Conference Report

Diet and physical activity in patients with type 1 diabetes

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Abstract. Patients with type 1 diabetes require adequate amounts of macronutrients to support their training and sustain performance during regular exercise and during competitions. A frequent goal in competitive sports is to improve performance, and athletes may resort to a number of practices that can adversely affect blood glucose control and health in general in an attempt to gain a competitive advantage. These may include unsafe dietary patterns, and the use of nutritional supplements, other ergogenic aids and illegal substances. In this paper we review data on the relationship between insulin therapy and needs of single macronutrients before, during and after regular and competitive exercise in young subjects and athletes with type 1 diabetes. We also list nutrition integrators, available in the gymnasium or as over-the-counter drugs, which are increasingly being used by athletes, and describe their interactions with diabetes. (www.actabiomedica.it)

Key words: Diet, physical activity, type 1 diabetes mellitus

Introduction

Regular physical exercise, together with insulin therapy and a correct diet, has long been acknowledged to be beneficial in the management of type 1 diabetes (1). Subjects with diabetes should be aware that regular exercise enhances physical fitness, reduces cardiovascular risk and improves social and emotional well being (2). Motivation to become involved in sports typically has little to do with health benefits. Children and adolescents with diabetes are more likely to spend time in sport activities than those without diabetes. This may be a consequence of diabetes education, which encourages active lifestyles, or it may be "compensating social behaviour" that allows young people with diabetes to feel more accepted by their peers (3). A study of schoolchildren revealed that excitement and competition, appearance, fun, team atmosphere, friendship, achievement and skill development were the main motives for taking part in sports (4). Whether the motivating factor is the "desire for an Olympic gold medal" or simply to be "part of the team", it should be remembered that the specific goals of the athlete may be far more important than blood glucose control or avoidance of complications (Fig. 1).

A frequent goal in competitive sports is to improve performance, and athletes may resort to a number of practices that can adversely affect blood glucose control and health in general in an attempt to gain a competitive advantage. These may include unsafe dietary patterns, and the use of nutritional supplements, other ergogenic aids and illegal substances. Common dietary problems seen in athletes include the female athlete triad: rapid weight loss to "make weight," and excessive consumption of a single macronutrient, such as protein. It is important to be familiar with these practices and to counsel athletes appropriately. The Italian association of diabetic athletes (*Associazione Nazionale Italiana Atleti Diabetici*; ANIAD) numbers more than 700 persons, which gives an idea of the relevance of correct information-giving in this part of the population.

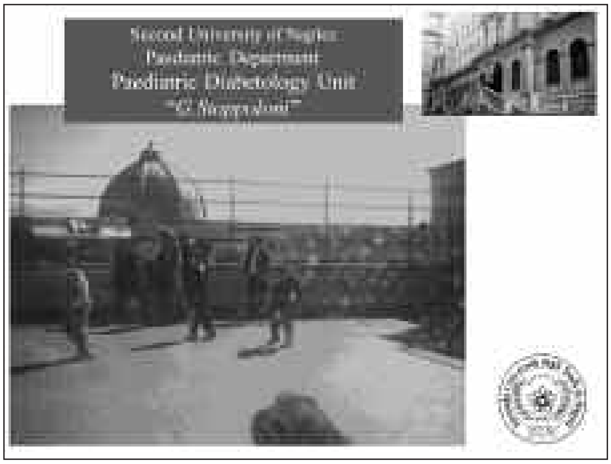

Figure 1. Young patients play football waiting to see the *"diabetes doctor"*

General dietary recommendations for diabetic athletes

Calories and nutrients composition

The diet of athletes with diabetes is not substantially different from the diet of healthy people. Athletes with diabetes require adequate amounts of macronutrients to support their training and to sustain performance during competition. A diet consisting of 55-60% carbohydrates, 25-30% lipids and 10-15% proteins is recommended for type 1 diabetic patients. The amount of total kcal/day is calculated on the basis of physical exercise: 30 kcal/kg if activity is moderate, 40 kcal/kg if it is medium and 50 kcal/kg if it is heavy. Differences between males and females are reported only for strenuous activities (females 44 kcal/kg, males 50 kcal/kg).

Carbohydrate consumption depends on the sport practiced, and in some cases cannot be lower than 60% and reaches 70% in case of long-lasting aerobic exercises. Complex carbohydrates should constitute 70% of the total. Diabetic athletes must avoid carbohydrate-restricted diets. It was previously assumed that smaller carbohydrate molecules (the simple sugars) were broken down and absorbed more quickly than the longer carbohydrate chains (the complex carbohydrates). We now know that this "theoretical" assumption is not correct and that other factors are more important than the size of the carbohydrate molecule in determining how quickly carbohydrate is digested and how it affects blood glucose levels. The factors that alter the rate at which a carbohydrate-containing food is digested and absorbed, as glucose, into the bloodstream include the specific form of carbohydrate in the food, the presence of other nutrients such as protein, fat, and fiber, and the type of processing the food has undergone.

Animal and vegetal *proteins* should be in a 1:1 ratio and 60% of *lipids* must be of vegetal origin with a monounsaturated/polyunsaturated ratio of 1:1. Fats are critically important in the diets of athletes because they provide energy, fat-soluble vitamins, and essential fatty acids necessary for daily activity and health. It has been suggested that the amount of fat ingested by athletes should be from 2 to 3 g/kg of body weight/day, depending on training intensity. There is no scientific evidence indicating that high-fat diets enhance athletic performance. Diabetic athletes are specifically recommended to reduce their fat intake before exercise in order to avoid ketosis.

Calories supplementation before and immediately after exercise is essentially constituted by simple and complex carbohydrates because they are rapidly absorbed and metabolised during aerobic activity. The substrates metabolised during physical activity depend on the intensity of the sport practiced, on the aerobic or anaerobic stress and on the athletic preparation of a person. The main substrates consumed during moderate physical activity are carbohydrates during the first 90-120 minutes. The main source of glucose is muscle and liver glycogen, and weakness during physical activity results from glycogen depletion. Also hypoglycaemia is prevented and corrected, during exercise, by muscle and liver glycogenolysis. At a practical level, while exercising, diabetic patients should have immediate access to rapidly absorbed carbohydrates in case of hypoglycaemia.

The metabolism of proteins during physical activity contributes very little (< 5%) to total energy expenditure. But in case of a reduction in the glycogen store, it increases to 10-15%, which negatively affects athletic performance. This is another reason to provide an adequate amount of carbohydrates in the diet.

Lipids and, in particular non-esterified fatty acid (NEFA) and triglycerides are utilized during low intensity aerobic exercise at a rate of 40% during the first hour and 70% in the next four hours. The utilization of NEFA is directly correlated to the type of training. In general, the dietary plan of a diabetic athlete foresees carbohydrates before beginning activity and lipids and proteins several hours after exercise.

Insulin therapy and its relationship with nutrients during physical activity

The primary risk of physical activity in patients with uncomplicated diabetes is exercise-induced hypoglycaemia and worsening of hyperglycaemia and/or ketosis when the level of insulin becomes insufficient. Therefore, before undertaking physical exercise, patients with type 1 diabetes should be advised to avoid behaviour that could put them at risk, and given specific recommendations to adjust their diet so that they are prepared to counteract or prevent a drop in glucose levels when taking part in sports (5).

Whether or not to reduce the dosage of insulin or to add carbohydrates before beginning exercise to prevent hypoglycaemia is still a matter of controversy (6). A decrease in insulin dose from between 20% and 30% before physical exercise seems a reasonable approach only for long duration exercise (> 60 min). On the other hand, the level of insulin must be sufficient to allow correct glucose uptake during physical training. In fact, in case of hypo-insulinization, the reduced uptake of glucose leads

According to Diabetes UK Association, exercise should be postponed when blood glucose is > 250 mg/dl, if ketonemia exceeds 1 mmol/l or if there is ketonuria.

Two hormones are important in the regulation of glycaemia during exercise: glucagon and insulin (7). Exercise induces an increase in glucagon – a process that stimulates glycogenolysis and gluconeogenesis. Glucagon also stimulates hepatic amino acid metabolism and fat oxidation thereby providing precursors for gluconeogenesis and energy to fuel it. The decrease in insulin during exercise is necessary for a complete glycogenolytic response. When the decline in portal vein insulin is eliminated, as for example in diabetic athletes who did not reduce their insulin dose, the increase in endogenous glucose production is reduced by 50%.

The ability to adjust both insulin and nutrition to allow safe participation in physical activity and high performance has recently been recognized as an important management strategy in patients with type 1 diabetes. A prime player in this strategy is the patient who should be "trained" to self-monitor blood glucose during physical activity and to use these data to improve performance and decrease hypoglycaemia.

Specific diet recommendations for diabetic athletes

Diet before, during and after the sport

Diet in the days preceding the sports event

During the week preceding an endurance physical activity, the diet should be rich in complex sugars in order to increase the supply of muscle and liver glycogen. This should prevent a hypoglycaemic attack during and after exercise in patients with type 1 diabetes.

The meal before physical activity

Diabetic athletes should not eat a meal in the three hours that precede a competition because the increased intestinal blood flow resulting from a meal may reduce muscle blood flow. The meal before a sports event should preferentially contain carbohydrates (pasta, rise and/or bread), which are soon digested and assimilated. Immediately before exercising many athletes drink a sugar-containing beverage such as fruit juice, still orange or coke that contain about 15 g of carbohydrates. This practice increases athletic performance as compared to the same exercises carried out during fasting (8). But the effect applies only to short duration exercise: carbohydrate ingestion immediately before exercise did not seem to improve 20 km time trial performance in well trained cyclists (9).

Eating during sports events

During an endurance competition glucose is consumed at a rate of about 40-50 g/h, and the level of carbohydrates must be increased in order to avoid hypoglycaemic episodes. During prolonged physical exercise muscle glucose uptake increases versus the uptake of 2-3 mg/kg bw/min in the case of light activities and of 5-6 mg/kg bw/min in the case of strenuous activities. An athlete calculates the rate of glucose to take based on both the entity of the physical activity and the level of glycaemia. If the latter is within normal range, the athlete may drink a hypotonic solution, e.g., Gatorade. Besides containing glucose, this beverage provides water and mineral salts. Fruit juices with a carbohydrate content above 10% can cause abdominal discomfort, pain, cramps, nausea and diarrhoea. In a recent study (10), the effect of ingesting a drink containing 6% carbohydrates (0.636 g/kg) on blood glucose concentration in type 1 diabetic adolescents was examined after 60 min of moderate exercise and after 30 min of recovery. At the end of the trial, blood glucose concentration was reduced by 21 mg/dl. Drinks containing 8% and 10% carbohydrates, ingested before and during exercise, in most cases, resulted in appropriate blood glucose concentrations in these type 1 diabetic adolescents. Four subjects stopped exercising during the 8% carbohydrate trial due to a drop in blood glucose concentration, therefore, 10% carbohydrate drinks could be recommended to avoid exercise-induced hypoglycaemia.

Eating after the sports event

Muscles continue to replenish glycogen stores for many hours after exercise, and increased insulin sensitivity may persist until the next day, particularly after endurance exercise. Therefore, diabetic athletes must be aware that hypoglycaemia can occur many hours after exercise. The ingestion of carbohydrates after a sports event together with a reduction in insulin dose prevents post-exercise-late-onset hypoglycaemia. The optimal dose of complex carbohydrates is 1.5 g/kg bw within 30 min followed by 1.5 g/kg bw within 120 min of stopping the physical activity. This amount of sugar restores the pre-exercise amount of liver and muscle glycogen within 24 h.

The diabetic athlete should be alert to the possibility of nocturnal hypoglycaemia after endurance activity. At night the liver is the main source of glucose, and iatrogenic hyperinsulinaemia could block this source. The evening or bed-time dose of intermediate-acting insulin may need to be reduced, and some patients find it helpful to have a larger than normal bed-time snack that should include carbohydrates from a slowly absorbed source.

It is important to prevent the loss of *water* and *electrolytes* during physical activity. Dehydration increases weakness and a 3% reduction in body weight can lead to convulsions and coma. Water loss in diabetic patients produces pseudo-hyperglycaemia and increases the risk of thrombotic phenomena and heart attacks. Before physical activity, the athlete should consider the climatic conditions and air temperature so as to calculate the amount of water to assume to prevent hypovolemia, particularly if the weather is hot and humid. About 300 ml of water should be taken

2 h before the sports event and 250 ml every 20-30 min during the physical activity. Considering that one liter of sweat contains 1.5 g of sodium, after prolonged physical activity the athlete should slowly drink sodium-containing hypotonic solutions to prevent the risk of hyponatremia and reintegrate body weight after the activity.

How does the diabetic athlete knows he/she is dehydrated? On way is to monitor the athlete's urine before and after the physical exercise. The athlete should drink enough fluid to urinate frequently. If the urine is dark and has a bad smell, there is a good chance the athlete is dehydrated.

Nutrition integrators

The use and abuse of many nutrition integrators, available in the gymnasium or as over-the-counter drugs, is increasing among athletes (11). In this section we list this integrators and their interaction with diabetes.

Amino acids are used to increase muscle mass. The intake of 14 g/day of proteins, which is the amount of proteins contained in 2 glasses of milk, will increase muscle mass by about 30 g/week. Moreover, substrate excess is converted into glucose and fatty acids. Evidence suggests that large amounts of proteins (i.e.,

> 2.4 g/kg/day) may place additional stress on the kidneys (12). Individuals with pre-existing renal disorders may be particularly susceptible to impaired kidney function during heightened protein consumption. Therefore, nutritional supplement with amino acids may be harmful for patients with diabetes.

Glycerol has osmotic activity and could prevent and correct dehydration. The dose is 1 g/kg and should be taken, in water, about 2 h before the sports activity.

Creatine is an ergogenic aid in the phosphagen system and supplies energy during the first 10-20 sec of anaerobic physical activity (13). Creatine is widely used by athletes (14) and, at a dose of 20-30 g/day for a week, it could increase the performance of "explosive" sport activity, for example weightlifting, discus throwing, 100 meters etc. Lower doses of creatine supplement (5 g twice daily for 7 days) was shown to improve the sprinting time in the last 50 m of a 400 m swimming competition (15). But these activities are not recommended for patients affected by diabetes. Similarly, also because of the stress on the kidney (16), creatine assumption is not advised in patients with diabetes.

Vitamins and minerals abound in diets rich in vegetables, fruits and cereals, which are normally prescribed for patients with diabetes, and supplementation with these elements is usually not necessary. However, vitamins C, E and A may be useful. Vitamin C facilitates iron absorption and helps collagen formation. High doses of vitamin E (1800 IU/day) is recommended for diabetic patients during mountain trekking. Nutritional supplementation with calcium, zinc and minerals is necessary in case of osmotic polyuria and iron deficiency is frequent in endurance athletes, particularly women. Magnesium deficiency is characterised by cramps and pain during movement.

Caffeine was removed from the International Olympic Committee's list of banned substances in 1972, and became increasingly popular among sportspersons as a means to enhance athletic performance (17). In 1984 the Olympic Committee defined the allowable limit of concentration of caffeine in the urine of athletes at 12 mg/mL, which corresponds to an oral assumption of 500-600 mg of coffee (5-6 cups). Caffeine increases the level of circulating fatty acids, which increases fat oxidation. Caffeine has been used for years by runners and endurance athletes to enhance fatty acid metabolism. It is particularly effective in non-habitual users. The lack of weakness during physical activity after assumption of coffee is due to delay of depletion of glycogen reserves. In type 1 diabetic patients, caffeine has been reported to enhance the symptomatic and hormonal responses to hypoglycaemia (18). It is a powerful diuretic and a risk of its assumption before sports is dehydration.

The diet of children practicing sports

The metabolic processes that supply energy for muscle contractions are classified either aerobic (with oxygen) or anaerobic (without oxygen) (5). In reality, most physical activity is a combination of aerobic and anaerobic exercise, but the activity is classified based on the predominating energy system. The anaerobic process predominates in children. With adequate training, children can improve their aerobic fitness but not to the same degree as adults. The diminished training effect in children could be related to a 'hormonal trigger' that limits cardiovascular trainability until puberty. It seems conceivable that the possibility of increasing heart size through endurance training is limited until growth hormone levels, such as testosterone, have reached an appropriate level, just as the possibility of increasing muscle size through strength training is limited until post-puberty (19). A child's heart is smaller than an adult's and does not achieve its natural full size until full height is reached. Thus, stroke volume, which is the amount of blood the heart can pump with one beat, is lower in children, which may limit any further improvements in VO_2max.

Aerobic metabolism is low in children because their enzymatic systems are not fully developed. However, also the capacity for anaerobic degradation of glycogen and glucose in muscles is lower in children than in adults. Consequently, adaptation to resistance exercise should be undertaken with caution in children and adolescents. The diet of children during sports activity should be rich in simple sugars (ingestion of carbohydrates before, during, and after exercise) and low in fat. The tendency to ketosis is a characteristic of children who are not able to metabolise NEFA completely. In case of insufficient metabolic control, exercise can provoke severe hypoglycaemic episodes, even after muscle activity has ceased, or increase glucose levels and lead to ketoacidosis. Lastly, it is very important in children to restore the water loss during physical activity in order to prevent dehydration.

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