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Research report

Effect of exercise on food consumption and appetite sensations in subjects with diabetes ☆

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ABSTRACT

Aim: Evaluate appetite sensations following 60-min moderate intensity exercise and to predict energy intake in adults with diabetes. Methods: Visual analogue scales measured appetite sensations before and after a fixed test meal. Fasting appetite sensations, 1 h post-prandial area under the curve (AUC) and the satiety quotient predicted energy intake. Two measures of energy intake were recorded: (1) following an *ad libitum* test lunch and (2) a 3-day self-report dietary record. Appetite sensations were assessed in a control condition (rest, C) and when two exercise sessions were performed: one associated with a free (F) blood glucose decrease and one with limited blood glucose decreases i.e. maintained (M) above 4 mmol/l by dextrose infusion. Results: 16 generally well-controlled (HbA_{1c}: 7.0 ± 0.6%) subjects (12 with type 1 diabetes, 4 with type 2 diabetes) ate 1020 ± 519, 1170 ± 282 and 1020 ± 304 kcal (NS between conditions nor diabetes type) during the buffet meal following the C, F and M conditions, respectively. Exercise induced a mean blood glucose decrease of 3.7 ± 0.6 and 3.1 ± 0.6 mmol/l for the F and M conditions, respectively. The greater the blood glucose decrease, the greater the appetite sensations of hunger and prospective food consumption measured fasting and before the test meal (all $p < 0.05$) in the whole group. One-hour post-prandial AUC for hunger and desire to eat represented the strongest predictors of *ad libitum* test lunch energy intake ($p < 0.05$), especially in type 1 diabetes. Conclusions: These results suggest that appetite sensations are predictors of spontaneous energy intake in both diabetes type. Moderate intensity exercise for 60 min induced a positive effect by lowering blood glucose which was associated with appetite sensations. These results support the glucostatic theory of food intake control which protects against exercised-induced blood glucose declines.

Introduction

Appetite sensations are a reliable and valid method of measuring subjective states of motivation to eat before and in response to meals (Flint, Raben, Blundell, & Astrup, 2000). Drapeau et al. (2005) showed that 1 h post meal area under the curve (AUC, i.e. appetite sensation responses to a test meal) and the satiety quotient (SQ, i.e. individual satiety signal capacity in response to a test meal) were identified as predictors of energy intake in men and women of different weight status.

Diet, physical activity and medication are the cornerstones of diabetes treatment. Some antidiabetic oral agents and insulin allow diabetic patients to reach optimal glycemia with the downside of possible hypoglycemia. Blood glucose (BG) values play a role in the control of energy intake because glycemic drop initiates meals, even in the normal range. Indeed, hunger is a key symptom in food intake following hypoglycemia (Deary, Hepburn, MacLeod, & Frier, 1993). In non-diabetic men, data have shown that transient insulin-induced hypoglycemia increased food intake, especially lipids, without modification of appetite scales (Dewan et al., 2004). This overconsumption, if not corrected at the following meal, may result in an energy imbalance favoring a weight gain. However, it is not known if this is also applicable to diabetes.

In type 1 diabetes (T1DM), 65% of subjects reported an imperative need for food during hypoglycemia, especially carbohydrate-rich food (Strachan, Ewing, Frier, Harper, & Deary, 2004). These data (Strachan et al., 2004) are in accordance with those of Mayer-Gross and Walker (1946) who support a homeostatic theory suggesting that when the brain needs glucose, food intake increases, especially carbohydrate-rich food, to increase BG.

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In human subjects, studies reported that exercise did not affect appetite, hunger or satiety sensations (Reger & Allison, 1987; Reger, Allison, & Kurucz, 1986; Thompson, Wolfe, & Eikelboom, 1988) while others noted changes in appetite sensations induced by exercise (Blundell, Stubbs, Hughes, Whybrow, & King, 2003; King, Burley, & Blundell, 1994; King, Tremblay, & Blundell, 1997). However, the effect of exercise on such sensations is unknown in subjects with diabetes where hypoglycemia is a major factor. Therefore, our first objective was to document the effect of exercise on food intake and related appetite sensations following moderate intensity exercise in subjects with T1DM and type 2 diabetes (T2DM). Moreover, our second objective was to evaluate the validity of appetite sensations to predict overall energy intake in adults with diabetes.

Methods

Subjects

Sixteen subjects (9 men and 7 women) with diabetes with T1DM (12) and T2DM (4) were recruited through advertisements in a university teaching hospital diabetes outpatient clinic and diabetes magazine. The women, who were all taking oral contraceptives, were studied in the follicular menstrual phase (Diamond, Simonson, & DeFronzo, 1989). All subjects were on anti-hyperglycemic oral agents or multiple daily insulin injections regimen except one subject who was treated by continuous subcutaneous insulin delivery system. 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, contra-indication for exercise and diabetic complications such as nephropathy, neuropathy and retinopathy. The study protocol was approved by the Laval University Medical Ethics Committee and informed consent was obtained from each participant.

Appetite sensation measurements

Appetite measurements were measured before and 1 h after a fixed breakfast test meal. This test aimed to investigate the impact of a certain amount of calories on acute appetite sensations. Subjects were asked to arrive at the laboratory in the morning after an overnight fast and to refrain from alcohol consumption, intense physical activity and avoid hypoglycemia for the previous 24 h. The standardized breakfast was served around 7 h30. The energy content of the meal was 600 kcal and 700 kcal for women and men, respectively. The standardized breakfast consisted of bread, butter, cheese, milk and orange juice. All subjects were instructed to consume all the food in no more than 30 min. Before, immediately after, and every 10 min for a 1-h period after the standardized breakfast test, subjects were asked to record their appetite sensations for «desire to eat», «hunger», «fullness» and «prospective food consumption» (PFC) on visual analogue scales (VAS) adapted from Hill and Blundell (1986). Subjects were asked to indicate, on a scale from 0 to 150 mm, how they felt at the moment they completed these questions: How strong is your desire to eat? (very weak-very strong); How hungry do you feel? (not hungry at all-as hungry as I ever felt); How full do you feel? (not full at all-very full); How much food do you think you could eat? (nothing at all – a large amount). Subjects were asked to rate the palatability of the breakfast using VAS.

The baseline appetite ratings immediately before the fixed breakfast test meal were referred to as fasting appetite sensations. The appetite sensation responses to the test meal were evaluated by calculating the 1-h post meal AUC (1 h post-prandial AUC) with the trapezoid method (Doucet, St-Pierre, Almeras, & Tremblay, 2003). The satiety signal efficiency was assessed with the SQ concept adapted from Green, Delargy, Joanes, and Blundell (1997). Thus, for each appetite sensation (AS), the SQ (mm/kcal) was calculated with this equation:

$$SQ = (\text{fasting AS-mean 60 min post meal AS}/\text{energy content of the test meal}) \times 100$$

A higher SQ would represent greater satiety whereas a lower SQ would represent a lower satiety.

Eating behaviors

A French version of the Three-Factor Eating Questionnaire was completed by our participants. The Three-Factor Eating questionnaire is a 51-item questionnaire assessing three factors related to cognitions and behaviors associated with eating: cognitive dietary restraint, disinhibition and susceptibility to hunger (Stunkard & Messick, 1985).

Ad libitum energy intake

At lunch, each subject was provided with an *ad libitum* buffet-style meal to measure *ad libitum* energy intake. To measure *ad libitum* food intake in an experimental context, where energy intake and macronutrient preferences can be assessed, the administration of a buffet-type meal in the laboratory was used as described by Arvaniti, Richard, and Tremblay (2000). Briefly, a cold buffet-type meal comprising a variety of foods was offered immediately after each experimental condition, and the subjects were instructed to eat *ad libitum*. Subjects had already completed a food preference questionnaire to ensure that they liked the buffet foods using a scale from 0 to 5 (0-do not like at all to 5-like very much). If subjects rated more than 50% of the foods lower than 3, they did not participate in the study. In order to control for external stimuli that could affect appetite, subjects were isolated in a quiet room with no sensory distraction other than the food they were provided with. Participants were instructed to eat as much as they liked during the course of the meal. Subjects had a maximum of 30 min to eat their meal, and portions of each food were larger than the expected subject's intake. All foods were weighed to the nearest 0.1 g immediately before and after the test meals. Energy, protein, lipid, and carbohydrate intakes were calculated using the Canadian Nutrient File by a dietician (Health (2001)).

Self-reported physical activity and food records

Energy intake was assessed using a 3-d food record, which was completed during two weekdays and one weekend day, 1–2 weeks before the exercise was performed. Portion sizes were estimated by household measurements. A registered dietitian explained to each subject how to complete their 3-d 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 with a computerized version of the Canadian Nutrient File (Arvaniti et al., 2000).

Subjects filled out a 3-d activity diary (Bouchard et al., 1983) including the same two weekdays and weekend day chosen to complete the food diary. In the activity record, a day (24 h) was divided into 96 periods of 15 min each. Subjects used a list of categorized activities to fill out their diary. Activities were classified according to mean energy expenditure on a 1–9 scale. Subjects recorded the dominant activity that they were engaged in for each 15-min period, using the gradation 1–9. For example, category 1