Closed loop systems and Exercise in T1DM
FIG. 2. Reference YSI values for all 98 successful sessions. Tracings are centered at the time when the YSI glucose value fell below 70 mg/dL. Solid black line represents the mean of low glucose suspend (LGS)-On sessions, the dashed black line represents the mean of LGS-Off, and the gray lines represent mean±SEM values.

ASPIRE study of threshold suspend in exercise-induced hypoglycemia
“PILGRIM” study – feasibility study

Next steps in monitoring for exercise-associated hypoglycemia
- *Predictive* low glucose suspend

16 separate experiments performed until predictive pump suspension
- **In 12 hypoglycemia was prevented**
- **Mean BGL at time of suspension** 92 mg/dL
- **Mean time of suspension** was 90 mins
Episodes of overnight treatable hypoglycemia (reference blood glucose <60 mg/dL) during OL and CL.

Sherr J L et al. Dia Care 2013;36:2909-2914
A: Overnight insulin delivery in units/h 7–11 h postexercise (10:00 p.m. to 2:00 a.m.), with CL associated with lower insulin delivery (P = 0.008).

Again about 20-30% less basal delivery overnight
Exercise with Single Hormonal Closed Loop Control may still be challenging...

**Figure 1**—Plasma glucose (A), insulin infusion rates (B), and plasma insulin (C) for conventional insulin pump therapy and closed-loop basal insulin delivery (median [interquartile range]). Meals (M), snacks (S), and exercise sessions are indicated. A: Episodes of hypoglycemia requiring treatment (○, insulin pump therapy; ●, closed-loop delivery).

**FROM:**
Closed-Loop Basal Insulin Delivery Over 36 Hours in Adolescents With Type 1 Diabetes Randomized clinical trial. Elleri et al. Diabetes Care 2013 Apr; 36(4): 838–844
Light cycling 30 mins > 4 hrs post-meal (minimal IOB)

Other Physiologic signals such as Heart Rate may help closed loop control around Exercise

Adapted from Breton et al. Diabetes Technol Ther. 2014 Aug 1; 16(8): 506–511
Closed Loop Systems for Exercise Depend on CGM accuracy during Exercise-
Dexcom G4 Platinum vs Medtronic Enlite System, at Rest and During Exercise

Adapted from Taleb et al, Diabetes Technology & Therapeutics. September 2016, 18(9)
Hyperglycemia

Weightlifting
Sprints, gymnastics, baseball,
Wrestling, volleyball

Rugby, football, basketball, tennis, lacrosse
Skiing (downhill)
Middle distance events

Road cycling
Skating
Nordic skiing
Hiking/backpacking
Long-distance running/swimming/cycling

Hypoglycemia
BGL and Performance**

**Clinical Experience, personal communication, others (Scheiner G.)
Teach insulin on board

![Graph showing the effect of aerobic exercise on blood glucose levels with and without insulin.](Image)
Insulin on Board - dose dependence

Courtesy of Tim Heise and colleagues
Factors affecting risk of hypoglycemia:
- Exercise Type, intensity, duration
- Time since last meal and insulin dose
- Time of Day
- Physical Fitness
- Recent hypoglycemia, hypo unawareness
- Emotional/stress hormone factors

Frequent Monitoring of BGL and/or CGM

Possible Actions
- Reduce insulin bolus
- Reduce basal insulin

Risk of delayed hypoglycemia

Preceding meal
- snack
- +/- max effort

Following meal
- snack
- Resume basal insulin
- Reduce insulin bolus

Night
- Reduce basal insulin

Adapted from Nadine Taleb and Rémi Rabasa-Lhoret. Diabetologia August 2016,59(8),1632–1635
Is the activity primarily aerobic?

Discuss the advantages and disadvantages of insulin dose reduction and carbohydrate intake for exercise. Activities that include anaerobic exercise will require less carbohydrate intake and/or less insulin adjustments. If both resistance/anaerobic and aerobic are to be performed, suggest performing resistance/anaerobic first.

Is the activity prolonged resistance exercise (weight lifting for >30 minutes)?

Is the activity prolonged intermittent high intensity activity?

Discuss the possibility that intense anaerobic sprint-based exercise may increase glucose levels and require conservative insulin correcting in recovery if hyperglycemia exists.

Is the patient willing and able to lower insulin levels for exercise?

Consider the timing of exercise relative to the last meal.

Is the activity ≤ 3 hours after a meal?

Consider increased carbohydrate intake at a rate of ~0.5 grams/kg body mass/hour of activity.

Reduce bolus insulin by 25-75% at the meal before exercise depending on the intensity (i.e. light=25%; moderate=50%; heavy=75% reduction).

Reduce bolus insulin by 50-75% at the meal before exercise (i.e. light=50%; moderate/heavy 75%).

Is the activity ≥60min in duration?

Reduce basal insulin by 50-90% 60-90 minutes before the start of exercise until the exercise stops. Or consider pump suspension at the start of exercise.

Is the patient on CSII?

Consider basal insulin reduction.

Consider bolus insulin reduction.

Consider a 20% reduction in basal insulin on days with prolonged activity. Consider CSII therapy if repeated hypo- or hyperglycemia persists.

Other notes:
1) Pump suspension at the onset of aerobic exercise may require initial carbohydrate intake (15-20g);
2) Consider CGM where patient or parent preference dictates, or with history of nocturnal or severe hypoglycemia;
3) Downward trending arrows on CGM during exercise should be responded to by the ingestion of 8-20 grams of rapidly acting carbohydrate;
4) Consider overnight basal rate reduction of 1-40% on the evenings after prolonged aerobic exercise or resistance training.
Case - “Oh no- I’m low!”

- Emma is a 15 year old competitive cyclist.
- During a 30 mile ride, despite her strategy to reduce insulin prior to exercise and take in adequate carbohydrates, she feels her blood glucose dropping.
- She starts to feel weak and stops to check blood glucose which is 60 mg/dL.
- She takes 25g of carbohydrate and is determined to finish her ride.
- 20 minutes later she checks again and her blood glucose is 59 mg/dL, still feeling a bit weak and is on the fence about whether she can finish.

What should Emma do?
• For many athletes, the competitive instinct can be powerful and interfere with smart decision-making.

• Hypoglycemia itself can impair decision-making. There is a fine line between the optimal performance range and inability.

• Ideally hypoglycemia is prevented with insulin adjustment, carb replacement, and/or intermittent high intensity exercise.

• If hypoglycemia occurs, competition should be stopped to allow for treatment and recovery.

• Consider the benefits of continuous glucose monitoring or frequent glucose monitoring to predict/prevent lows.
Case-

**Spontaneous** Exercise with T1D

- James is an 13 year old with type 1 diabetes who loves basketball. He ate lunch 90 minutes ago and now his blood glucose is 280 mg/dL. He has 3.5 units of insulin on board from his pump bolus.
- He has a sensitivity of 1:50 mg/dL >120mg/dL.
- His I:C ratio is 1:15 grams.
- He was originally planning on practice in 3-4 hours when his blood glucose would be at target but his coach calls for an early practice today.
What would be the best option for James in this situation? (Assume his ketones are negative)

A. Skip practice today. His blood sugar is just too high.

B. Take additional correction dose of insulin and wait until his blood sugar starts coming down

C. Go ahead and play without additional insulin.
Key Points

• Know the effect of insulin-on-board (IOB) under normal circumstances versus during exercise

• In this case:
  – Blood glucose of 280 mg/dL with 3.5 units IOB with a correction factor 1:50 mg/dL would normally drop blood glucose to 105 mg/dL

• This same scenario in the presence of exercise will almost certainly cause hypoglycemia

• Thus he needs to take carbohydrates to cushion the fall

• He can use a temporary basal rate or remove his pump for exercise <60-90 minutes to avoid lows but in this case it is too late –these interventions will have little impact due to the high IOB
Here’s the math I would take him through...

- Predicted BGL due to IOB = 105 mg/dL
- Basketball usually causes him to drop by ~80 mg/dL per hour at his normal basal rate (without any carbs eaten) based on his experiences.
- Thus he could theoretically be 25 mg/dL (yikes) after/during exercise. This requires a “reverse correction” equivalent to a rise of 100 mg/dL to get/keep him at about 125 mg/dL.
- That is equivalent to 2 units of insulin for him (1:50 sensitivity)
  - minimum 30 grams uncovered carbs, and likely more (based on 1:15 grams).
  - He may also reduce his basal (if even an option)
How to cushion the fall?

Treating blood glucose based on trend information will:
• Allow him to keep exercising
• Require less carbs
• Help him feel better and stronger during and after basketball