Pump Adjustment for Exercise

How to fine-tune your pump's insulin doses when active.

Insulin pumps use a single type of insulin that meets the individual's basal and bolus needs. Every few milliseconds, an insulin pump delivers micro-bolus doses of a rapid-acting insulin analog that take effect quickly and disappear fast. As a result, you can make fairly rapid changes in your circulating insulin concentrations by changing either the basal insulin dosing or by giving an extra bolus dose.

BASAL INSULIN ADJUSTMENTS

For athletes with diabetes, control of basal insulin dosing using an insulin pump is very helpful in ensuring blood sugar stability for training and competition. For instance, during aerobic exercise, a pump allows you to decrease insulin delivery so your liver can produce glucose at the same rate as your muscles are consuming it. During early recovery after exercise, a pump allows insulin levels to rise back toward normal to help keep glucose in control and restore muscle and liver glycogen when food is consumed.

A pump also allows for temporary basal rate reductions in late recovery after exercise when the risk of post-exercise hypoglycemia is high. The advantage of the pump is that you can customize your basal insulin to suit your individual needs, plus make 'temp' basal settings for things like exercise, recovery from exercise overnight, illness and snacking.

Pumping affords athletes the freedom to exercise at any time of day by adjusting their basal (or bolus) insulin accordingly. With a pump, you can help prevent low blood glucose while sleeping by programming the basal insulin level to drop by approximately 20 percent for a period of six hours starting at bedtime. To do this, a temp basal can be set at bedtime (for 6 hours), or a new pattern basal can be made and saved for use on the evenings after exercise.

REDUCING BASAL INSULIN INFUSION DURING EXERCISE

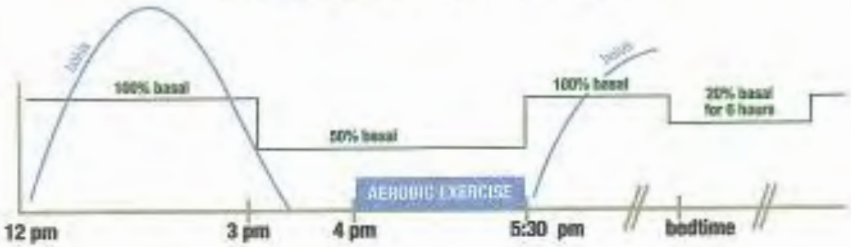
The degree by which you should reduce your basal insulin infusion rate depends on the type of exercise you're doing, plus the duration and intensity of your activity. Here are some tips and guidelines to help get started:

- **Moderate to heavy intensity activities:** If you engage in running, cycling, climbing or similar individual and / or team sports that last more than one hour, reduce your basal insulin levels by 50 to 90 percent (i.e., a temporary basal set between 50 and 10 percent of the usual basal rate). You can cancel this temp basal rate at the end of exercise or in early recovery, depending on your own personal response.
- **Remember to commence the reduced basal rate about 60 to 90 minutes before the start of your planned exercise**, since your pump's last micro-bolus is still peaking an hour later. An example of a basal rate reduction for aerobic exercise is shown in the diagram below.

This diagram provides additional information on how to manage basal insulin adjustments:

ADJUSTING BASAL INSULIN FOR AEROBIC EXERCISE

(90 minutes, between 4:00 p.m. and 5:30 p.m.)



1. Begin with a 50 percent basal rate reduction at 3 p.m. (one hour before exercise begins).
2. Do not reduce your lunchtime bolus insulin since your aerobic exercise takes place more than three hours after lunch; its impact will have largely disappeared by the start of exercise at 4 p.m.
3. Have a good recovery meal with a reduced insulin bolus in early recovery.
4. At bedtime, reduce basal insulin by 20 percent for six hours to help prevent a nighttime low.

Pump Adjustment for Exercise

Other tips for adjusting basal insulin with aerobic exercise:

- For *mild-to-moderate aerobic exercise*: Try reducing your basal rate by about 50 percent. Some people find that they need a complete insulin suspension for mild exercise and the results are highly variable.
- For *high-intensity aerobic exercise*: Reduce your basal rate by 75 to 100 percent (in other words, infuse at 0 to 25 percent of your regular rate). If you drop your basal rate to zero, check your glucose every 30 minutes (ideally by wearing a CGM). As well, make sure to add some basal insulin after about an hour of exercise if your blood sugar begins to rise.
- For *all-day activities*: When you participate in an activity like a soccer tournament, marathon race or ultra-long distance cycling, it's important to maintain some basal insulin, eat carbohydrates and infuse some bolus insulin in order to prevent excessive ketone production.
- *Remember to stay hydrated*: A six percent carbohydrate-electrolyte sport beverage will maintain hydration while delivering essential electrolytes and carbs.
- *Snacking:* Even after making basal insulin adjustments, snacking on carbohydrates without insulin may still be needed to prevent hypoglycemia.

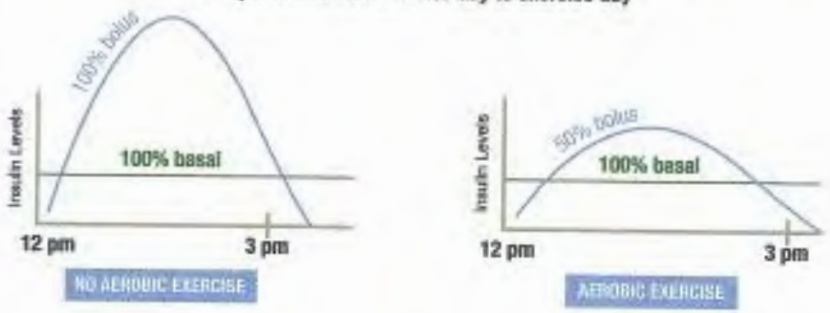
BOLUS INSULIN ADJUSTMENTS

In addition to adjusting basal insulin for exercise, athletes also need to consider adjustments to their bolus insulin dosing.

If you plan to begin prolonged aerobic exercise soon after a bolus and a meal, you usually need to reduce the amount of insulin administered at the meal before exercise. That's because your insulin-to-carb ratio (ICR) is based on the amount of insulin needed – in your resting state – to dispose of a certain quantity of carbs into your muscles, liver and fat tissue.

ADJUSTING BOLUS INSULIN FOR AEROBIC EXERCISE

Comparison of non-exercise day to exercise day



Compared to the resting state, exercise causes glucose to be taken up into muscle tissue very rapidly, with less need for insulin. Therefore, you need less insulin to take up carbs when you exercise compared to when you rest. This reduction in circulating insulin allows your body to release glucose from the liver to help keep blood glucose stable.

When exercising after a meal, your ICR usually needs to decrease (less insulin for a given amount of carbs). This can be a bit confusing, since some people say that ICR increases with exercise (meaning that they need more carbs for a given amount of insulin). In fact, they are talking about the reciprocal carb-to-insulin relationship, which means the same thing. Instead of changing the ICR settings on your pump settings for exercise, it's easier to simply remember to lower the amount of insulin to be delivered by a certain percentage once the pump provides its recommendation on how much insulin to take. (For example, if your pump recommends four units of insulin for a meal, you can manually lower the amount to two units if you are going to exercise for about 30 minutes at a moderate intensity soon after the meal.) This is effectively reducing your ICR by 50 percent.

The percentage reduction in bolus insulin prior to exercise depends on the intensity and duration of the activity. This table presents some general recommendations:

DEGREE OF BOLUS INSULIN REDUCTION FOR EXERCISE

AEROBIC EXERCISE	EXERCISE DURATION: 30 Minutes	EXERCISE DURATION: 60 Minutes
Mild Aerobic Exercise	25% Bolus Reduction	50% Bolus Reduction
Moderate Aerobic Exercise	50% Bolus Reduction	75% Bolus Reduction
Heavy Aerobic Exercise	75% Bolus Reduction	75% Bolus Reduction

Example: If your resting ICR is 1:8 and you eat 40 grams of carbs, then your pump will advise you to take 5 units of insulin. But if you are going to exercise at a mild intensity for 30 minutes within two to three hours of that meal, you should lower your bolus insulin dose by 25 percent (i.e., 3.75 units of insulin for the 40 grams of carbs).

Over time, as your body becomes more used to exercise, it will likely consume fuels differently. (You tend to get better at burning fat as a fuel.) Consequently, you may require smaller adjustments to your basal and bolus insulin levels; you may have already made some of these daily adjustments through trial-and-error experimentation.

Even with insulin reductions, some additional carbohydrate may still

be needed during prolonged activities to help provide fuel and prevent hypoglycemia.

RECOMMENDATIONS FOR RECREATIONAL ATHLETES

In people without T1D, aerobic exercise lowers circulating insulin levels. For people with T1D, the best way to *mimic* this result is to lower basal or mealtime bolus insulin levels. The amount and type (basal or bolus) of insulin reduction depends on the timing, duration and intensity of the exercise. Since your body needs some insulin during exercise to prevent ketones and to control glucose production by the liver, it is not advisable to remove your pump for longer than 90 minutes. Recreational athletes can use the table above for insulin dose reductions for exercise after meals. Or they can use ExCarbs without changes to insulin levels. ExCarbs are described in Chapter 2.

RECOMMENDATIONS FOR ELITE ATHLETES

Top athletes who train regularly get accustomed to exercise. That is, they often require much less total daily insulin than non-athletes. Athletes also need a great deal more calories to maintain a healthy body weight since they typically burn more daily calories. (For instance, former Olympic rower Chris Jarvis would eat over 400 grams of carbohydrate each day when he was training for Team Canada and still takes less insulin than an average person eating just 200 grams of carbs per day.)

Since they consume less insulin, elite athletes tend to change their basal or bolus insulin patterns less drastically than recreational athletes. While they work at keeping their glucose in a very tight range (between 6 and 8 mmol/L) to maximize their performance, elite athletes still need to fine-tune their insulin levels and take snacks as needed, which is where pumps and CGM are useful.

When recovering after exercise, top athletes closely manage glucose levels by taking enough insulin and by consuming carbs and protein in a 4:1 ratio.

In addition to fine-tuning glucose levels during exercise, top athletes also closely manage their glucose levels during recovery after exercise. The goal is to help get fuel and nutrients back into their muscles and liver to maximize muscle repair and recovery. This is best accomplished by consuming carbohydrates and protein in a 4:1 ratio, along with taking enough insulin to maintain glucose control.

6 In This Chapter

Five Insights for Pump Users who Exercise

There are no 'one-size-fits-all' guidelines for active individuals who use an insulin pump.

People with T1D who are physically active need to be aware of a number of factors when they plan for and conduct their exercise. The following five sections present some key considerations:

DIFFERENT TYPES OF EXERCISE AFFECT GLUCOSE LEVELS DIFFERENTLY

Since individuals with T1D perform various types of exercise, each using different combinations of fuel, our blood glucose levels can respond in a variety of ways. For example:

- Purely aerobic activities (e.g., brisk walking and cycling) often lead to a drop in glucose levels
- Purely anaerobic activities (e.g., sprinting) often cause a rise in glucose levels.
- Activities that are both aerobic and anaerobic (e.g., team and field sports, high intensity interval training) are typically associated with a smaller drop in blood sugar levels than purely aerobic activities.
- Resistance exercise (e.g., weight lifting, muscle building) is associated with better blood glucose stability than aerobic activities or sprint-based activities.

TRAINING AND COMPETING ARE NOT THE SAME

Even if the intensity and duration of the activity are similar, competition can promote a different blood glucose response than training.
This is because competition for most athletes is associated with heightened stress hormones (adrenaline, noradrenaline and cortisol), which can reduce glucose disposal into muscle and increase glucose production by the liver. As a result, glucose levels can rise even before the competition begins. (Swimmer Gary Hall Jr. claims that during a 21-second sprint race at the 2000 Olympics, his blood sugar rose from 7.7 mmol/L to 21.5 mmol/L!)

Glucose levels often rise during anaerobic activities like sprinting.

Here are some ways to address pre-game hyperglycemia:

- Avoid eating too close to the event start time, since this typically increases the likelihood of pre-exercise hyperglycemia and may cause on-board insulin levels to be elevated when the exercise is being performed.
- Use a small correction bolus, or a temporary basal increase, about 60 to 120 minutes before the start of the event.
- Check your pump with CGM to confirm that blood glucose levels are heading in the right direction.
- Start doing a mild aerobic warm-up before the competitive event (e.g. walk around and try to relax as you stay moving).

HIGH BLOOD GLUCOSE MUST BE MANAGED CAUTIOUSLY

Hyperglycemia can occur before, during or after exercise. The causes can include the high intensity of the competition, or the fact that you reduced your basal insulin too much, or that you ate too many carbs. (In my case, it's usually that I eat a lot of food when I'm finished exercising.)

- If your blood glucose is high (>14 mmol/L) before you start exercising, check your blood or urine for ketones. If you test positive for ketones, avoid vigorous activity until your blood glucose drops to a safer range (5-14 mmol/L). If you do not have ketones in your blood or urine and you feel well, it should be fine to exercise at a mild-to-moderate intensity.
- Correcting pre-activity hyperglycemia with a full insulin correction bolus should be avoided since it may increase your risk of having a low during the activity (try a 50% correction).
- Aggressive insulin corrections after exercise can cause late-onset hypoglycemia (which can occur during sleep).
- For exercise in the late afternoon or evening, it may be best to avoid an insulin correction for hyperglycemia, but if you do perform a correction, do it conservatively (e.g., 50 percent of your usual correction dose).
- Once again, wearing CGM and/or a sensor-augmented pump should reduce the risk if a conservative insulin correction is performed.

It may be best to avoid an insulin correction if you exercise in the evening.

Five Insights for Pump Users who Exercise

Post-exercise hypoglycemia can occur any time after exercise and for up to 24 hours later.

JUST BECAUSE THE EXERCISE IS OVER, IT DOESN'T MEAN THE RISK OF HYPOGLYCEMIA IS GONE

Most of the time, we can handle low blood sugars during exercise by stopping and having a fast-acting carbohydrate snack (e.g. 15-20 grams of dextrose). We can also improve our pre-exercise prevention strategies for next time, such as by more aggressively reducing our insulin infusions or ingesting more carbs. But one challenge that remains frustrating for most of us is trying to predict a post-exercise low. Post-exercise hypoglycemia can occur any time after exercise and for up to 24 hours later. To help guard against post-exercise hypoglycemia, monitor glucose using CGM and set low glucose alarms at a slightly higher threshold (e.g., 4.9 mmol/L versus than 3.9 mmol/L) if you have already been exposed to a recent low. At bedtime, setting a six-hour, 20 percent basal reduction (i.e., 80 percent of your usual rate) can also help prevent post-exercise nighttime hypoglycemia.

EXERCISE FOR WEIGHT LOSS MAY BE CHALLENGING WITH T1D

More and more people with T1D are struggling to lose weight and to keep it off. This may be because weight gain is a potential side effect of intensive insulin therapy. In addition, because exercise can decrease blood glucose levels and create the need for snacking on carbohydrates, people with T1D may find it difficult to lose weight when they begin an exercise weight-loss routine. The best way to promote gradual weight loss is to gradually lower the insulin-to-carb ratio and basal insulin settings on your insulin pump as you train and become more insulin-sensitive. Wearing a pump with CGM can help monitor glucose control during this transition period. These changes should be discussed with your healthcare provider.

Staying Safe when Exercising

There are many actions you can take to avoid putting your health at risk when you exercise.

TIPS FOR EXERCISING SAFELY

- Always wear diabetes identification (e.g., MedicAlert bracelet).
- Consider a temp basal insulin reduction 60 to 90 minutes before prolonged aerobic exercise.
- Remember to bring all your diabetes supplies (e.g., insulin, meter, extra infusion sets, spare syringes and a ketone meter).
- Monitor your glucose level at least twice before starting to exercise, every 30 minutes during the activity, and within 30 minutes after completing the activity.
- Have fast-acting carbohydrates with you when you exercise, and treat low blood glucose or predictive low blood glucose alerts with 15 to 20 grams of fast-acting carbs (e.g., 4-5 Dex4 tablets, 125mL of fruit juice, 7 or 8 gummies or regular LifeSavers, 1 tablespoon of sugar or jelly).
- Stay properly hydrated (500 to 1000mL of fluid per hour of exercise; note that sports drinks and energy drinks range markedly in carbohydrate content – G2 only has 20 grams of carbohydrate per 1000mL, whereas Gatorade® Endurance has 62 grams per 1000mL); drink sugar-free fluids if your glucose levels are elevated.
- For intense exercise sessions lasting longer than 1 hour, consume a drink containing 6 percent carbohydrates to help maintain hydration, prolong endurance and stabilize blood glucose levels.
- Replenish in recovery with a carbohydrate and protein meal or snack, usually taken with an insulin bolus.
- Treat post-exercise hyperglycemia with caution, particularly if near bedtime (i.e., reduce your correction bolus or just continue monitoring).
- Know your glucose level before going to bed, and aim to be above 7.0 mmol/L.

Always wear diabetes identification.

Keep fast-acting carbs handy when you exercise.

Suggested Exercise Strategies

The following series of tables contain suggestions for how you can adjust your food and insulin intake – before, during and after exercise – in order to stabilize your blood glucose level and feel your best.

- Each table in the series contains three differently coloured rows, corresponding to the different types of exercise (anaerobic / resistance; aerobic; and mixed).
- In some cases, the same food or insulin suggestions apply to all three types of exercise.
- There are seven tables in the series, each applying to a different time period relative to when you're exercising.

How to use the tables:

1. Identify which row in the tables matches the type of exercise you're doing.
2. At the start of the first time period (i.e., 3–4 hours before exercising), take a blood glucose reading and record it in the second column of that table (or on a separate sheet with the time period noted).
3. Reading across the row, follow the guidelines for food and insulin intake.
4. At the next time interval (i.e., 1–2 hours before exercising), again record your blood glucose level and follow the food and insulin suggestions.
5. Repeat until you've reached the last of the applicable time periods.

3-4 HOURS BEFORE EXERCISING

Exercise Type	BG Reading	Food	Insulin
ANAEROBIC / RESISTANCE	(PRE-MEAL) BG = _____	**Load up** on protein and carbs well before the activity to boost glycogen levels.	**BOLUS:** Use typical insulin-to-Carb-ratio. **BASAL:** Maintain typical rate.
AEROBIC			
MIXED			

1-2 HOURS BEFORE EXERCISING

Exercise Type	BG Reading	Food	Insulin
ANAEROBIC / RESISTANCE	(2 HOURS POST-MEAL) BG = _____	**Snack only if your BG is trending low, or if you were unable to eat the large meal previously.**	**CORRECTION BOLUS:** Consider a conservative bolus if BG is trending high (e.g., >9.0 mmol/L).* **TEMP BASAL:** May not be needed.
AEROBIC			**CORRECTION BOLUS:** Do not perform bolus unless BG is high (>14 mmol/L with ketones). **TEMP BASAL:** Decrease rate by 50% to 80%.
MIXED			**CORRECTION BOLUS:** Do not perform bolus unless BG is high (>14 mmol/L with ketones). **TEMP BASAL:** Decrease rate by about 50%.

***NOTE:** Using your pump's **bolus calculator** for determining how much insulin to administer with food or as a correction bolus will help prevent **insulin stacking** from prior boluses. However, before, during and after exercise, you should also consider reducing the pump's bolus dose recommendation by 50 to 100 percent to help prevent hypoglycemia.

15-30 MINUTES BEFORE EXERCISING

Exercise Type	BG Reading	Food	Insulin
ANAEROBIC / RESISTANCE	(PRE-EXERCISE) BG = _____	If BG <5.0 mmol/L, treat with 15 g of fast-acting carbs.	**TEMP BASAL:** Maintain any temp basal as set above.
AEROBIC		If BG <8.0 mmol/L, consume 15 g of fast-acting carbs.	
MIXED		If BG <8.0 mmol/L, consume 15 g of fast-acting carbs.	

Suggested Exercise Strategies

DURING EXERCISE

Exercise Type	BG Reading	Food	Insulin
ANAEROBIC / RESISTANCE	(START OF EXERCISE) BG = _____	If activity lasts >30 minutes, consume 15 g to 30 g of carbs per hour of activity.	Wear insulin pump if possible. Initiate a temp basal reduction or suspension if glucose levels drop below 5.0 mmol/L.
AEROBIC		Consume carbs at a rate of 0.5 g per minute of activity.	Wear insulin pump if possible. Continue with decreased basal rate. Suspend insulin if glucose levels drop rapidly on CGM and approach 5.0 mmol/L.
MIXED Perform resistance exercise before aerobic exercise if possible, or use intermittent sprints to help maintain BG.		Consume carbs at a rate of 0.5 g per minute of activity.	• Wear insulin pump if possible. • Continue with decreased basal rate. • Suspend insulin if glucose levels drop rapidly on CGM and approach 5.0 mmol/L.

15 TO 30 MINUTES AFTER EXERCISING

Exercise Type	BG Reading	Food	Insulin
ANAEROBIC / RESISTANCE	(POST-EXERCISE) BG = _____	**SNACK:** small amount of carbs and protein to maximize rate of glycogen storage and help prevent delayed hypoglycemia.	Resume normal basal rates unless hypoglycemic. If hyperglycemic, perform conservative correction bolus.* Follow usual insulin-to-Carb ratio.
AEROBIC			Resume normal basal rates unless hypoglycemic. Reduce bolus insulin by about 25%. If BG >14 mmol/L and you will not be going to bed for another 4 hours, perform conservative correction bolus.*
MIXED			• Resume normal basal rates unless hypoglycemic. • Reduce bolus insulin by about 25%. • If BG >14 mM and you will not be going to bed for another 4 hours, perform conservative correction bolus.*

***NOTE:** Using your pump's **bolus calculator** for determining how much insulin to administer with food or as a correction bolus will help prevent **insulin stacking** from prior boluses. However, before, during and after exercise, you should also consider reducing the pump's bolus dose recommendation by 50 to 100 percent to help prevent hypoglycemia.

Suggested Exercise Strategies

1 TO 2 HOURS AFTER EXERCISING

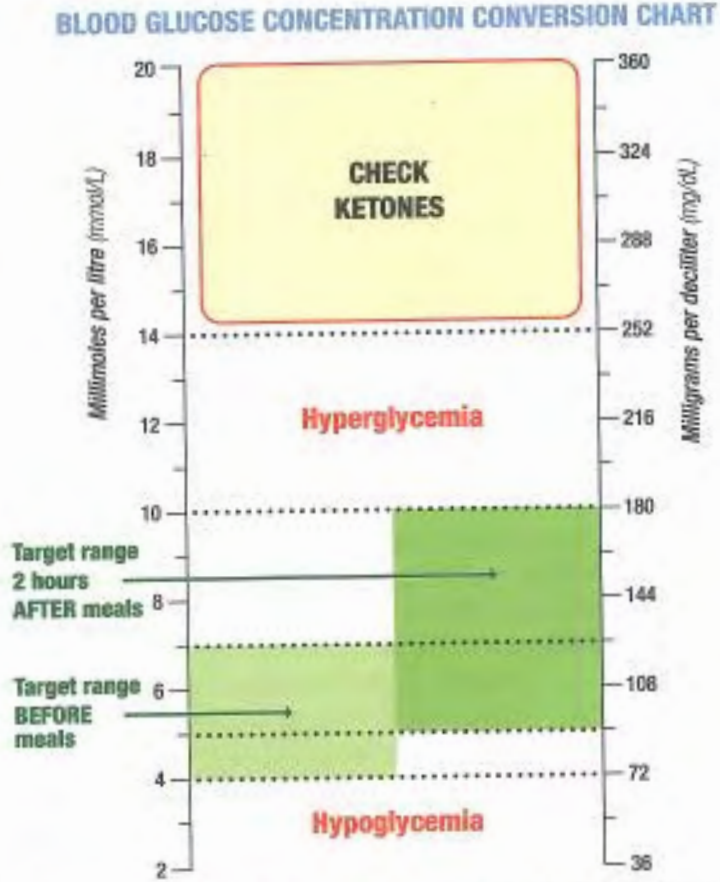
Exercise Type	BG Reading	Food	Insulin
ANAEROBIC / RESISTANCE	(POST-EXERCISE MEAL) BG = _____	**MEAL:** Consume a mixed macronutrient meal (carbs, protein and fat) to replenish glycogen stores in liver and muscles, maintain energy balance and help prevent delayed hypoglycemia.	If hyperglycemic, perform conservative correction bolus.* Follow usual insulin-to-Carb ratio.
AEROBIC			Reduce bolus insulin by about 25%. If hyperglycemic, perform conservative correction bolus.* Follow usual insulin-to-Carb ratio.
MIXED			• Resume normal basal rates unless hypoglycemic. • Reduce bolus insulin by about 25%. • If BG > 14 mmol/L and you will not be going to bed for another 4 hours, perform conservative correction bolus.*

***NOTE:** Using your pump's **bolus calculator** for determining how much insulin to administer with food or as a correction bolus will help prevent **insulin stacking** from prior boluses. However, before, during and after exercise, you should also consider reducing the pump's bolus dose recommendation by 50 to 100 percent to help prevent hypoglycemia.

BEFORE BED

Exercise Type	BG Reading	Food & Insulin
ANAEROBIC / RESISTANCE	(BEFORE BED) BG = _____	**SMALL SNACK:** Consume carbs (10 to 15 g), protein (6 to 8 g) and fat (10 to 15 g) to continue replenishing glycogen stores and help prevent overnight hypoglycemia. **INSULIN:** Do not infuse insulin for the snack. — OR — **INSULIN:** Infuse temp basal at 80% of regular dose (i.e., a 20% basal rate reduction) to help prevent overnight hypoglycemia.
AEROBIC		
MIXED		

Blood Glucose Concentration Conversion Chart



In Canada, blood glucose is measured in mmol/L. In the United States and other places around the world, blood glucose is measured in mg/dL. The difference between the two scales is a factor of 18.

According to the Canadian Diabetes Associations (CDA) Clinical Practice Guidelines, the blood glucose target range for people with diabetes should be 4.0 to 7.0 mmol/L (72 to 126 mg/dL) before meals, and from 5.0 to 10.0 mmol/L (90 to 180 mg/dL) two hours after meals. The guidelines also state that blood glucose targets should be individualized based on age, duration of diabetes, risk of severe hypoglycemia, presence or absence of cardiovascular disease, and life expectancy. Persons with T1D should discuss their blood glucose target ranges with their healthcare provider.

Source: Canadian Diabetes Association Clinical Practice Guidelines Expert Committee. Canadian Diabetes Association 2013 Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada.Can J Diabetes 2013; 37(suppl 1): S1-S212.