Physical activity and exercise in children with diabetes mellitus type 1

Dr. Zahra Alian
pediatric endocrinologist
References:

- ISPAD Clinical Practice Consensus Guidelines 2009 Compendium
• Regular exercise has important health and social benefits for children and adolescents with type 1 diabetes mellitus (T1DM) and should be encouraged.
• ADA recommended that all children with diabetes should be encouraged to do exercise at least 60 min of physical activity each day.
• Exercise also presents several important challenges to diabetes management. It requires special management by patients and clinicians.
Benefits of exercise

- Exercise can help prevent cardiovascular disease, stroke, osteoporosis, and reduces the risk for some forms of cancer (eg, colon, breast, prostate).
- Increased cardiovascular and cardiorespiratory fitness
- Enhanced muscle mass and strength
- Reduced adiposity
- Improved insulin sensitivity
- Improved cardiovascular risk profile
- Improved sense of well-being
Blood glucose in different type of exercise

- In general, aerobic activities are associated with reductions in blood glucose (BG) concentrations.

- By contrast, anaerobic activities usually do not reduce BG concentrations, and may be associated with elevations in glycemia in certain circumstances.
### Blood glucose response to different types of exercise

<table>
<thead>
<tr>
<th>Activity</th>
<th>Type of exercise</th>
<th>Effect on blood glucose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking, jogging, running, rollerblading, bicycling, cross-country skiing</td>
<td>Mostly aerobic</td>
<td>Usually ↓</td>
</tr>
<tr>
<td>Basketball, soccer, tennis, lacrosse, field hockey, rowing/canoeing, downhill skiing, middle distance running, playground activities, speed skating, golf, skateboarding, hula hooping, hopscotch, dancing, yoga, tag, rope jumping, swimming, capture the flag, dodge ball</td>
<td>Both aerobic and anaerobic</td>
<td>May ↓ or ↑</td>
</tr>
<tr>
<td>Weightlifting, track (sprinting and field events), football, baseball, gymnastics, fencing, wrestling, volleyball, ice hockey, diving, swimming (sprints), climbing trees, tug of war</td>
<td>Mostly anaerobic</td>
<td>Usually ↑</td>
</tr>
<tr>
<td>Competitions, try-outs or performances</td>
<td>Either aerobic or anaerobic</td>
<td>Usually ↑ because of the &quot;stress&quot; of competition</td>
</tr>
</tbody>
</table>

*Courtesy of Michael Riddell, PhD.*
The main fuel sources for exercise are lipid and carbohydrate.
The mix of fuel utilization during aerobic exercise (and the amount of disturbance to BG levels) primarily depends on the intensity and duration of the activity.
Initially, the energy used for muscular contraction is derived from stores within the muscle itself, including a very small amount of stored energy in the form of high energy phosphates (adenosine triphosphate [ATP] and phosphocreatine), and a somewhat larger store of glycogen.
With increased exercise duration, there is a gradual shift to fuels from outside of the muscle, including plasma free fatty acids (FFA) and BG.

During prolonged exercise, the main sources of BG are from the breakdown of liver glycogen or ingested carbohydrates.
Non-diabetic

Increased blood flow to muscle and increased non-insulin mediated glucose transport

\[ \text{Glucose uptake} \]

\[ \downarrow \text{[Glucose]} \]

via beta-cells

\[ \downarrow \text{[Insulin]} \]

\[ \uparrow \text{Counter-regulation} \]

NORMOGLYCEMIA

Well controlled diabetic after insulin

Increased blood flow to muscle and increased non-insulin mediated glucose transport

\[ \text{Glucose uptake} \]

\[ \downarrow \text{[Glucose]} \]

\[ \text{or} \uparrow \text{[Insulin]} \]

\[ \downarrow \text{Counter-regulation} \]

HYPOGLYCEMIA
Factors affecting glucose response to exercise
Duration and intensity

- Nearly all forms of activity lasting >30 min will be likely to require some adjustment to food and/or insulin.
Type of activity.

- Anaerobic efforts last only a short time, but may increase the blood glucose level dramatically because of the release of the hormones adrenaline and glucagon.
- This rise in blood glucose is usually transient, lasting typically 30–60 min, and can be followed by hypoglycemia in the hours after finishing the exercise.
Type of activity

- **Aerobic activities** tend to lower blood glucose both during (usually within 20–60 min after the onset) and after the exercise.
Metabolic control.

• Where control is poor and pre-exercise blood glucose level is high, circulating insulin levels may be inadequate and the effect of counter-regulatory hormones will be exaggerated, leading to a higher likelihood of ketosis.
Blood glucose level.

- If HbA1c < 7.0% diabetic children can have normal aerobic and endurance capacity

- If HbA1c > 7.5% aerobic capacity is lower and the fatigue rate is higher
Type and timing of insulin injections:

- When regular (soluble) insulin has been injected prior to exercise, the most likely time for hypoglycemia will be 2–3 h after injection, and the high-risk time after rapid analogue insulin is between 40 and 90 min.
Type and timing of insulin injections:

- When playing morning or all-day tournaments, a long-acting basal insulin given once daily in the evening can be substituted for one with shorter action (NPH) to reduce the basal insulin effect while exercising.
Type and timing of food

- A meal containing carbohydrates (CHO), fats, and protein should be consumed roughly 3–4 h prior to competition to allow for digestion and for a maximizing of endogenous energy stores.
- This is especially important for longer-duration activities.
Type and timing of food

- Glycogen stores can be enhanced with a carbohydrate beverage (1–2 g CHO/kg) approximately 1 h prior; this also helps to supplement energy stores and provide adequate fluids for hydration.
Type and timing of food

- Because insulin sensitivity remains elevated for hours postexercise, carbohydrate stores must be replenished quickly to lower the risk of hypoglycemia during the first few hours postactivity.
Type and timing of food

- Short duration and high-intensity anaerobic activities (such as weight lifting, sprints, diving, and baseball) may not require carbohydrate prior to the activity, but may produce a delayed drop in blood sugar.
Type and timing of food

- For activities of these types, extra carbohydrate after the activity is often the best option to prevent hypoglycemia (carbohydrate reloading).
Type and timing of food

- Longer-duration, lower intensity aerobic activities such as soccer (often described as a mixture between aerobic and anaerobic exercise), cycling, jogging, and swimming will require extra carbohydrate before, possibly during, and often after the activity.
Absorption of insulin

• **Choice of injection site:** When an extremity (arm or leg) has been injected with insulin and is then exercised vigorously, the increased blood flow to the limb is likely to result in more rapid absorption and metabolic effect of the insulin.
Absorption of insulin

• **Ambient temperature**: High temperature will increase insulin absorption and low temperature the converse
Timing of the activity

- Morning activity, done before insulin administration, may not result in hypoglycemia as circulating insulin levels are typically low and glucose counterregulatory hormones may be high.
- Indeed, severe hyperglycemia may occur with vigorous exercise in these circumstances, even precipitating ketoacidosis.
Training

• Exercise causes enhanced muscle insulin sensitivity and increased activation of non-insulin sensitive glucose transporters (GLUT-4)
Training

• During and immediately after exercise and from 7–11 hours in recovery, the insulin sensitivity is elevated in adolescents with type 1 diabetes

• In practical life, exercise for >1 hour can lead to increased insulin sensitivity and therefore an increased risk for hypoglycemia for at least 24 hours
Hypoglycemia

- If a child with diabetes is feeling unwell during exercise with signs and symptoms of hypoglycemia, glucose tablets or other form of quick-acting carbohydrate should be given as for treatment of hypoglycemia, even if blood glucose cannot be measured to confirm hypoglycemia.
Hypoglycemia

• To treat hypoglycemia with a rise in BG of approximately 3–4 mmol/L (55–70 mg/dl), approximately 9 g of glucose is needed for a 30 kg child (0.3 g/kg) and 15 g for a 50-kg child.
Late Hypoglycemia

- Hypoglycemia can occur several hours after exercise especially when this has been prolonged and of moderate or high intensity.

- This is because of the late effect of increased insulin sensitivity and delay in replenishing liver and muscle glycogen stores.
Post exercise nocturnal hypoglycemia:

- Risk of postexercise nocturnal hypoglycemia is high, and particular care should be taken if bedtime blood glucose $<7.0\, \text{mM} (125\, \text{mg/dl})$.
- Reduction in basal insulin
- Reduced boluses at postexercise meals
- Snack of complex CHO, fat and protein at bedtime
Insulin adjustments

For evening exercise:

• reduce the rapid analog before the evening meal by 25 to 75 percent,

• taking 10–15 grams of fast acting carbohydrate before the activity.
Insulin adjustments

- With daylong or unusual activities such as camps, long-distance walking, skiing, water sports, etc., consider a 30–50% reduction of long-acting insulin the night before and on the day of the activity.
Examples of percent reduction in pre-meal insulin bolus for a carbohydrate-containing meal, in order to strictly avoid hypoglycaemia

<table>
<thead>
<tr>
<th>Intensity of exercise</th>
<th>Duration of exercise</th>
<th>Recommended reduction in insulin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (~25% VO₂ max)</td>
<td>30 minutes</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60 minutes</td>
</tr>
<tr>
<td>Moderate (~50% VO₂ max)</td>
<td></td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75%</td>
</tr>
<tr>
<td>Heavy (~75% VO₂ max)</td>
<td></td>
<td>75%</td>
</tr>
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<td></td>
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<td></td>
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</tbody>
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Note: %VO₂ max = percentage of maximal aerobic capacity.
School activity and diabetes camps

• Small snack of 10-15g carbohydrate, for example a fruit or fruit juice, dried fruit, a cereal, fruit or granola bar or sports bar.
School activity and diabetes camps

- Chocolate contains fat that will cause the sugar to be absorbed more slowly.

- This can make it more suitable for low-grade, longer-lasting activity, for example hiking, swimming, or long walks. However, the extra calories will not benefit a child with weight problem.
Diabetes complications

• Competitive sports are generally safe for anyone with type 1 diabetes who is in good metabolic control and without long-term complications.
Diabetes complications

- Patients who have **proliferative retinopathy** or **nephropathy** should avoid exercise conditions that can result in high arterial blood pressures (systolic pressures >180 mmHg), such as lifting heavy weights (or any tasks in which a Valsalva maneuver is involved) or performing high-intensity sprints.
Glycemic management during exercise

- **BG levels <90 mg/dL** – Treat by ingesting 10 to 15 grams of fast-acting carbohydrate, depending on the size of the child, and raise the BG concentration to >90 mg/dL prior to initiating exercise.

- **Low to normal BG levels (BG 90 to 150 mg/dL)** – The child should consume supplemental carbohydrate at the onset of exercise (approximately 0.5 to 1.0 grams/kg / hour of exercise, depending on the energy expenditure and the amount of circulating insulin at the time of exercise).
• **High to normal BG levels (BG 150 to 250 mg/dL)**
  – Initiate mild or moderate intensity exercise.

• **Hyperglycemia (BG> 250 mg/dL)** – Intense exercise should be delayed until normoglycemia is restored because intense exercise may exaggerate the hyperglycemia.
• Strenuous exercise is dangerous and should be avoided if preexercise blood glucose levels are high (>14 mmol/L or 250 mg/dL) with ketonuria/ketonemia.

• Give approximately 0.05 U/kg or 5% of total daily dose and postpone exercise until ketones have cleared.
Summary

• The children with diabetes should be allowed to choose their favorite sports.
• Diabetes does not limit their ability to do exercise.
• They should record details of their activity, insulin, food and glucose results for good diabetes control during exercise.
Summary

Recommendation:

• Adjusting insulin regimen to activity
• Reducing insulin dosage before exercise if necessary
• Discussing type and amount of carbohydrate required for specific activities
• Having snacks and sugar in case of emergency
Summary

- Avoiding any exercise if pre-exercise blood glucose levels are high (>250 mg/dl) with ketonuria/ketonemia. Pre-exercise Blood glucose between 90 up to 250 mg/dl is safe.
- Drinking a lot of sugar-free fluids during exercise.
- Not having injected insulin at a site that will be heavily involved during activity.