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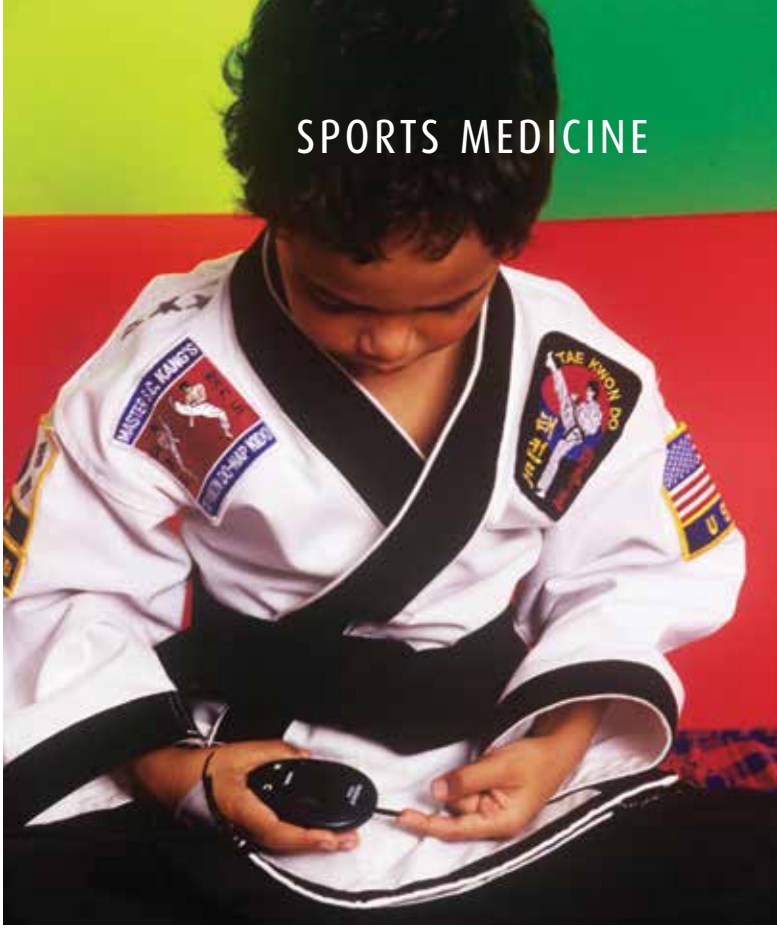

# Type 1 diabetes and exercise

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**Children and adults with type 1 diabetes experience a range of benefits from regular exercise. Careful planning is required in order to minimise the risks, particularly for elite athletes and for all athletes who participate in endurance sports.**

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Regular exercise reduces cardiovascular risk and mortality in people with type 1 diabetes,[1] but the fear of hypoglycaemia deters many from physical activity. To ensure that exercise is safe, careful planning of insulin dosing and carbohydrate intake and regular monitoring of blood glucose level (BGL) are important for these individuals. This review provides practical advice for clinicians who prescribe exercise to people with type 1 diabetes, and covers specific issues that are relevant to athletes performing at an elite level.

## EXERCISE CAPACITY

Studies evaluating aerobic fitness in children and adults with type 1 diabetes have reported mixed results. However, most studies describe comparable levels of aerobic fitness in people with uncomplicated type 1 diabetes compared with healthy peers.[2,3]

## EFFECTS OF TYPE 1 DIABETES ON EXERCISE

Although the cardiorespiratory responses to exercise in individuals with uncomplicated type 1 diabetes are unimpaired compared with healthy peers, the metabolic responses differ. Administration of exogenous insulin does not allow the same flexibility of metabolic response as occurs in the absence of diabetes. Endurance exercise of moderate intensity is usually associated with a lowering of BGL in people with type 1 diabetes, and the resultant hypoglycaemia can impair endurance performance.

## EFFECTS OF EXERCISE ON TYPE 1 DIABETES

The short-term effects of exercise on BGL have been widely studied and differ according to the duration, intensity and type of exercise involved. Prolonged aerobic exercise of mild to moderate intensity

will generally result in a lowering of BGL whereas short bouts of high intensity exercise are more likely to increase BGL.[4,5]

In a person without diabetes, the insulin level decreases with the onset of exercise and there is a concomitant decrease in the ratio of liver insulin to glucagon. This results in increased hepatic glucose production that matches utilisation, thus maintaining euglycaemia. In a person with type 1 diabetes, the insulin level does not decrease with the onset of exercise and the glucagon level is stable. This means that hepatic glucose production does not keep pace with glucose utilisation, resulting in hypoglycaemia.

Endurance exercise also increases the risk of late hypoglycaemia. This may occur many hours after a bout of endurance exercise. The mechanism for this late hypoglycaemia, at least in type 2 diabetes, is the translocation of surface GLUT4 transporters in skeletal muscle following exercise, which results in an increase in cellular glucose uptake.[6]

In contrast to endurance exercise, high intensity exercise of short duration can increase BGL in people with type 1 diabetes. Release of catecholamines in response to intense exercise results in an increase in glucose production that may outstrip the rate of utilisation, resulting in hyperglycaemia. High intensity interval training of short duration can be utilised at the end of a longer moderate intensity training session to counteract the trend to hypoglycaemia.[7]

## BENEFITS OF EXERCISE

Children and adults with type 1 diabetes experience the same benefits from exercise as their peers without diabetes – namely, improved fitness and strength and decreased risk of cardiovascular and malignant disease.[8-12] There are other benefits that are particularly important for people with type 1 diabetes, including reduced insulin requirements, improved strength and bone mineral density (BMD), decreased blood pressure, improved lipid profile and improved survival.[1]

Minimising the risk of diabetic complications depends on good glycaemic control. Although there is no evidence that aerobic exercise improves glycaemic control in type 1 diabetes,[13] there is emerging evidence that resistance (strength) training may improve glycaemic control and should be a component of the exercise program unless contraindicated due to hypertension or proliferative retinopathy. Resistance training has been shown to lower $HbA_{1c}$ levels in type 1 diabetes.[14] Following a single bout of resistance training there is a less marked but more prolonged period of BGL lowering than after aerobic exercise of similar duration.[15]

## RISKS OF EXERCISE

The main risk of exercise for people with type 1 diabetes is hypoglycaemia, which can occur during, immediately after or many hours after exercise. The signs and symptoms of hypoglycaemia can be difficult to recognise during exercise because they are similar to those of exhaustion and hyperthermia.

Hyperglycaemia is another risk of exercise, and most commonly occurs following high intensity exercise of short duration. The risk of hyperglycaemia during and after exercise is also increased in those using an insulin pump (continuous subcutaneous insulin infusion [CSII] therapy) who suspend their insulin infusion during exercise for any prolonged period.

Other risks of exercise include myocardial ischaemia in patients with coronary artery disease, exacerbation of proliferative diabetic retinopathy (especially with resistance or high intensity exercise) and lower limb injury in people with peripheral neuropathy participating in high impact activities.

## PRE-EXERCISE ASSESSMENT

A full medical evaluation should be undertaken for adults who have diabetes complications (e.g. diabetic retinopathy, peripheral neuropathy, severe autonomic neuropathy or coronary artery disease) before they embark on an exercise program. This should include a careful history and physical examination, with a thorough eye and foot evaluation. Routine screening for coronary artery disease is no longer recommended for asymptomatic patients with diabetes because there is a lack of evidence to support this approach.[16]

The pre-participation medical evaluation provides a good opportunity to remind children and adults with type 1 diabetes of the effects of different types of exercise on BGLs and of the need to adjust insulin doses and carbohydrate intake accordingly.

## PRESCRIBING EXERCISE IN TYPE 1 DIABETES

Participation in regular exercise, particularly endurance exercise, requires careful planning in the person with type 1 diabetes. Pre- and post-exercise insulin doses usually need to be reduced and glucose snacks need to be readily accessible for preventing and managing hypoglycaemia. As BGL responses to exercise vary between individuals and are dependent on the nature, duration and intensity of exercise sessions, changes in insulin dosing and carbohydrate intake are best determined by trial and error based on BGL responses to different exercise settings.

### How much exercise and at what intensity?

The current exercise recommendation for people with uncomplicated type 1 diabetes is 150 minutes of moderate intensity aerobic activity (50 to 70% maximum heart rate) per week spread over at least three days, plus at least two sessions of resistance training per week in those without contraindications.[17]

### Monitoring BGL

BGL should be checked prior to exercise to determine whether or not additional carbohydrate is required. If BGL is less than 5.6 mmol/L, additional carbohydrate should be ingested prior to commencing exercise, with the amount being dependent on the duration and intensity of the exercise planned. In previous guidelines, exercise was contraindicated if BGL was over 16.7 mmol/L but this has been amended and the latest guidelines state that there is no need for a person to postpone exercise due to an elevated BGL provided that he or she feels well and there are no ketones in the urine.[17]

### Adjusting carbohydrate intake and insulin dosing

Fear of hypoglycaemia is the greatest barrier to exercise in people with type 1 diabetes.[18] Strategies that can help prevent hypoglycaemia include the following.

- For people using multiple daily insulin injections, reducing the pre- and post-exercise insulin boluses. For people using CSII, the basal infusion rate should be decreased during exercise or suspended if the exercise is to last less than two hours.
- Ingesting carbohydrate snacks during exercise. Sports drinks can be used for this purpose. In general, for exercise of more than 30 minutes duration, carbohydrate should be replaced at the rate of 0.5 to 1 g/kg/hour, depending on the intensity of the exercise.[19] This equates to approximately 500 mL of a sports drink, six jelly beans, two muesli bars or two bananas for a 60 kg person exercising at a moderate intensity.
- Performing a short burst of intense physical activity before or immediately after an exercise session.

Continuous glucose monitoring has been associated with reduced risk of hypoglycaemia but it is not currently in widespread use.

### Using insulin pumps during exercise

CSII offers greater flexibility for people with diabetes who are physically active and is associated with a lower risk of late hyperglycaemia and hypoglycaemia following exercise than multiple daily injections of insulin.[20] It also enables more spontaneous exercise because basal insulin infusions can be reduced or suspended before and during exercise (whereas people using multiple daily injections of insulin may have to delay exercise or use carbohydrate supplementation if the usual bolus has already been given).

There are, however, practical difficulties associated with CSII in certain sports. Most insulin pumps need to be removed and suspended for swimming and contact sports. Also, suspending CSII for more than two hours during exercise increases the risk of diabetic ketoacidosis.

## ELITE SPORTS PARTICIPATION

Perhaps the most challenging activity for the diabetic athlete is endurance sport. Maintaining optimal glycaemic control for long duration physical activity requires close monitoring and intervention. Type 1 diabetes does not preclude elite sports participation, and athletes with type 1 diabetes have reached the highest level of international competition in a variety of sports. However, meticulous planning is required for good glycaemic control for diabetic athletes. Particular issues to consider include travelling with teams, therapeutic use exemption in elite sport, multiple training sessions throughout the day, and changing schedules.

### Team travel

Travelling with sports teams requires careful planning. Athletes with diabetes need to notify airport security that they are carrying insulin needles (and pumps if applicable). They should travel with both short- and long-acting insulin cartridges even if they use an insulin pump (because the pump may fail and replacement parts are not readily available in many countries). Athletes should also travel with glucose snacks at all times.

The American Diabetes Association has useful additional information regarding air travel on its website (www.diabetes.org/living-with-diabetes/know-your-rights/discrimination/public-accommodations/air-travel-and-diabetes/what-can-i-bring-with-me.html).

### Therapeutic use exemption

Insulin is a prohibited substance in elite sport and as such requires a therapeutic use exemption (TUE) for athletes with diabetes. For athletes competing at a national level and below, this can be obtained by submitting the relevant medical information to the Australian Sports Drug Medical Advisory Committee (www.asdmac.gov.au/TUE.html). For athletes competing internationally, there is a requirement to apply to their International Sports Federation, unless that Federation accepts local Australian TUEs.

**TYPE 1 DIABETES AND EXERCISE: TAKE-HOME MESSAGES**

- Regular exercise reduces cardiovascular risk and mortality in people with type 1 diabetes.
- There is no strong evidence to suggest aerobic exercise improves glycaemic control in type 1 diabetes.
- A pre-participation medical evaluation prior to commencement of an exercise program is important for people with type 1 diabetes who have diabetes complications so that advice can be given regarding appropriate exercise regimens that minimise risk.
- High-level sports training is possible for people with type 1 diabetes, but it requires planning with regard to insulin dosage and carbohydrate intake to maximise performance and minimise the risk of hypoglycaemia.
- High intensity exercise can result in hyperglycaemia.
- High intensity interval training of short duration can be utilised at the end of a longer moderate intensity training session to counteract the trend to hypoglycaemia.
- CSII allows greater flexibility for people with diabetes who are physically active and is associated with a lower risk of late hypoglycaemia than multiple daily insulin injections.

## CONCLUSION

Regular physical activity is both safe and beneficial for people with type 1 diabetes. It does, however, require careful planning in regard to insulin dosing and carbohydrate intake to minimise the risk of hypoglycaemia. MT

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A list of references is included in the website version (www.medicinetoday.com.au) and the iPad app version of this article.

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