International Diabetes Federation

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Glycemic control during consecutive days with prolonged walking exercise in individuals with type 1 diabetes mellitus

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ARTICLE INFO

ABSTRACT

Aims: Despite its general benefits for health, exercise complicates the maintenance of stable blood glucose concentrations in individuals with type 1 diabetes. The aim of the current study was to examine changes in food intake, insulin administration, and 24-h glycemic control in response to consecutive days with prolonged walking exercise (∼8 h daily) in individuals with type 1 diabetes.

Methods: Ten individuals with type 1 diabetes participating in the worlds' largest walking event were recruited for this observational study. Simultaneous measurements of 24-h glycemic control (continuous glucose monitoring), insulin administration and food intake were performed during a non-walking day (control) and during three subsequent days with prolonged walking exercise (daily distance 40 or 50 km).

Results: Despite an increase in daily energy (31 ± 18%; $p < 0.01$) and carbohydrate (82 ± 71 g; $p < 0.01$) intake during walking days, subjects lowered their insulin administration by 26 ± 16% relative to the control day ($p < 0.01$). Average 24-h blood glucose concentrations, the prevalence of hyperglycemia (blood glucose >10 mmol/L) and hypoglycemia (blood glucose <3.9 mmol/L) did not differ between the control day and walking days ($p > 0.05$ for all variables). The prolonged walking exercise was associated with a modest increase in glycemic variability compared with the control day ($p < 0.05$).

Conclusion: Prolonged walking exercise allows for profound reductions in daily insulin administration in persons with type 1 diabetes, despite large increments in energy and carbohydrate intake. When taking such adjustments into account, prolonged moderate-intensity exercise does not necessarily impair 24-h glycemic control.

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1. Introduction

Regular exercise has been associated with many health benefits, including cardiorespiratory fitness, muscle strength, cardiovascular and metabolic health, and increased life expectancy. Such health benefits are even more important for persons with type 1 diabetes, as this population is characterized by an increased prevalence of cardiovascular complications and premature death. Therefore, exercise is an important cornerstone in the management of type 1 diabetes [1–3].

Despite its general benefits for health, exercise has been associated with an increased risk for developing hypoglycemia [4,5]. Such exercise-induced hypoglycemia may develop during and immediately after exercise, and even the day after performing exercise [5]. Several factors contribute to the occurrence of exercise-induced hypoglycemia. In persons with type 1 diabetes, the increase in blood glucose disposal during and following exercise is not compensated by a physiological reduction in circulating insulin concentrations. The resulting (relative) excess in circulating insulin concentrations inhibits the hepatic glucose output and stimulates the insulin-dependent blood glucose disposal [6]. Consequently, blood glucose concentrations further decline and hypoglycemia may develop. This process is further potentiated by the impairment in glucose counter-regulatory responses after exercise that is often present in individuals with type 1 diabetes [6,7]. Since severe hypoglycemia has been associated with severe complications, such as cardiac dysrhythmia, seizure, coma and even death, preventing exercise-induced hypoglycemia is of utmost importance.

Two important strategies are well-recognized for the prevention of exercise-induced hypoglycemia, i.e. reductions in insulin administration and supplementation of carbohydrates before and after exercise [2,8]. These strategies will, at least partly, correct for the relative insulin excess resulting from exercise. Accurate predictions of adequate adjustments in insulin administration and dietary carbohydrate needs are difficult, and under- or over adjustment may potentially induce or worsen hypo- or hyperglycemia before and after exercise [9]. The optimal adjustments required to achieve stable blood glucose concentrations may vary dependent on the characteristics of the exercise performed (e.g. type, intensity, duration, and timing of exercise) [10]. Therefore, much research has focused on blood glucose responses to different exercise characteristics, along with the optimization of insulin administration and carbohydrate intake in preparation or in response to exercise [9,11–15]. Despite the incremental knowledge in this area, only limited information is available regarding the impact of prolonged endurance-type exercise (>2 h duration) on blood glucose control. Such information is essential given the growing number of people with type 1 diabetes engaging in prolonged endurance-type exercise or leisure time physical activity (e.g. day hiking, cycling tours, or athletic events).

In the current observational study, we assessed changes in 24-h blood glucose concentrations, physical activity, dietary intake, and insulin administration in individuals with type 1 diabetes in response to consecutive days of prolonged moderate-intensity walking exercise (~8 h/day). For this purpose, we conducted simultaneous measurements with continuous glucose monitoring devices, physical activity monitors, and food and insulin records in 10 individuals with type 1 diabetes participating in the worlds' largest walking event, i.e. the Nijmegen Four Day Marches. We hypothesized that large adjustments in insulin administration and carbohydrate intake are required to prevent exercise-induced impairments in glycemic control.

2. Methods

2.1. Subjects

A total of 10 individuals with type 1 diabetes volunteered to participate in this study. Subjects were recruited after registration for the 'Nijmegen Four Day Marches' walking event (an annual 4-day walking event in The Netherlands). The characteristics of the subjects are listed in Table 1. A written informed consent was obtained from all subjects before the start of the study. The study was approved by the Medical Ethical Committee of the Radboud University Nijmegen Medical Centre, and was conducted in accordance with the Declaration of Helsinki.

2.2. Study design

All individuals participated in this observational study, comprising simultaneous measurements of 24-h glycemic control, insulin administration, food intake, and physical activity (Fig. 1). These variables were assessed the day before the 'Nijmegen Four Day Marches' walking event (control assessment), and over the course of this 4-day walking event (walking assessment). Upon registration for the walking event, participants selected to walk a daily distance of 40 or 50 km. In 2013, the walking event took place from July 16th to July 19th. All subjects were monitored at the same time.

2.3. Study protocol

The study was conducted over a 6-day period (Fig. 1). On day 1 of the study period, subjects reported to the research laboratory in the afternoon. A venous blood sample was drawn for the assessment of HbA1c content, and subjects completed a short screening questionnaire on their diabetes and training

Table 1 – Participants' characteristics.	
N (male/female)	10 (1/9)
Age (y)	45 ± 13
BMI (kg/m^2)	24.2 ± 3.6
Pump/multiple injections	4/6
Diabetes duration (y)	26 ± 11.3
HbA1c (%)	7.9 ± 1.2
HbA1c (mmol/mol)	63 ± 13
Exercise training[*] (h/week)	7.2 ± 3.9

Data are means ± SD or frequencies.

[*] Exercise training refers to all structured exercise over the last month prior to the walking event.