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Original research

Relation between energy intake and glycemic control in physically active young adults with type 1 diabetes

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ABSTRACT

Objectives: To examine the relationships between daily energy expenditure, energy intake and glycemic control in young adults with type 1 diabetes.
Design: Cross-sectional study.
Methods: Energy expenditure (kcal kg^{-1} d^{-1}) and duration of participation in physical activity were measured from a 3-d activity diary and categorized according to their intensity on a 1–9 scale. Energy intake was measured by a 3-d food record. Glycemic control was measured using the HbA_{1c}.
Results: Energy expenditure and intake were assessed in 35 young adults with type 1 diabetes (age: 28 ± 7 years). Participants with higher energy expenditure from moderate to intense physical activity (categories 6–9) presented higher proportion of energy intake derived from carbohydrate and lower proportion of lipids in the diet with significantly higher HbA_{1c} values (7.3 ± 1.0% *vs* 6.7 ± 0.6%).
Conclusions: These results suggest that highly physically active individuals with type 1 diabetes consume more carbohydrates than lipids, a strategy that may affect their glycemic control. Further studies are needed to develop interventions to improve glycemic control in highly active individuals with type 1 diabetes.

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1. Introduction

The balance between energy intake (EI), energy expenditure (EE) and insulin dosage is the cornerstone of optimal glycemic control in individuals with type 1 diabetes. A limited number of studies have been performed to document the associations between EI, EE, metabolic and glycemic control in young individuals with type 1 diabetes.[1,2] Adolescent girls with type 1 diabetes showed a slightly higher EI than their non-diabetic counterparts[2] but a lower level of physical activity than age-matched controls.[1] Furthermore, it has been shown in a large cohort of participants with suboptimal glycemic control, that sedentary diabetic women had higher HbA_{1c} compared to active women (8.8 ± 1.4% *vs* 8.3 ± 1.4%) whereas this difference was not observed in men.[3] Diets higher in fat and saturated fat and lower in carbohydrate have been shown to be associated with worse glycemic control, independent of the level of physical activity and body mass index (BMI) in the Diabetes Control and Complications Trial (DCCT).[4]

Most of these studies have examined patient populations with HbA_{1c} values far above actual clinical targets. Therefore, the relations between EI, EE, and glycemic control in physically active young adults with generally well-controlled type 1 diabetes remain unknown.

2. Methods

Thirty-five participants (23 men and 12 women) with type 1 diabetes were recruited through advertisements in a University teaching hospital diabetes outpatient clinic and a diabetes educational magazine. Exclusion criteria included age less than 18 years, HbA_{1c} > 8.5%, current smoking, unstable weight in the last 3 months (defined as ±2 kg), pregnancy and diabetic complications such as nephropathy, neuropathy and retinopathy. The study protocol was approved by the Laval University Medical Ethics

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Committee and informed consent was obtained from each participant. All participants were on multiple daily insulin injection regimen using N-Lispro. Participants were accustomed with carbohydrate counting and adjustment of insulin doses according to individual algorithms to maintain capillary blood glucose between 4–7 mmol/l before meals and 7–10 mmol/l 1 h post-prandial.[5] No participants were on insulin pumps.

Participants filled out a 3-d activity diary[6] including two weekdays and one weekend day. In the activity record, a day (24 h) was divided into 96 periods of 15 min each. Participants used a list of categorized activities to fill out their diary. Activities were classified according to mean EE on a 1–9 scale. Participants recorded the dominant activity that they were engaged in for each 15-min period, using the gradation 1–9. For example, category 1 indicated activities of very low EE such as sleeping or resting in bed. Category 6 indicated activities of moderate EE such as light manual work or light exercise such as riding a bike. Finally, category 9 indicated activities of very high EE such as running. In the present study, only mean daily EE and duration of participation for categories of EE 6, 7, 8 and 9 (EE6-9), which have an energy cost $\geq$1.2 kcal kg^{-1} $\times$ 15 min^{-1} ($\geq$4.8 METs) were considered for the analyses. EE6-9, expressed as kcal kg^{-1} d^{-1}, was calculated by multiplying the number of 15-min periods of categories 6–9 by the approximate median energy cost of each category as previously determined by the authors of the activity diary[6] (*i.e.*, 1.2, 1.4, 1.5 and 2 kcal kg^{-1} $\times$ 15 min^{-1} for categories 6, 7, 8 and 9, respectively). The following formula was used: EE6-9 = (number of 15-min periods of category 6 $\times$ 1.2) + (number of 15-min periods of category 7 $\times$ 1.4) + (number of 15-min periods of category 8 $\times$ 1.5) + (number of 15-min periods of category 9 $\times$ 2). The mean EE6-9 value of the 3-d was then calculated (kcal kg^{-1} d^{-1}) and used for analyses.

Dietary intakes were collected using a 3-d food record, which was completed during the same two weekdays and one weekend day of the 3-d activity record. A registered dietitian explained to each participant how to complete their food record and encouraged them to continue to consume usual amounts of typical foods and beverages. After completion of the record, the registered dietitian reviewed it with the participant, and nutrient intakes were calculated using a computerized version of the Canadian Nutrient File.[7]

BMI was calculated (kg/m^2) using weight measured to the nearest 0.1 kg with the participant in bathing suit and height was measured to the nearest centimeter using a standard beam scale with the participant barefoot. Blood pressure (BP) was measured in the sitting position after a 5-min rest using a mercury sphygmomanometer.

Maximal aerobic power (VO_{2max}) was assessed using a progressive test conducted on an electromagnetically braked ergocycle (Lode Instrument, Holland). The initial workload was set at 50 W and increased by 25 W every 2 min until exhaustion. During the test, VO_{2max} was measured using an open circuit system (AEI, California). The VO_2 plateau reached during the test was considered the VO_{2max}. Criteria for reaching VO_{2max} were (1) a plateau in oxygen uptake despite an increase in work rate, (2) attainment of age-predicted maximal heart rate, (3) a respiratory exchange ratio of greater than 1.05 and (4) a score of 17 and higher on the Borg scale of perceived exertion.

All values are expressed as means ± standard deviation (SD). Results are presented as overall group means and separated by sex subgroups when anthropometric variables are involved. Student's *t*-test was used for comparisons between men and women. Spearman's correlations were calculated for EE6-9 and EI in relation to metabolic and anthropometric variables. Statistical significance was set at $p < 0.05$ for all tests. All statistical analyses were performed using the JMP statistical software 7.0 (SAS Institute, Cary, NC).

3. Results

Participant characteristics' are shown in Table 1. Men displayed significantly higher weight and BMI, higher SBP but were younger and had shorter duration of diabetes. Men required higher total daily insulin dose compared to women (65.3 ± 19.4 U *vs* 48.3 ± 9.6 U, $p < 0.01$) but similar dose when adjusted for weight (0.81 ± 0.25 U *vs* 0.76 ± 0.16 U/kg, NS). Men and women's mean HbA_{1c} was not different with respective values of 7.1 ± 0.9% and 6.8 ± 0.7%. Men and women were considered as moderately fit (mean VO_{2max}: 45 ± 8 and 33 ± 6 ml O_2 kg^{-1} min^{-1}, respectively, $p < 0.05$).

Participants nutritional and energy expenditure profiles are shown in Table 1. Men reported significantly higher total EI, EE, intake of monounsaturated fatty acids (MUFA), saturated fat and cholesterol than women. However, when those parameters were expressed in proportion to EI, all sex differences disappeared. Participants generally respected protein (15–20%) and carbohydrate requirements (45–65%) of the diabetic nutrition recommendations.[8] The average minimum requirement for carbohydrates of 130 g/day was reached in both men and women (336 ± 87 and 220 ± 59 g/d). However, participants did not meet recommendations for dietary fat, cholesterol and fiber. Indeed, it is recommended that saturated fat should be limited to less than 7% of total calories and it was found to be over-consumed in both groups with an average intake of 12%. The dietary cholesterol recommendation of ∼200 mg/d was also surpassed in these groups, especially in men. Moreover, men and women did not consume enough fiber to reach the goal of 14 g/1000 kcal with values of 6.4 ± 3.0 and 8.2 ± 2.6 g/1000 kcal, respectively.

The daily physical activity participation in the nine categories used in the physical activity record was such that frequency of 15-min periods spent in every category decreased as the category's

Table 1
Participants nutritional and energy expenditure profiles.

Variables	All (n = 35)	Men (n = 23)	Women (n = 12)
Age (years)	27.7 ± 6.9	25.6 ± 5.9	31.6 ± 7.2*
Duration of diabetes (years)	12.7 ± 8.4	10.4 ± 5.9	16.9 ± 10.9*
HbA_{1c} (%)[a]	7.0 ± 0.8	7.1 ± 0.9	6.8 ± 0.7
VO_{2max} (ml O_2 kg^{-1} min^{-1})	43 ± 9	45 ± 8	33 ± 6*
Weight (kg)	75.5 ± 12.5	81.6 ± 9.5	63.8 ± 8.5**
Body mass index (kg/m^2)	25.4 ± 2.9	26.3 ± 2.8	23.8 ± 2.4*
Systolic BP (mmHg)	116 ± 8	118 ± 8	111 ± 8*
Diastolic BP (mmHg)	73 ± 6	73 ± 7	71 ± 5
Energy intake			
Daily EI (Kcal)	2640 ± 698	2981 ± 580	2016 ± 403**
EI from lipids (%)	36 ± 6	36 ± 6	37 ± 6
EI from carbohydrates (%)	44 ± 7	45 ± 7	43 ± 7
EI from proteins (%)	17 ± 3	16 ± 3	19 ± 3*
EI from alcohol (%)	2 ± 4	3 ± 5	1 ± 1
Total fiber (g)	18 ± 9	19 ± 11	16 ± 6
MUFA (g)	38 ± 14	43 ± 14	30 ± 11*
PUFA (g)	17 ± 7	18 ± 6	14 ± 8
Saturated (%)	12 ± 4	12 ± 4	11 ± 4
P:S ratio	0.55 ± 0.24	0.51 ± 0.17	0.62 ± 0.33
Cholesterol (g)	277 ± 132	314 ± 140	209 ± 81*
Energy expenditure			
Daily EE (kcal)	3283 ± 801	3606 ± 761	2692 ± 477**
EE1-5 (number of periods/d)	91.8 ± 5.5	90.9 ± 6.2	93.4 ± 3.6
EE6-9 (number of periods/d)	4.1 ± 5.2	4.6 ± 6.0	3.0 ± 3.2

Data are means ± SD. BP, blood pressure; EE, energy expenditure; EE1-5, frequency of participation for energy expenditure in categories 1–5; EE6-9, frequency of participation for energy expenditure in categories 6–9; EI, energy intake; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; P:S, polyunsaturated to saturated fat ratio.

[a] Adjusted for VO_{2max} and PA level.

* Significant differences between men and women, $p < 0.05$.

** Significant differences between men and women, $p < 0.01$.

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