Exercise and Type 1 Diabetes
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JDRF TypeOne Nation – March 5, 2016
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My Background

Diagnosed T1DM at age 15

Competed in NCAA division III cross country and track at Trinity University

Completed 10 Chicago Marathons

Northwestern University

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Special interests:
Type 1 Diabetes
Diabetes and Exercise
Use of Insulin pumps and Continuous Glucose Monitors
Overview

- Introduction to Exercise Physiology
- Challenges with Exercise in Type 1 Diabetes
- Practical Guidelines for managing Type 1 Diabetes and Exercise
- Illustrative Case Examples using Continuous Glucose Monitoring
Why exercise?

- Improves mood / Relieves stress
- Feeling of accomplishment
- Satisfies competitive spirit
- Improved blood glucose control
  - Reduces insulin requirement
- Maintain healthy body weight

"Be honest—how much are you exercising?"
Misconceptions about Type 1 Diabetes and Exercise

#1: You can’t exercise with T1DM

#2: Exercise will make you lose weight

#3: Exercise makes your Type 1 Diabetes easier to manage
Why is it so difficult to manage type 1 diabetes while exercising?

- Type 1 diabetes is difficult enough already!
  - Matching carbs to insulin, accounting for stress, illness...

- Workouts are not always the same
  - Variable workout times
    - Before or after meals
  - Variable workout durations
    - 30 minutes, 60 minutes, 2 hours
  - Variable workout intensity
    - Cross training days
  - Training versus competition
  - Gradual improvement in fitness during training
Exercise Physiology

- Heart beats stronger and faster
- Blood flow increases to muscles to deliver oxygen and glucose
- Sympathetic nerves “fight or flight” are activated
- Endocrine response:
  - Release of adrenaline, epinephrine, and cortisol – “stress hormones”
  - Suppression of insulin release
  - Stimulation of glucagon release
Glucose Metabolism During Exercise

1. Glycogen Breakdown
2. Gluconeogenesis

Liver

Pancreas

Adipose Tissue

Muscle

Brain

Adrenal Gland

Glucose

NEFA

Ongoing Lipolysis

Muscle glycogen breakdown

Insulin

Glucagon

Epinephrine, Norepinephrine
How does the body increase glucose uptake?

**Fasting**

1. Blood → Extracellular
2. Extracellular → Intracellular
3. Intracellular → GLUT4 → Hexokinase II

**Insulin or Exercise**

1. Blood → Extracellular
2. Extracellular → Intracellular
3. Intracellular → GLUT4 → Hexokinase II
How do insulin and exercise differ in where the glucose ends up?

- **Glycogen Synthesis**
  - Promotes storage of glucose
  - Less desirable during exercise

- **Glycogen Breakdown and Glycolysis**
  - Promotes utilization of glucose
Challenges with T1DM and exercise
Where is the exercise in this picture?
Case #1: “Why am I not losing weight?”

- 6pm: Ate dinner, did not bolus for 25g carbs due to previous insulin on board from snack
- 7pm: Removed insulin pump for 1h run
  - Given IOB and glucose trends – 70g carbs consumed during run (8.5 miles)
- BG 90 at finish, had 60g of carbs bolused 50% of usual bolus
- BG low at bedtime, had 40g carbs, started 80% basal for 6 hours
- BG low 1h later, 20g carbs again.
- Total extra carbs used to treat prevent/treat lows: **190g = 760 calories**!
Fear of hypoglycemia is the greatest barrier to exercise in people with type 1 diabetes.
Professional Athletes

“I check my blood sugar about four or five times before the game—I try to stay around 150-160 before kickoff. When you get the adrenaline rushing, things can change pretty quickly, so when we come off the field after an offensive series in the first half, I'll test to make sure I'm not getting low.”

“I was aware I was having an issue...against Kansas City...early in the game, first or second series, and I just didn't feel right—I felt out of it a little, shaky. My second pass got picked for a touchdown, and we went to the sideline and tested. I was at around 95—which isn't that bad. There are worse numbers. But I felt off. We got it back up to about 150, 160, and ended up winning the game.”

Take-aways:

- The trend prior to exercise is extremely important

- A dropping blood sugar can feel just as bad as a low blood sugar
Normal Response to Hypoglycemia

< 90 mg/dL: counter-regulatory response begins
< 81 mg/dL: suppression of insulin secretion
< 65-70 mg/dL: glucagon and epinephrine increase
< 60 mg/dL: autonomic symptoms (sweating, shaking) develop
< 50 mg/dL: neuroglycopenic (confusion) symptoms develop

Exercise-induced hypoglycemia in diabetes

- In individuals with type 1 diabetes:
  - The counter-regulatory response is diminished
  - Insulin is NOT shut off appropriately with exercise
  - Glucagon production is suppressed

- Net effect: Glucose production < glucose utilization

- Without carbohydrate intake you will develop hypoglycemia
Hypoglycemia-associated Autonomic Failure

- A single hypoglycemic event will predispose to further hypoglycemic events especially during exercise.
- This is known as hypoglycemia-associated autonomic failure (HAAF).
- Result is too much insulin, not enough glucagon, epinephrine, or norepinephrine the next time.

Non-diabetics who were made hypoglycemic the day before exercise versus that with normal glucose levels.

Carbohydrate Intake

- Decreases body’s need to break down glycogen or create glucose
- If you are low/imminently low: simpler is better
- To prevent lows: can try more complex carbs/bars/foods
- Try different types to determine effects (caffeine vs no caffeine, thicker vs thinner)
- Maximum GI absorption is ~1 gram per minute or 1g/kg/hour
Avoiding Hypoglycemia – Decreasing Insulin

- Minimize “insulin-on-board” and monitor trends prior to exercise

- Some strategies for insulin pump:
  - Decrease basal insulin by 50% starting 1 hour prior to exercise which is expected to last >1 hour
  - Stop or remove insulin pump completely prior to brief exercise

- If using subcutaneous injections
  - Decrease meal bolus insulin by 50%
  - Take in extra carbohydrates
Avoiding Hypoglycemia – Taking in Carbs

- If blood sugar is <150 before exercise, take 15-30g carbs before you start
- Take 15-30g carbs every 30-45 minutes (carbohydrate gel, gatorade, simple solids)
- Monitor your blood sugar more frequently during exercise – strongly recommend using continuous glucose monitor
- Avoid the 1st hypoglycemic event to avoid having the 2nd
Hyperglycemia

"Your blood sugar is too high."

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www.glasbergen.com
Exercise Intensity affects glucose balance

**Aerobic exercise**
- Endurance events
- Swimming
- Cycling
- Running

**Anaerobic Exercise**
- Short sprints
- CrossFit
- Weightlifting
- Basketball
Intense Exercise leads to hyperglycemia

- Exercise intensity is based on the percent of maximal oxygen consumption: %VO$_2$\text{max}

- At >80% %VO$_2$\text{max}:
  - Norepinephrine, epinephrine increase 14-18x
  - Glucose production increases 7x
  - Glucose utilization only increases 3-4x

Insulin dependent diabetics cannot increase their insulin secretion and become hyperglycemic

Post-Exercise Hyperglycemia

- Immediately post-exercise:
  - adrenaline remains high
  - glucose production remains high, however
  - glucose utilization drops precipitously

- Nondiabetics:
  - Adapt with higher insulin levels during this period

- Diabetics:
  - cannot easily mimic normal insulin secretory physiology
  - may have delayed absorption of carbohydrate consumed during exercise

Avoiding hyperglycemia

- Monitor blood sugars closely
- Recommend use of continuous glucose monitoring to learn response, may give “pre-emptive bolus” if you can predict a high
- Give a partial bolus if hyperglycemia develops
- Limit carbohydrate replacement to only what is needed
- Do not stop insulin delivery completely during prolonged exercise >2 hours
Glucose Metabolism Post-Exercise

Short term response:

- Body focus shifts to replenishment of energy stores
- Effects on insulin sensitivity last 12-24h

Long term response:

- Decreased insulin secretion in response to exercise training (nondiabetics)
- Increased muscle GLUT4 transporters
- Increased ability to mobilize and store fatty acids, oxidize fatty acids

↑Glycogen formation
↑GLUT4 and hexokinase maintains persistent glucose uptake
Continuous Glucose Monitoring
The old way of monitoring blood sugars
Advancing CGM Technology

DEXCOM Seven Plus
2010

DEXCOM G4 Platinum
2014

DEXCOM G5
2016
The advantage of trending information

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

Trend Arrows are secondary to the trend graph.
Real-life example:

Joe uses an insulin pump to manage his diabetes. Imagine Joe just ate a big lunch. Now his blood sugar reading is 300mg/dL and he wants to go for a run. (lets assume he checked his ketones just to be safe and they are negative). What should he do?

A. Skip the run. His blood sugars are just too high.

B. Give a correction dose of insulin and then go run once it is coming down

C. Take off his pump, go ahead and run and eat another 80g of carbs while he runs

What important information are we missing?

**Insulin on board!**
Cushioning the fall

5 units
Insulin on board
CF = 1:40mg/dL

11 miles, 7:33 pace, 1h 23 min
Cushioning the fall

Treating the blood sugar based on trend information will:
- Allow you to keep working out
- Require less carbs
- Help you feel better and stronger during and after the workout
Use of CGM during marathon training

CGM correlates well with fingerstick glucose during exercise and helps guide proper carbohydrate replacement.

Maximum glucose: 193
Minimum glucose: 100 (sensor) 79 (meter)
Start glucose: 176 (sensor)
Finish glucose: 104 (sensor) 90 (meter)
Total carbs consumed: 105 grams
Total duration of exercise: 3 hours, 48 minutes
Basal rate 50%. 1 unit bolus given after completion of exercise.
Marathon Race Day

CGM allows you to react to unexpected changes in blood glucose in real-time

Starting glucose: 175 (meter) 171 (sensor)
Peak glucose: 279 (sensor)
Lowest glucose: 132 (sensor)
Carbs: 25, 10 (pre-race) 10, 10, 20, 20, 20 (during race) 20 (after sensor stopped)
Basal decreased to 50% 1 hour prior to race
Lost sensor adherence at 22 miles
Case #2: Endurance Cyclist

58 year old male, rides 200-300 miles per week
Takes Lantus and Apidra, does not want to be on pump
Wearing DEXCOM: Dropped A1c from 6.9% to 5.8% in the last 2 years

CGM allows athletes who want to maintain glucose in a tight range while exercising to do so safely.
Case #3 – Lower pre-run glucose

- 4am: BG 100, 4 glucose tabs
- 5:30am: BG 188, started 50% temp basal
- 8:30am: Finish – 21 miles - 2h 45min 7:50 pace BG 130. No post-run bolus given.
- Total carbs: 131 grams
Case #4 – Higher pre-run glucose

- 2:45am: BG 230, pump suggests 3.4 units, give 2.5 units
- 5:45am: BG 150 with - 45 carbs eaten at start of run (50% basal)
- 6:45am: BG 80 with - 45 carbs eaten
- 7:30-8:30am: BG 100 and - 25 carbs eaten
- 8:30am: Finish – 1h 50 min run 7:41 pace 14 miles BG 109. No post-run bolus given.
- Total carbs: 115 grams
Summary and Recommendations

- Exercise presents significant challenges to blood sugar control

- Always consider:
  - Type of Exercise
  - Duration and Intensity of exercise
  - Timing of exercise in relation to meals
  - Insulin on board
  - Impact of recent exercise and recent hypoglycemic events

- There is no single strategy that will work for everyone

- Plan ahead, test your plan, and revise as needed

- Be safe:
  - Wear medical identification bracelet or necklace, have a workout partner
  - Use CGM / have ability to test blood sugar at all times
Summary and Recommendations

- Prevent hypoglycemia
  - Decrease insulin
  - Increase carb intake
  - Minimize hypoglycemia preceding exercise

- Insulin injections
  - Decrease meal dose by 50% preceding exercise event
  - Consider decreasing insulin dose further if injected into exercised portion of body

- Insulin pump management
  - Suspend or remove pump prior to exercise of short duration
  - Use temporary basal prior to prolonged exercise
    - Make changes prior to exercise
  - Give partial bolus if hyperglycemic during prolonged exercise
Summary and Recommendations

- Post-exercise:
  - May need to replenish muscle and liver glycogen stores with carbohydrate
  - After endurance exercise take 30-60g carbs with ½ insulin dose

- Monitor blood sugars closely for hyperglycemia or hypoglycemia
  - Hyperglycemia often <2 hours after exercise
  - Hypoglycemia up to 12-24 hours after exercise

- Reduce overnight basal if needed by 10-20%
Acknowledgements

Questions and Comments:

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