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Applied nutritional investigation

Postprandial substrate use in overweight subjects with the metabolic syndrome after isomaltulose (Palatinose™) ingestion

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ABSTRACT

Objective: Dietary interventions with a low glycemic index have shown to be successful for the prevention and therapy of the metabolic syndrome. In the present study, we investigated the postprandial metabolic response at rest and during physical activity the low glycemic carbohydrate isomaltulose (Palatinose™) intake compared with a conventional carbohydrate (glucose syrup/sucrose [glc/suc]) with a higher glycemic index.
Methods: Twenty overweight or obese men (32–64 y old) with the metabolic syndrome and insulin resistance were enrolled in this double-blinded, randomized, cross-over study. In the morning, a breakfast consisting of a 250-mL drink and 140 g of cookies containing in a total of 50 g of Palatinose™ or glc/suc was consumed. Two hours after breakfast, subjects exercised at moderate intensity on a treadmill for 30 min. Thereafter, subjects ingested a standardized lunch consisting of a 250-mL drink with 10% Palatinose™ or glc/suc, mini pizzas, and an apple.
Results: Blood levels of glucose and insulin were measured and the postprandial substrate metabolism was determined. The glycemic and insulinemic responses were considerably lower after the ingestion of Palatinose™ (incremental area under the curve, $P < 0.05$). The total fat oxidation was significantly higher with Palatinose™ from breakfast to the beginning of lunch including the exercise and postexercise periods ($P < 0.05$). Fat oxidation with Palatinose™ was numerically higher throughout the entire examination period ($P = 0.09$).
Conclusion: In obese subjects with insulin resistance and the metabolic syndrome, the partial substitution of carbohydrates with a higher glycemic index in foods and drinks by Palatinose™ resulted in greater postprandial fat oxidation at rest and during physical activity. It is hypothesized that this increased fat oxidation may confer further benefits for long-term weight management and for an improvement in metabolic risk factors.

Introduction

Postprandial substrate use influences key metabolic factors such as whole-body energy balance, body composition, aerobic energy provision, and endurance performance. Carbohydrates and fats are the most important energy sources at rest and during exercise [1–4] and the organism has a distinct metabolic flexibility to switch between fat and carbohydrate use [3,5]. A major regulatory factor for substrate use is the presence or relative preponderance of one energy source over the other. Another pathway consists of the modulation of the glycemic index (GI) in the diet. Fat oxidation has been shown to increase after the consumption of foods with a low GI compared with a meal with a high GI [6–10].

Several investigations have demonstrated that dietary interventions with a low GI are successful for the prevention and therapy of insulin resistance and other components of the metabolic syndrome [11–13]. In part, this could be explained by a lower postprandial insulin response because high postprandial insulin levels inhibit lipolysis and switch energy consumption toward an increased carbohydrate use [8,14,15]. It has been proposed that a lower lipolysis and a decrease fatty acid use would favor extra adipocyte lipid accumulation and thus insulin resistance [16,17]. In addition, there is evidence that greater fat oxidation is responsible for an improved weight loss and

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Table 1
Anthropometric characteristics and laboratory findings in investigated subjects

Age (y)	50.7 ± 9.8
Height (cm)	179 ± 8.62
Weight (kg)	102 ± 15.1
BMI (kg/m^2)	32.1 ± 3.3
Waist circumference (cm)	112 ± 9.7
Total cholesterol (mg/dL)	201 ± 33.2
Triacylglycerol (mg/dL)	217 ± 144
HDL cholesterol (mg/dL)	46.2 ± 12.1
LDL cholesterol (mg/dL)	118 ± 23.4
SBP (mmHg)	149 ± 19.3
DBP (mmHg)	96.1 ± 8.2
Glucose (mg/dL)	105 ± 15.1
Insulin (μU/mL)	24.1 ± 17.6
HOMA-IR	6.23 ± 4.58

BMI, body mass index; DBP, diastolic blood pressure; HDL, high-density lipoprotein; HOMA-IR, homeostasis model assessment for insulin resistance; LDL, low-density lipoprotein; SBP, systolic blood pressure
Values are presented as mean ± SD

long-term weight control [18]. Furthermore, it has been hypothesized that a lower insulin response would prolong satiety and fullness [19,20].

In the present study, we investigated the postprandial metabolic response after an intake of breakfast and lunch that contained 50 g of the low GI carbohydrate isomaltulose (Palatinose™) or a combination of glucose syrup and sucrose (1:1; glc/suc) with a higher GI and load, respectively.

Isomaltulose (Palatinose™) is a disaccharide with glucose and fructose linked by an α-1,6-glycosidic bond. The low GI of Palatinose™ of 32 [21] results from the slow hydrolysis of the α-1,6-glycosidic bond by the sucrase–isomaltase complex situated on the brush border membrane of the small intestinal cells [22]. Therefore, the rate of absorption of Palatinose™ is rather slow. Nevertheless, after hydrolysis, the resulting monosaccharides glucose and fructose are efficiently taken up, and it has been shown that Palatinose™ is a fully digestible carbohydrate [23]. In the present investigation, the most important target value was the postprandial and exercise-related substrate use, mainly the oxidation of fatty acids, as measured by indirect calorimetry. Compared with previous studies, we investigated the respective parameters in insulin-resistant subjects with the metabolic syndrome at rest and during moderate physical activity. The scientific background for this selection is based on various investigations suggesting that fat oxidation is impaired in insulin-resistant subjects, implying that interventions targeted to alter substrate use would be particularly important in this group as a risk panel for the development of, e.g., diabetes mellitus and cardiovascular diseases.

Materials and methods

The study was performed using a double-blinded, randomized, cross-over design. Twenty overweight or obese men 32 to 64 y old were enrolled in this investigation. All subjects completed a comprehensive medical examination and routine blood testing. Anthropometric data and baseline laboratory data are listed in Table 1. Subjects were included if they were free from acute diseases, were overweight or obese (body mass index >25 kg/m^2), had a normal physical activity profile (no athletes or endurance-trained subjects), were able to carry out a physical activity protocol (specified below), fulfilled three of five of the National Cholesterol Education Program/Adult Treatment Panel III (NCEP/ATP III) criteria for the metabolic syndrome (National Institutes of Health, 2002; waist circumference >102 cm, triacylglycerol level >150 mg/dL, high-density lipoprotein cholesterol <40 mg/dL, blood pressure >130/85 mmHg, fasting blood glucose level >100 mg/dL), and were insulin resistant according to a homeostasis model assessment index higher than 2.5 (insulin [μU/mL] × blood sugar [mg/dL]/405). Exclusion criteria were generally accepted contraindications to physical exercise, type 1 diabetes, liver and kidney impairments, psychiatric disorders, other disorders of an acute or chronic nature (gastrointestinal, pulmonary, renal, cardiac, neurological, or psychiatric disorders), known allergies to foods or their ingredients, use of weight-reducing preparations or appetite suppressants, participation in a clinical study within 30 d before the beginning of this study or during this study, and use of β-blockers, oral antidiabetic medications, and insulin therapy. Written informed consent was given by all subjects; the study protocol was approved by the ethical committee of the University of Freiburg.

In the morning at 09:00 h after an overnight fast (12 h), each subject consumed in a randomized fashion a breakfast (891 kcal, 110 g of carbohydrates, 46 g of fat, and 10 g of protein) consisting of a 250-mL drink with 25 g of Palatinose™ (Beneo GmbH, Mannheim, Germany) or glc/suc (1:1) and 140 g of cookies containing 60 g of carbohydrate, of which 25 g was from Palatinose™ or glc/suc. The drinks and the cookies were comparable in appearance, taste, and sweetness. Two hours after breakfast, subjects exercised at moderate intensity (4 km/h, inclination 5%) on a treadmill for 30 min followed by a 30-min post-exercise regeneration period. Thereafter, 180 min after breakfast, subjects ingested a lunch (640 kcal, 85 g of carbohydrates, 20 g of fat, and 18 g of protein) consisting of a 250-mL beverage with 25 g of Palatinose™ or glc/suc, a standardized mini pizza, and a medium-sized apple (~125 g). Combined, breakfast and lunch contained 195 g of carbohydrate, of which 75 g consisted of the test carbohydrates. The replacement of conventional sugars in the breakfast and lunch resulted in a decrease of the combined glycemic load by around one-third (from 145 to 100).

Figure 1 shows the time flow of the investigation and the times when the respective parameters were investigated. At each time point, blood levels of glucose, oxygen uptake, and carbon dioxide production (ZAN 600 CPET, nSpire, Oberthulba, Germany) were determined. The sampling duration at each time point for oxygen uptake and carbon dioxide production was 5 min. Insulin concentrations were determined at each time point until lunch. Triacylglycerols, cholesterols (total, low-density lipoprotein, high-density lipoprotein, very low-density lipoprotein), cortisol, and non-esterified fatty acids were analyzed from

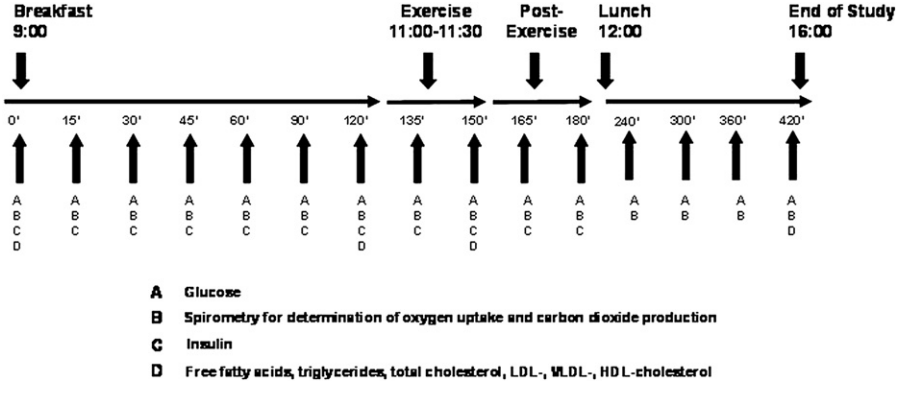

Fig. 1. Time flow of blood sampling and the determination of oxygen uptake and carbon dioxide expiration. HDL, high-density lipoprotein; LDL, low-density lipoprotein; VLDL, very low-density lipoprotein.