2, who was hyperglycemic (~20 mmol/l) before the event, experienced an increase in blood glucose levels throughout the first two hours of competition, and eventually delivered a bolus of insulin to bring his glucose levels under control. The final two participants (Participants 2 and 7) managed to complete the event with their blood glucose levels in a "safe" glycemic range (between 6 and 10 mmol/l) from start to finish. All participants experienced some level of hyperglycemia ranging from very mild (~8 mmol/l) to severe (>22.2 mmol/l) in the six hours following the race. There were no instances of nocturnal hypoglycemia post-race.

DISCUSSION

This observational study monitored interstitial glucose concentration by means of CGM in six athletes with type 1 diabetes (ranging from recreational to elite) during a long distance intense cycling race. As they were all taking part in the same endurance event (a cyclocross bike race), the timing, environmental conditions, and race terrain were comparable for all involved. In spite of this, the six monitored athletes showed a great deal of inter-subject variability in their approach to competition in terms of reducing insulin intake and increasing carbohydrate consumption. All six athletes managed to finish the race successfully, albeit not without some difficulty (mild hypo- and hyperglycemia).

A number of guidelines exist for insulin adjustments and nutritional strategies for exercise and sport for patients with type 1 diabetes (8, 9, 17). To date, only a handful of field studies have been published evaluating strategies of individuals with type 1 diabetes during competition (19, 20). In a group of type 1 diabetes marathoners, participants reduced both basal insulin (~23 and 20%) and pre-race breakfast insulin (~30 and 15%) when followed in the same race for two consecutive years. Carbohydrate ingestion was increased from a mean of 50 g to a mean of 60 g during the race from one year to the next in order to prevent hypoglycemia (19). In a 75km cross country ski race, excessive pre-race carbohydrate loading (65g) and a dramatic reduction in short-acting insulin (by 58%) resulted in pre-race hyperglycemia, while in the following year hyperglycemia was attenuated by dropping the pre-race carbohydrate to 40g with less of a reduction in short-acting insulin (by 35%) (20). In that cross country ski field study, ~40g of carbohydrate per hour of exercise appeared to prevent hypoglycemia in a majority of subjects (8 of 9) in both years (20). Similarly, we found that a combination of reduced circulating insulin levels, via reductions in either basal insulin 60 to 90 minutes before the start of the race or by reducing pre-race bolus insulin, and the consumption of carbohydrates at a rate of about 40-60g/hour of cycling helped to reduce the occurrence of hypoglycemia and did not result in hyperglycaemia during the race.

With the exception of the participant who started the race with severe hyperglycemia (blood glucose ~20 mmol/L), all race participants with type 1 diabetes experienced a decline in blood glucose concentration throughout the race in spite of taking in Ex Carbs and/or decreasing insulin dosage. Even the patient who had hyperglycemia initially experienced a dramatic decline in blood glucose once a small insulin correction was taken. In addition to the expected declines in glucose concentration during the race, five out of six participants experienced a steady increase in glucose levels upon completing the race, with peak glucose concentration being reached approximately three hours post-exercise. A similar trend towards post-exercise hyperglycemia was also found after 45 minutes of aerobic exercise in a study comparing aerobic and resistance exercise in individuals with type 1 diabetes where glucose levels were monitored by CGM for 12 hours post-exercise (1). As no study to date has collected hormonal and/or metabolic data related to this post-exercise period in individuals with type 1 diabetes, it is difficult to ascertain the cause of this phenomenon. The concentrations of plasma non-esterified fatty acids (NEFA) as well as the levels of lipid oxidation are both elevated post-exercise, with levels increasing in proportion to exercise intensity (21) and duration (22). The exercise-induced increase in free fatty acid mobilization peaks within two to three hours of exercise cessation, and can persist for up to 24 hours (23). Elevated lipid oxidation is known to suppress carbohydrate metabolism. When combined with elevated epinephrine levels stimulating glycogenolysis for up to two hours post-exercise (22), this could result in an increase in blood glucose concentration in individuals with type 1 diabetes unless a bolus of insulin is delivered. Consistent with this theory, the only participant who did not experience significant post-exercise hyperglycemia delivered frequent insulin correction boluses in the hours following exercise.

In addition to an increase in glucose uptake into the muscles during exercise, physical activity can increase insulin sensitivity for several hours post-exercise (24), thereby increasing the risk of post-exercise hypoglycemia. The DirecNet consortium found that when children exercised for 75 minutes at moderate-intensity the number of nights where nocturnal hypoglycaemia (blood glucose < 3.3 mmol/L) was experienced was more than double (42 versus 16%) compared to a day without exercise (25). Conversely, there is evidence to indicate that in regularly active individuals with well-controlled type 1 diabetes, the frequency of nocturnal hypoglycemia is not increased after days where exercise has been performed as compared to relatively sedentary days (26), presumably due to having developed effective prevention strategies. Participants in the present study were all habitually active with relatively well-controlled type 1 diabetes (mean HbA_{1c} 8.3±2.0%), which may explain why no nocturnal hypoglycemia was seen post-race. It should also be noted that the observed post-exercise hyperglycemia, caused either by a transient reduction in insulin sensitivity or because of increases in energy intake that were not properly matched with appropriate insulin delivery, may help prevent post-exercise late-onset nocturnal hypoglycemia as long as corrective insulin is not administered. Indeed, post-exercise hyperglycemia corrected with aggressive insulin administration has been linked to at least one death in a patient with type 1 diabetes (27).

In summary, athletes with type 1 diabetes are capable of taking part in high level athletic competition successfully. While the tools for managing and monitoring blood glucose have improved over the years, a knowledge and understanding of one’s own responses to exercise intensity and competition stress is essential in the decision-making processes required for adjusting insulin dosage and carbohydrate intake. Frequent testing of capillary glucose can be used as an adjunct to real-time CGM to ensure that blood glucose levels remain in a healthy range before, during and after competition.

ACKNOWLEDGEMENTS

Author Disclosure

M. Riddell has received speakers' fees from Medtronic Canada. J. Yardley is supported by a Canadian Institutes of Health Research Post-Doctoral Fellowship.

Contributions

The manuscript was drafted by J. Yardley and D. Zaharieva. C. Jarvis assisted in participant recruitment and data collection. J. Yardley and D. Zaharieva performed the data collection and presentation. M. Riddell provided support and guidance in data collection, and reviewed and edited the manuscript.

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Table Legends

Table 1 – Insulin adjustments and carbohydrate (CHO) intake before and during event

Table 2 - Insulin adjustments and carbohydrate (CHO) intake immediately post-race and in the evening after the event

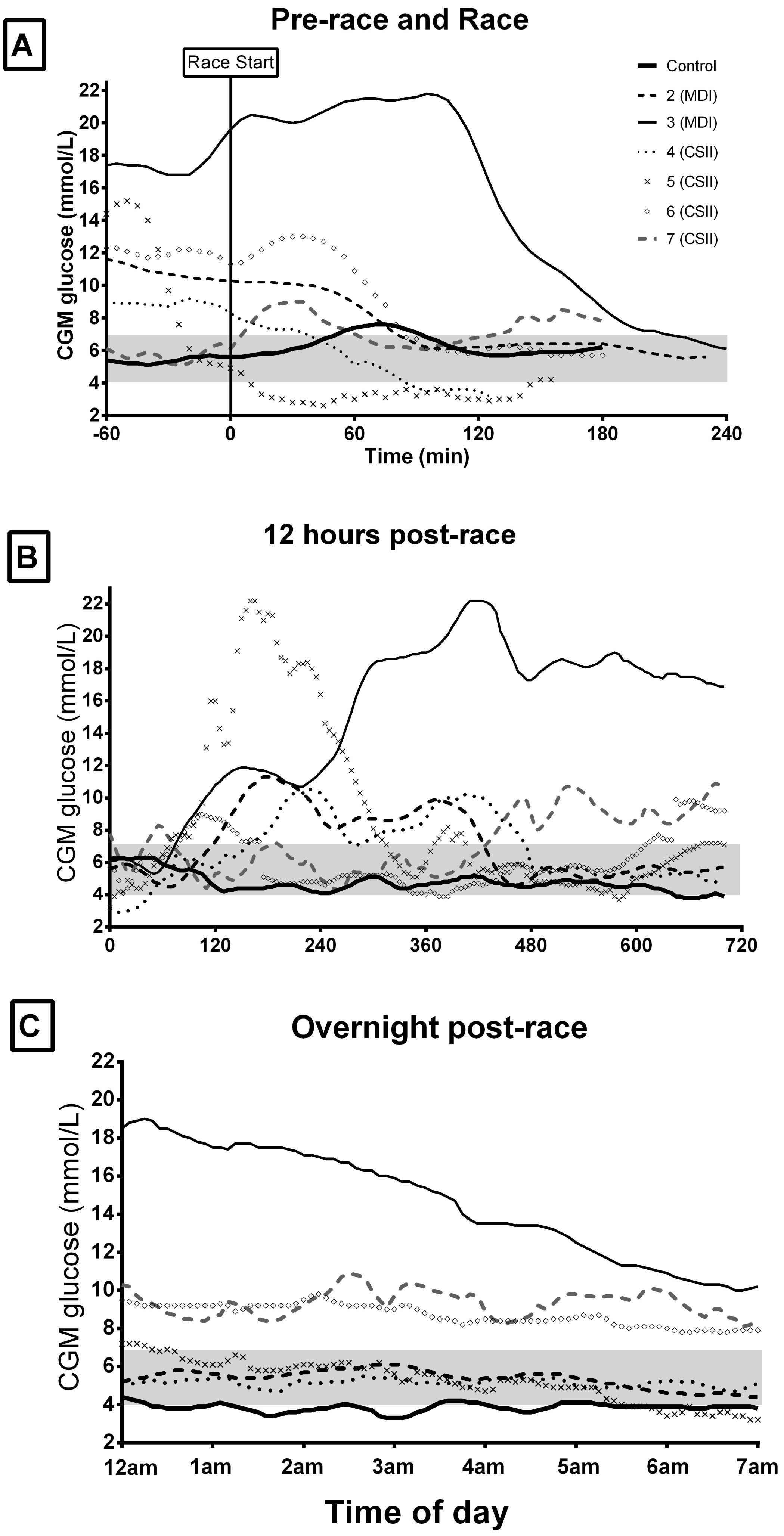
Figure Legends

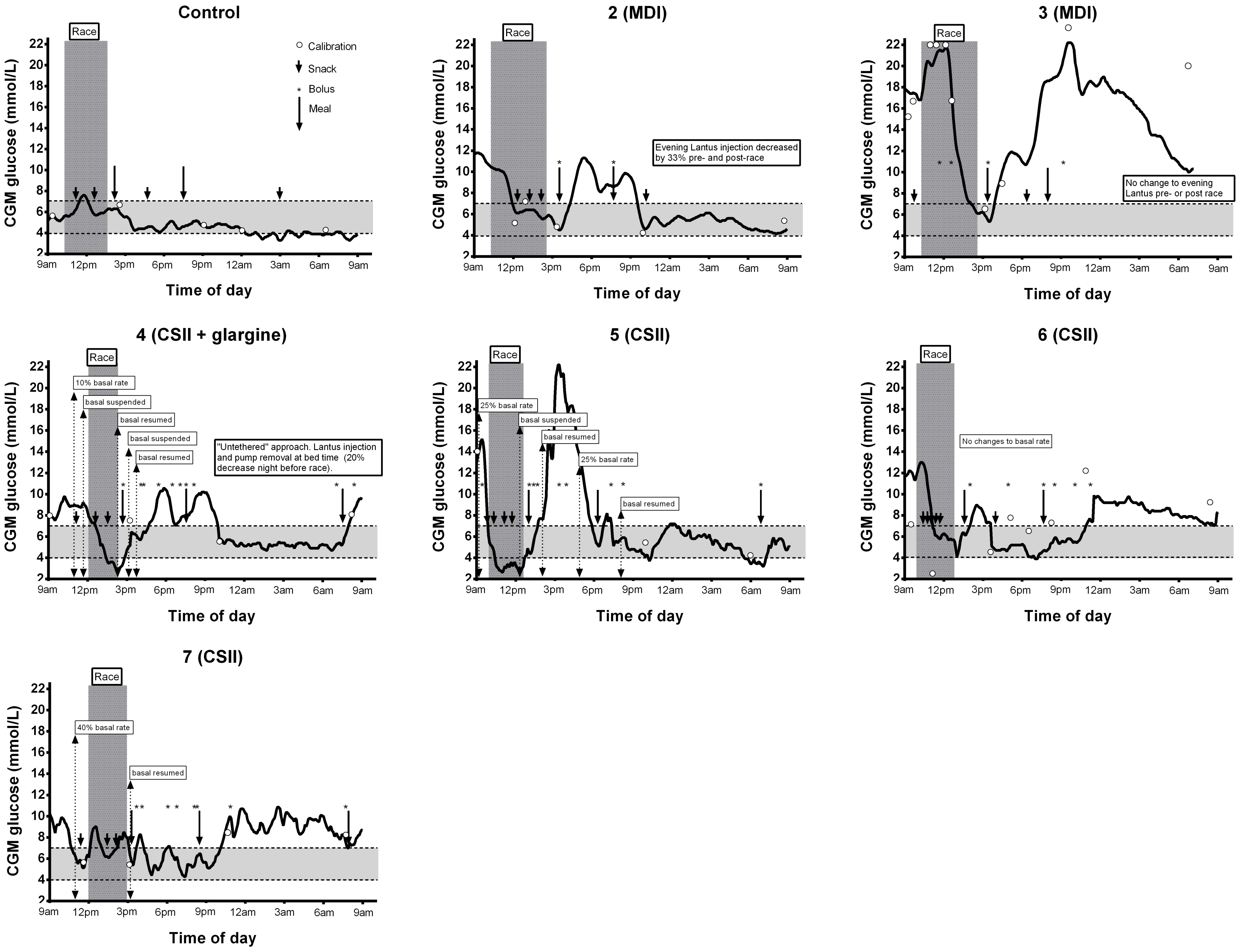
Figure 1. A) Continuous glucose monitoring profiles as measured during the event for one control participant without diabetes (participant 1), and six individuals with type 1 diabetes (Participants 2-7). B) Continuous glucose monitoring profiles for all participants in the 12 hours post-exercise. C) Post-race nocturnal continuous glucose monitoring profiles for all participants.

Figure 2. CGM glucose profiles for 6 participants with type 1 diabetes demonstrating different approaches to blood glucose management during competition as compared to a control participant without diabetes.

Participant	HbA_{1c}	Insulin Delivery	Pre-race CHO (g)	Pre-race insulin adjustment	Ride time (mins)	Race CHO (g)	Hypoglycemia during race (y/n)
1	N/A	N/A	68	N/A	179	102	N/A
2	11.7	MDI	120	Evening glargine ↓ 33%	227	105	No
3	9.5	MDI	34	None	244	7	No
4	7.6	MDI + CSII	54	20% ↓ pre-race evening glargine, basal rate suspended during race	123	53	Yes
5	6.9	CSII	115	↓ basal rate to 25% 1-hour pre-race	135	165	Yes
6	7.4	CSII	33	None	177	156	Yes
7	6.6	CSII	53	↓ basal rate to 40% 1-hour pre-race	176	103	No

Participant	Post-race CHO (g)	Post-race insulin adjustment	Total afternoon bolus insulin	Evening CHO (g)	Total evening bolus insulin	Overnight insulin adjustments	Nocturnal hypoglycemia (y/n)
1	110	N/A	N/A	144	N/A	N/A	N/A
2	170	Regular bolus for food (insulin lispro)	9	56	3	Evening glargine ↓ 33%	No
3	116	Regular bolus for food (insulin lispro)	11	117	11	None	No
4	140	Multiple small adjustments + regular bolus for food	6.9	132	6	Regular basal	No
5	10	Multiple small adjustments + regular bolus for food	13.55	66	4.55	Regular basal	No
6	160	One large adjustment + regular bolus for food	9.5	152	4.95	Regular basal	No
7	103	Multiple small adjustments + regular bolus for food	4.9	52	6.9	Regular basal	No


A
Pre-race and Race
Race Start
Control
2 (MDI)
3 (MDI)
4 (CSII)
5 (CSII)
6 (CSII)
7 (CSII)
CGM glucose (mmol/L)
2
4
6
8
10
12
14
16
18
20
22
-60
0
60
120
180
240
Time (min)
B
12 hours post-race
CGM glucose (mmol/L)
0
120
240
360
480
600
720
C
Overnight post-race
CGM glucose (mmol/L)
12am
1am
2am
3am
4am
5am
6am
7am
Time of day


Control
Race
Calibration
Snack
Bolus
Meal
CGM glucose (mmol/L)
Time of day
9am
12pm
3pm
6pm
9pm
12am
3am
6am
2 (MDI)
Evening Lantus injection decreased by 33% pre- and post-race
3 (MDI)
No change to evening Lantus pre- or post race
4 (CSII + glargine)
10% basal rate
basal suspended
basal resumed
basal suspended
basal resumed
"Untethered" approach. Lantus injection and pump removal at bed time (20% decrease night before race).
5 (CSII)
25% basal rate
basal suspended
basal resumed
25% basal rate
basal resumed
6 (CSII)
No changes to basal rate
7 (CSII)
40% basal rate
basal resumed