Preventing & Managing Exercise-Related Hypoglycemia

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Successful T1D 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)
Perform best with blood glucose (BG) levels of 80-180 mg/dl

Some start out higher, but few lower
Why Avoid Exercise Lows?

* Early, rapid-onset fatigue
* Potential loss of coordination
* Reduced strength and endurance
* Suboptimal performance
Hypoglycemia Symptoms

- Can vary by person and by activity
- Release of adrenaline causes similar symptoms
Glucose Uptake into Muscle
Insulin vs. Other Hormones

**Euglycemia**
- ↓ Insulin
- ↑ Counterregulatory hormones

**Hypoglycemia**
- ↑ or ↔ Insulin
- ↑ or ↔ Counterregulatory hormones

**Hyperglycemia**
- ↓ or ↔ Insulin
- ↑↑ or ↔ Counterregulatory hormones

Exercise Fuel Systems

Adapted from Colberg, S. *Diabetic Athlete’s Handbook*, 2009
**Hypo Prevention Steps**

1. Assess risk of exercise low BG
   - Higher with new/unaccustomed exercise
   - Higher when insulin levels ↑ during exercise
2. Reduce insulin doses (pre/during/post)
3. Increase carbohydrate/food intake
4. Watch out for delayed-onset hypoglycemia (for up to 48 hours after activity)
5. *Use high-intensity exercise to ↑ BG levels
Any insulin “on board” during exercise will affect BG

Lower insulin or other medication doses

Short- or rapid-acting insulin will likely need to be lowered for exercise within 1-2 hours

Basal insulin can be lowered as well

Less insulin needed post-exercise while insulin action ↑ (low muscle glycogen)
Peak and Action of Insulins

- Rapid-acting insulin analogs (Humalog, Novolog, Apidra, Fiasp*): *peak in 1-2 hrs*
- Short-acting Regular: *2-3 hrs*
- Intermediate-acting (NPH): *peak in 4-6 hrs*
- Long-acting, basal (Lantus, Basaglar, Levemir, Tresiba): *mild or no peak*
<table>
<thead>
<tr>
<th>Duration</th>
<th>Low Intensity</th>
<th>Moderate Intensity</th>
<th>High Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 min</td>
<td>None</td>
<td>10-20%</td>
<td>10-30%</td>
</tr>
<tr>
<td>60 min</td>
<td>10-20%</td>
<td>20-40%</td>
<td>30-60%</td>
</tr>
<tr>
<td>90 min</td>
<td>15-30%</td>
<td>30-55%</td>
<td>45-75%</td>
</tr>
<tr>
<td>120 min</td>
<td>20-40%</td>
<td>40-70%</td>
<td>60-90%</td>
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<tr>
<td>180 min</td>
<td>30-60%</td>
<td>60-90%</td>
<td>75-100%</td>
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</tbody>
</table>

Adapted from Colberg, S. Diabetic Athlete’s Handbook, 2009
Adjustments by Insulin Type

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

* Basal:
  * Pump: ↓ basal rate by 50% starting 1 hr prior, or
  * Reconnect hourly to give 50% of usual basal rate
  * Prior to prolonged ex ↓ injected basal up to 25%
### 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>

50% better than 75% or 100% lunch dose 4 hours post-ex (but not later on)

Hypo Prevention (Carbs/Food)

* ↑ carb/food intake, based on exercise intensity, duration, type, etc.
* May need to ↑ carb intake *prior* to exercise
* Adjust quantity based on pre-exercise BG levels (none may be needed)
* Snack more when insulin levels are higher
* Snack hourly during prolonged exercise to provide alternate carbs (besides BG)
<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>

Adapted from Colberg, S. Diabetic Athlete’s Handbook, 2009
Carb Algorithm for CGMS

Sensor Glucose < 7.0 mmol/L during exercise and dropping =
Take Action

- < 5.0 mmol/L
  - Take 16 g CHO
  - Protocol A

- 5.0-6.0 mmol/L
  - Directional arrows indicate ↓↓; Take 20 g CHO
  - Protocol B

- 6.1-6.9 mmol/L
  - Directional arrows indicate ↓↓or ↓; Take 8 g CHO
  - Protocol D

8% vs. 10% Carb Sports Drink

- 60 min of exercise at 55-60% VO$_2$max
- Av. ~22 oz. (53.3 vs. 66.5 gm carbs)

Perrone C, et al., Diab. Care, 28(10): 2537-8, 2005
Treatments for Acute Hypos
Carbohydrate intake, if too low, may ↓ endurance capacity

Muscle glycogen levels ↓ by frequent, prolonged training

High-carb intake for T1 athletes is not necessarily recommended, though

59% vs. 50% carbs for 3 weeks resulted in 10% higher BG, ↑ insulin needs, and ↓ muscle glycogen and performance

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 and/or ↑ food intake
Post-Exercise Hypos Biphasic

7–11 hours later

McMahon SK et al. JCEM 92:963-968, 2007
Prevent Delayed-Onset Hypos

Best Post-Workout Snack?

Chocolate milk, anyone?
A Vicious Cycle: Hypoglycemia-Associated Autonomic Failure

Antecedent hypoglycemia blunts neuroendocrine and metabolic responses to exercise. Prior exercise may blunt counterregulatory responses to same- or next-day hypoglycemia.
Next-Day Hypoglycemia Risk

Lower adrenaline (epinephrine) release during hypoglycemia following both exercise intensities.

Sandoval DA, et al., Diabetes, 53(7):1798-806, 2004
Next-day ex following varying levels of hypo affects blood glucose production due to blunted hormone (epi+) release.
Optimizing Exercise Blood Glucose Levels
Predicting Glycemic Responses

- Checking BG before, often during, and after exercise is key to learning your unique BG responses.

- BG levels during usual activities can become somewhat predictable, pattern established.
* Carbs main fuel: glycogen (~80%), BG (20%)
* Only ~5 grams of glucose in blood (100 mg/dl)
* Fuel mix normal in well-controlled T1D exercisers

Romijn JA et al., JAP, 88(5): 1707-14, 2000
BG Exercise Responses

Exercise Intensity Effects

* Competitive events shorter, but much more intense than practices
* Greater release of glucose-raising hormones causes BG to ↓ less
* Mental stress of competition alone can ↑ levels of hormones as well
* Extra insulin may be needed after competition to lower BG (↓ dose)
High Adrenaline Activities

* Sports w/ intense “bursts”
* Sprinting of any type
* Heavy weight lifting
* Intense competition (mental stress)
* Scary activities (downhill skiing)
The longer an activity lasts, the greater glucose-lowering effect it can have.
- Rate of muscle glycogen use ↑ with increasing exercise intensity.
- Longer duration at same intensity will result in greater muscle glycogen use.
- Greater glycogen depletion will cause ↑ reliance on BG use.
An Exercise Dilemma

“Pulling open a bag of potato chips... would that be considered as ‘aerobic’ or ‘anaerobic’ exercise?”
* Aerobic vs. anaerobic activities – is there a metabolic difference?
* BG easier to maintain during short, intense exercise (like sprinting or heavy weights)
* Longer duration generally requires greater diabetes regimen changes
* Increased muscle mass improves insulin sensitivity overall
Use Intermittent High-Intensity Ex

4 sec sprints every 2 min during 30 min of moderate (~40%) ex keep BG ↑ during & after (at least for 1 hour)

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

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.
Mean 6 SE glucose as measured by CGM from 1 to 12 h postexercise.

▫ no-exercise control session;
▲ aerobic exercise session;
◆ resistance exercise session. The box represents the period of time where glucose was significantly higher after aerobic exercise compared with resistance exercise (P < 0.05). n = 11 (no-exercise control), n = 10 (aerobic), and n = 12 (resistance).

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

Aerobic vs. Resistance Ex Effects
Effects of Timing of Exercise

- Cortisol and growth hormone higher in AM, ↓ insulin action, ↑ BG levels
- When same exercise done later in the day (even post-breakfast) ↓ BG more
- Exercise done right after eating prevents post-meal BG spikes
Post-Dinner Self-Paced Walking

Colberg S et al. JAMDA, 10: 394-7, 2009
Regular exercise improves insulin action
May need lower insulin doses overall
Lesser carb intake may be needed

Must ↑ absolute intensity for same blood glucose effect after training
Training effects specific to activity
Other Factors to Consider

* Poor BG control ↓ insulin action
* Physical/mental stress can ↓ insulin action
* Insulin action ↓ during 2\textsuperscript{nd} half of menstrual cycle in teen girls/women
* Environmental conditions (hot/cold/high & low pressure)
Stay in good control of your blood glucose levels to perform optimally
Avoid or minimize hypoglycemia during (and after) exercise
Balance carbohydrate intake with exercise use
Lower insulin doses appropriately for prolonged or frequent training
Activity-Specific Information

Diabetic Athlete’s Handbook
© 2009

Over 100 sports and activities included
Exercise Rx (for Clinicians)

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

American Diabetes Association © 2013
Diabetes & Keeping Fit for Dummies

Wiley and American Diabetes Association © 2018
Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association

Diabetes Care 2016;39:2065–2079 | DOI: 10.2337/dc16-1728

The adoption and maintenance of physical activity are critical for blood glucose management and overall health in individuals with diabetes and prediabetes. Recommendations and precautions vary depending on individual characteristics and health status. In this Position Statement, we provide a clinically oriented review and evidence-based recommendations regarding physical activity and exercise in people with type 1 diabetes, type 2 diabetes, gestational diabetes mellitus, and prediabetes. Physical activity includes all movement that increases energy use, whereas exerci-
Exercise management in type 1 diabetes: a consensus statement

Michael C Riddell, Ian W Gallen, Carmel E Smart, Craig E Taplin, Peter Adolfsson, Alistair N Lumb, Aaron Kowalski, Remi Rabasa-Lhoret, Rory J McCrimmon, Corin Hume, Francesca Annan, Paul A Fournier, Claudia Graham, Bruce Bode, Pietro Galassetti, Timothy W Jones, Inigo San Millan, Tim Heise, Anne L Peters, Andreas Petz, Lori M Laffel

Type 1 diabetes is a challenging condition to manage for various physiological and behavioural reasons. Regular exercise is important, but management of different forms of physical activity is particularly difficult for both the individual with type 1 diabetes and the health-care provider. People with type 1 diabetes tend to be at least as inactive as the general population, with a large percentage of individuals not maintaining a healthy body mass nor achieving the minimum amount of moderate to vigorous aerobic activity per week. Regular exercise can improve health and wellbeing, and can help individuals to achieve their target lipid profile, body composition, and fitness and glycaemic goals. However, several additional barriers to exercise can exist for a person with diabetes, including fear of hypoglycaemia, loss of glycaemic control, and inadequate knowledge around exercise management. This Review provides an up-to-date consensus on exercise management for individuals with type 1 diabetes who exercise regularly, including glucose targets for safe and effective exercise, and nutritional and insulin dose adjustments to protect against exercise-related glucose excursions.

Introduction

Despite tremendous advances since the discovery of insulin almost 100 years ago, management of type 1 ketoacidosis and a reduced risk of developing severe hypoglycaemia with coma. However, older women who are physically active have higher rates of severe

http://thelancet.com/pdfs/journals/landia/PIIS2213-8587(17)30014-1.pdf
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