# Diabetes and exercise

## Introduction

Medication, a balanced meal plan and exercise form the basis of the treatment of diabetes.[1] Regular exercise is beneficial to all individuals with diabetes,[2] provided that blood glucose levels are controlled.[1,3]

Individuals with diabetes should consult with their healthcare team before starting an exercise programme,[3-7] to assess individual tolerance, physical or medical condition and diabetic control. The exercise plan should vary depending on interest, age, general health and level of physical fitness.[4,8]

Individuals with type 1 diabetes can participate in all levels of exercise if they have good blood glucose control and no complications.[3] If complications are present, certain precautions need to be taken by most before they can exercise.

Exercise can prevent or delay the onset of type 2 diabetes in persons at risk.[4,5] Individuals with type 2 diabetes are typically overweight and sedentary. Many older individuals with type 2 diabetes develop complications during the course of the disease[9] or have age-related disabilities that limit the viability of exercise.[2] Their exercise plan must make provision for a gradual start, and must take all risk factors into consideration. Long-term adherence is important in lifestyle interventions, especially for exercise.[2]

Given proper guidelines, most individuals with diabetes can exercise safely.[8]

## The benefits of exercise

Exercise can increase glucose utilisation and decrease glucose production from the liver,[4] while helping to improve insulin sensitivity.[1,2,5,8] Exercise as part of a healthy lifestyle assists with weight loss[4,9,10,11] and weight management.[10,12] With energy restriction,[3] exercise can help decrease the percentage of body fat.[1,5] Exercise also reduces associated cardiovascular risk factors,[4,11] improves well-being,[4,8] and enhances quality of life.[10]

Together with diet, exercise therefore improves metabolic outcomes associated with type 2 diabetes, including those related to blood pressure, and blood glucose and lipid levels.[3,4,5,9] Weight loss of 4.5 to 9 kg improves insulin resistance, blood lipid levels and blood pressure.[3] The benefits of regular, long-term exercise for the prevention and treatment of type 2 diabetes are therefore considerable.[3,8,10]

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*S Afr J Diabetes Vasc Dis* 2009; **6**: 8–12.

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## The effect of exercise on the body

Although glucose uptake by muscles increases during exercise, blood glucose levels change little in individuals without diabetes.[8] Exercise causes blood insulin levels to drop while counter-regulatory hormones (glucagon and epinephrine) increase.[8,12] The increased glucose utilisation by the exercising muscle is matched with increased glucose production by the liver. [8]

The balance between insulin and counter-regulatory hormones is the major controller of glucose production by the liver, which emphasises the need for insulin adjustment as well as adequate carbohydrate (CHO) intake during exercise.[8]

### Type 1 diabetes

The glycaemic response to exercise depends on diabetic control,[2] plasma glucose levels[4,5] at the start of exercise, timing of the last injection,[2] peak action of the medication;[5] timing,[5] intensity and duration of exercise;[2,5] timing of previous meal;[2] and previous training.[8]

In individuals who use insulin, the hormonal balance that controls blood glucose is disrupted.[8] Blood glucose levels drop during exercise because injected insulin promotes rapid utilisation of glucose by the exercising muscle,[2,8] and also blocks glucose production by the liver.[2] Insulin should therefore not be injected immediately before exercise, to prevent hypoglycaemia.

On the other hand, hyperglycaemia can develop in poorly controlled individual with diabetes, because of the increased levels of glucose and free fatty acids.[8] Too little insulin limits the uptake of glucose by the cells, resulting in a significant increase in plasma glucose and ketone levels.[8]

### Type 2 diabetes

Blood glucose control improves with exercise, due to decreased insulin resistance[8] and improved insulin sensitivity,[5,8] resulting in increased peripheral use of glucose during and after exercise.[8,13] This exercise-induced enhanced insulin sensitivity[8,12] takes place independently of any change in weight.[8] Exercise also lowers the effects of the counter-regulatory hormones which, in turn, reduce glucose production by the liver.[8] All of this plays a part in improved glucose control.[8]

Regular exercise, furthermore, helps to reduce triglyceride levels and blood pressure.[5,8]

## Potential problems for active individuals with diabetes

### Hypoglycaemia

Exercise-induced hypoglycaemia is a potential risk in individuals taking insulin or insulin secretagogues (sulfonylureas).[4,5,8]

Blood glucose levels before exercise reflect the value at that moment only and do not reveal if it is a stable blood glucose level or one that is dropping.[8] If blood glucose values are dropping before exercise, adding exercise can contribute to hypoglycaemia during exercise.[8] In addition, hypoglycaemia on the day before exercise can increase the risk of hypoglycaemia on the day of exercise.[8]

An important variable is the level of plasma insulin during and after exercise.[8] Insulin causes increased utilisation of glucose by the exercising muscle,[8] resulting in hypoglycaemia. Hypoglycaemia can occur during, immediately after or several hours (up to 36 hours) after exercise.[3,8,14] Hypoglycaemia is more common after exercise, especially long, intensive, strenuous or sporadic exercise, than during exercise.[8] This is due to increased insulin sensitivity after exercise and the replenishment of liver and muscle glycogen, which can take 24 to 30 hours.[8]

A further risk related to hypoglycaemia is impaired temperature regulation, therefore sufficient fluid intake is necessary for optimal performance.[1]

### Hyperglycaemia

It is not necessary to postpone exercise in the case of hyperglycaemia (14 mmol/l) if the individual feels well and urine and/or blood ketones are negative, but vigorous activity should be avoided if ketones are present.[4]

When a person exercises at what for him/her is a high level of exercise intensity[8] or during extremely strenuous exercise,[2] there is a greater-than-normal increase in counter-regulatory hormones.[8] As a result, more glucose is released by the liver than is used by the muscle,[8] raising blood glucose levels which can persist into the post-exercise state.[8] This can occur in individuals with type 1 diabetes even in the presence of insulin.[2]

Hyperglycaemia can also be due to infection, the over-consumption of food or highly concentrated sports drinks (usually fear of the onset of hypoglycaemia), too little insulin, or alcohol consumption (sweet wines, liqueurs or sweetened cold drinks used in mixed drinks).[1,2]

## Medication

Medication, a balanced meal plan and exercise form the basis of treatment for individuals with diabetes.[1] It is therefore recommended that planned exercise form part of diabetes management.

### Type 1 diabetes

With planned exercise, the insulin dosage can be reduced as an alternative strategy to increased CHO intake.[14] Insulin can be reduced in the short term for particularly strenuous exercise or in the longer term in the case of a permanent increase in the daily level of physical activity.[14] Such reductions should be made with care. If exercise is undertaken with too little insulin available, the glucose uptake by the muscles will be reduced and blood glucose control will worsen.[14]

Reductions in insulin should be made when moderate to strenuous exercise is undertaken that lasts 45 to 60 minutes.[8] Most individuals can start with a decrease of one to two units of rapid- or short-acting insulin.[8] Regular, long-term exercise (> 60 minutes) needs an insulin reduction of 15 to 30%.[8,15]

If exercise takes place after a meal, the insulin dosage should be reduced.[8] Exercise at 25% $VO_{2max}$ for 60 minutes requires a 50% reduction in mealtime rapid-acting insulin, while exercise at 50% $VO_{2max}$ for 30 to 60 minutes requires a 50 to 75% reduction in mealtime rapid-acting insulin.[8] Such reduction in mealtime rapid-acting insulin for exercise after a meal has resulted in a 75% decrease in exercise-induced hypoglycaemia.[8]

Individuals should not exercise during periods of peak action of insulin.[1,12] Insulin should be injected in the abdomen[1,2] rather than in the exercising limb.[1,2,12,16] After exercise, insulin may also need to be decreased.[1,8]

Frequent insulin adjustments should be made with insulin pumps to maintain glycaemic control, particularly during exercise of longer duration or higher intensity.[17]

### Type 2 diabetes

Oral hypoglycaemic medication may need adjustment in individuals who exercise regularly. As individuals with type 2 diabetes are typically overweight, it is usually better to reduce the medication than to increase CHO intake. Adjustments will vary according to the type, intensity and duration of exercise.[2]

## Blood glucose and ketone monitoring

Individuals vary in their response to exercise and their glucose control.[2,14] The type, intensity and duration of exercise should be considered when making recommendations regarding the frequency of blood glucose monitoring.[2] Blood glucose should be monitored before and after exercise,[3,9] and in the case of prolonged exercise, it can also be monitored during exercise.[8]

Before exercise, blood glucose levels should ideally be between 4 and 8 mmol/l.[1,14] If they are below 5.6 mmol/l,[4]

extra CHO is needed.[1,14] The amount of CHO taken will depend on blood glucose values, and intensity and duration of the exercise.[14]

If blood glucose levels are above 14 mmol/l, the urine needs to be checked for ketones. Vigorous exercise should be avoided if ketones are present.[1,4]

Response patterns to exercise should be recorded and adjustments made on the basis of individual responses,[8] depending on the intensity, duration and type of exercise, which is often a process of trial and error.[1] Predicting the exact adjustments in diet and insulin becomes easier as an individual becomes more experienced in maintaining blood glucose control.

## Precautions and practical tips for exercise

Medical assessment is recommended before an individual starts with an exercise programme.[3,4,5,6,7] Hypertension, retinopathy and neuropathy need special precautions.[2,4,6-8,13]

In general, the recommended CHO intake before, during and after exercise is the same as for the athletes without diabetes, as long as the individual has good metabolic control.[3]

Individuals with diabetes should train with a partner/trainer who can identify and treat hypoglycaemia appropriately.[2,3] This is very important in activities such as long-distance running and swimming.[2] High glycaemic index (GI) food (CHO that is quickly absorbed) should be readily available at all times.[1,3,12]

The diet for the athlete with diabetes is the same as for those without diabetes.[1] The training diet should include CHO-rich foods with low glycaemic response (CHO that are absorbed slowly).[1] Low-fat foods should be chosen.[1,2] Both low-GI and low-fat foods enhance diabetes control and sports performance.[1,2]

Rather than changing the diet to suit the insulin or medication dosage, medication adjustments must be made according to lifestyle[1] and training schedule.[1,2] Regular training and eating schedules help with good diabetes management.[1] Individuals with diabetes should exercise at the same time every day for easier fine-tuning of insulin dosage and food intake.[1,2] Timing of meals, snacks, insulin dose and predicted peak in relation to the exercise routine have to be taken into account.[1] Blood glucose must be monitored regularly.[1]

CHO loading should only be practised in well-controlled diabetics,[2] but with caution.[1,2] Insulin adaptations should be made to match changes in food intake, as insulin is needed to store muscle glycogen.[1,2]

Adequate fluid intake should be encouraged[12] before and during exercise, as dehydration can negatively affect blood glucose levels and heart function.[4] Water and/or sugar-free squash, cold drinks and sports drinks (if CHO are needed) should be taken during exercise, especially during hot weather.[14]

Some form of diabetes identification, such as a bracelet or necklace, should be worn.[4,7]

## Recommended CHO intakes for individuals with diabetes

Additional CHO before exercise is generally not needed in individuals not using insulin or insulin secretagogues.[8]

Blood glucose levels decline gradually in all individuals during exercise, and consuming a CHO snack during prolonged exercise can maintain the availability and oxidation of blood glucose.[8] The CHO snack can therefore improve performance.[8] In individuals with diabetes, blood glucose levels may drop sooner and lower than in the exerciser without diabetes.[8] It is recommended that CHO be taken after 40 to 60 minutes of exercise, which assists in preventing hypoglycaemia.[8] Drinks with a CHO content of 6% or lower (≤ 6 g/100 ml drink) empty from the stomach at the same rate as water. These drinks provide CHO and fluids.[8]

### The type of CHO

The recommended type of CHO depends on the intensity of exercise.[14] Slowly absorbed CHO, e.g. a sandwich or biscuits with a low GI, are appropriate before lower intensity exercise.[14] Rapidly absorbed CHO, e.g. a sports/cooldrink is more appropriate before intense bursts of activity and after any exercise.[14]

### CHO for insulin or insulin secretagogue users

Table 1 contains recommendations for CHO intake for exercise of varying intensity and duration.[1] The recommended CHO intakes before, during and after exercise for individuals with diabetes are the same as for individuals without diabetes.[1,3]

A shorter, less detailed recommendation for CHO intake before exercise can also be used, taking into account that individual responses will differ:[14]

- 30 minutes of light exercise 10 g CHO
- 30 minutes of intense exercise 20 g CHO
- 60 minutes of light exercise 20 g CHO
- 60 minutes of intense exercise 40 g CHO

Individuals with diabetes who exercise must monitor blood glucose levels frequently and adapt CHO recommendations on the basis of their own responses to exercise.[2,8] The most appropriate method is by trial and error.[2] During moderate-intensity exercise, glucose uptake is increased by 8 to 13 g/hour, underling the recommendation to add an additional 15 g CHO for every 30 to 60 minutes of activity (depending on the intensity).[8]

### CHO intake after exercise

For the individual doing exercise on repeated days, a CHO-rich diet with a larger proportion of high-GI foods may be required to minimise the cumulative effect of glycogen depletion, chronic fatigue and fluctuating diabetes control.[2]

Consuming high-GI CHO within two hours of strenuous exercise[2,14] optimises the resynthesis of muscle and liver glycogen stores.[2,8] The recommendation is 1 to 1.5 g CHO per kg immediately after exercise and again 60 minutes later.[2]

**Table 1.** Recommended dietary CHO intakes before and during exercise (adapted from Brown *et al*. 2006: 678).

| Type and duration of exercise | Blood glucose level (mmol/l) | Increase food intake by | Suggestion |
|---|---|---|---|
| Brief high-intensity and light training<br>(< 30 min weight-lifting, sprints, cycling, leisurely walk) | 6–10<br>> 14 test for ketones | No food needed | |
| Short, light<br>(< 30 min walking) | < 6<br>> 6 | 15 g<br>None | 1 fruit or 1 starch |
| Moderate<br>(< 45 min swimming, jogging, cycling, tennis, golfing) | < 6<br>6–10<br>10–14<br>> 14 | 30–45 g<br>15 g<br>No food needed<br>Exercise not advised | 2 starch + milk or fruit<br>1 starch or fruit |
| Moderate<br>(> 60 min cycling, soccer, rugby) | 10–14 + ↓ insulin<br>> 13–14 + ketones<br>> 17 (no ketones) | 10–15 g/hr<br>Exercise contraindicated<br>Exercise not advised | 1 fruit or 1 starch |
| Strenuous<br>(< 60 min triathlon, marathon, cycling, canoeing) | < 6<br>6–10<br>10–14<br>14+ | 45 g<br>30–45 g<br>15–30 g<br>Exercise not advised | 2 starch + milk or fruit<br>2 starch (+ milk or fruit)<br>1–2 fruit or starch |
| Strenuous<br>(> 60 min soccer, hockey) | < 6<br>6–10<br>10–14 | 50 g/hr<br>25–50 g/hr<br>10–15 g/hr | 2 starch + milk or fruit<br>1 starch + milk or fruit<br>1 starch or 1 fruit |

Exercise at any level is contraindicated if ketones are present.

For the individual with diabetes, this is especially important to prevent potential late-onset hypoglycaemia.[8,14]

## Exercise prescription

A balanced exercise programme should include both aerobic and strength training.[4] When prescribing an exercise plan, the age of the individual with diabetes,[4] their complications,[4,9] as well as the previous level of exercise[4,5] should be taken into consideration.

Each exercise session should include a five- to 10-minute pre-exercise warm-up and a five- to 10-minute post-exercise cool-down of low-intensity aerobic activity.[4,12] Gentle stretching should be done for five to 10 minutes after the warm-up session to prepare the muscles, heart and lungs for a progressive increase in exercise intensity, and after exercise to gradually bring down the heart rate.[4]

### Type 1 and type 2 diabetes

The American Diabetes Association (ADA) recommends a graded exercise test be undertaken before aerobic exercise with an intensity exceeding the demands of everyday living (more intense than brisk walking in previously sedentary individuals whose 10-year risk of a coronary is likely to be higher) .[4,8] On the other hand, there is no proof that such testing is normally necessary for those intending moderately intense exercise such as walking.[8]

To promote and maintain health, at least 150 minutes per week of moderate-intensity aerobic exercise (50–70% of maximum heart rate)[4-6,8,11,18] or at least 60 to 90 minutes per week of vigorous aerobic exercise (70% of maximum heart rate) is recommended.[5,8,11,18] These guidelines can be met by combining moderate- and vigorous-intensity exercise.[18] Low- to moderate-intensity exercise can be done every day.[5] Exercise should be spread over at least three days per week with no more than two consecutive days without exercise.[8]

For long-term maintenance of major weight loss, 60 minutes of moderate or vigorous exercise per day may be helpful.[6,11]

In the absence of contraindications, individuals should be encouraged to also do resistance training two to three times per week, targeting all major muscle groups, advancing to three sets of eight to 10 repetitions at a weight that cannot be lifted more than eight to 10 times.[4,5,8,18] The last repetition should be challenging to complete.[5] Weight-training sessions normally last 30 to 60 minutes.[5] This amount of time is needed to exercise all muscle groups and make provision for adequate rest between sets of exercise.[5]

Stretching exercises must be performed to improve flexibility.[5] It is recommended to do 10 minutes three to seven times per week.[5] Each muscle group must be stretched four to five times, and each stretch should be maintained for 15 to 30 seconds at a point just before discomfort.[5]

### Type 2 diabetes

Persons with type 2 diabetes may have a lower $VO_{2max}$ and therefore need a more gradual training programme.[8] Rest periods may be needed and this does not reduce the training effect of the exercise.[8]

Exercise routines at an intensity of 50 to 80% $VO_{2max}$ three to four times per week for 30 to 60 minutes a session can lead to an improvement of 10 to 20% in the baseline $HbA_{1C}$ values. These are most valuable in persons with type 2 diabetes and in those who are likely to be the most insulin resistant.[8] Moreover, resistance training improves insulin sensitivity to about the same extent as aerobic exercise.[4] Resistance training can also help lower $HbA_{1C}$ levels in older adults.[4]

### Tips to help start exercising

An activity must be identified that requires large-muscle activity, that will be enjoyed, is safe and tailored to the individual patient.[5,7] The key is to start slowly (even as little as five to 10 minutes at a time) and to increase the duration and intensity slowly. Exercising in a group or with a partner may improve sustainability. Boredom can be prevented by varying activities. Realistic goals should be set. Encourage people to reward themselves (not with food) when goals are met.[19]

## High-risk sports

Individuals with diabetes who are treated with insulin or sulfonylureas are at risk of hypoglycaemia and disorientation.[2] Sporting activities that pose a risk to individuals with diabetes themselves or to others around them should be avoided.[2] It is difficult to administer glucose during hang-gliding, scuba-diving, rock climbing, solo yachting and motorcar racing. There is a lesser risk in surfing and long-distance running.[2] Exercising with someone who is familiar with the symptoms and treatment of hypoglycaemia is vital.[1,2] Regular blood glucose monitoring is essential because a person with type 1 diabetes must understand his/her own response to exercise.[2]

## Conclusion

Exercise forms part of a healthy lifestyle that can prevent the onset of type 2 diabetes or manage both types of diabetes. Although the complications of diabetes need special attention, with proper guidelines, most individuals with diabetes can participate in exercise that is safe, enjoyable and sustainable.

### References


1. Meltzer S, Fuller C. *Eating for Sport: Sports Nutrition*. South Africa: New Holland Publishers, 2005: 84–85.
2. Brown L, Wilson D, Cooper G, Deakin V. Special needs: the athlete with diabetes. In: Burke L, Deakin V, eds. *Clinical Sports Nutrition*. 3rd edn. Australia: McGraw-Hill, 2006: 677–697.
3. Whitney E, Rolfes SR. *Understanding Nutrition*. 11th edn. Australia: Thomson Wadsworth, 2008: 637–641.
4. American Diabetes Association. Standards of medical care in diabetes – 2008. *Diabetes Care* 2008; **31**(Suppl 1): S12-S54. Available at www.care.diabetesjournals.org/. Accessed 19 November 2008.
5. Going S, Dokken B. Diabetes and exercise. In: Zazworsky D, Bolin JN, Gaubeca VB, eds. *Handbook of Diabetes Management*. New York: Springer, 2006: 125–142.
6. Sigal RJ, Kenny GP, Wasserman DH, Castaneda-Sceppa C, White RD. Physical activity/exercise and type 2 diabetes. A consensus statement from the American Diabetes Association. *Diabetes Care* 2006; **29**: 1433–1438. Available at www.care.diabetesjournals.org/. Accessed 19 November 2008.
7. Bhaskarabhatla KV, Birrer R. Tailoring exercise to optimize fitness and glycemic control. *Physician Sportsmed* 2004; **32**: 13–17. Available at www.physsportsmed.com/issues. Accessed: 01 December 2008.
8. Franz MJ. Medical nutrition therapy for diabetes mellitus and hypoglycemia of nondiabetic origin. In: Mahan LK, Escott-Stump S, eds. *Krause's Food, Nutrition and Diet Therapy*. 12th edn. Philadelphia: Saunders Elsevier, 2008: 764–806.
9. Rolfes SR, Pinna K, Whitney E. *Understanding Normal and Clinical Nutrition*. 7th edn. Australia: Thomson Wadsworth, 2006: 790–813.
10. Hayes C, Kriska, A. Role of physical activity in diabetes management and prevention. *J Am Diet Assoc* 2008; **108**: S19-S23. Available at www.adajournal.org/issues/contents. Accessed 20 November 2008.
11. Buse JB, Ginsberg HN, Bakris GL, Costa F, Eckel R, *et al*. Primary prevention of cardiovascular diseases in people with diabetes mellitus. A scientific statement from the American Heart Association and the American Diabetes Association. *Diabetes Care* 2007; **30**: 162–172. Available at www.care.diabetesjournals.org/. Accessed 17 November 2008.
12. Robergs RA, Keteyian SJ. Endocrine adaptations to exercise. *Fundamentals of Exercise Physiology – for Fitness, Performance, and Health*. 2003; Boston: McGraw Hill: 185–206; 425–427.
13. American Diabetes Association. Physical activity/exercise and diabetes. *Diabetes Care* 2004; **27**(Suppl 1): S58–S62. Available at www.care.diabetesjournals.org/. Accessed 17 November 2008.
14. Thomas B, Bishop J. In: Thomas B, Bishop J, eds in conjunction with The British Dietetic Association. *Manual of Dietetic Practice*. 4th edn. England: Blackwell Publishing, 2007: 555.
15. Grimm JJ, Ybarra J, Berné C, Muchnick S, Golay A. A new table for prevention of hypoglycaemia during physical activity in type 1 diabetic patients. *Diabetes Metab* 2004; **30**: 465–470. Available at www.e2med.com/dm. Accessed 21 November 2008.
16. Birrer RB, Sedaghat VD. Exercise and diabetes mellitus – optimizing performance in patients who have type 1 diabetes. *Physician Sportsmed* 2003; **5**: 29–33, 37–41. Available at www.physsportsmed.com/issues. Accessed: 01 December 2008.
17. Colberg SR, Walsh J. Pumping insulin during exercise. What healthcare providers and diabetic patients need to know. *Physician Sportsmed* 2002; **30**: 33–38. Available at www.physsportsmed.com/issues. Accessed: 01 December 2008.
18. Haskell WL, Lee I, Pate RR, Powell KE, Blair SN, Franklin BA, *et al*. Physical activity and public health. Updated recommendations for adults from the American College of Sports Medicine and the American Heart Association. *Circulation* 2007; **116**: 1081–1093. Available at www.circ.ahajournals.org. Accessed 20 November 2008.
19. International Diabetes Federation. Physical activity. Section 2. Curriculum module III-4. Until 2008. Available at www.idf.org/home/index.cfm. Accessed: 03 July 2008.