



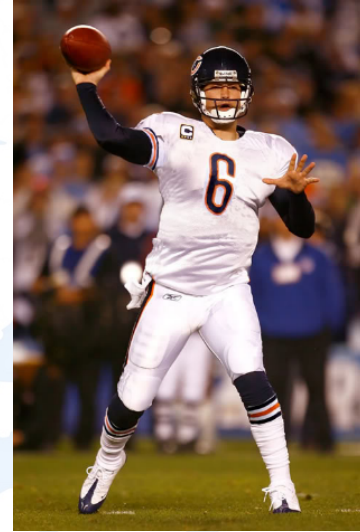
Type 1 Diabetes & Exercise- Cases



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Pro Athletes with Type 1 Diabetes

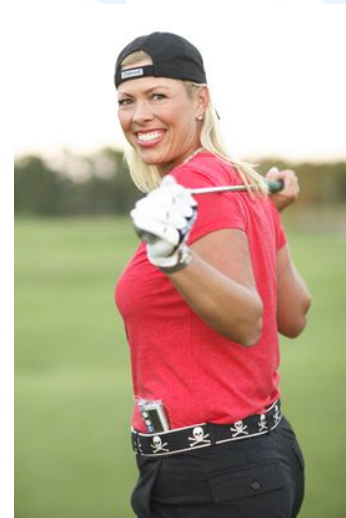
Jay Cutler
Miami Dolphins



Max Domi
Montreal Canadiens



Team Type 1



Michelle McGann
LPGA

Extreme Athletes with Type 1 Diabetes



Will Cross

1st person with T1D to summit Everest



Sébastien Sasseville

2nd person with T1D to summit Everest
1st person with T1D to run across Canada



Every Day Patients with Type 1 Diabetes

Dysglycemia occurs with exercise and sport in active/fit patients with T1D

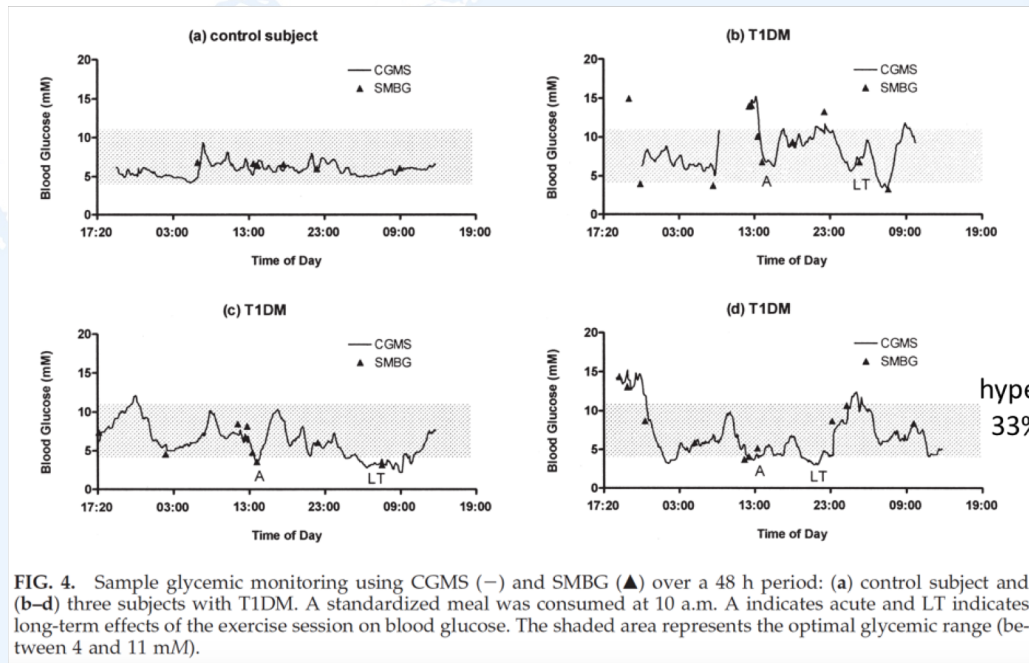
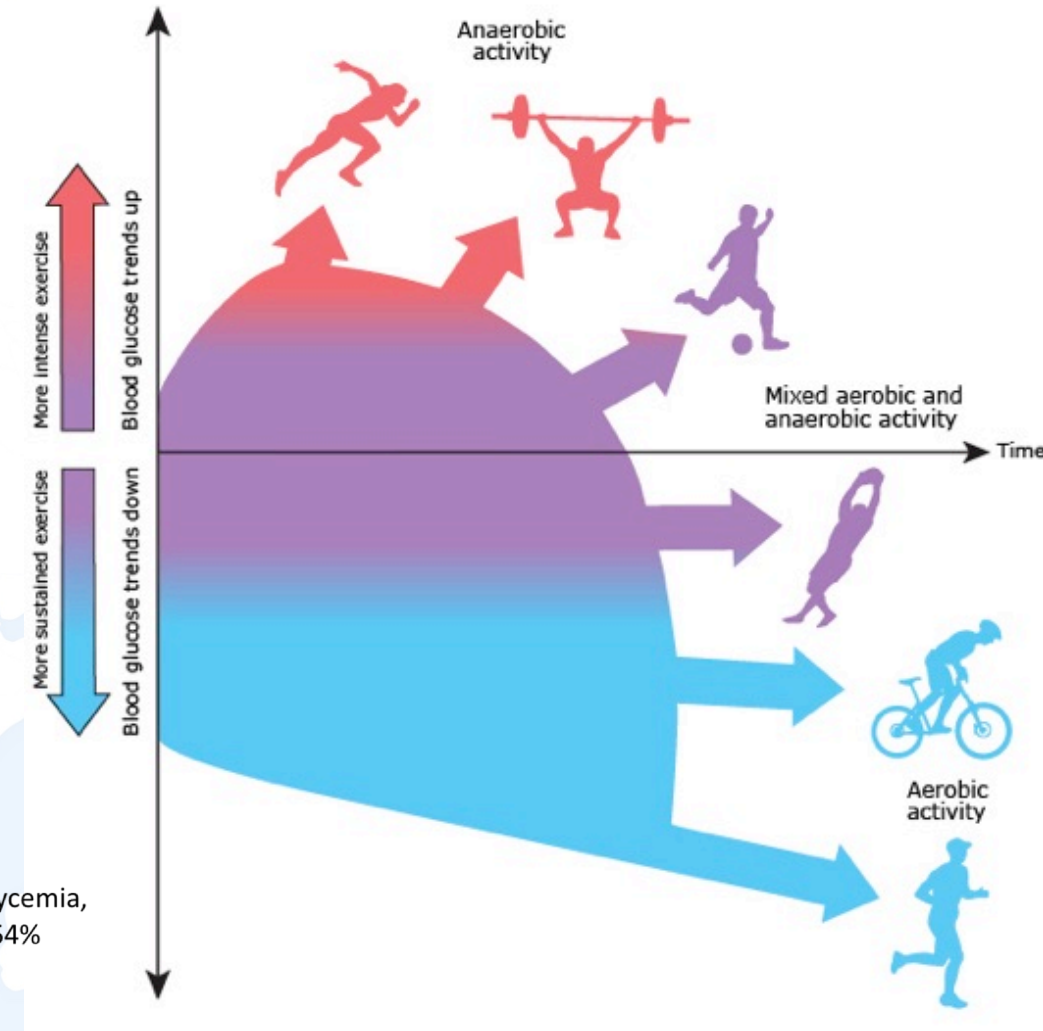
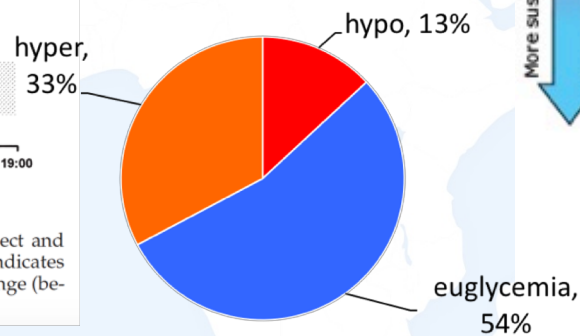
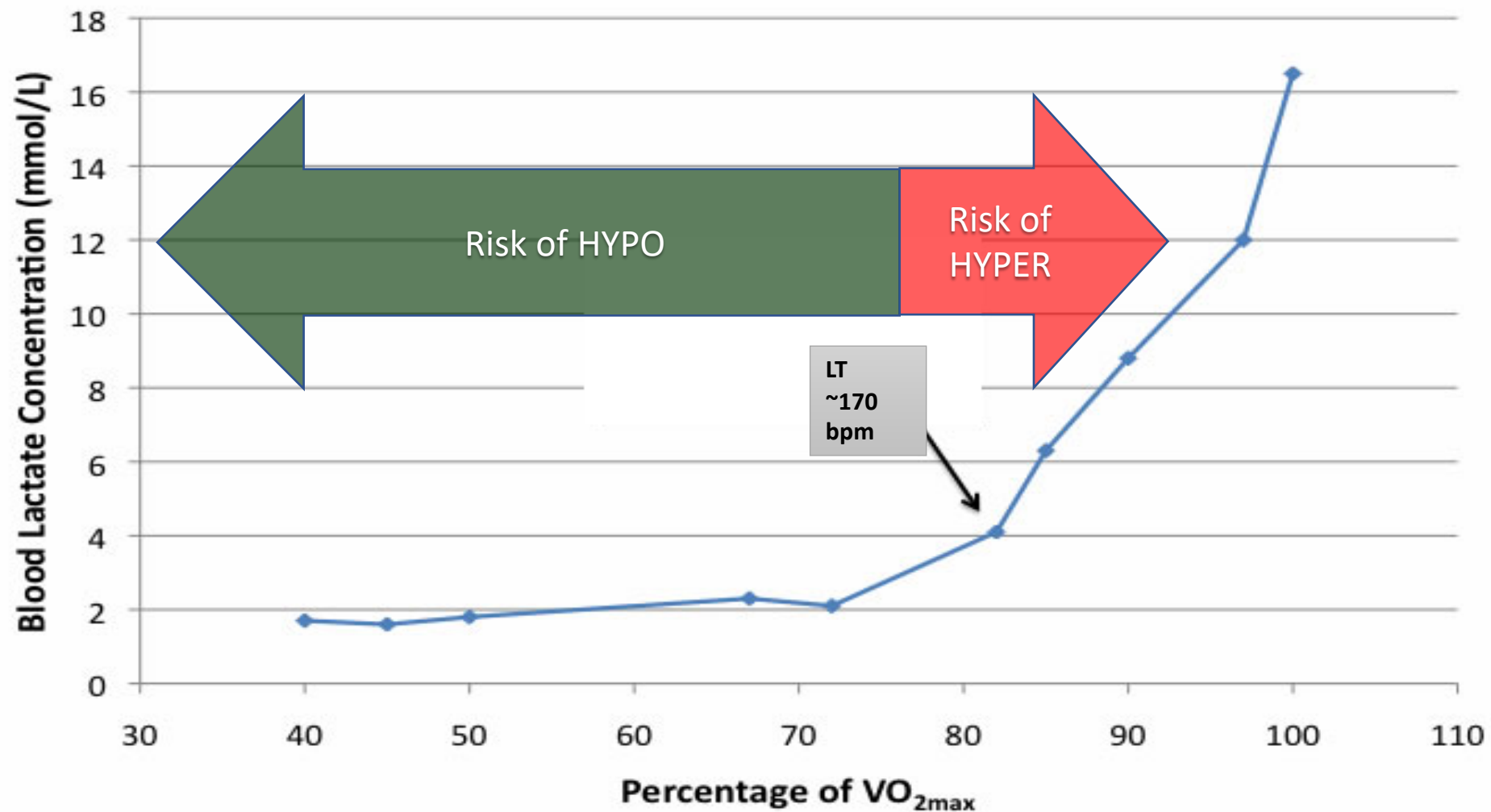


FIG. 4. Sample glycemic monitoring using CGMS (—) and SMBG (▲) over a 48 h period: (a) control subject and (b-d) three subjects with T1DM. A standardized meal was consumed at 10 a.m. A indicates acute and LT indicates long-term effects of the exercise session on blood glucose. The shaded area represents the optimal glycemic range (between 4 and 11 mM).



Exercise intensity, lactate levels and glycemic risk

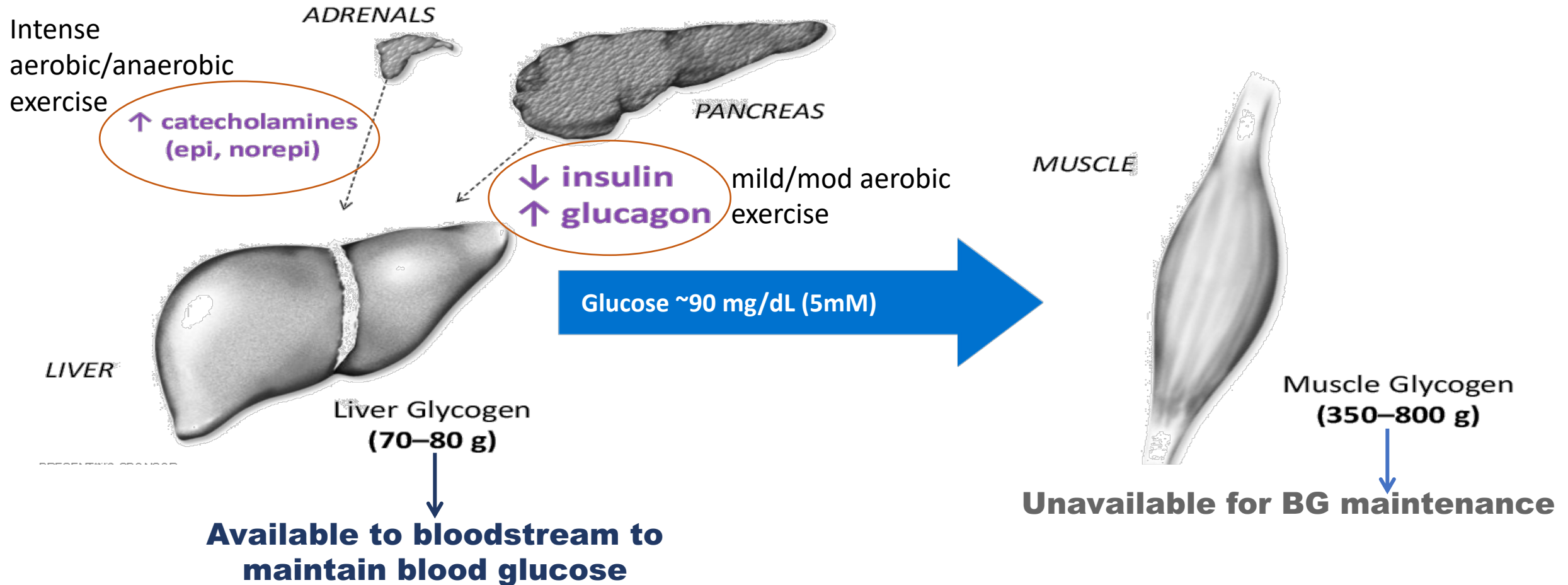
Figure 1. Blood Lactate Concentration at Different Exercise Intensities



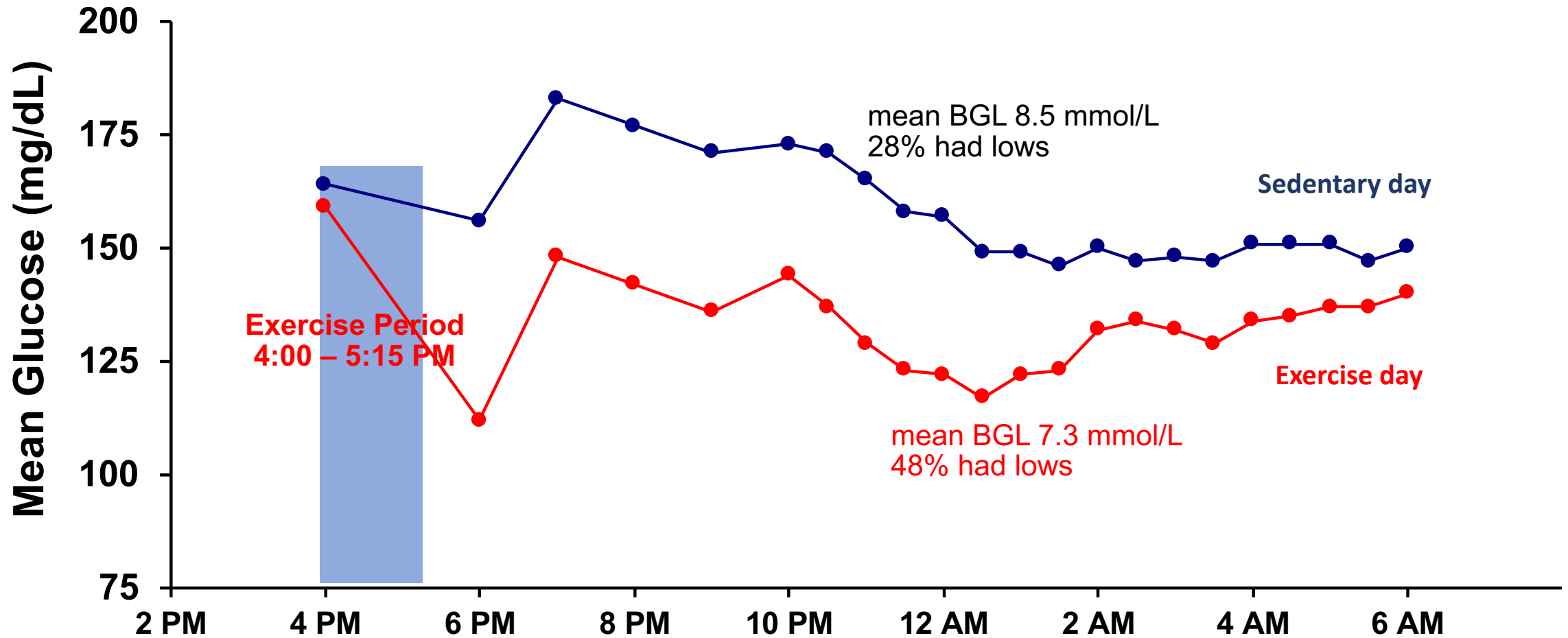


I know that predicting the metabolic responses to exercise in diabetes is challenging...

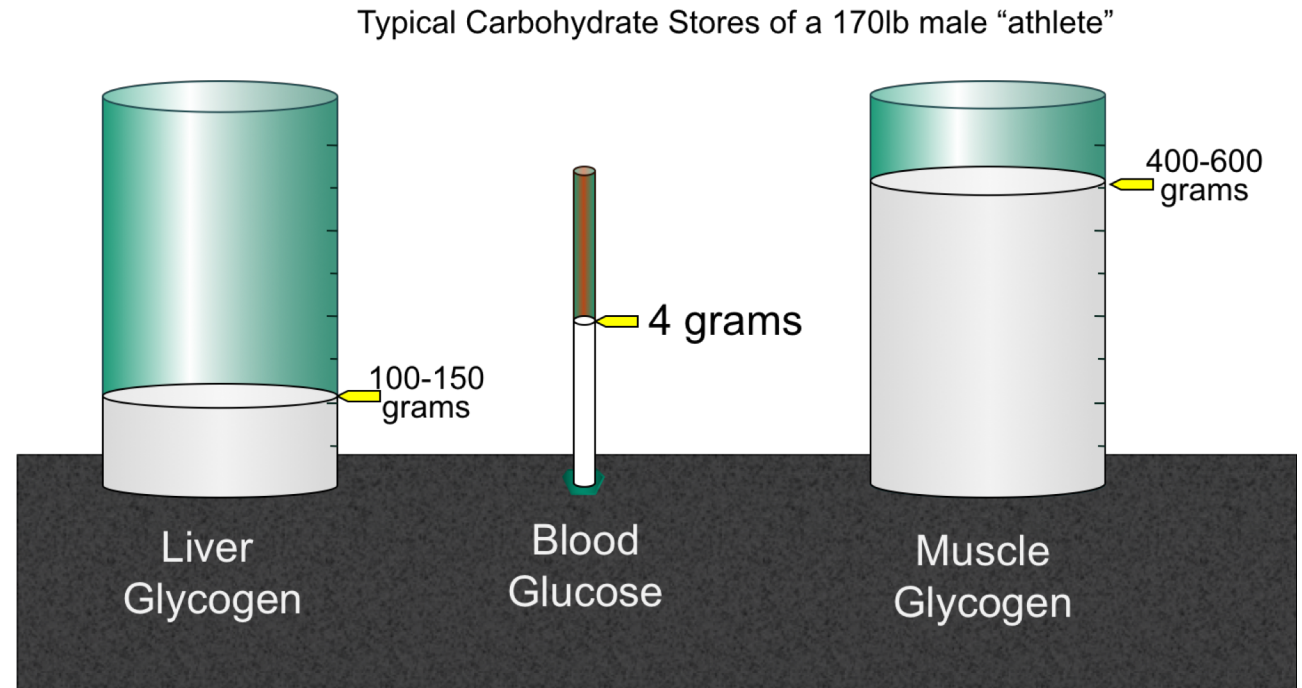
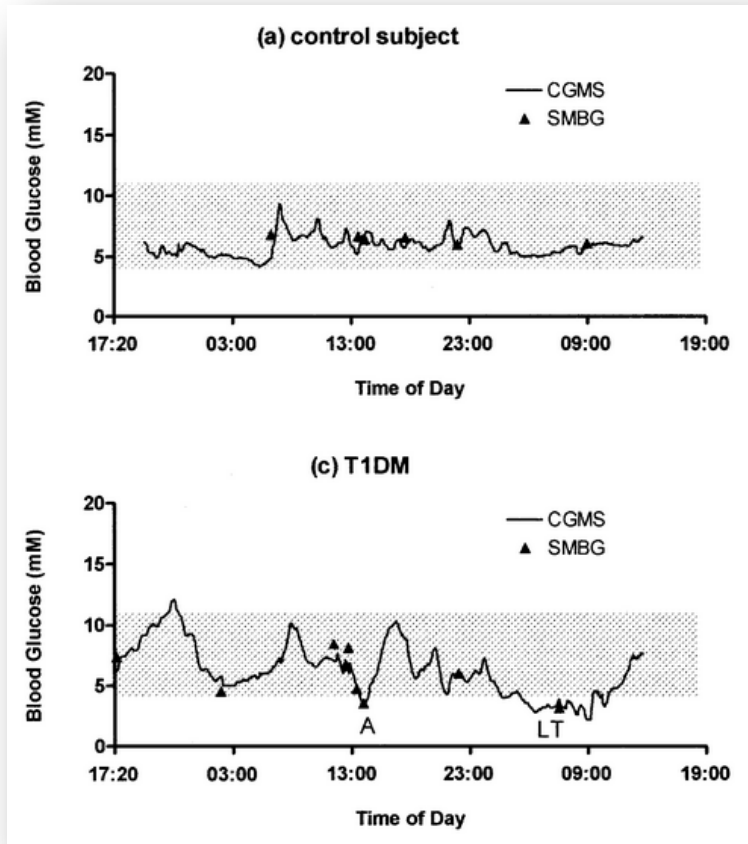
Glucose Provision During Exercise Requires Glycogen Mobilization



Overnight glucose levels after afternoon exercise in youth with T1D



Diminished carbohydrate stores after exercise and post exercise hypoglycemia



Intense exercise (HIIT) causes a reproducible rise in BGL, particularly if performed a fasted state...

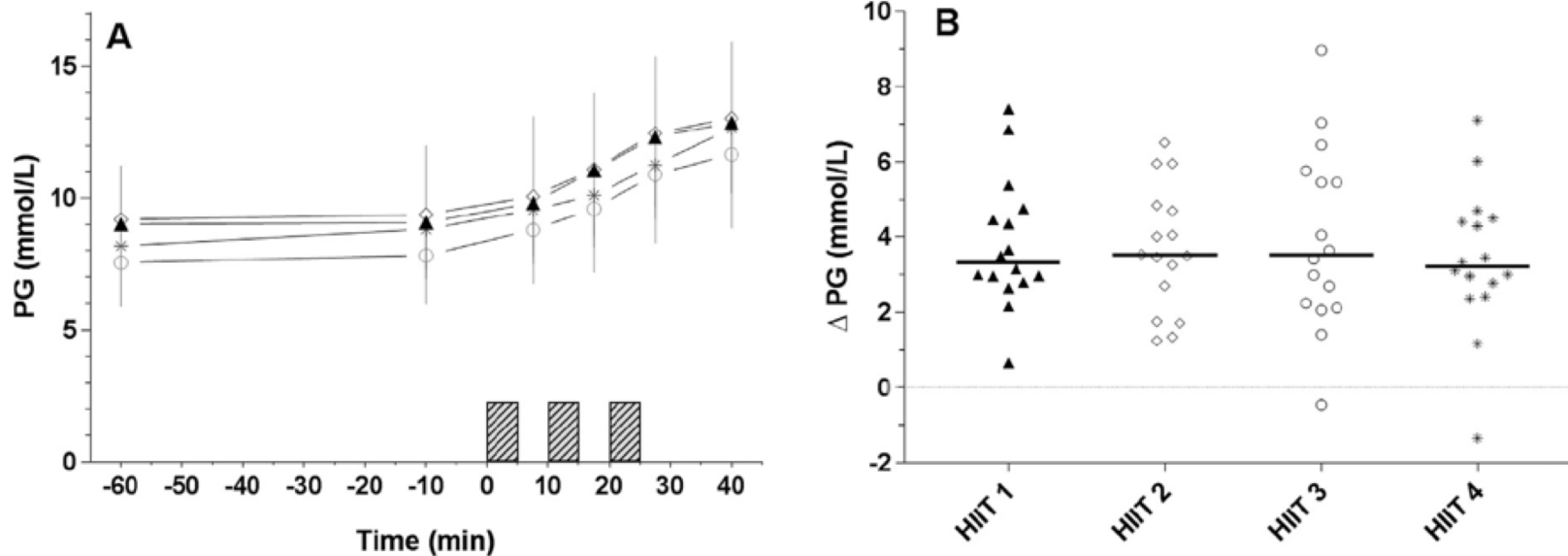
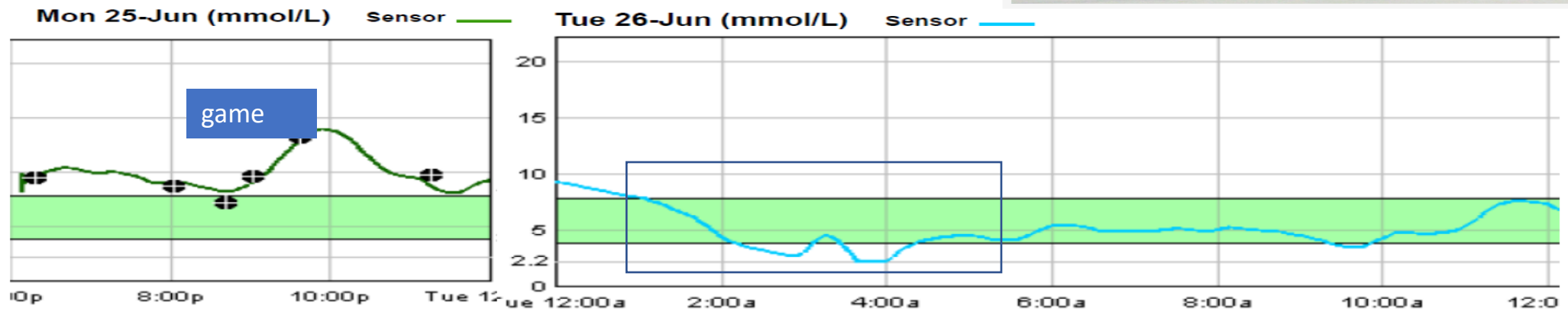


Fig. 2 – Effects of HIIT on plasma glucose (PG) concentration (panel A) and the change in plasma glucose concentration (Δ PG) during HIIT (panel B) across the four HIIT sessions. Note: \blacktriangle = HIIT session 1; \diamond = HIIT session 2; \circ = HIIT session 3; $*$ = HIIT session 4.

Even if the exercise does not initially cause a low- it can overnight

Exercise can transiently cause hyperglycemia.....
Then late-onset hypoglycemia....



Summary of Clinical Strategies

- *Low intensity – BG ↓ - NEED TO REDUCE INSULIN, PROVIDE CHO*
- *High intensity (short sharp)- BG ↑ - NEED TO CORRECT HYPERGLYCMIA, PREVENT KETONES*
- *Mixed- a bit of both +/- steady BG- LESS FUSS*
- *liver and muscle glycogen stores need to be replenished*
- *Each patient differs at least a little*
 - *But within themselves, are probably consistent with respect to glucose responses*

Frequent Monitoring of BGL and/or CGM

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

Risk of delayed hypoglycemia



Possible Actions

- ↑ Reduce Prandial insulin
- ↑ Reduce basal insulin (-50-80%)
- ↑ snack
- ↑ Maintain reduced basal insulin
- ↑ snack +/- max effort
- ↑ Resume basal insulin
- ↑ Perform hyperglycemic correction if needed
- ↑ Reduce prandial bolus
- ↑ Bedtime snack
- ↑ Reduce basal insulin overnight (-20%)

Adapted from Taleb and Rabasa-Lhoret. Diabetologia. August 2016,59(8),1632–1635

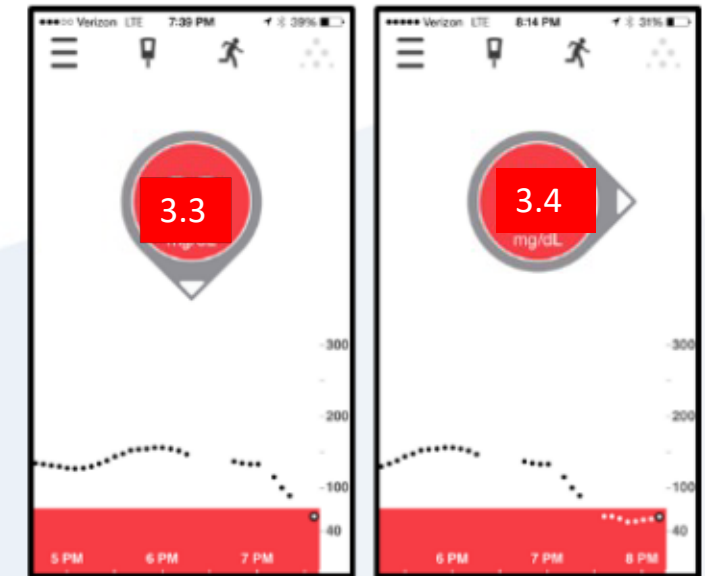
Case 1 - “Oh no, I’m low!”

Emma is a 20 year old recreational cyclist with a pre-exercise SMBG of 7.2 mmol/L.

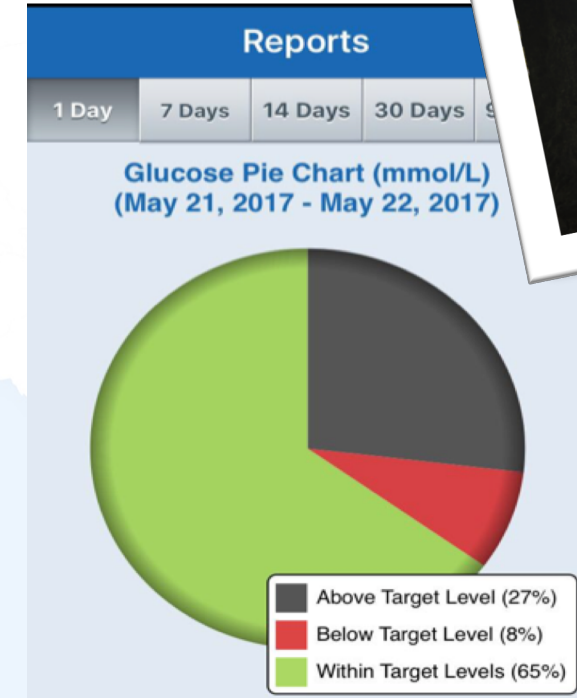
- During a 30 km ride post lunch, despite her strategy to reduce basal insulin at exercise start time and take in carbohydrates (~30 grams), she sees her blood glucose dropping on her CGM.
- She starts to feel weak and her CGM says her glucose is 3.3 mmol/L.
- She takes another 15 g of dextrose in the form of a partial sports gel, as she is determined to finish her ride without a rebound high glucose.
- 20 minutes later, still riding, she checks again and her CGM glucose is still 3.4 mmol/L, 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 decision-making
- Hypoglycemia itself can impair decision-making. There is a fine line between the optimal performance range and inability to perform at all!
- Ideally hypoglycemia is prevented via reductions in prandial insulin reductions and/or basal adjustments, carb replacement, and/or intermittent high intensity intervals
- If hypoglycemia occurs, cycling should be stopped to allow for safe treatment and recovery
- Consider the benefits and limitations of continuous glucose monitoring



8% of 24 hours=115
minutes/day below target





Any thoughts so far?

How to fuel (carbs) for prolonged aerobic exercise? estimate per duration/intensity?

- High quality meal 3-4 hours prior – increase glycogen stores
- Try to avoid with prandial insulin in circulation (i.e. > 3 hours post meal), otherwise bolus insulin reduction usually required
- For high performance in activities > 30 minute duration, 30-60 grams CHO/hour for adults (limited by absorption and reduced GI perfusion under high stress conditions)
- Shorter duration or pure strength sessions likely will not require CHO and may require insulin administration in recovery to combat post-exercise hyperglycemia.

Carbohydrate (CHO) Intake for Aerobic Exercise



**Brief, mild exercise
performed soon
after a meal**

Typically no extra CHO



**Prolonged
exercise**

~10-15 gm CHO



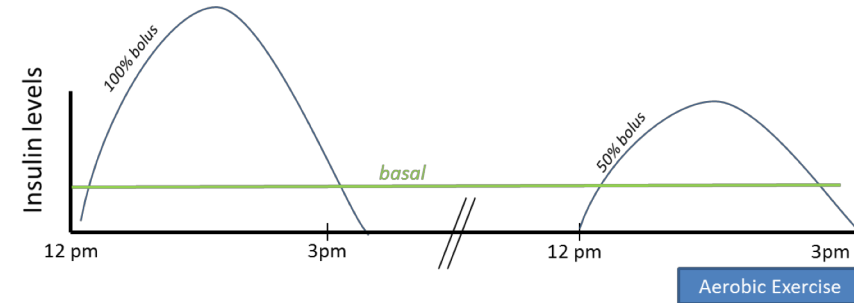
**Endurance/performance
activities**

0.5-1.0 g/kg/hr

Insulin management strategies for the prevention of exercise-induced hypoglycemia

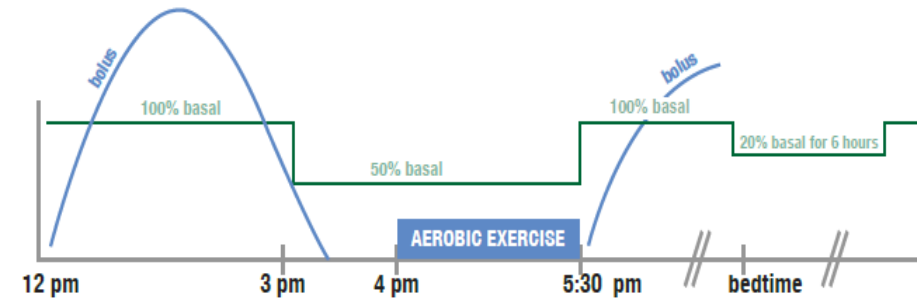
1. Reduce the mealtime bolus by 25-75% when exercise occurs 1-2 hours after a meal
2. Suspend basal insulin delivery during exercise for up to 60 min
3. Reduce basal insulin by 50-80%, 60-90 minutes BEFORE the start of exercise until the end of the activity

ADJUSTING BOLUS INSULIN FOR AEROBIC EXERCISE



ADJUSTING BASAL INSULIN FOR SAMPLE AEROBIC EXERCISE

(90 minutes, between 4:00 p.m. and 5:30 p.m.)



Practical Guide to Goal BGL at beginning of Exercise by *Exercise Type*

BGL	Aerobic/ Low Intensity	Anaerobic/ High Intensity
< 5 mM; 90 mg/dL	Major risk of hypoglycemia 10-20 g and recheck before starting	May be OK if predictable rise seen before
5-7 mM; 90-124 mg/dL	10 grams CHO then start	OK to start
7-10 mM; 125-180 mg/dL	OK to start	OK, but BG may ↑
10.1- 15 mM; 180-270 mg/dL)	OK to start but performance may ↓	OK to start but performance may ↓ BG may ↑ further
> 15mM; > 270 mg/dL	Check ketones if unexplained If small to moderate, then light intensity OK, 50% correction bolus	Avoid

Exercise management in type 1 diabetes: a consensus statement. Lancet Diabetes Endocrinol. 2017 May;5(5):377-390.

Other issues for the active person with T1D

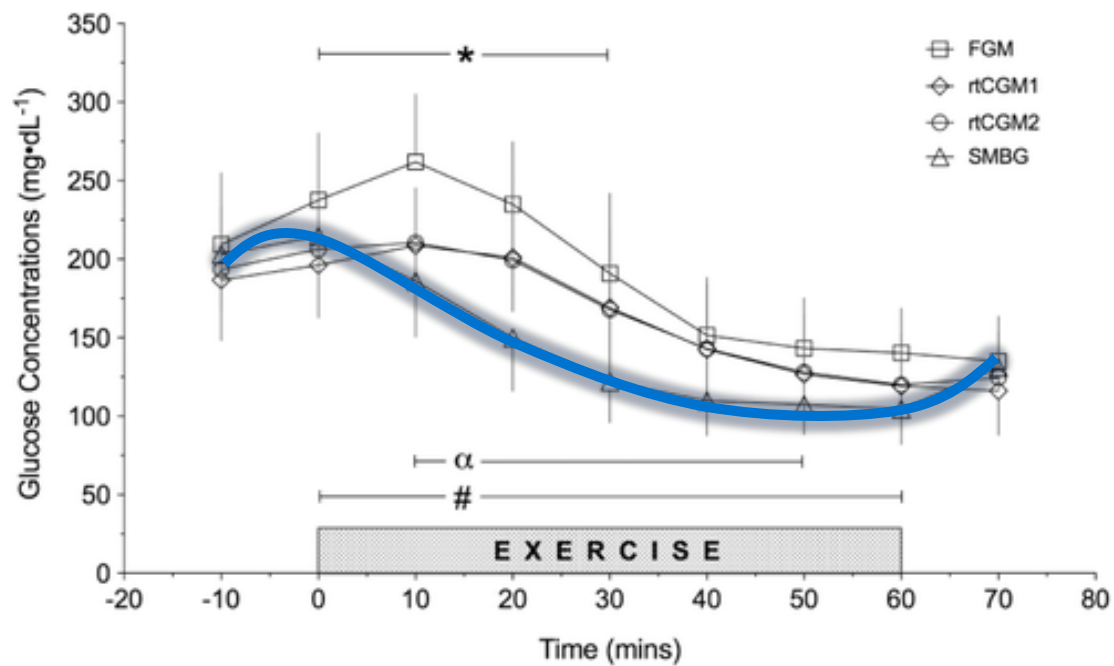
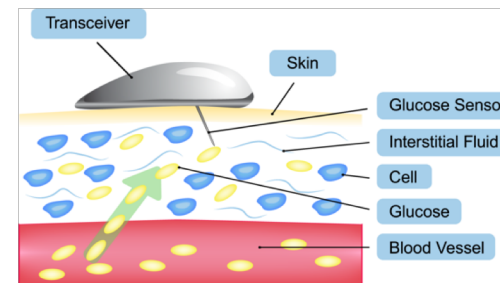
• **Hydration**

- Essential to performance
- Use electrolyte tablets/powders if needed
- Account for carbohydrate replacement in glucose-containing electrolyte solutions and carbohydrate in gel/solid forms

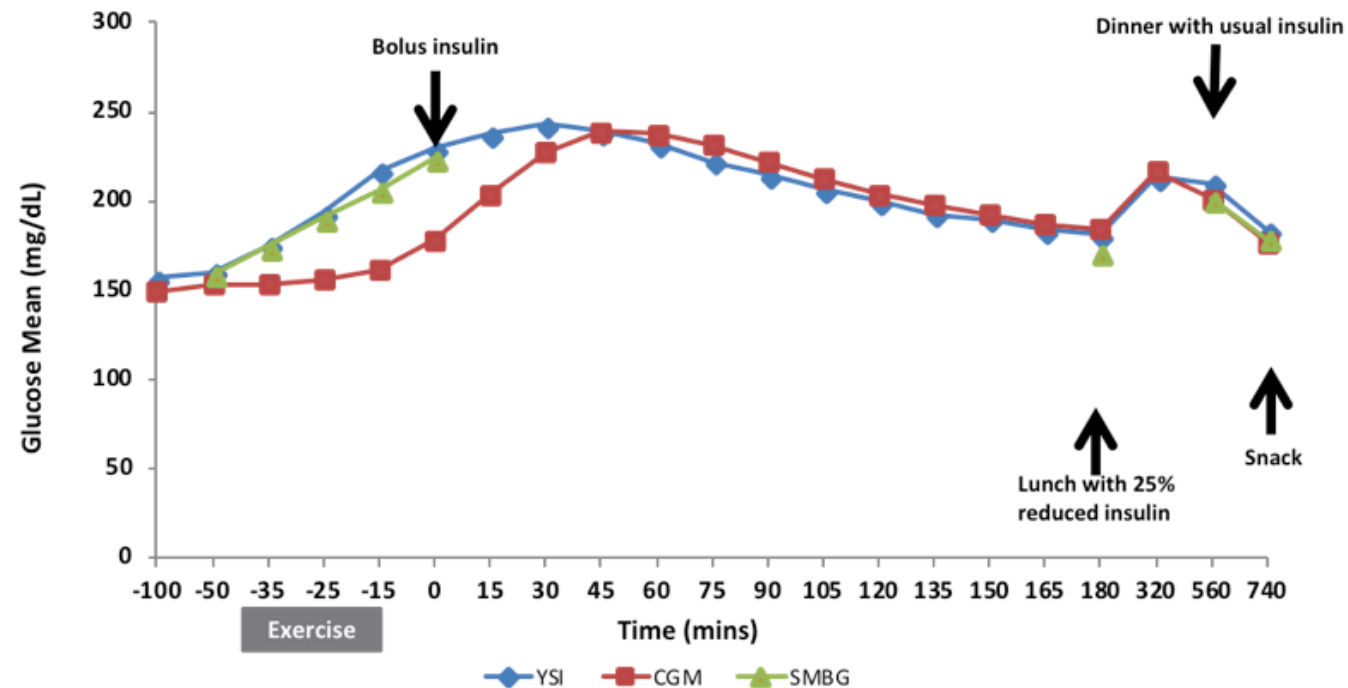
• **CGM/infusion set adhesion/issues**

- Much more difficult during exercise of long duration or in humid climate
- Results in loss of key glucose information or ability to manage
- *Change sites/sets 1 day prior to competition*
- Use additional adhesives as necessary (Tegaderm, Mastisol)
- Insulin is absorbed more quickly into exercised portions of the body
- CGM accuracy during exercise??

Sensor Lag and Exercise Type



Aerobic- CGM underestimates the drop



High Intensity Intervals-CGM underestimates the rise

Zaharieva et al., The Accuracy of Continuous Glucose Monitoring and Flash Glucose Monitoring During Aerobic Exercise in Type 1 Diabetes. J Diabetes Sci Technol. 2018 Oct 7

Li et al. Accuracy of Continuous Glucose Monitoring During High Intensity Interval Training in Adults with Type 1 Diabetes, Diab Tech Ther, in revisions

Case 2 - *Spontaneous* Exercise with T1D

James is an 17 year old with type 1 diabetes who loves basketball.

- He ate lunch 60 minutes ago and now his blood glucose is 15.5 mmol/L. He has ~3 units of active prandial insulin on board from his lunch bolus (target is 6.5 mmol/L).
- He has a sensitivity of 1:3 mmol/L
- 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.



Case 2 - *Spontaneous* Exercise with T1D

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 but monitor for development of hypoglycemia.



Case 2 - Spontaneous Exercise with T1D

Key Points:

- ▶ Know the effect of insulin-on-board (IOB) under normal circumstances versus during exercise
- ▶ **In this case:**
 - *Blood glucose of 15.5 mmol/L with 3 units IOB with a correction factor 1:3 mmol/L would normally drop blood glucose to 6.5 mmol/L*
- ▶ This same scenario in the presence of exercise will almost certainly cause hypoglycemia since he will be more insulin sensitive
- ▶ 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



Case 2 - Spontaneous Exercise with T1D

Here's how to think about this:

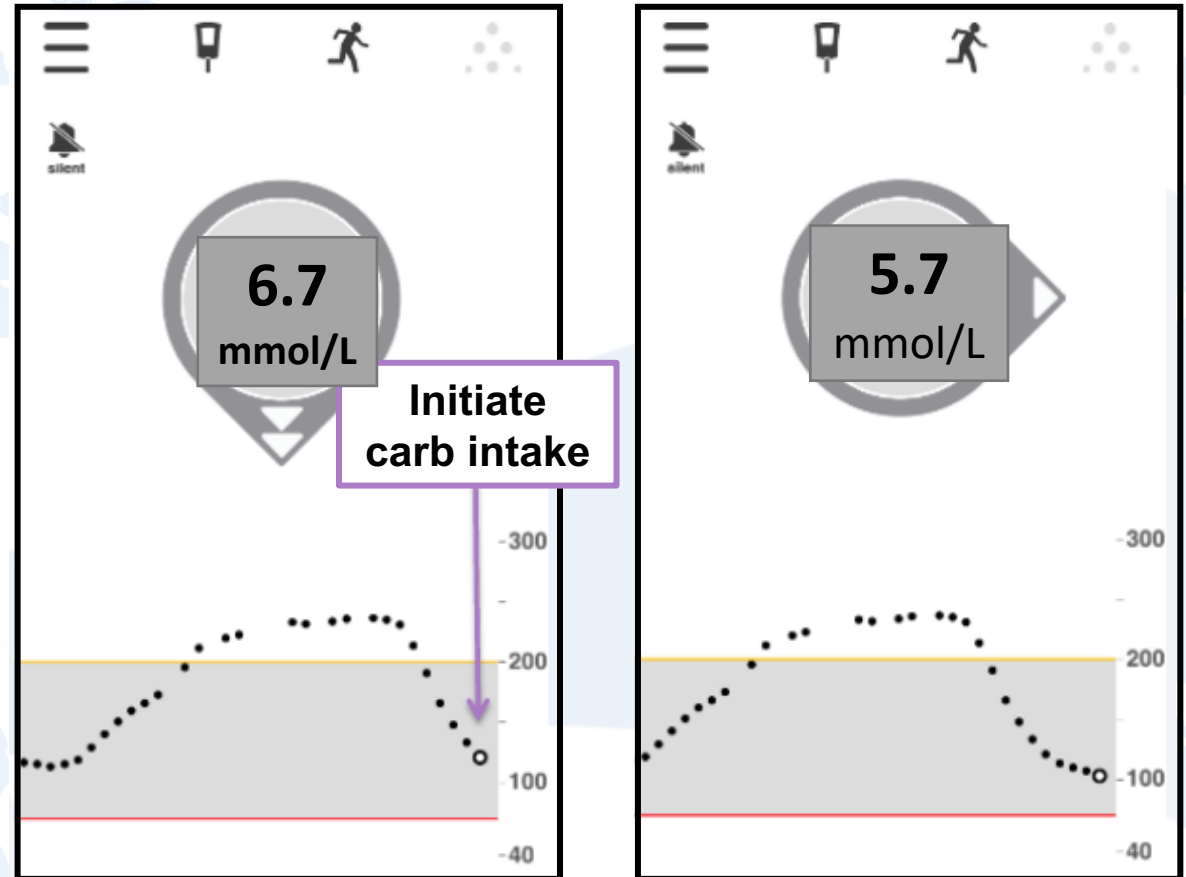
- ▶ 3 units IOB normally would drop his glucose by 9 mmol/L. If exercise increases his sensitivity by 50%, then he may drop theoretically by 13.5 mmol/L (to 2.0 mmol/L)
- ▶ This requires a “reverse correction” by adding an extra carbohydrate snack to boost the predicted value by 4.5 mmol/L to a target of 6.5 mmol/L.
- ▶ That is equivalent to ~1.5 units of ‘extra’ insulin for him (1:3 sensitivity) or about 23 grams uncovered carbs, and perhaps more (based on 1:15 gram insulin-to-carb ratio).
- ▶ He may also reduce his basal (if even an option)



How to cushion the fall? CGM?

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



Note: It is likely that interstitial glucose is lagging behind blood glucose

Case 3 - Patient with hyperglycemia issues

Richard is a 22-year-old male

- Duration of diabetes: 8 years, currently on CSII (occasional CGM)
- MDI until 2 years ago then switched CSII
- HbA1c 7%, BMI: 25 kg/m² (weight stable); very fit
- Impaired awareness of hypoglycemia

○ His Exercise Regimen:

- Strength training and Crossfit Mon, Wed, Fri



Case 3 - Patient with hyperglycemia issues

PUMP DATA

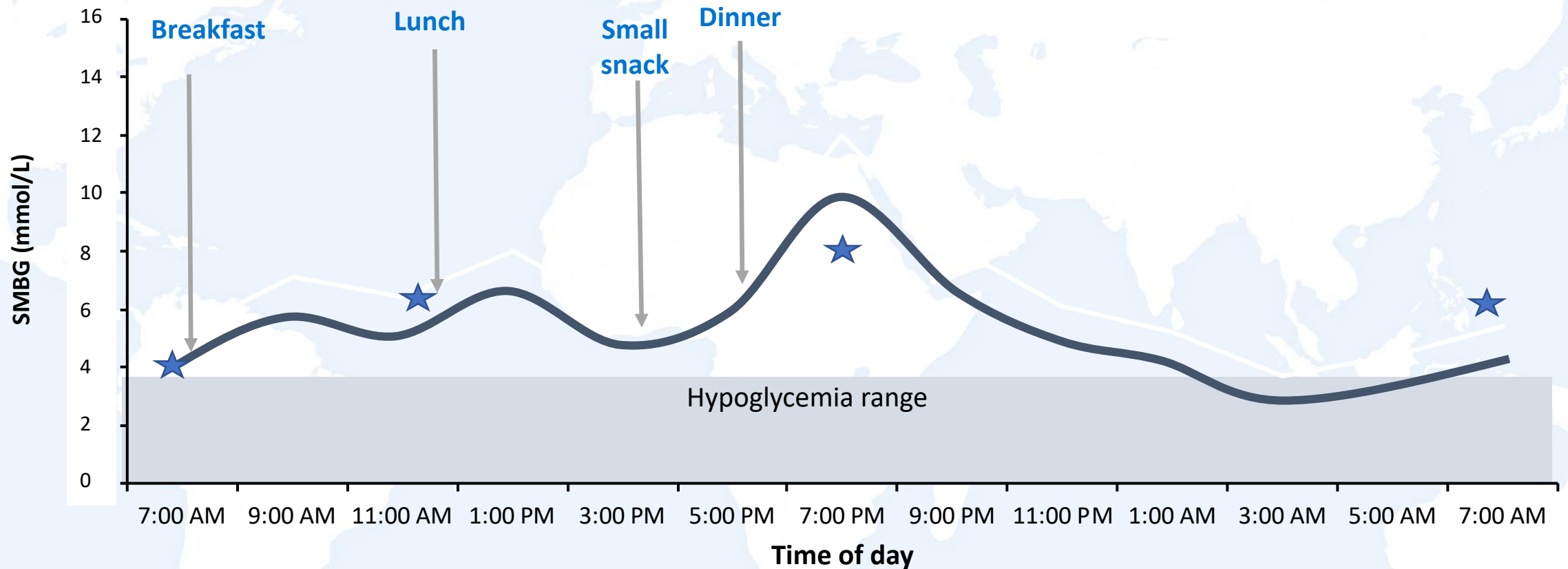
Daily schedule
Carbohydrates: 275 g
Insulin: 26.7 U <ul style="list-style-type: none">▪ Basal: 16.2 U (65%)▪ Bolus: 10.5 U (35%)
Food only: 8.92 U
Corrections: 1.58 U <ul style="list-style-type: none">▪ Number of corrections: 1.1

OVERALL BLOOD GLUCOSE CONTROL

- 7% low
- 50% in range
- 43% high

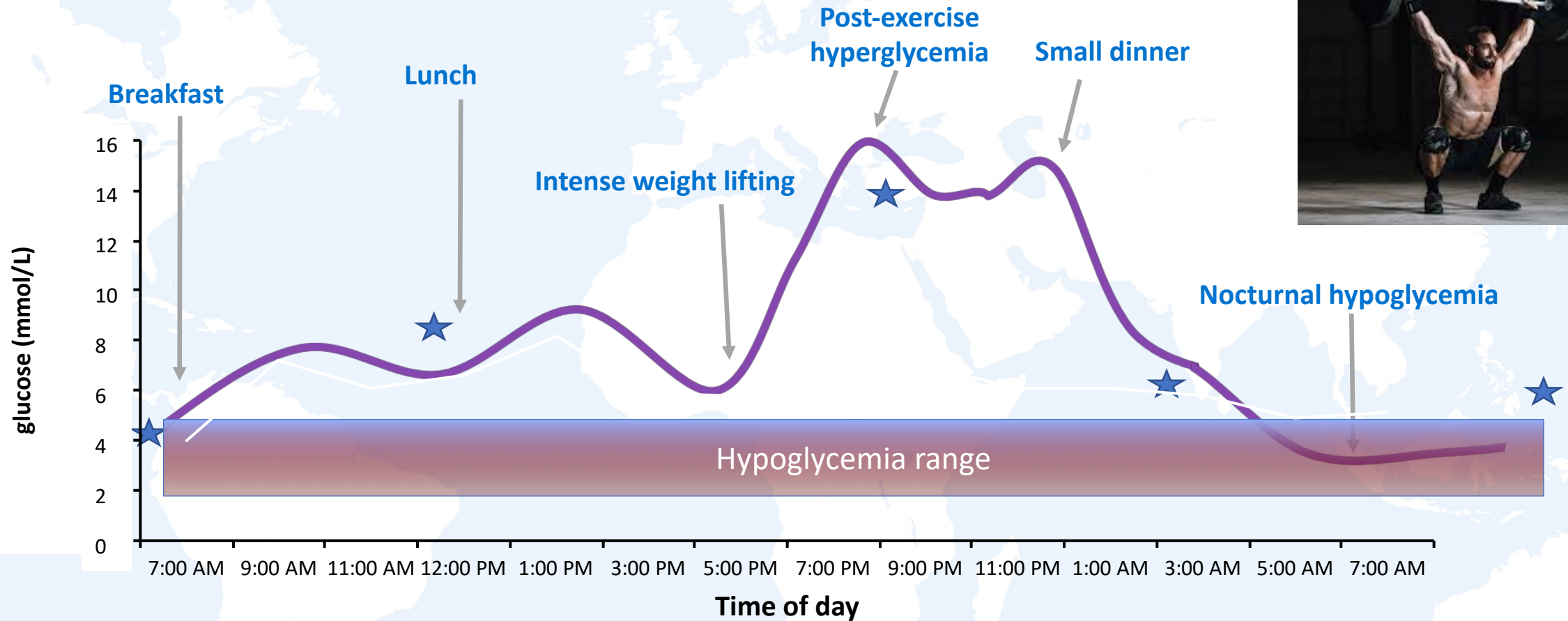
Case 3 - Patient with hyperglycemia issues

Non-Exercise Day Glucose Profile (CGM)



★ SMBG measurement

Case 3a - Patient with hyperglycemia issues



★ SMBG measurement

Case 3 - Patient with hypoglycemia unawareness

Clinical Questions

- What adjustments to basal insulin rate would you make at the following time-points for each type of exercise (weights, prolonged cycling) for Richard?
 - Pre-exercise
 - During exercise
 - Post-exercise?
- What changes to basal or bolus insulin do you recommend for each type of exercise?
- What CHO intake would you recommend for the prolonged exercise session?

Case 4 – *Ultra Endurance Canoeist with performance and glucose concerns*

John is a 63 years old, 6', 185 lb male who does marathon canoe and kayak racing. Races are generally 1 to 3 hours. However, this year he will be doing a 5 hour and an 8 hour race.

MDI- Lantus with Humalog rapid acting (duration 3 to 5 hours). HbA1c =0.69%

Peak HR is 175bpm, generally in races, average heart rate is 132 to 142 bpm

“My concern is becoming hyperglycemia in the longer races due to no meal blousing.



My 8 hour race is the MRX Huntsville to Bracebridge 58.5 km, including 7 portages up to 400 meters...
And I don't carry much food or my meter or my insulin...

Case 4 – *Ultra Endurance Canoeist with performance and glucose concerns*

John is advised to switch to R-insulin on race days since it has a longer time of action (5-7 hours) and take his long acting insulin as a split dose to increase circulating insulin levels. He is encouraged to have a mixed meal 1-2 hours before the start of the race

He is also advised to consume a 30 grams CHO snack per hour, starting in the 2nd hour and to consider 1/3 insulin dose after the time of peak R insulin action disappears (about 6 hours after injection).

He was also asked to consider wearing CGM and take a blood glucose/ketone meter, an insulin pen (rapid acting insulin analog) in a water proof fanny pack. He was also advised to wear a medical alert bracelet. Any symptoms of nausea should be accompanied by a glucose test and a ketone test.



My 8 hour race is the MRX Huntsville to Bracebridge 58.5 km, including 7 portages up to 400 meters...
And I don't carry much food or my meter or my insulin...

New (Consensus) Exercise Decision Tree for T1D

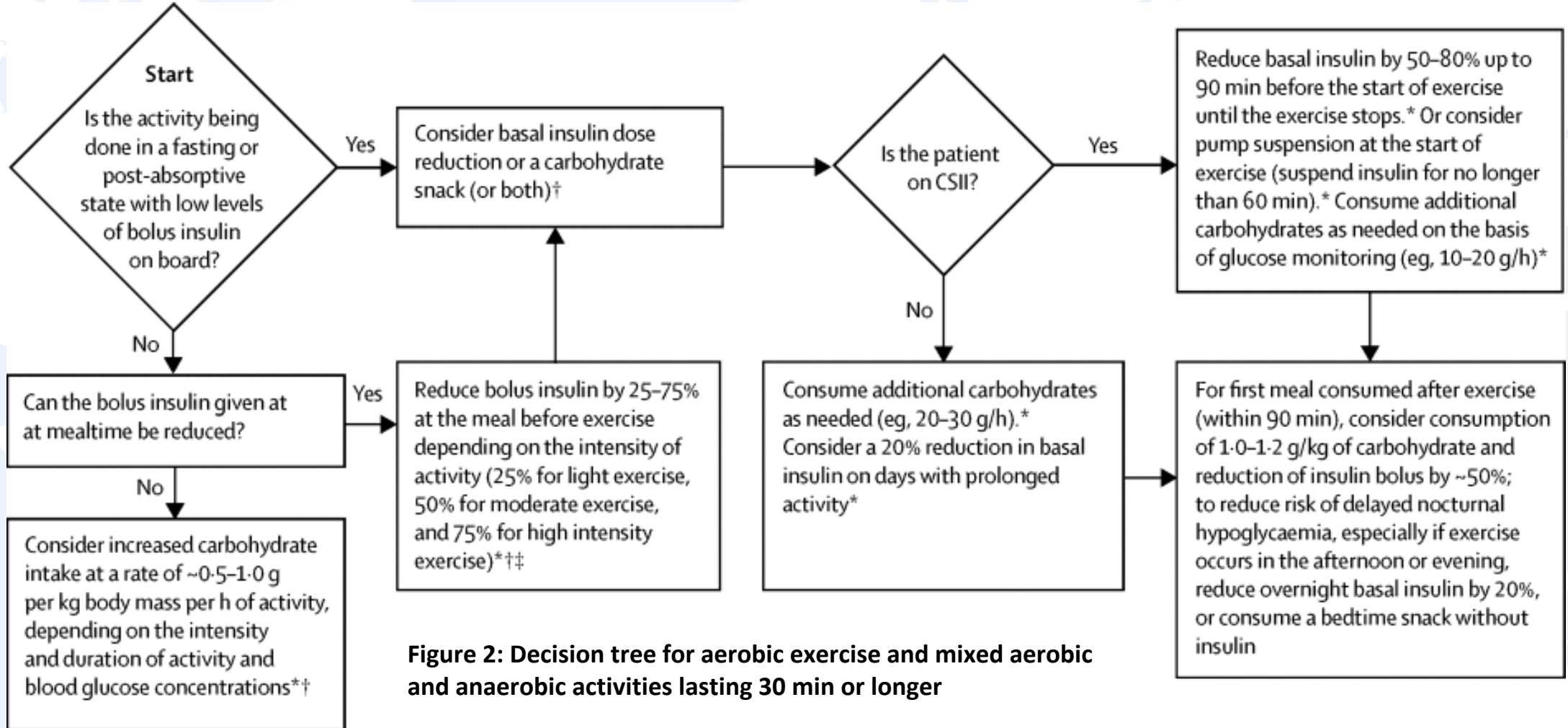


Figure 2: Decision tree for aerobic exercise and mixed aerobic and anaerobic activities lasting 30 min or longer