Diabetes and sport: managing the complex interactions

Many people with diabetes will want to perform sports, some at a competitive level. However, the changes in physiological responses with exercise seen in diabetes, combined with the effect of diet, tablet or insulin treatment, may impact on glycaemic control and increase the risk of hypoglycaemia. This article reviews these issues so that they can be managed effectively.

Diabetes is a common disorder, currently affecting approximately 150 million people worldwide, and is likely to increase to over 300 million by 2025 (Zimmet, 2003). Exercise improves glycaemic control, can assist with weight control, and improves quality of life; increasing exercise is recommended as part of the management of diabetes (American Diabetes Association, 2004). However, exercise may have an adverse impact on the treatment of diabetes. Two important issues need to be addressed in the management of diabetes in sport. First, how do people treated with insulin or oral hypoglycaemic agents adjust their therapy and diet so that they can reduce the risk of hypoglycaemia during and following sport? Second, how do the talented ensure that the treatment of diabetes is not a cause of impaired physical performance? It is important, therefore, that when a health-care professional is asked for advice on how to manage changes in medications and diet with sport, the likely effect on blood glucose is understood. This article reviews these issues and outlines some potential strategies to assist the sportsperson with diabetes.

Physiology of exercise

The physiology of exercise in diabetes is too large a subject to cover in this article, but it is known that the maximum oxygen consumption, carbon dioxide output, ventilatory capacity, aerobic capacity and cardiac output are similar in young adults with diabetes to those without diabetes (Fisher et al, 1989; Wanke et al, 1992; Nugent et al, 1997; Veves et al, 1997). However, people with type 2 diabetes may have reduced exercise capacity compared with subjects without diabetic, and this may precede the diagnosis of diabetes (Thamer et al, 2003). This implies that while people with type 1 diabetes may have the potential to perform maximally, people with type 2 diabetes show evidence of reduced potential for performance. Even so, many studies demonstrate that regular exercise will improve exercise capacity in people with type 2 diabetes (Boule et al, 2003).

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The increased energy requirement for exercise is met from intramuscular glycogen stores and by mobilization of other fuels from remote body stores of the liver and adipose tissues (Romijn et al, 1993). This metabolic response to exercise is altered in diabetes (Gallen, 2004). The counter-regulatory hormone response to exercise, essential for gluconeogenesis and lipolysis, may be impaired in diabetes (Koivisto et al, 1992; Ahlborg and Lundberg, 1996), and hepatic glucose production, which supports increased muscle glucose uptake during exercise, is reduced (Petersen et al, 2004).

There is a mismatch between glucose utilization and production (Berger et al, 1977, 1998; Koivisto et al, 1992; Marliss et al, 2002), and potential to reduce performance and stamina, and increase the risk of hypoglycaemia. There is also greater oxidation of glucose than other fuels in exercise in people with type 2 diabetes when compared with subjects without diabetes (Kang et al, 1999). Blood glucose levels therefore tend to fall during prolonged exercise, rather than remain constant (Giacca et al, 1998; Larsen et al, 1999a). The rate of the fall in glucose depends on the intensity of exercise, and at high exercise intensity, when glucose is the exclusive fuel, blood glucose may fall quickly.

If the duration of this high level effort is short, or the subject unfit, the increased counter-regulatory response results in glucose production that exceeds use, and paradoxically, glucose levels may rise. At all levels of intensity, post-exercise insulin release is unavailable to balance the effects of exercise-induced catecholamines, growth hormone and glucagon, resulting in post-exercise hyperglycaemia (Bohmer et al, 1989; Sigal et al, 1994). Following exercise, improved muscle insulin sensitivity and restoration of hepatic and muscular glycogen may leave athletes with type 1 diabetes prone to hypoglycaemia (MacDonald, 1987). This is also the case in type 2 diabetes, as exercise increases muscle insulin sensitivity, and increases muscle glycogen synthesis (Kishimoto et al, 2002).

Treatment, glycaemic control and hypoglycaemia

In type 1 and insulin treated type 2 diabetes, insulin therapy is injected subcutaneously, and insulin lies in

depots which take time to be absorbed and dissipated. Insulin concentrations following subcutaneous injection may be inappropriately high or low for concurrent glucose levels (Wasserman and Abrumrad, 1989). The insulin levels required to regulate hepatic glucose output after subcutaneous injection at rest may cause a supra-physiological peripheral concentration during exercise, which impairs fuel mobilization. This may reduce performance and lead to hypoglycaemia.

Most insulin-treated athletes will require multiple daily injections with short-acting or analogue insulin and appropriate basal insulin support overnight (Gallen, 2003, 2004). The newer analogue bolus insulin types (lispro and aspart) reach peak concentration and tail off more quickly after injection than soluble insulin and therefore assist in reducing hypoglycaemia (Koivisto and Tronier, 1983; Tuominen et al, 1995; Jacobs et al, 1997; Brunelle et al, 1998), and one of these is recommended as the bolus component.

Many diabetologists now use one of the new analogues (insulin glargine or detimir) as their preferred basal insulin because of their more predictable and prolonged action profiles. However, the pharmacological characteristics which optimize glycaemic control may be detrimental for the sportsperson with diabetes. While exercise does not appear to alter the rate of insulin absorption of glargine, there is a rapid fall in blood glucose with effort (Peter et al, 2005). It is not known whether an exercise induced fall in blood glucose is greater with glargine, detimir or isophane (NPH) insulin, but is likely that both newer analogues impair fuel mobilization to a greater degree than NPH insulin. Therefore, care must be taken in the choice of basal insulin, particularly if the exercise is predominantly prolonged aerobic (running or cycling). Once- or twice-daily NPH insulin may be the better preparation of insulin for some.

A further option for athletes in non-contact sports is the use of insulin infusion pumps. The ability to rapidly adjust insulin infusion rates may seem to offer potentially near-physiological insulin replacement (Sonnenberg et al, 1990; Oskarsson et al, 1999). However, widespread use may be limited by cost.

Tablet treatment in type 2 diabetes also has the potential to alter glycaemic control. The hypoglycaemic effect of oral agents is augmented by exercise (Massi-Benedetti et al, 1996; Larsen et al, 1999b), so people on these agents need to be advised that as with insulin treatment, blood glucose needs to be checked during and following exercise, and that it may be necessary to either reduce or omit oral hypoglycaemic agents (particularly the longer acting agents) before prolonged exercise. Rosiglitazone promotes glucose uptake into muscle (Hallsten et al, 2002) and increases the duration of aerobic exercise (Gallen and Qazi, 2005), but does not appear to be associated with hypoglycaemia. Metformin has little effect on muscle glucose uptake (Hallsten et al, 2002), and again is not associated with hypoglycaemia during or following exercise.

Planning for sport and exercise

The principle underlying insulin treatment is integration of the training and event plans, food intake, basal and bolus insulin requirement. Careful descriptions of the type, timing, intensity and duration of exercise are necessary to anticipate likely changes in blood glucose. Prolonged aerobic exercise is associated with a significant fall in glucose, and a significant risk of hypoglycaemia later. In contrast, intense short-lived exercise such as circuit training in the gym or a game of squash are likely to raise blood glucose substantially, with a low risk of hypoglycaemia later. Clearly extra carbohydrate will assist in the first case, but will add to hyperglycaemia in the second case.

Avoidance of hypoglycaemia is central to the management of diabetes and sport. Hypoglycaemia during training impairs performance, and may be dangerous if it occurs in a remote environment. Furthermore, there are concerns about the possibility of life-threatening arrhythmia with hypoglycaemia. Detection of hypoglycaemia is difficult as exercise produces similar symptoms, and concentration is diverted to sport. Therefore blood glucose must be checked frequently at the start, during and at the end of exercise. The athlete soon sees the pattern of response, and learns to predict when and how much extra glucose is needed, and how great a reduction is required in the pre-exercise meal insulin doses. The new continuous subcutaneous glucose monitors look very exciting in this context and allow a more accurate adjustment in therapy so that normal physiology might be replicated.

Previous advice to avoid hypoglycaemia has been to start exercise with blood glucose in the mid teens, pre-loading with glucose or sugary containing foods. While this will reduce the likelihood of hypoglycaemia, the resultant pre-exercise hyperglycaemia impairs physical performance. A more appropriate strategy is to start exercise with blood glucose in the range 7–10 mM, and then take glucose in small amounts regularly when blood glucose starts to fall. Ingestion of glucose during exercise (up to 1 g/kg/hr), improves performance and endurance, and reduces the frequency of hypoglycaemic events during and following exercise (Liu et al, 1993; McKewen et al, 1999; Hernandez et al, 2000).

Reduction in the meal-related bolus insulin dose before exercise assists in maintaining near euglycaemia (Rabasa-Lhoret et al, 2001; Jarvis et al, 2003). The size of this dose reduction can be marked, and may differ from the usual experience of people with insulin treated diabetes who may only adjust insulin dose by 2–4 units at a time. It may be necessary to reduce the dose by between 25–75% depending on the intensity and duration of the planned exercise. An alternate approach significantly increasing carbohydrate intake during and following exercise, with a smaller reduction in pre-exercise insulin dose, is also effective in reducing the risk of hypoglycaemia (Grimm et al, 2004). It is not known which strategy is best for optimum performance or long-term weight management. Diabetologists and specialist nurses routinely advise the reduction of basal insulin

after exercise, because of post-exercise augmentation of insulin sensitivity, and a reduced basal insulin dose of up to 25% following exercise may also be required to avoid nocturnal hypoglycaemia. This is more likely to be necessary when exercise is less frequent than daily, but may not be necessary if the exercise is very frequent, as insulin sensitivity is maintained. Alteration in basal insulin dose after exercise can again be problematic if the person is using one of the newer longer acting insulin analogues, as there may be hyperglycaemia the following day.

Hypoglycaemia during the previous day reduces the counter-regulatory hormone response provoked by exercise and increases the likelihood of hypoglycaemia during exercise (Galassetti et al, 2003). It seems sensible to advise athletes that if they have had a significant hypo the day or during the night before exercise they should consider whether exercise is possible or sensible, and be aware of the heightened risk associated with it.

One concern for both the person with diabetes and the health-care professional is whether frequent exercise will cause progression of complications of diabetes. Microalbuminuria and background retinopathy do not progress with regular exercise (Cruikshank et al, 1995; Heineman et al, 1996), although it seems reasonable to advise those with preproliferative retinopathy to perform only low intensity exercise to reduce the possible risk or retinal haemorrhage. People with reduced foot sensation can do sport, but need to be instructed in footcare to reduce the likelihood of ulceration. People with type 2 or longer duration type 1 diabetes, particularly those with multiple risk factors who wish to embark on a strenuous exercise programme (e.g. running a marathon) from a previous low exercise level, need cardiovascular assessment which should include a baseline electrocardiogram, and probably an exercise tolerance test to exclude occult coronary artery disease (American Diabetes Association, 2004).

KEY POINTS

- Diabetes is a common disorder, and increasing exercise is recommended as part of the management.
- Treatment with insulin or oral hypoglycaemic agents increases the risk of hypoglycaemia during and following exercise.
- The physiological response to exercise is altered in diabetes: while exercise generally causes blood glucose to fall, some types of exercise can cause blood glucose to increase.
- Inappropriate insulin treatment may reduce peak performance in athletes with diabetes.
- Planning for exercise, with significant reduction in pre-exercise bolus insulin dose is frequently required.
- Frequent blood glucose monitoring before, during and following exercise is essential to predict likely changes.
- The newer shorter-acting analogue insulins have a useful role in the management of diabetes and sport.
- Ingesting small amount of glucose (often in liquid form) during exercise promotes performance and reduces the risk of hypoglycaemia.
- People with diabetes should be encouraged to start or continue their chosen sport or exercise.

Dietary requirements

The dietary requirements of athletes with or without diabetes are similar, and nutrition is the key to promotion of performance and endurance. Therefore advice from a specialist dietician is helpful. With adequate replacement on training days, there is no need to take extra carbohydrate on rest days, as this can impair overall glycaemic control without improving muscle glycogen stores (McKewen et al, 1999). Extra carbohydrate during, and after exercise improves exercise capacity and protects against hypoglycaemia (Ramires et al, 1997; Hernandez et al, 2000; Grimm et al, 2004). While there is evidence that a low glycaemic index (GI) meal before exercise may improve performance in athletes (Wee et al, 1999), there is little evidence to advise on the type of carbohydrate, protein or fat content for athletes with diabetes. Until such data are available, it seems sensible to recommend that the ideal components of the diabetic diet remain as low GI carbohydrates and protein and a low fat content.

Sport drinks have a useful role in supporting performance. They typically contain about 6 g of glucose per 100 ml, and have some sodium and potassium. These are useful for replacing fluids when blood glucose is not falling rapidly. Higher concentration glucose drinks, which contain about 15 g of glucose per 100 ml and no salts, are appropriate for raising glucose quickly and replacing glucose when the athlete wants to limit fluid intake. Powdered sports drinks can be made up to vary glucose and water content, and thereby satisfy individual requirements, e.g. a cyclist may need less fluid and more glucose than a climber who is becoming dehydrated. These products are made from complex glucose polymers (maltodextrin), and have low osmotic pressure even at high concentrations. After exercise carbohydrate needs to be taken to replenish muscle and liver stores of glycogen – typically 60–120 g as a drink or in snack form (Ramires et al, 1997). This will need to be taken with further bolus insulin.

Conclusions

People with uncomplicated diabetes, who want to start or continue in their chosen sport, can be encouraged to do so. Appropriate education of the person with diabetes and support by their health-care professional is necessary, and careful consideration of the nature of the sport is required. A combination of reduction in pre-exercise insulin or oral hypoglycaemic agent dose combined with extra carbohydrate during and following exercise is required.

People with diabetes who participate in sport benefit substantially, and health-care professionals can use the skills acquired in the management of all people with diabetes. When asked if the person with diabetes should participate in sport, the answer should normally be yes. Further information on managing diabetes and specific sports can be found at http://www.runsweet.com BJHM

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