JDRF PEAK
T1D Performance in Exercise and Knowledge

PEAK PARTICIPANT CURRICULUM

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JDRF PEAK
T1D Performance in Exercise and Knowledge

RAMPING UP YOUR GAME

Participant Curriculum

Breakout Session

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Session agenda

- "Ramping up your game" – What does it mean?
- Physiological differences between recreational and competitive athletes
- Case example #1 – Katherine
- Case example #2 – William
- Summary of advice for competitive athletes with type 1 diabetes

RAMPING UP YOUR GAME

RAMPING UP YOUR GAME

What does it mean?

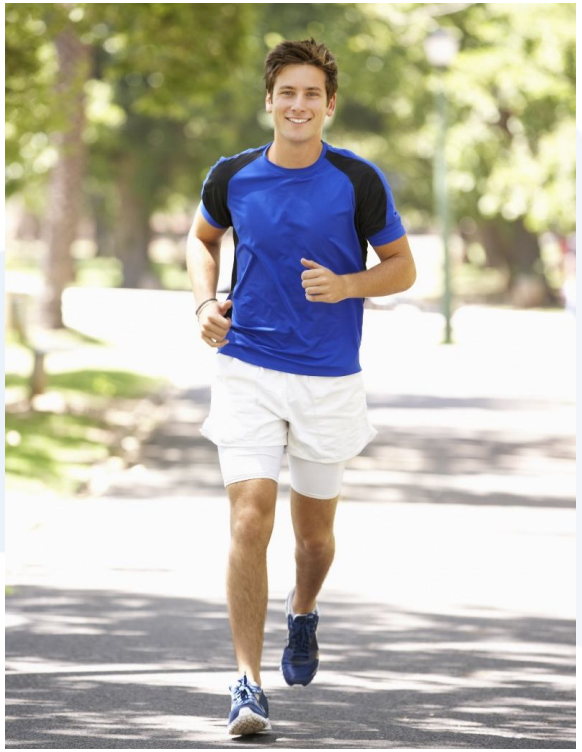
- Aiming to achieve optimal performance
- Preparing to exercise in variable conditions:
  - Times of day
  - Weather
  - Exercising when fasting or after a meal
- Anticipate the unexpected
  - High or low blood sugars prior to exercise
  - CGM or pump malfunction
- Take control of your blood glucose trends
  - "I'm going to keep my blood glucose at 'x' for this part of the race..."

RAMPING UP YOUR GAME

Competitive/endurance athletes with type 1 diabetes

Competitive & endurance athletes with type 1 diabetes face the same metabolic challenges as their recreational counterparts, in addition to:

1. Having higher muscle insulin sensitivity
2. Using a higher percentage of fuel from fat sources at lower exercise intensities
3. Having a higher training volume
4. Following a ritualized daily training routine
5. Dealing with a lack of flexibility for training and competition times



RAMPING UP YOUR GAME

Competitive/endurance athletes with type 1 diabetes

- First consider whether your diabetes is well-controlled at rest
  - Exercise only adds another layer of complexity to management
  - Basal insulin should be optimized
  - Carbohydrate ratios and insulin sensitivity should be understood
  - You will use fractions of these "resting conditions" to adjust insulin to accommodate varying exercise conditions:
    - Examples:
      - Reduce pre-exercise meal bolus by 25-75%;
      - Reduce basal by 50% if on a pump;
      - Reduce overnight basal injection by 10% post-exercise; etc.

RAMPING UP YOUR GAME

Competitive/endurance athletes with type 1 diabetes

Consider advantages and disadvantages of insulin pumps:

Advantages:

- Ability to use temporary decreases in basal for exercise or post-exercise overnight
- Fractional boluses offer more precision
- Possibility of integration with continuous glucose monitor

Disadvantages:

- Wearing device during certain sports adds weight and bulk
- Need to remove during contact sports or water sports
- Risk of infusion set problems, lack of skin adhesion can lead to DKA

DKA, diabetic ketoacidosis

RAMPING UP YOUR GAME

Competitive/endurance athletes with type 1 diabetes

- Consider benefits of continuous glucose monitoring
  - Real-time data
  - Ability to retrospectively evaluate glucose patterns for various forms of exercise
  - Management decisions based on trend
- Some controversy regarding accuracy of various devices
  - Consider individually (person, sport-specific) whether information can/should be used for management decisions

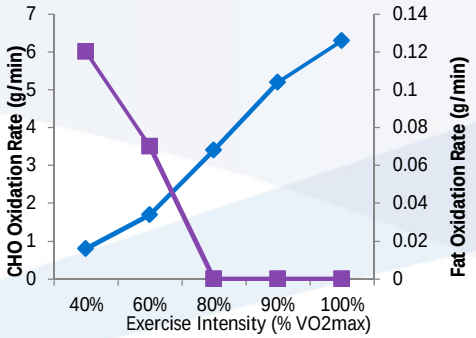
FUEL UTILIZATION

FUEL UTILIZATION

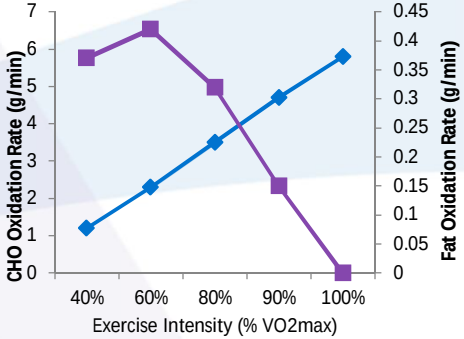
Trained vs. untrained athletes and pattern of fuel utilization

- As fitness improves, insulin sensitivity will increase
- The pattern of fuel utilization in trained and untrained athletes is based on:
  - Adaptations to exercise
  - Changes in skeletal muscle fibers

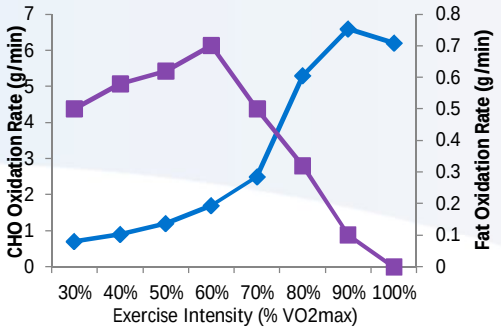
Sedentary



Recreational



World Class



Carbohydrate Fat

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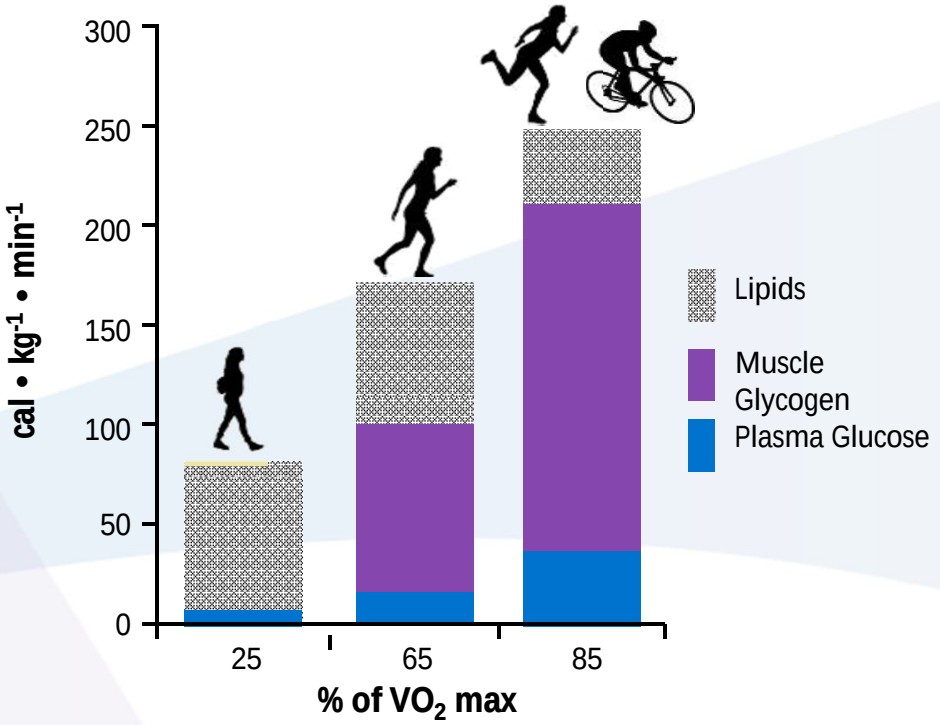
San Millan, I and Brooks, GA. 2015 Unpublished data (Submitted).

FUEL UTILIZATION

Intensity of exercise changes source of glucose

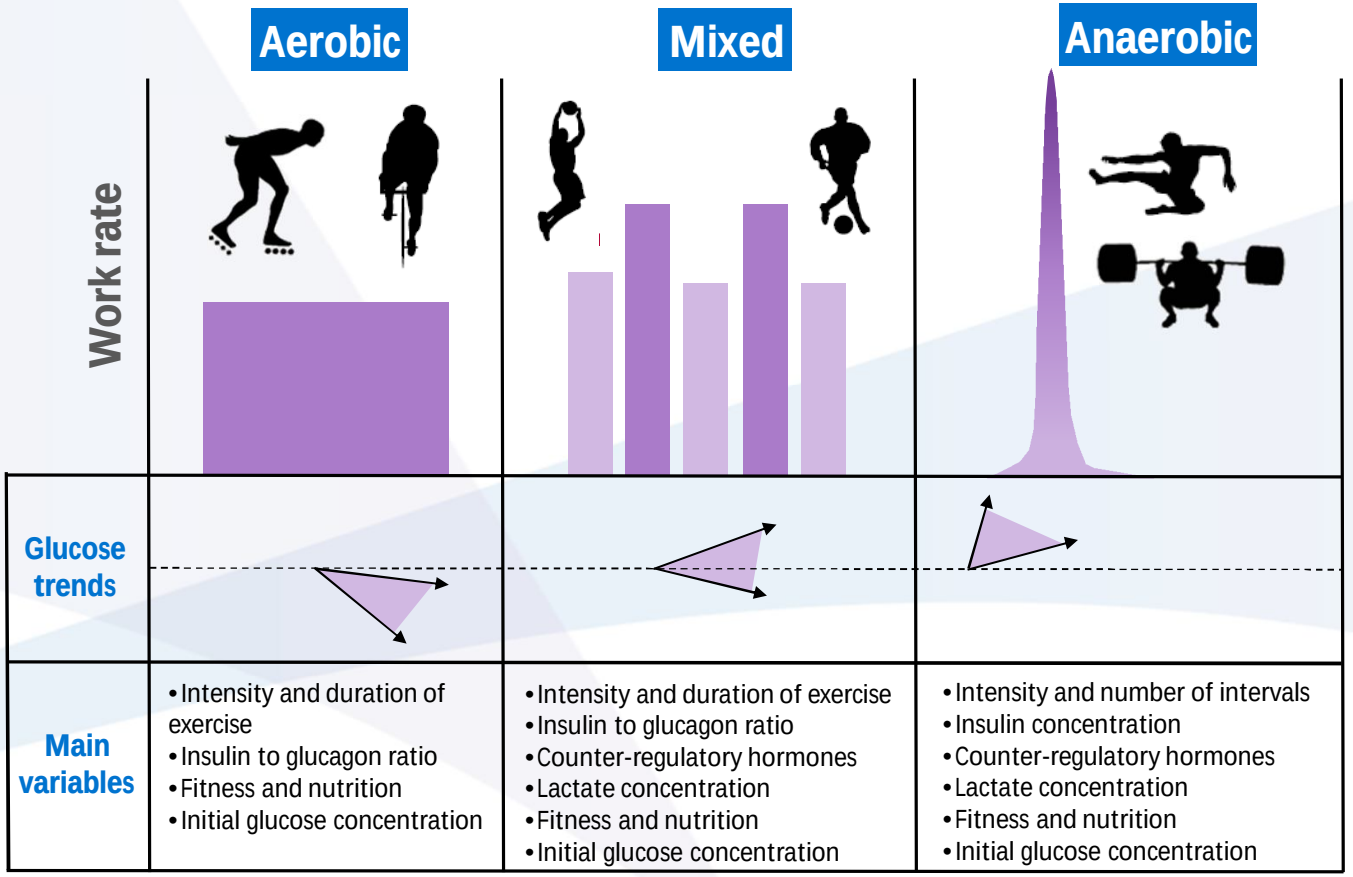
- Lower intensity exercise
  - High lipid utilization
    - "Fat-burning"
- Higher intensity exercise
  - High muscle glycogen use
  - High plasma glucose use



Romijn *et al., Am J Physiol* 1993; Van Loon *et al., J Physiol* 2001.

FUEL UTILIZATION

Different exercises affect glucose differently



Adapted from: Riddell MC, *et al. Lancet Diabetes Endocrinol.* 2017. Published online January 23, 2017: http://dx.doi.org/10.1016/S2213-8587(17)30014-1.

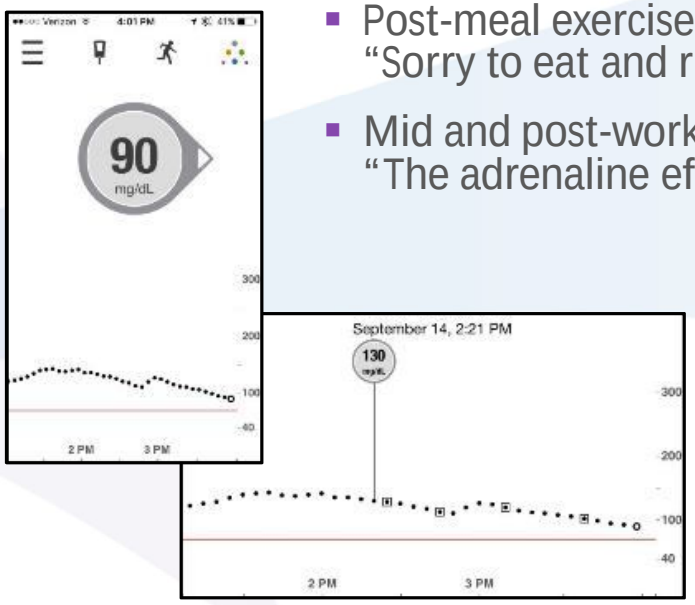
CASE EXAMPLES

CASE EXAMPLES - OVERVIEW

Challenges faced by advanced or competitive athletes

- **Case #1: Katherine has the "*low blood sugar blues*"**
  - Pre-workout hypoglycemia: "Can I work out anyway?"
  - Mid-workout hypoglycemia: "Uh-oh, I'm low"
  - Weight management: "I'm exercising like crazy, why am I not losing weight?"

- **Case #2: William gets "*hassled by the highs*"**
  - Pre-workout hyperglycemia: "How high is too high?"
  - Post-meal exercise: "Sorry to eat and run"
  - Mid and post-workout hyperglycemia: "The adrenaline effect"



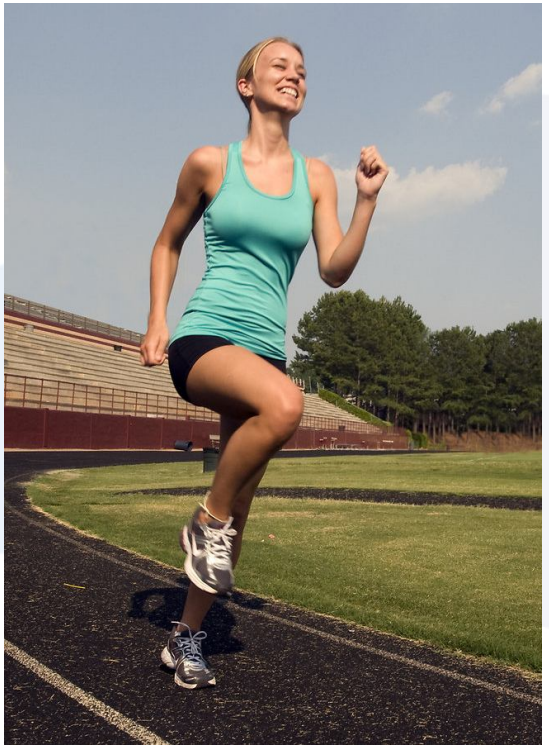
Ideal blood glucose levels often seem more the exception than the rule

CASE #1: KATHERINE

CASE #1

Katherine has the "*low blood sugar blues*"

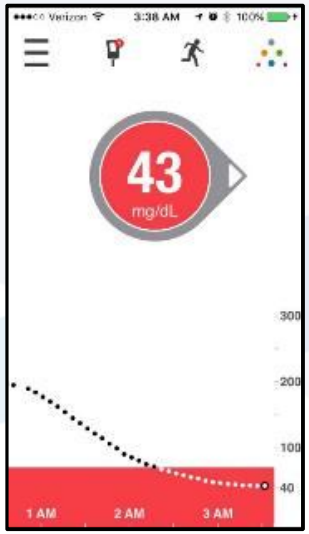
- 28 years of age
- Undergoing intense preparation for a half-ironman triathlon
- Significantly increased frequency and duration of her workouts in the last month
- HbA_{1c} is down to 6.2% from 7.8%
- Noticed an increased frequency of hypoglycemia, especially overnight



CASE #1 – PRE-WORKOUT HYPOGLYCEMIA

"Can I work out anyway?"

- Katherine awoke at 3:30am last night with her heart racing and feeling confused
- Husband checked her blood glucose
  - = 43 mg/dL



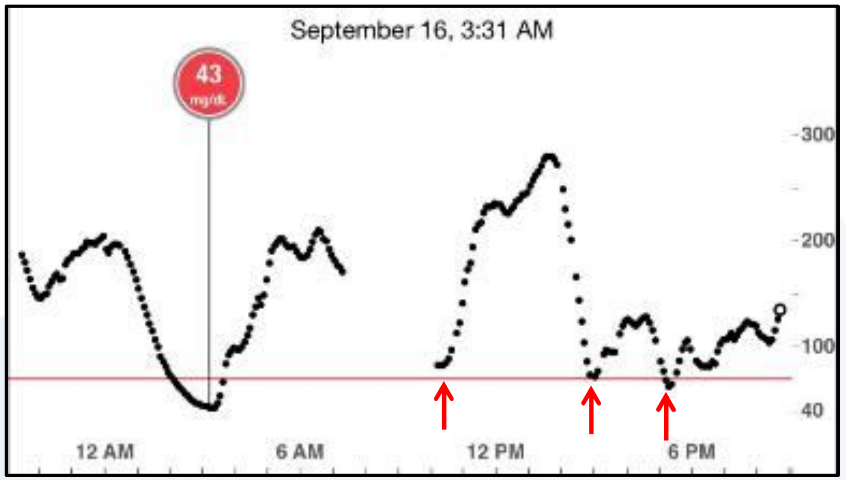
- Had juice and glucose tablets and within 20 minutes blood glucose was up to 120 mg/dL
- She is planning on doing a long bike ride followed by a run for her workout today

- What should Katherine do?
  - A. Continue with her workouts as planned because her blood sugars are now in a good range
  - B. Do the bike ride but not the run
  - C. Skip today's workout completely

CASE #1 – PRE-WORKOUT HYPOGLYCEMIA

"Can I work out anyway?"

- **Do not** perform strenuous exercise within 24 hours of a severe hypoglycemic event , defined as:
  - Blood glucose <50 mg/dL or requiring assistance from another individual to treat
- A single severe hypoglycemic event will predispose her to further hypoglycemic events, especially during exercise
- If she exercises, her body will not be able to release adequate hormones to avoid recurrent hypoglycemia
- This phenomenon is known as: **"hypoglycemia-associated autonomic failure"**



Example of glucose tracing if exercise is attempted after severe low blood sugar with recurrent subsequent lows

CASE #1 – PRE-WORKOUT HYPOGLYCEMIA

"Can I work out anyway?"

Hypoglycemia-associated autonomic failure

- Hormones which elevate blood sugars in response to hypoglycemia are severely diminished the next time a hypoglycemic event occurs
  - Occurs with hypoglycemia <55 mg/dL (3.0 mmol/L)

Take home message:

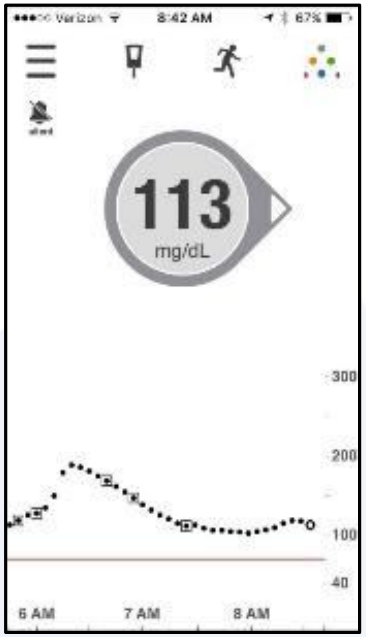
Do not exercise for 24 hours after a severe hypoglycemic event

Diabetes. 2000 Jan;49(1):73-81.

CASE #1 – PRE-WORKOUT HYPOGLYCEMIA

"Can I work out anyway?"

- If Katherine had *milder* hypoglycemia, *not* requiring assistance, she would have been able to continue as planned
- In that case:
  - Ideal treatment would be to raise blood glucose into target range of 140-180 mg/dL
  - Monitor trends and be sure to minimize IOB
  - Use carbohydrate replacement as needed
  - Adjust regimen if frequent pre-workout hypoglycemia is seen
  - Avoid overtreatment with carbohydrate for pre-workout lows, as this can lead to:
    - Hyperglycemia and suboptimal performance
    - A need to take insulin and potential for "roller-coaster" phenomenon



Example of pre-workout treatment of blood sugar <100 mg/dL raising BG into target range to allow drop with exercise over 2 hours

BG, blood glucose, IOB, insulin-on-board

CASE #1 – MID-WORKOUT HYPOGLYCEMIA

"Uh-oh, I'm low"

- Having previously attended a JDRF PEAK summit, Katherine decided to take the day off after her severe low
- Two days later, she decides to complete a 50-mile bike ride to catch up on some of her missed training
- During the ride, despite her strategy to reduce insulin prior to exercise and take in adequate carbohydrates, she feels her blood glucose dropping
- She feels weak and stops to check her blood glucose
  - = 60 mg/dL
- She consumes 25g of carbohydrate and is determined to finish…

CASE #1 – MID-WORKOUT HYPOGLYCEMIA

"Uh-oh, I'm low"

- Twenty minutes later, she checks to find her blood glucose is 59 mg/dL and she is still feeling weak

- What should Katherine do now?
  - A. Stop the ride to treat her hypoglycemia again (once confirmed with fingerstick blood glucose)
  - B. Keep going because there's only a couple miles to go
  - C. Ride faster to bring up her blood glucose

CASE #1 – MID-WORKOUT HYPOGLYCEMIA

"Uh-oh, I'm low"

- The competitive instinct can be powerful and interfere with making the right choices
  - Hypoglycemia itself can impair decision-making
- There is a fine line between the optimal performance range and inability to perform at all
- Example: Kris Freeman, Olympic Gold Medalist in Cross-Country Skiing, collapsed while competing in the 2010 Vancouver Olympics
- Intermittent high intensity efforts/sprints can raise blood glucose
  - This should not be attempted during a hypoglycemic event (BG < 70mg/dL)

CASE #1 – MID-WORKOUT HYPOGLYCEMIA

"Uh-oh, I'm low"

- Consider the benefits of CGM or frequent glucose monitoring to predict/prevent lows
- Remember that CGM is most reliable for trend information, not absolute values
  - Periods of rapid change such as those seen during exercise may cause a delay in results
  - Accuracy is lowest in the hypoglycemic range and should be confirmed with fingerstick
  - CGM delay is most pronounced in recovery from hypoglycemia
- If hypoglycemia occurs, competition must be stopped to allow for treatment and recovery
- If mild hypoglycemia is treated and resolved, exercise may be resumed with close monitoring once blood glucose is stable in the normal range

CASE #1 – PRE-WORKOUT AND MID-WORKOUT HYPOGLYCEMIA

Managing pre-exercise and mid-exercise hypoglycemia

Issue	Recommendations (rule of thumb)
Self-treated hypoglycemia within 1 hour of planned activity	▪ In case of exercise, treat hypoglycemia to stabilize blood glucose before activity ▪ If glucose level increases, it is okay to exercise; monitoring is necessary ▪ May need to retreat as hypoglycemia is more likely to occur
Severe hypoglycemia within 24 hours of planned activity	▪ Exercise should not be undertaken
Hypoglycemia during exercise	▪ Discontinue the activity and treat hypoglycemia ▪ Do not resume until hypoglycemia is resolved and blood glucose is stable

Note: People with type 1 diabetes should not exercise within 24 hours of severe hypoglycemia

CASE #1 – WEIGHT MANAGEMENT

"I'm working out like crazy, why am I not losing weight?"

- 6 weeks into her training, Katherine develops a new frustration
- After working out 6 days/week she is astonished that she has actually gained 2 pounds!
- She feels that she is eating "healthy foods" and her meals are not any larger than before she started ramping up her workouts

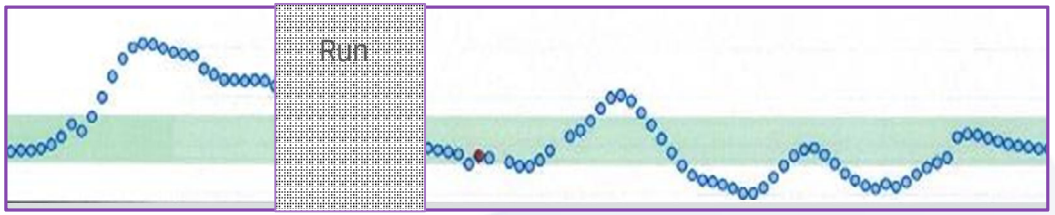
- What is going on with Katherine?
  A. Her scale is broken
  B. It's just "water weight"
  C. She is consuming more calories than she realizes

- Katherine visits her friend, a dietitian, who asks her to record all of her food intake surrounding her workouts for several days

CASE #1 – WEIGHT MANAGEMENT

"I'm working out like crazy, why am I not losing weight?"

Katherine's workout/food journal:



- 6pm: Dinner – did not bolus
- 7pm: Removed insulin pump for 1-hour run
  - Given IOB and glucose trends – 70g of carbs consumed during run
- Post-run: BG = 90 mg/dL – had 60g of carbs + 50% of usual bolus
- Bedtime: BG is low – had 40g of carbs and started 80% basal for 6 hours
- 1 hour later: BG is low – had another 20g of carbs
- Total extra carbs used to prevent/treat lows: **190g = 760 calories!**

BG, blood glucose, carbs, carbohydrates, IOB, insulin-on-board

CASE #1 – WEIGHT MANAGEMENT

"I'm working out like crazy, why am I not losing weight?"

- After realizing that all of these carbohydrates are adding up, she develops a new plan to reduce her lows and need for treatment
- Plan recommendations:
  - Minimize "insulin-on-board" by exercising in a fasting state or reducing pre-meal bolus by 25-75%
    - This will reduce mid-workout hypoglycemia
  - Reduce basal insulin 60-90 minutes ahead of exercise by 50-80% or suspend pump
  - Reduce basal overnight after exercise by 10-20%
  - As fitness improves, continue to evaluate basal and bolus insulin needs weekly or monthly, as total daily insulin use can drop 10-20%

Adapted from: Riddell MC, *et al. Lancet Diabetes Endocrinol.* 2017. Published online January 23, 2017: http://dx.doi.org/10.1016/S2213-8587(17)30014-1.

CASE #2: WILLIAM

CASE #2

William gets “hassled by the highs”

- 50 years of age
- Type 1 diabetic for 30 years
- Recent HbA_{1c} = 7.6%
- Competes in a variety of sports and activities, including recreational basketball, weightlifting and hiking
- Despite having a great deal of experience, he is still amazed that sometimes he has high blood glucose levels with exercise
- Not quite knowing what to expect, he feels every day is a new “adventure” when it comes to managing his diabetes

CASE #2 – PRE-WORKOUT HYPERGLYCEMIA

"How high is too high?"

- William often checks his blood glucose in the middle of the night to optimize his levels before his 6:30am group run.
- Unfortunately at 4am his reading was a bit surprising = 270 mg/dL
- He knew that if he took too much insulin, he might crash when he starts his exercise, but if he didn't take enough, his performance would suffer

- What should William do?
  A. Give his usual correction of insulin
  B. Give a reduced correction of insulin and drink water in order to keep hydrated
  C. Don't give a correction at all - allow for the exercise alone to lower his blood glucose

CASE #2 – PRE-WORKOUT HYPERGLYCEMIA

"How high is too high?"

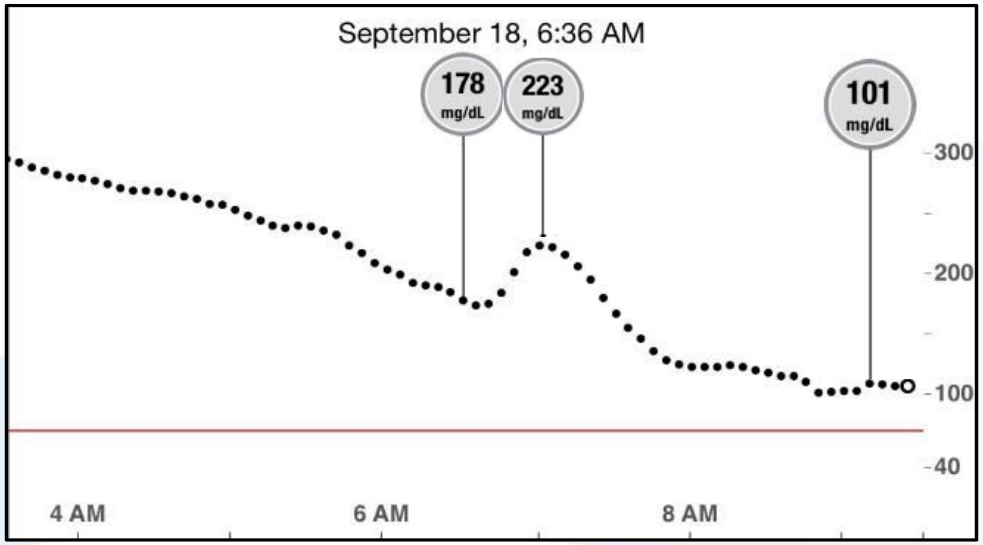
- Optimal performance requires blood sugars to be <180 mg/dL
- Check for ketones prior to exercise if hyperglycemic
  - Do not exercise if ketones are elevated in presence of hyperglycemia
  - Blood ketones should be <10.8 mg/dL or urine ketones <2+ prior to exercise
- Dehydration as a result of prolonged hyperglycemia will significantly adversely affect performance
  - Hydrate to achieve clear or nearly clear urine

Adapted from: Riddell MC, *et al. Lancet Diabetes Endocrinol.* 2017. Published online January 23, 2017: http://dx.doi.org/10.1016/S2213-8587(17)30014-1.

CASE #2 – PRE-WORKOUT HYPERGLYCEMIA

"How high is too high?"

- To address his hyperglycemia, William gave a 50% bolus for correction at 4am
  - 2.5 hours later, he started with a BG of 178 mg/dL
- Using 50% temporary basal rate and taking 40g carbohydrates per hour, his BG stabilized and finished at 101 mg/dL



CASE #2 – POST-MEAL EXERCISE

"Sorry to eat and run"

- A few days later, William faces another puzzling situation:
- 1 hour ago, he ate a high-carb meal for lunch and now his BG is 300 mg/dL but he wants to go run
- He figures that he has about 5 units of "active insulin" in his body and his normal insulin sensitivity is 1 unit: 40 mg/dL

How should William manage this situation? (Assume again his ketones are negative)

A. Don't even consider working out – BG is too high
B. Take an additional correction dose of insulin and then run once his BG starts coming down
C. Go ahead and run without additional correction, knowing that he may actually need to take in a considerable amount of carbohydrates during the run

CASE #2 – POST-MEAL EXERCISE

"Sorry to eat and run"

- Key to this case: know the effect of IOB under normal circumstances vs. during exercise
- In this case:
  - He does not need to take any additional insulin despite the high BG
  - A BG of 300 mg/dL with 5 units IOB would normally drop BG perfectly to 100 mg/dL based on his correction factor (sensitivity) of 1 unit: 40 mg/dL
  - Given his aerobic exercise he will certainly have severe hypoglycemia
- He will likely need to take carbohydrates to "cushion the fall"
- With excess IOB, he would likely need about 40-60g of carbohydrates per hour to keep BG from going low
- Simple carbohydrate options during endurance exercise include liquids (Gatorade, Powerade) and gels (GU, Clif Shot, PowerGel)

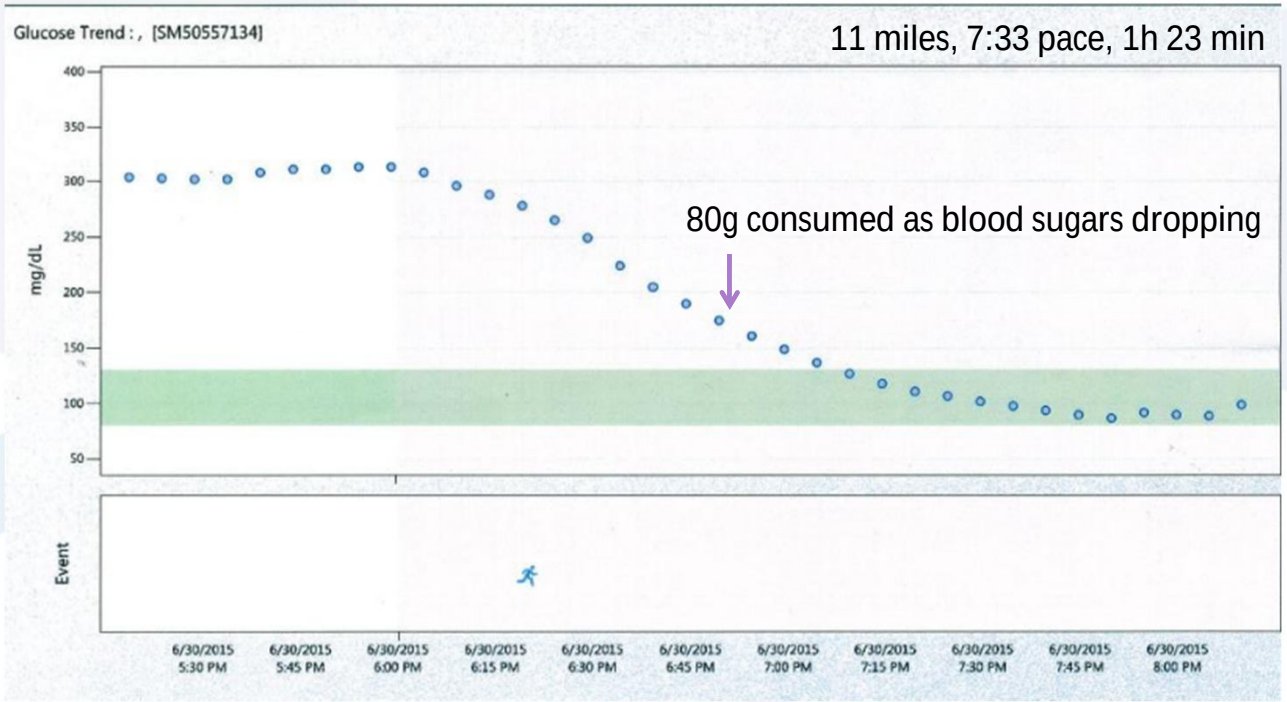
IOB, insulin-on-board; BG, blood glucose

CASE #2 – POST-MEAL EXERCISE

"Sorry to eat and run"

Cushioning the fall:

- Knowing that he had significant IOB, William ran without additional correction, taking 20g carbohydrate every 20 minutes with the following result:

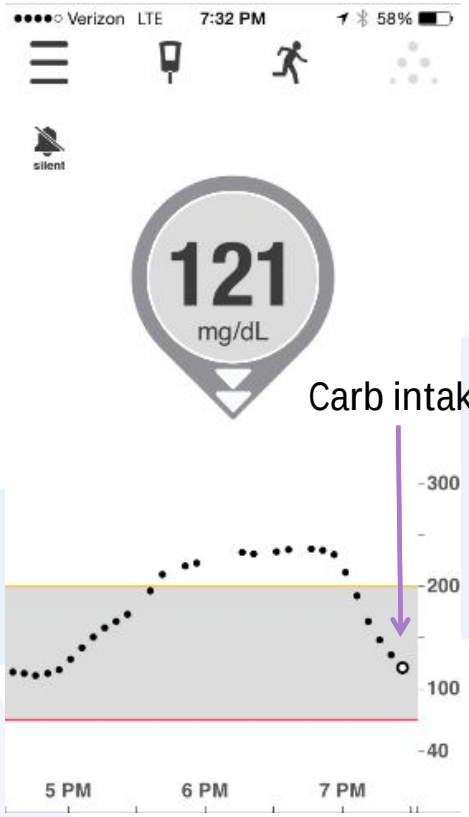


CASE #2 – POST-MEAL EXERCISE

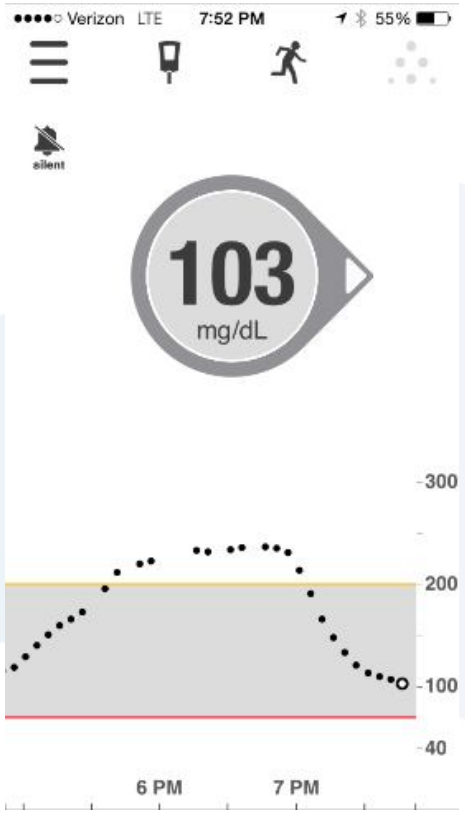
"Sorry to eat and run"

Cushioning the fall:

- Treating BG based on trend information will:
  - Allow you to keep exercising
  - Require less carbohydrates
- Carbohydrate absorption may be limited to 60-75g/hr
- This can be increased to 100g/hr if multiple sources (e.g. rapid & slow-digesting carbs) are used



(need to address the trend)



(20 minutes later)

BG, blood glucose; carbs, carbohydrates

CASE #2 – POST-MEAL EXERCISE

"Sorry to eat and run"

- 3 keys to managing blood sugar in real-time:
  - Glucose value
  - Direction of glucose change
  - Speed of glucose change
- To "cushion the fall" you must become experienced in how and when to address the downward trending arrows
- Definitions for arrows vary from system to system – consult the owner's manual for specifics:
  - Medtronic Enlite
  - Abbott Freestyle Libre
  - DEXCOM (example pictured on right)

Trend Arrows show the direction and speed of glucose change and can only be seen with CGM. Catch highs and lows before they happen.

Constant	Slowly Rising	Rising	Rapidly Rising	Slowly Falling	Falling	Rapidly Falling
0-30 mg/dL up or down in ½ hour	30-60 mg/dL up in ½ hour	60-90 mg/dL up in ½ hour	90 or more mg/dL up in ½ hour	30-60 mg/dL down in ½ hour	60-90 mg/dL down in ½ hour	90 or more mg/dL down in ½ hour

Trend Arrows are secondary to the trend graph.

CASE #2 – POST-MEAL EXERCISE

"Sorry to eat and run"

Use CGM and carbohydrate intake to reduce/avoid hypoglycemia while exercising

CGM Glucose level	Trend arrow(s)	Action	Comments
90 mg/dL (<5.0 mmol/L)	None or downward trending	20g CHO	Stop exercise if plasma glucose 70 mg/dL (≤ 3.9 mmol/L)
91-120 mg/dL (5.0-6.7 mmol/L)	↓ Medtronic ↘ Dexcom	15g CHO	
91-120 mg/dL (5.0-6.7 mmol/L)	⇊ Medtronic ↓ or ⇊ Dexcom	20-30g CHO	
121-140 mg/dL (6.8-7.8 mmol/L)	Any downward trending arrows (both manufacturers)	10g CHO	

Note: Treatment of hypo or hyperglycemia should not be based solely on CGM. Self monitoring of blood glucose level is recommended. CHO intake is generally recommended for long duration aerobic exercise for performance reasons (~1 gm/kg body mass per hour).

CASE #3 – MID AND POST-WORKOUT HYPERGLYCEMIA

"The adrenaline effect"

- Working with his endocrinologist, William made great strides and has qualified for the Boston Marathon
- He is extremely anxious because he has a whole contingent of family and friends watching and raised $5000 for Team JDRF and doesn't want to let anyone down
- He has decided to try to keep pace with a friend whose race-pace is about 20 seconds per mile faster than he has ever run

- What will likely happen to William?
  - A. He will keep a steady pace the entire time and run the perfect race
  - B. He will struggle with severe hypoglycemia
  - C. He will be at risk for stress hyperglycemia

CASE #3 – MID AND POST-WORKOUT HYPERGLYCEMIA

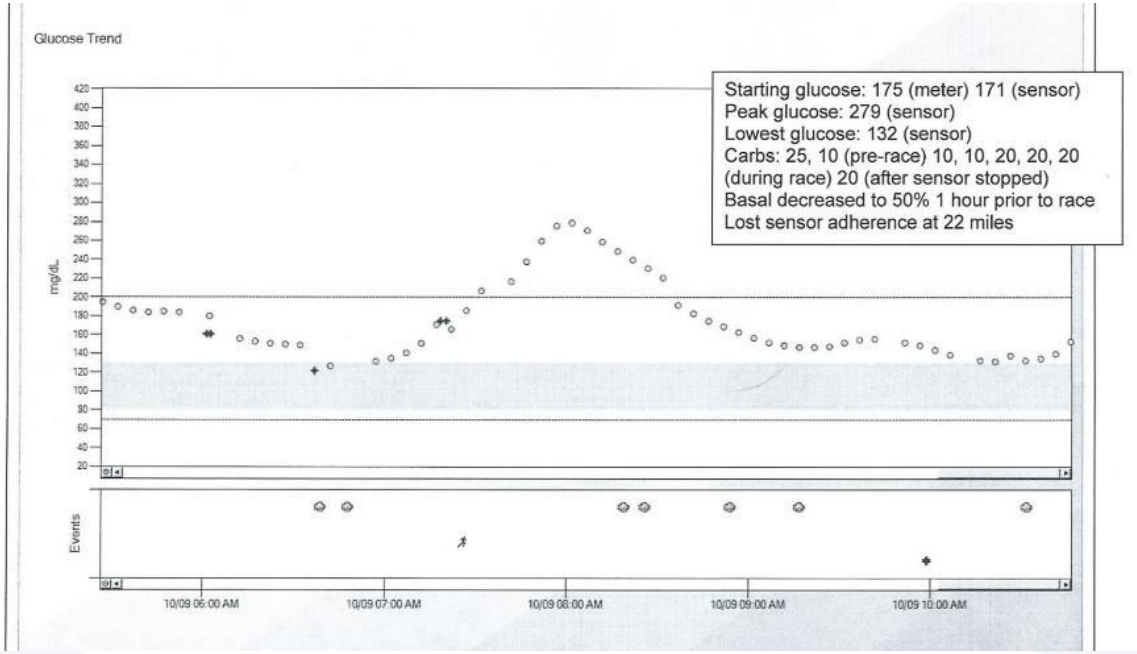
"The adrenaline effect"

- Race day can lead to higher levels of excitement, anticipation, and anxiety
  - "Race-pace" can push the athlete into anaerobic metabolism beyond what they are accustomed to in training
- This leads to release of stress/counter-regulatory hormones
- These hormones induce insulin resistance, and in the absence of changes to management strategies, lead to higher blood glucose levels
- Similar effects are seen with weightlifting, sprinting, Cross-Fit, and any exercise which causes intermittent bursts of high intensity exercise (football, basketball)

CASE #3 – MID AND POST-WORKOUT HYPERGLYCEMIA

"The adrenaline effect"

- Suggestions for management:
  - Decrease carbohydrate intake if hyperglycemia occurs
  - Cautious use of corrective insulin for BG >250 mg/dL
  - Be particularly aware of dehydration
- Other considerations:
  - Inhaled insulin (rapid on/off action)



Actual marathon CGM tracing showing unusually high peak blood glucose with adjustment in carb intake

CASE #3 – MID AND POST-WORKOUT HYPERGLYCEMIA

"The adrenaline effect"

- Post-workout hyperglycemia may occur due to:
  - Continued elevation of stress hormones
  - Sharp decrease in glucose use by muscles
  - Delayed carbohydrate absorption consumed during exercise
- Can be mitigated by:
  - Post-exercise bolus based on prior experience (starting with 50% of usual correction)
  - Low-intensity cool-down period (walking or light aerobic activity)
  - If on insulin pump where basal was reduced, may resume usual basal 30-60 minutes prior to finishing exercise
  - Simple monitoring
    - Hyperglycemia may be self-limited to 30-60 minutes

SUMMARY AND IMPORTANT CONSIDERATIONS FOR COMPETITIVE ATHLETES WITH TYPE 1 DIABETES

IMPORTANT CONSIDERATIONS FOR COMPETITIVE ATHLETES

Other factors that may have an impact on performance

- Water sports (swimming, diving) and contact sports (wrestling, rugby, judo)
  - Most insulin pumps are not 100% waterproof or protectable from damage
  - Likely require insulin pump removal
  - May use bolus insulin in order to replace 50% of basal to be missed or re-connect intermittently throughout activity and give corrective bolus
  - CGM receivers are not waterproof and CGM signals do not transmit well through water
- Hydration
  - Essential to performance
  - Calculate anticipated sweat loss/replacement regimen
  - Use salt tablets if needed in some cases
  - Need to account for carbohydrate content of glucose-containing electrolyte solutions in overall nutrition plan

IMPORTANT CONSIDERATIONS FOR COMPETITIVE ATHLETES

Other factors that may have an impact on performance

- Practical issues with insulin pumps:
  - Skin adhesion of infusion set is compromised during exercise of long durations in heat and/or humidity
  - Remember that insulin is absorbed more quickly into exercised portions of the body
    - Choose infusion site away from muscles being exercised for more predictable absorption
- Recommendations:
  - Change sites/infusion sets 1-2 days prior to competition
  - Use additional adhesives as necessary (Tegaderm, Hypafix, Grif Grips, Mastisol)
  - Insert a 2nd "backup" infusion set to be used if primary site falls out

Other factors that may have an impact on performance

- Potential issues with continuous glucose monitors:
  - Skin adhesion can also be problematic - use additional adhesives (Hypafix, Grif Grips, Mastisol)
  - CGM performance is also affected by:
    - Ambient temperature
    - Intensity of exercise
    - Blood flow to surrounding tissue
    - Altitude
  - CGM bluetooth signal may be lost or have poor connectivity in certain areas
  - If circumstances suggest that CGM values may be unreliable, have blood glucose monitor available at all times
    - Remember that blood glucose test strips can also be light/moisture sensitive and should be kept in original vial

Summary and recommendations

- Plan ahead → test the plan → revise as needed
- Complete a portion of your training under circumstances which simulate the “race-day”
  - Time
  - Weather
  - Carbohydrates
  - Hydration
- Be safe
  - Wear medical identification
  - Have a workout partner who is knowledgeable regarding your diabetes
  - Use CGM or ensure that you have the ability to test blood glucose at all times

IMPORTANT CONSIDERATIONS FOR COMPETITIVE ATHLETES

Summary and recommendations

Lessons from Katherine:

- Do not exercise within 24 hours of severe hypoglycemia requiring assistance
- Do not continue exercise during hypoglycemia – stop and treat
- Preventing/avoiding recurrent hypoglycemia during exercise will assist in weight management

Lessons from William:

- Hyperglycemia prior to exercise should be addressed but should not necessarily prevent participation
- Use insulin-on-board information and glucose trends to guide carbohydrate replacement, especially when exercising after a meal
- Be aware of adrenaline-induced hyperglycemia and adjust carbohydrate and insulin plan accordingly

Acknowledgements:

Thank you!

JDRF PEAK
T1D Performance in Exercise and Knowledge