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Exercise and diabetes

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Abstract. Physical activity activates has acute and chronic effects on glucose, lipid and protein metabolism. In type 1 diabetic subjects, the lack of the physiological inhibition of insulin secretion during exercise results in a potential risk of hypoglycemia. On the other hand, exercise-induced activation of counterregulatory hormones might trigger an acute metabolic derangement in severe insulin-deficient subjects. Thus, diabetic patients, before starting exercise sessions, must be carefully educated about the consequences of physical activity on their blood glucose and the appropriate modifications of diet and insulin therapy. Long-term effects of regular exercise are particularly advantageous for type 2 diabetic patients. Regular aerobic exercise reduces of visceral fat mass and body weight without decreasing lean body mass, ameliorates insulin sensitivity, glucose and blood pressure control, lipid profile and reduces the cardiovascular risk. For these reasons, regular aerobic physical activity must be considered an essential component of the cure of type 2 diabetes mellitus. In this regard, individual behavioral strategies have been documented to be effective in motivating sedentary type 2 diabetic subjects to the adoption and the maintenance of regular physical activity. (www.actabiomedica.it)

Key words: Metabolism, energy expenditure, insulin treatment, behavioral science

Introduction

A large number of studies have shown that habitual physical activity reduces the risk of coronary heart disease, stroke, colon cancer and mortality from all causes (1,2). Physical activity affects the metabolism of glucose and other intermediate substrates in normal subjects and in subjects with diabetes mellitus (1). In type 1 diabetic subjects, physical exercise has important effects on insulin and dietary requests that cannot be ignored to avoid severe hypo or hyperglycemia (1). In type 2 diabetes mellitus, regular aerobic physical activity is an effective tool for both prevention and treatment and needs to be fully implemented (1).

Type 1 diabetes mellitus

Despite the results of some studies show a reduction of insulin dosage and a better glucose control in type 1 diabetic patients who practice regular physical activity, there is no general agreement on these subjects (1). Certainly, the long-term benefits of regular aerobic physical activity described for general population can be extended to type 1 diabetic subjects. Thus, they should be encouraged to perform aerobic exercise similarly to non-diabetic subjects. However, diabetic patients, before starting exercise sessions, must be carefully educated about the consequences of physical activity on their blood glucose and the appropriate modifications of diet and insulin therapy.

During exercise, lack of endogenous insulin secretion makes diabetic subjects totally different in comparison to non-diabetic subjects. An essential mechanism for adequate glucose supply to exercising muscles is the physiological suppression of endogenous insulin secretion (3). In normal subjects, exercise-induced hypoinsulinemia augments hepatic gluconeogenesis and glycogenolysis, because of the reduction of

insulin/glucagon ratio (3). In contrast, type 1 diabetic subjects, who are dependent on the amount of previously injected insulin, cannot rely on this physiological mechanism (4). Thus, diabetic subjects performing exercise under full insulin action are at risk of severe hypoglycemia. Their hepatic glucose output cannot increase enough to supply augmented peripheral demand. On the other hand, if diabetic subjects, before starting exercise, are severely insulin-deficient, the exercise-induced increase of counterregulatory hormones (glucagon, epinephrine, cortisol and GH) deteriorates glucose control and could trigger diabetic ketoacidosis (4).

Insulin-treated patients can limit the jeopardy of exercise induced hypo or hyperglycemia by respecting some simple rules concerning blood glucose monitoring, site and amount of insulin injections and appropriate dietary supplementation (Table 1). The exercise sessions must be planned in advance to cut 10-40% of the dose of regular insulin injected before, on the basis of previous experience and of intensity and duration of physical activity. Insulin must not be injected into exercising arms or legs. The session should be performed when insulin action is declining, i.e. 2 hours after fast-acting analogue or 3-4 hours after regular insulin injections. Before starting physical activity, it is mandatory to check blood glucose concentration in order to decide whether or not to perform the exercise and/or ingest simple carbohydrates. Ideally, an optimal blood glucose concentration before starting lies between 120-180 mg%. For moderate or low intensity exercise sessions, these values do not require dietary supplementation. If the exercise lasts longer than 30 minutes, it is important to verify the trend of blood glucose concentration, especially when the intensity of exercise is different from usual. The 30 min test consent to the patient to learn about his/her response to exercise and, often, it is useful to prevent hypoglycemia. During physical activity of moderate (60-75% maximal heart rate) or higher intensity, supplementation with 20-60 g of simple carbohydrates is required every 30 minutes and, also, 15-30 min before starting when blood glucose concentration is near to normal. Physical activity of low intensity, usually, requires only cutting by 10-20% insulin dosage without dietary supplementation. Elevated blood glucose values (>250 mg%), before starting exercise, might be the result of either current intestinal carbohydrate absorption or severe insulin deprivation. In these circumstances to avoid acute metabolic derangement, exercise sessions can be performed only if blood or urine tests are negative for ketones. Since the metabolic effects of exercise continue a few hours after exercise, a cut of 10-30% of the insulin dosage subsequent to exercise is, generally, necessary.

Table 1. The rulebook of physically active insulin-treated diabetic subjects

1. Inject regular insulin or fast-acting insulin analogues into abdominal subcutaneous region
2. Cut regular insulin or fast-acting insulin dosage by 10-40% before the exercise, dependent on duration and intensity of the session
3. Plan to exercise 3-4 hours after the injection of regular insulin or 2 hours after the injection of fast-acting insulin analogue
4. Before starting the exercise session, check your blood glucose
5. Before starting, ingest 20-60 g of simple carbohydrates if your blood glucose is less than 120 mg%
6. Before starting, delay the exercise session if your blood glucose is less than 80 mg%
7. Before starting, delay the exercise session if your blood glucose is greater than 250 mg%; you can exercise only if your blood or urinary ketones are negative
8. During exercise of moderate (60-75% maximal heart rate) or higher intensity supplement with 20-60 g of simple carbohydrates, every 30 minutes
9. Check your blood glucose after 30 minutes of exercise
10. After exercise, cut your usual pre-meal regular insulin or fast-acting insulin dosage by 10-30%

Aerobic physical activities of low-moderate intensity, enduring less than 1 hour, should be suggested to type 1 diabetic subjects. However, also type 1 diabetic subjects, keeping in mind that regular moderate-intensity exercise has the best risk/benefit ratio and that some activities must be avoided, can perform competitive professional sports. Sports involving special alertness (car or motorbike racing, scuba diving, rock climbing, etc.), contact fighting and weight lifting sports are not indicated because of the potential risk of hypoglycemia or retinal bleeding.

Type 2 diabetes mellitus

There is enough evidence in literature to use physical activity as an effective therapeutic tool for prevention and management of type 2 diabetes mellitus. Intervention trials have demonstrated that in subjects with impaired glucose tolerance diet plus exercise programs reduce by ~60% the risk of developing diabetes (5,6). In subjects with overt type 2 diabetes, diet and exercise produce greater weight loss and allow greater reductions in hypoglycemic medications than diet alone (7).

Exercise reduces blood glucose through an increase of insulin-dependent and insulin-independent glucose transport to working muscles (8). Exercise increases the translocation of glucose transporter 4 (GLUT 4) to the surface of muscle cells (9). There is evidence for the presence of two distinct pools of GLUT4 in skeletal muscle, one responding to exercise and one responding to insulin (10, 11). Muscle contraction increases the AMP/ATP and creatinine/phosfocreatinine ratios, which rapidly activate adenosine monophosphate protein kinase (AMPK), a key mediator of fatty acid oxidation (12) and glucose transport (13) in mammalian cells. During muscle contraction, AMPK appears to produce the translocation of GLUT 4 of either the insulin-dependent (14) or the insulin-independent (13) pools. In type 2 diabetic subjects, physical training increases insulin stimulated non-oxidative glucose disposal (15,16), presumably activating glycogen synthesis. The beneficial effects of regular physical activity on insulin sensitivity appear to be the final result of sum of specific effects of exercise on GLUT 4 content, oxidative capacity and capillary density of skeletal muscle (8). Preliminary data suggest that insulin-independent glucose transport, induced by exercise, is promoted by augmented endothelial and muscle production of nitric oxide (17,18). Since impaired nitric oxide production often complicates type 2 diabetes mellitus, physical exercise might be utilized to improve as well insulin sensitivity and endothelial dysfunction.

Despite the evidence about the benefits of exercise, many diabetologists do not spend time and efforts convincing type 2 diabetic subjects to practice physical activity. It is likely that the limited diffusion of exercise as a standard therapeutic tool among diabetologists is caused by the poor adherence of older adults to comply with their recommendations. Survey studies have shown that adults with diabetes are less likely than adults in general to engage in regular physical activity (19) and that only 23% of older adults with type 2 diabetes reported >60 minutes of weekly physical activity (20). There is the need for simple and reproducible strategies of counseling to motivate type 2 diabetic patients to the practice of exercise. Recently, we have demonstrated that using an individual behavioral approach, primarily based on the social learning theory (21), it is possible for physicians to motivate the majority of type 2 diabetic subjects to long-term practice of exercise (22). The intervention consisted in a first counseling of at least 30 minutes conducted by a diabetologist and designed to advice physical activity, followed, after 1 month, by home calling and every 3 months by an ambulatory visit of about 15 minutes (22). The intervention was effective in reducing BMI, HbA1c, coronary risk and treatment costs with a significant correlation between the amount of voluntary physical activity and the beneficial effects (23).

Data of literature showing that modest increments of physical fitness in diabetic subjects reduce by two-fold the risk of overall mortality (24), urge to institute physical activity programs in the cure of type 2 diabetes mellitus. Since it is possible for diabetologists to motivate the majority of type 2 diabetic to long-term practice of physical activity, it is time to move exercise from theory to daily ambulatory practice.

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