Type 1 Diabetes and Exercise

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Presenter Disclosure Info

• I have no financial relationships pertinent to this presentation to disclose.
Objectives

- Understand the basic physiology of glucose and insulin with exercise
- Understand ways to prevent high and low BG’s during and after exercise
Normal Physiology
Ying and Yang

Glucagon

Insulin
Physiology of Fasting

- Insulin goes down
  - Glucose doesn’t enter tissues
  - Liver pushes glucose into the blood via glucagon
Quick segue on ketones

- **Ketosis**
  - Physiologic occurrence during times of starvation and liver has depleted its glycogen stores

- **Ketoacidosis**
  - Not good
  - Ketones have accrued to a point that it has made the blood acidotic and subsequent clinical deterioration ensues
• Eat carbs $\rightarrow$ insulin goes up.
  – Insulin stops liver from putting sugar in the blood and moves sugar into muscle, liver, and fat.
Physiology of Exercise

- Insulin is suppressed
- Glucagon and catecholamines cause glucose to move from liver to blood
- Catecholamines can make it harder for glucose to enter muscle
Tanks of Sugar

- Insulin independent mechanisms stimulate glucose uptake in the muscle.
- Liver and muscles provide glucose to keep a steady fuel source using glucagon.

Our defense against hypoglycemia

Pancreas Response
↓ Insulin
↑ Glucagon

~ 72-108 mg/dL

Autonomic Response
Shaky
Palpitations
Anxious
Sweating
Hunger
Numbness

~ 65-70 mg/dL

Brain Alert
Warmth
Weakness
Fatigue
Confusion

~ 50-55 mg/dL

Warmth
Weakness
Fatigue
Confusion
Our defense against hypoglycemia - Summary

- Decrease Insulin
- Increase Glucagon
- Increase of counter-regulatory hormones
The issues with diabetes type 1

- Can’t decrease the insulin once it’s given.
- Glucagon release may be impaired.
- Adrenaline response can be attenuated in type 1 diabetes.
- And yet adrenaline can also increase BG’s.

So you are susceptible to lows and highs!
Diabetes and Exercise

- Insulin is already in the body
  - Glucose goes into muscle more easily
- Glucagon is impaired
Effects of exercise on Type 1 teens

n = 50 children and teens
Exercise: 4x15 min treadmill periods with 3 x 5 minute rest periods at VO$_{2\text{max}}$ of 60%

Diabetes Care, Vol 29, Number 1, January 2006
Hypoglycemia overnight

- 2x as many kids aged 11-17 years old had a low BG overnight after an exercise day compared to when they had no exercise (Tsalikian et al, 2005).

\[ n = 50 \text{ children and teens} \]

Exercise: 4x15 min treadmill periods with 3 x 5 minute rest periods at VO\(_{2\text{max}}\) of 60%
Hypoglycemia the night after exercise

- McMahon et al. noted that glucose needs to maintain targets may be increased not only during exercise but 7-11 hrs after.

n = 9 teens

Exercise: 4 pm 45 min on cycle at 50% VO_{2max}
And the next day…

- Adrenaline response to hypoglycemia was blunted the day after low or moderate exercise.

n = 27 adults with type 1 DM

Exercise: 2 groups either VO$_{2\text{max}}$ of 30% or 50% had two bike sessions 90 min each with a 180 min rest period.
Adrenaline effect is gone

Muscle  + Insulin  Liver  + Glucagon

Glucose in the Blood
Hyperglycemia?

- Too many carbs
- Too little insulin, or disconnecting
- Short periods of intense exercise can cause adrenaline responses which can last up to 2 hours in adults with type 1 DM (Marliss et al, 2002)
So why exercise?

- Reduces risk of:
  - Heart attacks
  - Stroke
  - High cholesterol
  - High blood pressure
  - Increase life expectancy
- Increases team comaraderie
- Improves mental health and self-confidence
“People with diabetes should be advised to perform at least **150 min/week of moderate-intensity aerobic physical activity** (50–70% of maximum heart rate), spread over at least **3 days per week** with no more than 2 consecutive days without exercise. (A)"
Athletes with Type 1 Diabetes

Gary Hall Jr
Wasim Akram
Mimmi Hjorth
Chris Dudley
Sir Steve Redgrave
Jason Johnson
Bill Carlson
Hypoglycemia and teens

Baseline BG level (mg/dl)

- <120: 86%
- 120-180: 13%
- >180: 6%

Hypoglycemia risk (% of subjects)

Diabetes Care, Vol 29, Number 1, January 2006
BG Targets

Non-diabetic
70
140
200

Diabetic
70
80
180
200

Diabetic during exercise
70
80
120
140
200
Factors affecting response to exercise

- Duration and Intensity
- Type of activity
- Metabolic control
- BG level
- Type and timing of insulin injections
- Type and timing of food
- Absorption of insulin
Types of Activity

- Most team sports have repeated bouts of intensive activity interrupting longer periods of low to moderate-intensity activity of rest.
  - Has less fall of BG compared to continuous moderate-intensity exercise
Anerobic vs Aerobic

- Period of maximal $O_2$ use
- Anaerobic is only a short time, sometimes seconds
- Lack of $O_2$ causes lactate formation
- BG rises lasting typically 30-60 min
  - Adrenaline
  - Glucagon

- Aerobic tends to lower BG both during (usually within 20-60 min after onset) and after the exercise
Typical Aerobic Exercise

Exercise

Glucose Appearance ↑
Glucose Utilization ↑↑

Recovery

Glucose Appearance ↔
Glucose Utilization ↑↑
Riddle me this…

• With 10 s of maximal exercise (> VO$_{2peak}$) there is a transient increase in BG for up to 2 hours after exercise (Bussau VA, 2006)

\[ \text{n = 7 T1DM males (age 21±4)} \]

Exercise: cycling at 40% VO2 max x 20’ followed by rest or 10 second max sprint
Intermittent high intensity vs continuous moderate intensity

Effect of 30 min (represented by box) of MOD (•) or IHE (○) on rate of endogenous glucose production (Ra; A) and rate of glucose utilization (Rd; B).

Less glucose needed for IHE in early “recovery” phase, but once adrenaline is back to baseline, glucose needs increased again, to restore glycogen stores.

n = 13 adults with type 1 DM

Exercise: IHE – continuous cycle at 40% \( \text{VO}_2\text{max} \) for 30 min interspersed with 4 s max sprint every 2 min

MOD – 30 min cycle at 40% \( \text{VO}_2\text{max} \)

Increased adrenaline inhibits muscle glucose uptake at rest and during exercise and promotes liver glucose production
- Shown that 10-15 min at > 80% VO$_{2\text{max}}$ increases BG appearance more than utilization

GH levels, cortisol, and lactate increase

Build up of intramuscular glucose-6-phosphate

Diabetics have no insulin response to bring BG’s back down during recovery
Typical Aerobic Exercise Revisited

- Exercise:
  - Glucose Appearance $\uparrow$
  - Glucose Utilization $\uparrow$

- Recovery:
  - Glucose Appearance $\leftrightarrow$
  - Glucose Utilization $\uparrow$
Aerobic exercise followed by short sprint

10 sec sprint

Glucose Appearance $\uparrow \uparrow \uparrow$
Glucose Utilization $\downarrow \downarrow$

Exercise

Glucose Appearance $\uparrow$
Glucose Utilization $\uparrow$

Recovery

Glucose Appearance $\leftrightarrow$
Glucose Utilization $\uparrow$
Aerobic exercise followed by short sprint

Glucose Appearance $\uparrow$ Glucose Utilization $\uparrow$

Glucose Appearance $\uparrow$ Glucose Utilization $\uparrow$

Glucose Appearance $\uparrow\uparrow\uparrow$ Glucose Utilization $\downarrow\downarrow$

10 sec sprint

Exercise

Recovery

After 2 hrs
Resistance Exercise vs Aerobic Exercise

- Resistance exercise relies more on lipids for fuel and has greater increase in GH levels, and lactate levels which increase gluconeogenesis, and increased catcholamines which augments glycogenolysis.

n = 12 adult type 1 DM

Exercise: aerobic - treadmill at 60% VO_{2max} x 45 min

Exercise: resistance - 3 sets of 8 repetitions with 90 sec rest in between sets x 45 min
Performing resistance exercise prior to aerobic exercise improves glycemic stability throughout the exercise and reduces duration and severity of hypoglycemia after, but notably not number of hypoglycemic events.

Yardley J E et al. Dia Care 2012;35:669-675
Metabolic control

• When control is bad, circulating insulin may not be enough, and counter-regulatory hormones may be exaggerated
  – Ketosis
• High BG associated with reduced beta-endorphins during exercise
Timing of Insulin


<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Serum Insulin Conc. (ng/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-60</td>
<td>0 (baseline)</td>
</tr>
<tr>
<td>0</td>
<td>0 (baseline)</td>
</tr>
<tr>
<td>60</td>
<td>0 (baseline)</td>
</tr>
<tr>
<td>120</td>
<td>0.2 mU/min/kg insulin infusion</td>
</tr>
<tr>
<td>180</td>
<td>0.4 mU/min/kg insulin infusion</td>
</tr>
<tr>
<td>240</td>
<td>0.6 mU/min/kg insulin infusion</td>
</tr>
<tr>
<td>300</td>
<td>0.8 mU/min/kg insulin infusion</td>
</tr>
<tr>
<td>360</td>
<td>1.0 mU/min/kg insulin infusion</td>
</tr>
<tr>
<td>420</td>
<td>1.2 mU/min/kg insulin infusion</td>
</tr>
<tr>
<td>480</td>
<td>1.4 mU/min/kg insulin infusion</td>
</tr>
</tbody>
</table>

*Insulin Lispro (n=10)*

Injection

Mean + SE
Type and timing of food

- 3-4 h prior to competition meals with fat, carbs, and protein
- Faster acting glucose just prior to exercise or within an hour to help build glycogen stores faster
Absorption of insulin

- Choice of site
  - Avoid extremity which will be used
- Ambient temperature
  - Increases metabolic demands and greater potential for BG drop
Other considerations

- More muscles used
  - Greater drop
- Weight bearing vs non-weight bearing
  - Greater drop
- Adrenaline, being amp’ed up
  - Increase in BG
- Mornings have higher counter-regulatory hormones
  - May have less likelihood of lows
  - More likelihood for ketosis
- Sports unfamiliar with may have more likelihood of low
Things to keep in mind…

• Newly diagnosed kids appear to be protected from severe hypoglycemia (Davis EA, et al, 1997)

• The lower the HbA1c, the greater the likelihood of lows, especially below 8%
  – Rate doubled if < 8%, tripled if < 7%

• Younger children were most susceptible if less than 6 years old.
Prevention

• Remember effects of alcohol
  – Impairs liver’s ability to make glucose by gluconeogenesis (not glycogenolysis)
• Remember to hydrate
  – In general, whatever you sweat and lose with breathing needs replacement
  – As much as 1.3 L an hour in teens
Filling the tank...
Exercise and Liver stores of glucose
## Carbs before exercise

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Duration</th>
<th>&lt; 20 minutes</th>
<th>20-60 minutes</th>
<th>&gt; 60 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 60% of Maximal Heart Rate</td>
<td>&lt; 20 minutes</td>
<td>15 g</td>
<td>30 g/h</td>
<td></td>
</tr>
<tr>
<td>60 - 75%</td>
<td>&lt; 20 minutes</td>
<td>15 g</td>
<td>30 g</td>
<td>75 g/h</td>
</tr>
<tr>
<td>&gt; 75%</td>
<td>&lt; 20 minutes</td>
<td>30 g</td>
<td>75 g</td>
<td>100 g/h</td>
</tr>
</tbody>
</table>

- Insulin dosage: - 20% - 30%

Grimm et al. Diabetes Metab 2004; 30: 465-70
Reducing pre-exercise insulin for meals

<table>
<thead>
<tr>
<th>Exercise intensity (% VO2max)</th>
<th>% Dose reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 min of</td>
</tr>
<tr>
<td></td>
<td>60 min of</td>
</tr>
<tr>
<td>25</td>
<td>25*</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>75</td>
<td>75</td>
</tr>
</tbody>
</table>

*Extrapolated.

## Estimated number of min covered by 15 grams of extra carb and no change in basal activity

<table>
<thead>
<tr>
<th>Activity</th>
<th>Body mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Cycling</td>
<td></td>
</tr>
<tr>
<td>10 km/h</td>
<td>65</td>
</tr>
<tr>
<td>15 km/h</td>
<td>45</td>
</tr>
<tr>
<td>Walking</td>
<td></td>
</tr>
<tr>
<td>4 km/h</td>
<td>60</td>
</tr>
<tr>
<td>6 km/h</td>
<td>40</td>
</tr>
<tr>
<td>Swimming</td>
<td></td>
</tr>
<tr>
<td>30 m/min breast stroke</td>
<td>55</td>
</tr>
<tr>
<td>Tennis</td>
<td>45</td>
</tr>
<tr>
<td>Cross-country ski</td>
<td>40</td>
</tr>
<tr>
<td>Basketball (game)</td>
<td>30</td>
</tr>
<tr>
<td>Snow shoeing</td>
<td>30</td>
</tr>
<tr>
<td>Soccer</td>
<td>30</td>
</tr>
<tr>
<td>Figure skating</td>
<td>25</td>
</tr>
<tr>
<td>Ice Hockey (ice time)</td>
<td>20</td>
</tr>
<tr>
<td>Running</td>
<td></td>
</tr>
<tr>
<td>8 km/h</td>
<td>25</td>
</tr>
<tr>
<td>12 km/h</td>
<td>20</td>
</tr>
</tbody>
</table>

Riddell et al, 2006
Carbing Up

- In general, 1.5 g CHO/kg/hr
- Gatorade is about 6% glucose
- G2 is about 2% glucose
- Generally drinks > 8% is too much
  - Juice is about 11% glucose
  - Slows gastric absorption
- Powerade is about 8% glucose
Exercise without Insulin

- Glucose can’t get into muscles, so muscles make lactate
  - Cause cramping and fatigue
- Lack of insulin causes ketone formation
Why is “no insulin” bad?

• Uninhibited action of counterregulatory hormones cause BG to rise further (Wahren et al, 1978)

• Impaired glucose uptake in muscles from lack of insulin and increased ketones can cause acidosis, abdominal pain, nausea and vomiting

• So if urine ketones are moderate or more, or serum ketones > 0.5 mmol/L hold off exercise
  – Serum ketones normalize faster than urine ketones
  – Precision Xtra glucometer can measure both ketones and glucose
Suspending basal rates on pumps

BG < 70 mg/dL

16% 43%

n = 50 children and teens
Exercise: 4x15 min treadmill periods with 3 x 5 minute rest periods at VO$_{2\text{max}}$ of 60%

Insulin Pumps

- Do not disconnect for > 2 hours
- May need to reduce basal 90 min prior to exercise.
- After reconnecting, may need to correct with 50% of usual dose.
- Can use temp basals, before, during, and after exercise.
Recovery

• Quickly provide carbs post-exercise to rebuild glycogen stores within the first few hours
  – Take advantage of the heightened insulin sensitivity
  – Adding protein helps with glycogen formation

• For short duration high intensity anaerobic activities (weight lifting, sprints, diving, and baseball), you can have delayed drops and may only need carbs after activity
  – Remember, opposite for aerobic or mixed (soccer, cycling, jogging, and swimming)
    • Use carbs before, during, and after
Practical points

• Always have a form of glucose readily available
• On activities, buddy system
• On hikes, if possible, use groups of four minimum
• Have at least one person who knows how to use glucagon
• Remember to remind athlete to not keep insulin in direct sunlight or warm temperatures

• Keep meter and strips close to skin and insulated when skiing
• Higher altitudes may increase BG’s
  – Skeletal muscle insulin resistance
  – Increased adrenaline
## Troubleshooting

<table>
<thead>
<tr>
<th>Hypoglycemia</th>
<th>Hyperglycemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too much insulin (bolus and/or basal)</td>
<td>Too little insulin</td>
</tr>
<tr>
<td>Not enough carbs, or carbs not given at right time</td>
<td>Too many carbs</td>
</tr>
<tr>
<td>Higher intensity aerobic exercise (&gt;50-75% VO$_{2peak}$) or prolonged (more than 30-60 min)</td>
<td>Short, intermittent bouts of anaerobic exercise</td>
</tr>
<tr>
<td>Not well trained</td>
<td>Emotions, adrenaline</td>
</tr>
</tbody>
</table>
Signs & Symptoms

- **Hypoglycemia**
  - Shaky
  - Fast heartbeat
  - Sweating
  - Anxious
  - Dizzy
  - Hunger
  - Impaired vision
  - Fatigue
  - Headache
  - Irritable

- **Hyperglycemia**
  - Frequent urination
  - Increased thirst
  - Blurred vision
  - Fatigue
  - Headache
  - Hunger
  - Nausea
Red Flags

- **Hypoglycemia**
  - Glazed look
  - Incoherent
  - Unresponsive
  - Pale

- **Hyperglycemia**
  - Fruity-smelling breath
  - Nausea and vomiting
  - Shortness of breath
  - Dry mouth
  - Weakness
  - Confusion
  - Coma
  - Abdominal pain
What to do for hypoglycemia

- With symptoms, check the BG
- If < 80 mg/dL, treat with 15 grams of fast acting carbs (ie juice, glucose tabs, gels)
- Re-check in 10 minutes, if still < 80 mg/dL repeat 15 grams of fast acting carbs
- If > 80 mg/dL give 15 grams of slow acting carbs (ie snack bar, powerbar, trail mix) and go and play
- Remember to give around 15 grams of fast acting carbs for every 30 minutes of play but may need more depending on activity
- If unresponsive, unable to swallow, or SEIZURE, 1 mg of glucagon given IM (remember to mix powder with liquid)
  - Patient’s BG should increase within 10 min, but patient may throw up from the glucagon
- Let parents know so they can give extra carbs at bedtime and check BG’s overnight
What to do for hyperglycemia

- Check the BG
- Target BG to be $< 200$ mg/dL
- If $> 250$ mg/dL check for ketones, but keep in mind, you can still have ketones with normal or low BG’s
- If there are moderate to large ketones, sub out, hydrate, give insulin
- If no ketones, use insulin scale but give 50% of what they normally use, may need even less for some activities
- If they are unconscious or vomiting with elevated BG, call 911, or take to the ER.
Good things to have on hand

- Glucagon
- Fast acting glucose
- Meter and strips
- Serum ketone meter
- Insulin and needles
- Water
- Snack bar (mixed protein/fat/carbs)
- Doctor’s phone numbers
- Parent’s phone numbers
- Don’t need to have it, but good if the athlete has a paper with their doses.
Let’s sum up…

• Reduce pre- and post-exercise insulin boluses
• Reduce/suspend basal 1-hr pre-exercise
• Carb up before exercise, make sure glycogen stores are replete
  – May want to mix low glycemic index foods with fast acting carbs
    • Remember powerbars may take 30 min before BG rises
  – In general, 15 grams for every 30 min
• For daylong activities (camp, long distance walking, skiing, water sports) consider 30-50% reduction in long acting insulin or basal the night previous and following night
• Check BG’s before exercise and every 30 min or so during exercise if possible
Let’s sum up…

• Bursts of anaerobic (high intensity) activity before or after.
• Weight training before conditioning.
• Exercise in AM instead of PM.
• To prevent overnight hypoglycemia
  – Bedtime snack (low glycemic index) if BG < 120 mg/dL
  – Lower overnight basal (by 20-30%)
  – Reduce pre-dinner bolus (with PM exercise)
  – Exercise in AM instead of PM
• Consider a serum ketone meter
• Keep accurate records 😊
So......

- Carb up hours before the exercise
  - Consider a fraction of insulin to cover
- Check BG just prior to exercise
  - <120 give free carbs
  - 120-200 consider carbs but give a fraction of insulin
  - >200 correct by 50%
- During the exercise
  - 15 grams for every 20-30 min of exercise
  - Check BG’s every 30-40 min
- After the exercise
  - Replete carbs
    - Consider a fraction of insulin to cover

- Before bed
  - Check BG (pumpers consider decreasing rates with temp basals)
    - <80 give juice/tabs
    - 80-120 give free carbs
    - 120-200 if carbs are eaten give a fraction of insulin and correct by 50%
    - >200 correct by 50%
    - >250 check for ketones
- Overnight
  - Consider checking at 2 AM if BG < 120 at bedtime and no carbs were given or if there were ketones
Childrens Hospital Oakland and Research Institute
Division of Endocrinology

- Diabetes Nurses
  - Kathy Love (R.D)
  - Barb King-Hooper
  - Lois Carelli
  - Veronica Monti
  - Victor Woolworth
  - Rosibel Silva
- Endocrine Nurses
  - Anita Markoff
  - Andrea Pederson
- Research Nurse
  - Betty Flores
- Social Workers
  - Amy Warner
  - Kristin Avicolli
  - Karen West
- Office Staff
  - Kim Lawas
  - Juliet Miller
  - Sherita Joseph
- Physicians
  - Jenny Olson
  - Ivy Aslan
  - Sonali Belapurkar
  - Alison Reed
  - Tariq Ahmad
THANK YOU