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  - Please refer to learning goals and objectives
  - Learners must attend the full activity and complete the evaluation in order to claim continuing education credit/hours
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Type 1 Diabetes and Physical Activity: Integrating Data

Successful T1 Diabetic Athletes

Keys to Exercise Success

- Optimize athletic performance via fuel availability, i.e., balance exercise blood glucose (and glycogen) use and availability
- Prevent and rapidly manage hypoglycemia caused by or following exercise, as well as hyperglycemia
What Effects Exercise BG?

- Exercise
  - Type/mode
  - Frequency
  - Intensity
  - Duration
  - Timing
  - Training status
- Environment
  - Heat
  - Humidity
  - Cold
  - Altitude
- Regimen Changes
  - Starting blood glucose levels
  - Circulating insulin levels
  - Food intake
- Bodily Concerns
  - Physical and mental stress
  - Weight loss
  - Hypoglycemia Associated Autonomic Failure
  - Menstrual cycle phase (women)
- Prior hypoglycemia
- Prior exercise
- Hypoglycemia-Associated Autonomic Failure

Balancing Exercise Blood Glucose Use and Fuel Availability

Optimal Balance for Exercise

- Perform best with BG of 80-180 mg/dL
- Some start out higher, but few lower

Exercise Duration and Intensity

High Adrenaline Activities ↑ BG

- Sports w/ intense “bursts”
- Sprinting of any type
- Heavy weight lifting
- Competitions (mental stress)
- Scary activities (downhill skiing)

Dual Glucose Uptake in Muscle

AADE15

AADE15

AADE15

AADE15
**Insulin vs. Counterregulation**

Modified from Riddell MC & Perkins BA. Can J Diab, 10: 53-7, 2006

**Carbs Used Most for Exercise**

- For most ex, carbs are main fuel: muscle glycogen (~80%), blood glucose (20%)
- Fuel mix normal in well-controlled T1D exercisers

**Supplemental Carbs Can Help**

- 60 min of exercise at 55-60% VO₂ max
- Av. ~22 oz. (53.3 vs. 66.5 gm carbs)

**Treatments for Acute Hypos**

+ Carb intake, if too low, may ↓ endurance capacity
+ Muscle glycogen levels ↓

**Is Carb Loading Advisable?**

- High-carb intake for T1D athletes is not necessarily recommended, though
- 59% vs. 50% carbs, 3 weeks: 10% ↑ BG, ↑ insulin needs, ↓ muscle glycogen, performance

**Preventing and Managing Hypoglycemia & Hyperglycemia**
The Power of BG Monitoring

- Checking BG before, often during, & after exercise is key to learning responses
- BG levels during usual activities can become somewhat predictable, pattern established

Time Ex with Insulin Peak & Action

- Rapid-acting insulin analogs: peak in 1-2 hrs
- Short-acting R: 2-3 hrs
- Intermediate-acting: 4-6 hrs
- Long-acting, basal: mild or no peak

Multiple Daily Injections (MDI)

- Long-acting basal insulin plus rapid-acting before meals requires 4-6 injections per day

Insulin Pump Therapy + CGM

- More convenient
- Better control of blood glucose levels

Integrating Data with CGM

- Better CGM accuracy during aerobic exercise than during resistance exercise or rest
- Due to augmented blood flow better equilibrating plasma and interstitial fluid or combo of systematic sensor underestimation and sensor lag time?
Hypoglycemia Symptoms

• Can vary by person and by activity
• Exercise adrenaline with similar symptoms

Why Avoid Low BG with Exercise?

• Early, rapid-onset fatigue with hypoglycemia
• Potential loss of coordination
• Reduced strength and endurance
• Suboptimal performance

Hypoglycemia Prevention Steps

1. Assess risk of low BG during and after
   – Higher with new/unaccustomed ex
   – Higher when insulin levels elevated
2. Reduce insulin doses (pre/during/post)
3. Increase carbohydrate/food intake

Hypoglycemia Prevention Steps

4. Watch out for delayed-onset hypoglycemia (for up to 48 hours)
5. *Use high-intensity exercise to boost BG levels

Insulin Levels & Exercise

• Any insulin “on board” affects blood glucose response
• Higher circulating insulin levels will lower BG more
• Pre-exercise short- or rapid-acting insulin doses will likely need to be lowered for most activities

Insulin Levels & Exercise

• Basal insulin can be lowered as well
• Less insulin will be needed post-exercise while insulin action ↑ (when muscle glycogen levels are lower)
• Athletic individuals have lower overall insulin needs
Insulin Reductions Pre-/Post-Exercise

Campbell MD et al. Diab Care, 36(8):2217-24, 2013

- 50% better than 75% or full dose for 4 hrs post-ex (but not later)

Rabasa-Lhoret R et al. Diab Care, 24: 4: 625-630, 2001

- 25% dose

Pre-Meal Insulin Dose Reductions

<table>
<thead>
<tr>
<th>Intensity of Aerobic Exercise</th>
<th>30 minutes of exercise</th>
<th>60 minutes of exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild (~25% of maximal aerobic capacity)</td>
<td>25%</td>
<td>50%</td>
</tr>
<tr>
<td>Moderate (~50%)</td>
<td>50%</td>
<td>75%</td>
</tr>
<tr>
<td>Heavy (~75%)</td>
<td>75%</td>
<td>–</td>
</tr>
</tbody>
</table>

Sample Insulin Adjustment

- Meal Boluses/Injections:
  - Low intensity cardio exercise ↓ 25%
  - Moderate cardio ↓ 33%
  - High intensity cardio ↓ 50%
  - Short/intense ↓ 0%, plus bolus afterwards

- Basal Doses:
  - Pump: ↓ basal rate by 50% starting 1 hr prior, or reconnect hourly to give 50% of usual basal rate
  - Injections: Prior to prolonged exercise, ↓ basal by up to 25%

General Snacking Guidelines

- Begin carb intake prior to exercise
- Adjust quantity based on pre-exercise glucose levels (none may be needed)

Carbohydrate Intake (Grams)

<table>
<thead>
<tr>
<th>Exercise Duration</th>
<th>Exercise Intensity</th>
<th>BG &lt;100</th>
<th>BG 100-150</th>
<th>BG 150-200</th>
<th>BG &gt;200</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 min</td>
<td>Low</td>
<td>5-10</td>
<td>0-10</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Mod.</td>
<td>10-25</td>
<td>10-20</td>
<td>5-15</td>
<td>0-10</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>15-35</td>
<td>15-30</td>
<td>10-25</td>
<td>5-20</td>
</tr>
<tr>
<td>60 min</td>
<td>Low</td>
<td>10-15</td>
<td>10-15</td>
<td>5-10</td>
<td>0-5</td>
</tr>
<tr>
<td></td>
<td>Mod.</td>
<td>20-50</td>
<td>15-40</td>
<td>10-30</td>
<td>5-15</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>30-45</td>
<td>25-40</td>
<td>20-35</td>
<td>15-30</td>
</tr>
</tbody>
</table>

Prevent Delayed-Onset Hypos

- Most common following long duration or repeated bouts of high-intensity exercise
- Caused by enhanced insulin action during time of muscle glycogen repletion
- May occur up to 24-48 hours afterwards, but 6-12 hours most common
- May be prevented by ↓ insulin doses and/or ↑ food intake

Prevent Hypo with High-Intensity Ex

4 sec sprints every 2 min during 30 min of moderate (~40%) ex keep BG ↑ during & after (at least 1 h)
10-Sec Maximal Sprint (After Ex)

20 min of moderate (~40%) cycle ex, followed by 10 sec sprint at end of ex keeps BG ↑ for 2 hrs

Bussau VA et al., Diabetes Care, 29(3): 506-6, 2006

10-Sec Maximal Sprint (Before Ex)

10 sec sprint at start of ex followed by 20 min of mod. cycle ex, keeps BG higher early in recovery

Bussau VA et al., Diabetologia, 50(9): 1815-1818, 2007

Aerobic vs. Resistance Ex Effects

Aerobic or Resistance Exercise First?

A Vicious Cycle: Hypoglycemia-Associated Autonomic Function

Prior hypos blunt metabolic, neuroendocrine responses to exercise

Prior exercise may blunt counterregulatory responses to same- or next-day hypoglycemia or exercise

Same-Day Hypoglycemia Risk

Afternoon hypoglycemia following both prior AM exercise and hypo affects glucose turnover, production


Yardley JE et al., Diab Care, 35:669-675, 2012

Yardley JE et al., Diab Care, 36(3):537-42, 2013
Next-Day Hypoglycemia Risk

Lower epinephrine release during next-day hypo following both low & moderate exercise

Sandoval DA, et al., Diabetes, 53(7):1798-806, 2004

Next-day mod. ex following varying levels of hypo affects blood glucose production due to blunted hormone (epi+) release


Hyperglycemia Ex Decrements?

Isokinetic and isometric strength measures before and after 3 hours of hyperglycemia (16 mmol/L)
Isometric strength only decreased

Andersen H et al., Diab Med, 22(10):1401-7, 2005

Aerobic Exercise w/ Hyperglycemia

Greater Reliance on Carbs
Glycogen
Glucose infusion
Endogenous glucose
Lipids
Protein


Type 1 Diabetes Case Study

• 20 years old, female, T1D since 16
• Basal-bolus insulin regimen (gliargine/lispro)
• Gained 15 pounds; takes higher insulin doses to control blood glucose levels
• No regular physical activity (except cycling to class, some walking)
• Goals are to lose the 15 pounds, get A1C value below 6.5%

Type 1 Diabetes Case Study

• Variety of activities: conditioning machines, swimming, and cycling
• Variety, alternating hard/easy days optimizes insulin action, lowers injury risk
• Consistency with training makes glycemic control easier
• Biggest fear is more hypoglycemia
**Type 1 Diabetes Case Study**

- Possible insulin adjustments:
  - Lower pre-exercise meal doses of Humalog by 20-50%, based on activity and timing
  - Lower post-exercise doses for food intake following, depending on ending blood glucose
  - Lower evening Lantus dose by 0-25%, based on past responses and evening food intake
- Combine ↓ insulin, ↑ carbs/food intake

**Type 1 Diabetes Case Study**

- Possible food adjustments:
  - Increase pre-exercise carb intake by 10-20 grams, depending on activity and meal timing
  - Consume 0-15 grams carbs every 15 minutes, based on intensity and duration
  - Increase post-exercise intake of carb, protein, and fat to refuel, prevent later-onset hypos
  - Treat lows with less to prevent rebound highs

**Keys to Exercise Success**

- Stay in good control of your blood glucose levels to perform optimally
- Avoid or minimize hypoglycemia and hyperglycemia during and after exercise

**Keys to Exercise Success**

- Balance carbohydrate intake with exercise use to maintain euglycemia
- Lower insulin doses appropriately for prolonged or frequent training

**Activity-Specific Information**

*Diabetic Athlete’s Handbook*
© 2009

Over 100 sports and activities and real-life examples included

**Easier Exercise Rx (for Clinicians)**

*Exercise and Diabetes: A Clinician’s Guide to Prescribing Physical Activity*

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Thank you!

For more information, visit www.SheriColberg.com

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