The effect of intensive exercise on type 1 diabetes control: A case study

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For people with type 1 diabetes it is difficult to balance the amount of insulin to inject and the number of times to inject during an intensive exercise regimen in order to sustain clinically safe glycaemic levels. In this article, Jo Butler briefly discusses the effect of exercise on an individual's diabetes with respect to glycaemic control. She then gives an account of a 38-year-old male with type 1 diabetes who underwent intensive physical training in order to swim across the English Channel.

To understand how people with diabetes are affected during exercise one must first consider the process of metabolism during exercise in people who do not have diabetes. Glucose is stored as glycogen in the muscles and the liver; during exercise, glycogen from the muscles is used as an energy source first (Diabetes Insight, 2001). In people without diabetes the fall in blood glucose levels is detected by the beta-cells of the pancreas and the rate of production of insulin is reduced. Low insulin levels allow increased glucose release from the liver due to glycogenolysis and gluconeogenesis, which help maintain blood glucose levels (Farrell, 2003). Low insulin levels also allow the breakdown of fats into free fatty acids, which form another source of energy that can be used by the muscles (Farrell, 2003). The key to this homeostatic process is the amount of insulin produced (Farrell, 2003). Added to this, exercise, particularly when of high intensity, increases the production of other hormones such as glucagon and adrenaline which further increase fuel release and oppose insulin actions (Cryer, 2001).

In people with type 1 diabetes, because of the inability of current insulin technology to react to such glucose shifts during exercise, there is a difficult balance between the amount injected and the timing of injecting insulin and glucose availability during exercise. Prior to exercise if an individual's 'usual' amount of insulin is injected and blood glucose levels are within a healthy range, glycogen stored in the muscles is used up first (Diabetes Insight, 2001); the muscles then take up glucose from the blood stream to replenish the used glycogen. Despite a fall in blood glucose levels, the circulating insulin does not decline appropriately and remains relatively high (Diabetes Insight, 2001). This prevents the production of free fatty acids and inhibits gluconeogenesis and glycogenolysis in the liver (Gallen, 2005). The muscles continue to use glucose as a fuel and eventually blood glucose levels fall below safe levels and the individual could become hypoglycaemic unless additional glucose or carbohydrate is ingested.

Alternatively, if insulin levels are low either because insulin doses have been reduced by too much or insulin was injected too long before exercising and its effect is, therefore, wearing off, then blood glucose levels will rise (Farrell, 2003). This is particularly relevant when the

Article points

1. In order to carry out any intensive exercise regimen, people with diabetes must carefully monitor their glycaemic control.
2. Records of blood glucose levels at as many time points as possible must be kept in order to maintain safe levels.
3. Quite often, discovering safe amounts of insulin to inject involves trial and error.
4. The amount of insulin and the time it is injected becomes more crucial when performing intensive exercises.

Key words

- Glycaemic control
- Intensive exercise
- Insulin dose adjustment
- Self-monitoring of blood glucose
- Hypoglycaemia

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1. As well as the intensity of exercise undertaken the type of exercise also determines the changes in blood glucose levels.
2. Following exercise, people with diabetes are at risk from hypoglycaemia.
3. The muscle cells continue to take up glucose from the blood for a number of hours to replenish glycogen stores.
4. There could be a risk of hypoglycaemia for as much as 31 hours postexercise.

exercise involves high-intensity bursts of energy that stimulate adrenaline and steroid release; in this circumstance exercise could potentially result in ketoacidosis (Farrell, 2003). Diabetes UK recommends that if blood glucose levels are above 15 mmol/l then physical activity should not be undertaken (Diabetes UK, 2003). Urine and blood should be checked for ketones and medical advice sought if they are present (Diabetes UK, 2003). Only when blood glucose levels are back to normal and there are no ketones should exercise be resumed (Diabetes UK, 2003).

For a person with diabetes the following are vital to be able to exercise safely and effectively.

- Injecting the correct amount of insulin.
- Keeping a detailed record of insulin doses injected.
- Keeping a detailed record of blood glucose measurements.
- Keeping a detailed record of carbohydrate intake.

The type of exercise undertaken also determines the changes in blood glucose levels (Gallen, 2005; Guelfi et al, 2005) and detailed records of activity levels and their related effects on glycaemic control should be kept. Guelfi and colleagues (2005) compared blood glucose levels in people with type 1 diabetes who undertook intermittent high-intensity exercise (IHE) with those undertaking moderate-intensity exercise (MOD). Both groups exercised for 30 minutes on two separate occasions at the same and controlled rate; but those in the IHE group intermittently sprinted to mimic team sports. Blood glucose levels fell in both groups but the fall was significantly greater in the MOD group. During the 60-minute recovery phase blood glucose levels continued to fall in the MOD group but remained stable in the IHE group. This is due to the metabolic and hormonal response, which alters hepatic glucose production (Guelfi et al, 2005). Guelfi and colleagues concluded that during prolonged exercise, blood glucose levels are more likely to fall and in short intensive exercise may initially rise (Guelfi et al, 2005). The time of day exercise is done also affects blood glucose levels; this is related to the action of insulin and the hormone response during the day (Gallen, 2005).

Patrick drinking a high-energy supplemented drink during a break from his swim.

Following exercise, people with diabetes are at risk from hypoglycaemia (Zinman et al, 2003): the muscle cells continue to take up glucose from the blood for a number of hours to replenish glycogen stores. Guelfi and colleagues (2005) suggest there is a risk of hypoglycaemia for as much as 31 hours postexercise. MacDonald (1987) suggested that delayed hypoglycaemia could occur between 4 and 48 hours after exercise. Gallen (2005) recommends reducing the pre-exercise insulin dose and increasing carbohydrate intake to prevent hypoglycaemia during and after exercise.

Mauvais-Jarvis and colleagues (2003) recommend a reduction of 50–90% of the insulin dose depending on the insulin regimen and the type and duration of exercise; but the dose required can only be calculated by trial and error, which involves frequent monitoring and keeping good records of insulin dose and carbohydrate intake and time of exercise.

Injecting insulin into an exercising limb should be avoided as insulin is absorbed more quickly than when not exercising, thus increasing the risk of hypoglycaemia (Williams and Pickup, 1999).

Case study

Patrick Turner, a 38-year-old teacher, was diagnosed with type 1 diabetes in November 2004. At that time he was in training to swim the English Channel. In order to do so, following his diagnosis, he had to be accompanied by a specialist nurse in the support boat.

Patrick began training about a year before the swim. His training started with 1-hour sessions in a swimming pool, swimming approximately

2 miles three times a week, combined with running and weight-training. As his training progressed he swam five times a week, increasing his distance to 6.5 miles in the pool. At weekends he swam for up to 7 hours between two sea walls in Dover harbour, with hourly breaks to take on carbohydrates in the form of high-energy supplements and food. In Patrick's case he was not only taking on the challenge of prolonged strenuous exercise but also the difficulties he would encounter in managing his diabetes.

Although heat from muscles speeds up the absorption of insulin (Farrell, 2003), Patrick's problem would be the cold. During the swim he would use up all of his glycogen reserves and some of his body fat for energy. If he were to slow down he would not produce enough glucose from his muscles for energy and his core body temperature would drop, thus resulting in hypothermia (Read, 2003).

The insulin plan

Over time a plan was devised to help Patrick in his final swim. He was on a basal–bolus regimen, using 8–10 units of a rapid-acting insulin analogue with meals and 14 units of long-acting insulin analogue before bed. Patrick discovered he could maintain his blood glucose levels around 9 mmol/l by stopping his rapid-acting insulin analogue completely while he was training and reducing his long-acting insulin analogue. It was decided to reduce his long-acting insulin analogue from 14 to 8 units 2 days before the swim to ensure that the reduction in dose had taken effect. During this time he continued to inject the rapid-acting insulin analogue according to his blood glucose levels. Approximately 3 hours before the swim he ate a pasta-based meal to increase his glycogen reserves and took 8 units of rapid-acting insulin analogue, which was roughly equivalent to his usual dose. He took no more insulin until he had finished the swim.

Patrick made adjustments to his insulin regimen based on his blood glucose levels and the quantity of carbohydrate he required during training. He kept a detailed record of these results to allow him to estimate how much insulin and carbohydrate he would require during the final swim.

It is estimated a Channel swimmer uses 600–900 calories per hour (Read, 2003). Patrick explained that he used a powdered high-energy supplement which contains glucose, vitamins and essential calories. One measured scoop contains 20 g of carbohydrate, which can be added to drinks or sprinkled onto food. Patrick calculated that he would need 90 g of carbohydrates every hour for the first 3 hours and then 45 g every half-hour thereafter. High-energy foodstuffs such as chocolate and rice pudding would also be ingested during the swim.

The swim

Patrick's blood glucose was 10.8 mmol/l before the start of the crossing.

Patrick was given high-energy supplements diluted in warm squash (warm to help maintain his body temperature) in a sports bottle. Four-and-a-half hours into the swim Patrick began to complain that he felt tired. He stopped swimming and began to tread water. It was impossible for him to test his blood glucose while in the sea (the rules say that any English Channel swimmer must not touch the support boat or crew). Perhaps he had hit 'the wall' whereby his glycogen stores had been used up and his body had switched to utilising fat as an alternative energy source. As Patrick appeared to be behaving out of character the author concluded he was probably hypoglycaemic. High-energy supplement mixed with hot chocolate and a small chocolate bar was provided to boost his energy levels; shortly after he began swimming strongly again. During the swim the team intermittently counted Patrick's swim-stroke rate for 1 minute at a time to make sure he was not losing power and becoming hypothermic. However, from the author's perspective a steady stroke rate demonstrated that Patrick was not becoming hypoglycaemic.

Despite the 'insulin plan' Patrick apparently became hypoglycaemic. Why? The dose of rapid-acting insulin taken prior to starting the swim might have been too high, but the profile of the insulin would indicate it should have been metabolised by then. In the author's opinion, the reason was that the quantity of high-energy supplements he took varied every time. During training he was taking a regular quantity of high-energy supplements every hour. While swimming

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2. Patrick discovered he could maintain his blood glucose levels around 9 mmol/l by stopping his rapid-acting insulin analogue completely while he was training and reducing his long-acting insulin analogue.
3. It was decided to reduce his long-acting insulin analogue from 14 to 8 units 2 days before the swim to ensure that the reduction in dose had taken effect.
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the Channel Patrick was permitted to stop for 30 seconds at a time to take sustenance; sometimes he took a long drink and ate some food, sometimes hardly anything – this was possibly the cause.

Patrick finished the swim in 14 hours and 12 minutes. Once back on the boat and warmed up his blood glucose was tested and found to be 8.7 mmol/l.

After the swim

To avoid delayed hypoglycaemia Patrick reduced his next rapid-acting insulin analogue dose and those the next day but took his usual dose of long-acting insulin analogue as this would take a couple of days to take full effect (MacDonald, 1987). He tried to increase his intake of carbohydrates but found swallowing painful after having vomited a number of times during the swim. He maintained his blood glucose level with soups and other soft foodstuffs.

Patrick succeeded because he did not let having diabetes become an issue. However, people with complications of diabetes who wish to undertake strenuous exercise are prone to exacerbating their specific complications (Zinman et al, 2003) and this must be taken into consideration before starting an exercise programme.

As for Patrick there is no doubt that embarking on this journey meant trial and error – insulin and carbohydrate adjustment was based on frequent monitoring of blood glucose levels, intense training and utmost dedication. Before undertaking a new exercise regimen people with diabetes should discuss their plans with their diabetes team, as adjustments to their insulin dose, carbohydrate intake and a medical assessment may be necessary. ■

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A brief account of Patrick's training, the swim across the English Channel and the aftermath of the swim, including some advice for others with diabetes who may wish to participate in such a physical activity.

Ten months before my swim date, I was diagnosed with type 1 diabetes. I asked each doctor and nurse I saw at Ashford Hospital (Middlesex) whether the diabetes would prevent me from attempting to swim the English Channel. Not one told me that I'd be any more foolhardy than other aspiring Channel swimmers! So the training continued.

Fortunately, I received advice from Mark Blewitt, who has diabetes and had swum the Channel several years previously, and from Dr Ian Gallen at High Wycombe Hospital. I learnt what effect 1 hour of swimming in cold water, at 10–16°C would have upon my blood glucose level and, by trial and error, adjusted the strength of my feeds to prevent me from having a hypoglycaemic episode. With the energy that I was expending, it was improbable that my blood glucose level would go too high. By the time I crawled on to a French beach, I was absolutely exhausted! Was the exhaustion due to the challenge itself, to my diabetes or to a few short-cuts in training? I don't know.

Advice to other people with diabetes

Seek help from the specialists – I couldn't have undertaken the swim without the reassurance of having Jo Butler on the support boat. Detailed records of blood glucose levels and carbohydrate intake should be kept during training. During intense physical training your control of blood glucose level may be better than ever.