Exercise and Type 1 Diabetes:

Strategies for Glucose Control

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Exercise is a fun and an important part of living a long and healthy life with type 1 diabetes. However, it is important to learn how your body will react to changes in physical activity and what you can do to help make exercise problem free.

Blood sugar control during, and after, exercise requires advanced planning, a good understanding of carbohydrate metabolism and knowledge about insulin action. Knowledge about the type of exercise that you do is also important (mild, moderate, heavy aerobic exercise, resistance and/or anaerobic exercise). To maintain stable blood glucose (BG) levels during exercise usually requires planning and adjusting insulin levels and/or carbohydrate intake.

Understanding how to properly adjust insulin and/or carbohydrates for the intensity of exercise will help avoid unwanted lows (hypoglycemia) or highs (hyperglycemia), while maintaining good sporting performance.

KEY POINT

Typically, when you are more physically active for greater than 30 minutes, you need to take less insulin and/or eat more carbohydrate compared to days when you are sedentary. Just how much less insulin and how much more carbohydrate depends on a number of variables and what we recommend below should be good starting points.

WHEN DO YOU NEED TO START MAKING CHANGES FOR EXERCISE?

Exercising with type 1 diabetes means that the effort must begin long before the start of the activity. This is particularly important if you take multiple daily insulin injections with intermediate or long-acting insulin (NPH, N, LANTUS, DETIMER, etc.). If the physical activity will be prolonged (i.e. 2 or more hours) and you are on multiple daily injections, then a reduction in basal insulin by about 20% should be used in the morning before the scheduled event. If long acting insulin is taken at bedtime, then a 20% reduction the evening following exercise is recommended. If you are on an insulin pump, you can turn down your basal rates about 90 minutes before exercise and have it turned down until the end of the activity (see below).

DO I NEED TO HAVE INSULIN IN MY BODY WHEN I EXERCISE?

There are many changes that occur in your body when you exercise. In short, when exercising, sugar (glucose) in your blood is used to fuel the activity, without the need for insulin to get the sugar into the muscle cells (scientists call this "non-insulin mediated glucose uptake"). However, some insulin in the blood stream is still needed so that your liver does not release too much glucose into the blood stream and so that your body does not produce ketone bodies, which can make you very sick. If you don't take any insulin on days when you exercise, you will likely develop very high blood sugar levels (severe hyperglycemia) and ketoacidosis. This is dangerous and will definitely impair your exercise performance.

KEY POINT

Your body needs less insulin when you exercise, but you still need some!

WHAT IF THE EXERCISE WAS UNANTICIPATED AND I CAN'T LOWER MY INSULIN LEVELS? DO I HAVE TO MISS OUT?

If no insulin adjustments have been made in anticipation of exercise, you can still exercise, but you will likely need to consume "extra" carbohydrates without injecting bolus insulin (we call these "Ex Carbs"). Consuming Ex Carbs is particularly important if the exercise is "aerobic" in nature and lasts more than 30 minutes. Aerobic exercise includes cycling, jogging, running, swimming, skiing and most team sports. Basically, aerobic exercise is any activity that causes you to breathe hard and work up a sweat.

Below is a table that can be used to estimate Ex Carbs based on your body mass and the type of activity that you perform. This table is only to be used if you have NOT made insulin adjustments for exercise.

	Body Mass Kg		
	20	40	60
Basketball	23	45	68
Cross-country Skiing	10	21	32
Cycling			
10 km/h	7	11	18
15 km/h	10	18	27
Figure Skating	18	36	54
Ice Hockey	23	45	68
Running			
8 km/h	17	30	41
12 km/h	–	41	55
Snow Shoeing	15	30	45
Soccer	17	32	48
Swimming			
30 m/min breast stroke	14	27	52
Tennis	11	19	28
Walking			
4 km/h	9	12	15
6 km/h	12	15	19

Table 1: Carbohydrate intake recommendations according to body weight and activity performed. Note: Values are the estimated number of grams of carbohydrate to consume for 30 minutes of exercise if the activity is performed during times of peak insulin action and no adjustments in insulin were made.

KEY POINT

Exercise can still be performed even if you have not lowered your insulin. *You just need Ex Carbs!*

General adjustments for aerobic exercise

Every person with diabetes has their own routine and a slightly different approach to managing their diabetes. When planning for exercise, it is important to remember that everyone will respond a little differently to exercise. This means that each individual will need to work on his or her own strategy based on their experiences.

KEY POINT

All forms of activity lasting longer than 30 minutes will typically require adjustments in insulin and/or carbohydrate ingestion (Ex carbs).

THE ONE GRAM CARB PER KILO PER HOUR RULE

Based on some experimental evidence (1), the general rule is that for aerobic exercise of moderate to vigorous intensity, about 1 gram of carbohydrate is utilized per kilogram of body mass per hour. If no adjustment in insulin is performed, one can simply ingest Ex Carbs at a rate of about 1g/kg body mass/hour or use the table of specific Ex Carbs for certain activities. So, for example, if you weigh 40kg, then you would consume 40 grams of Ex Carbs (typically a fast acting carb) over a 60 minute exercise bout using the one gram rule. The Ex Carb table differs a little from the one gram rule, since not all activities have the same level of carbohydrate utilization. Either way, it is best to spread that Ex Carb over the full duration of exercise. The first portion of the Ex Carb should be consumed 20 minutes before the exercise starts and then the remaining portions consumed at 20 minute intervals (e.g. 10g at 20 minutes before exercise, 10 grams at the start of exercise, 10 grams at 20 minutes of exercise and then 10 grams at 40 minutes exercise).

KEY POINT

Some form of rapidly absorbed glucose (e.g. dextrose tabs) should be carried at all times when exercising.

Carbohydrate is the main fuel for exercise. The type of carbohydrate to consume for Ex Carbs is a fast-acting one (dextrose, candy, sport beverages, etc.). Long acting carbs are good if they are consumed well before exercise (1 hour) and during very long aerobic exercise events like a marathon. Some other points about carbs and exercise are given below:

- Optimal fluid and carbohydrate absorption occurs with isotonic drinks of 6% simple sugar (e.g. Gatorade).
- Carbonated beverages and/or very sweet drinks can delay gastric absorption, cause stomach upset, and are best avoided
- After exercise, carb and protein intake at a 4:1 ratio helps recovery (e.g. chocolate milk), usually with some insulin administered to maintain good glucose control

BOLUS INSULIN ADJUSTMENTS: Sometimes you might not want to always consume Ex Carbs and may wish to lower your insulin levels (this helps with weight loss!). An alternative approach to Ex Carbs is based on reducing the bolus insulin at the meal before exercise. Based on experimental evidence (2), the reduction in pre meal insulin dose should be between 25-75%, depending on the duration and intensity of exercise. The following table can be used as a guideline on the percent reduction in bolus insulin (for either pump users or those on multiple daily injections).

	Duration of exercise and the recommended percent reduction in bolus insulin at the meal before planed exercise	
Intensity of aerobic exercise	**30 minutes**	**60 minutes**
Mild	25%	50%
Moderate	50%	75%
Heavy	75%	–

Table 2: Percent bolus insulin reductions in the meal before the start of exercise. For example, if you are going to exercise at a heavy intensity for 30 minutes after lunch, then you would take only 25% of your usual insulin dose for the carbohydrates ingested. Note: in this study (2), they did not bother to ask the subjects to exercise for 60 minutes at a heavy intensity. It was probably too hard to do!

INSULIN PUMPS AND BASAL RATE REDUCTIONS: Two key advantages of using an insulin pump are that you can change your basal insulin delivery through-out the day and you can do a temp basal for exercise. Temp basal rates should start 90 minutes BEFORE the start of exercise and should last the duration of the activity. Typically, longer duration activities (>60 minutes) at a heavy intensity require that basal insulin levels be dropped to 20%-40% of normal (80-60% reductions, respectively). Milder forms of exercise typically require less of a reduction in basal insulin delivery (i.e. 90%-50% of normal or 10-50% reductions, respectively).

IF YOU ARE ALWAYS ACTIVE, THEN DO YOU NEED TO MAKE SUCH DRAMATIC REDUCTIONS IN INSULIN (OR EAT THAT MUCH EX CARBS) EVERY DAY?

Regular conditioning in a particular sport may result in less reliance on blood sugar as fuel. As such, you may not need to lower you insulin levels as aggressively every time you anticipate exercise if you are used to that kind of activity. Moreover, if you are already a very active individual (exercising every day), then you are already probably on less insulin than if you were inactive.

As such, you probably already have incorporated these reductions in daily insulin dose and may find that such insulin reductions proposed in the table above are too aggressive.

HOW LONG DOES THE EXERCISE EFFECT LAST? AND WHEN SHOULD I EXPECT A POST EXERCISE LOW?

Insulin sensitivity remains elevated for up to 24 hours post exercise with peak insulin sensitivity occurring 7-11 hours after exercise[3]. This is the time to be particularly vigilant about preventing hypoglycemia.

The lowest blood glucose typically recorded during night time sleep is at about 3AM, so setting a testing alarm might be a good idea if the daily activity was especially vigorous.

IS IT IMPORTANT TO "MONITOR" MY BLOOD GLUCOSE DURING EXERCISE, OR CAN I JUST RELY ON MY SYMPTOMS?

We often hear the following "I don't need to test my blood when I exercise, because I feel my lows and highs." This may not be true. In fact, we don't think you can feel your highs and lows as well when you are exercising. In fact, exercise can often mask the symptoms of both hypo- and hyperglycemia. In one study conducted in adolescents with type 1 diabetes, it was found that adolescent boys with type 1 tended to underestimate their blood sugar when it was high and overestimate it when it was low (4). This means that you might be hypoglycemic or hyperglycemic during exercise even though you think your blood sugar is perfectly fine.

DOES BLOOD SUGAR AFFECT PERFORMANCE?

In another study in adolescents with type 1 diabetes, it was found that sport performance was best when blood sugar levels were near normal (5-7 mM)[5]. Sport performance decreased dramatically if blood sugar levels dropped below 4mM. Testing is the only way to be sure that you are in a safe range and that your performance will be maximal. Continuous glucose monitoring (CGM) and a low glucose suspend insulin pump system is of great value for active persons with type 1 diabetes since it can help prevent lows and reduce the risk of nocturnal hypoglycemia[6].

KEY POINT

Since the blood glucose response to exercise varies from person to person and from sport to sport, frequent blood glucose monitoring is the key to success!

Monitoring BG is a key component to successfully combining athletics and diabetes. Measuring before, every 30 min during and for several hours after, as well as at bedtime is the minimum required to gain the needed information to learn what your individual responses are. As mentioned, our typical symptoms of low blood sugar (sweaty, racing heart rate, exhaustion, disorientation) mimic what it is like to exercise vigorously. So you can't rely on symptoms or ignore them. You need to test!

It is helpful if careful notes are kept of: timing of exercise, intensity of activity, insulin used, carbohydrates ingested.

EXERCISE AND INSULIN PUMPS

The following are examples of basal reductions that can be done to compliment your exercise schedule if you are on an insulin pump:

- Reduce basal insulin by 20-90% about 60-90 minutes BEFORE the start of exercise (that lasts 60-120 minutes) until immediately at the end of exercise. The higher the intensity of aerobic exercise, the greater the reduction. In addition, if you are not going to snack during the activity, the greater the reduction.
- The greater the reduction in basal insulin, the lower the risk of hypoglycemia but the greater the risk for hyperglycemia.
- With day-long activities: reduce basal insulin for the day by 20-50% and by 20% for the night before and/or the night after the day of activity, but make

sure that you snack without taking bolus insulin if glucose is in range or a little low.

- Reduce bolus insulin for any meal within 2 hours of exercise by 25%-75%, depending on the intensity and duration of the activity as shown in table 2.

To get a significant lowering of insulin in the circulation for exercise, the pump should be disconnected ~60-90 minutes before the activity. If disconnecting a pump for exercise or contact sports for 1-2 hours: 50% of the missed basal dose may be injected as a bolus after reconnection if your blood sugar is too high.

KEY POINT

Prolonged pump disconnect increases the risk of hyperglycemia and ketone production. Reconnecting and infusing some insulin every hour helps minimize the risk for hyperglycemia.

EXERCISE AND MULTIPLE DAILY INJECTIONS (MDI)

If exercising for the entire day (such as in a summer sports camp), reduce your long acting morning insulin by 20%-50%. If you will be exercising the next day, or if you experienced hypoglycemia, or if the exercise was particularly strenuous, consider reducing evening basal insulin by 20% as well.

Reduce any bolus insulin dose within 2 hours of exercise by 25%-75%, depending on the intensity and duration of the activity as shown in the table above.

For both insulin pumps and MDI, if you choose not to lower your insulin for exercise you probably will need to increase your carbohydrate intake before, during and after the activity, as shown in Table 1 or according to the one gram rule described earlier.

WHY IS HYPOGLYCEMIA SO COMMON WITH AEROBIC EXERCISE?

When you exercise, insulin sensitivity is dramatically enhanced. In fact, if you have ever injected insulin and found that it is not lowering your glucose level fast enough simply go for a brisk walk and watch it drop! Exercising for just one hour increases insulin sensitivity for hours and leads to increased risk of hypoglycemia for up to 24 hours. Hypoglycemia is often masked during exercise as the signs of increased heart rate, sweating, hungriness, or unsteadiness mirror those of exercise fatigue. Frequent BG checking is important to avoid hypoglycemia.

KEY POINT

If hypoglycemia occurs during exercise: stop exercising and take 20 – 30 grams of fast-acting carbohydrate. Wait for 15 mins and retest.

BEDTIME PREPARATIONS POST EXERCISE. After exercise, hypoglycemia often occurs during night time sleep. At the very least, measure BG levels over the evening every few hours and at bedtime. For improved safety, wearing CGM can help by providing alerts and alarms for hypoglycemia and a low glucose suspend pump can minimize nocturnal hypoglycemia[7]. Help reduce hypoglycemia risk by consuming a bedtime snack of complex carbohydrates mixed with a little fat and protein (such as a sandwich) or consume a low glycemic snack like a Glucerna bar. Alternatively, reduce your bedtime basal insulin, if possible, as discussed earlier.

HYPERGLYCEMIA AND EXERCISE

WHY DOES MY BLOOD SUGAR TEND TO RISE WITH SOME FORMS OF EXERCISE? In some situations of competition stress or during brief and intense anaerobic exercise (sprinting, weightlifting), an adrenalin surge can cause hyperglycemia. Usually, this can be treated in recovery with a small amount of insulin (such as a 50% bolus correction factor).

Participating in sports with high BG levels, greater than 20mmol/l, and ketonuria (small or more) can lead to even greater elevations in BG. You may exercise if you are hyperglycemic (e.g. blood sugar or ~17-20 mM) but do not have elevated ketone production. The only way to know if you have elevated ketones is to test your blood with a ketone meter (e.g. the Precision Xtra® from Abbott Diabetes Care). If ketones are elevated in the blood or if blood glucose is very high (>20 mM), do not exercise and treat according to what is recommended by your health care team.

REFERENCES:

1. Riddell MC, Bar-Or O, Ayub BV, Calvert RE, Heigenhauser GJ. Glucose ingestion matched with total carbohydrate utilization attenuates hypoglycemia during exercise in adolescents with IDDM. Int J Sport Nutr. 1999 Mar;9(1):24-34.

2. Rabasa-Lhoret R, Bourque J, Ducros F and Chiasson JL. Guidelines for premeal insulin dose reduction for postprandial exercise of different intensities and durations in type 1 diabetic subjects treated intensively with a basal-bolus insulin regimen (ultralente-lispro). Diabetes Care. 2001 Apr;24(4):625-30..

3. McMahon SK, Ferreira LD, Ratnam N, Davey RJ, Youngs LM, Davis EA, Fournier PA, Jones TW. Glucose requirements to maintain euglycemia after moderate-intensity afternoon exercise in adolescents with type 1 diabetes are increased in a biphasic manner. J Clin Endocrinol Metab. 2007 Mar;92(3):963-8.

4. Riddell MC and Bar-Or O. Children and adolescents. In: Handbook of Exercise in Diabetes, edited by Ruderman NB, Devlin JT, Schneider S and Kriska A. Alexandra, VA: American Diabetes Association, 2002, p. 547-566.

5. Kelly D, Hamilton JK, Riddell MC. Blood glucose levels and performance in a sports camp for adolescents with type 1 diabetes mellitus: a field study. Int J Pediatr. 2010;2010. doi:pii: 216167. 10.1155/2010/216167. Epub 2010 Aug 2.

6. Riddell M and Perkins BA. Exercise and Glucose Metabolism in Persons with Diabetes Mellitus: Perspectives on the Role for Continuous Glucose Monitoring. J Diabetes Sci Technol. 2009 July; 3(4): 914–923.

7. Bergenstal RM, Klonoff DC, Garg SK, Bode BW, Meredith M, Slover RH, Ahmann AJ, Welsh JB, Lee SW, Kaufman FR; ASPIRE In-Home Study Group. Threshold-based insulin-pump interruption for reduction of hypoglycemia. *N Engl J Med.* 2013 Jul 18;369(3):224-32.