Short Communication

Short-term impact of sugar consumption on hunger and ad libitum food intake in young women

Fernanda RO Penaforte[1,2§], Camila C Japur[1,3], Letícia P Pigatto[2], Paula G Chiarello[3] and Rosa W Diez-Garcia[1,3]

[1]*Laboratory of Eating Practices and Behavior (PratiCA), Course of Nutrition and Metabolism, University of São Paulo, Ribeirão Preto, SP, Brazil*
[2]*Department of Nutrition, Federal University of Triângulo Mineiro, Uberaba, MG, Brazil*
[3]*Course of Nutrition and Metabolism, University of São Paulo, Ribeirão Preto, SP, Brazil*

Abstract

The hypothesis of this study was that greater sugar consumption at breakfast promotes a stronger sensation of hunger and a later increase in energy consumption. The objective was to assess the relation between sugar consumption in a meal and the subsequent sensations of hunger and ad libitum food consumption. Sixteen women consumed a breakfast accompanied by 2 drinks sweetened ad libitum with sugar. After 3 h, a lunch was offered to evaluate ad libitum food consumption. During the period from breakfast to lunch, hunger sensations were evaluated at 30 min intervals. Women were divided according to the median amount of sugar used to sweeten the breakfast drinks (20 g). The group who consumed sugar above the median showed a greater hunger sensation in the preprandial period, and a greater ad libitum intake at lunch (390 ± 130 g $\times$ 256 ± 67 g, $P = 0.002$), compared to the group who had a lower sugar consumption. The amount of sugar consumed at breakfast was correlated positively with the sensation of preprandial hunger and food intake at lunch. We concluded that foods with a high glycemic index can modulate the appetite within a short period of time.

Key Words: Sugar, glycemic index, hunger, food consumption, dietary strategy

Introduction

Recent studies have suggested that diets with a high glycemic index (GI) are associated with the development of obesity, type II diabetes, and cardiovascular diseases [1-4]. Thus, the role of the GI has attracted special attention regarding both the development and the treatment of these diseases.

The GI reflects the potential of different types of carbohydrates to increase serum glycemic 2 hours after their intake [5], with this potential being influenced by food processing, mastication, starch structure, fiber, protein, and lipid content [6]. Foods with a low GI are known to be absorbed more slowly, while foods with a high GI are rapidly digested and absorbed, stimulating lipogenesis and excessive food consumption [7,8].

On this basis, diets with a low GI have been indicated as auxiliary factors in the treatment of obesity [6,9-11], since they seem to promote more prolonged satiety and to favor fat oxidation (rather than carbohydrate oxidation) as a source of energy [6].

However, the impact of food GI and its effects on hunger, satiety, and food consumption, as well as its utility in the treatment of obesity continue to be controversial since divergent results have been observed in studies on this topic [12,13]. Thus,

for a better understanding of this subject, the objective of the present study was to assess the short-term impact of sugar consumption on hunger and on ad libitum food consumption in young women based on the hypothesis that a greater sugar consumption at breakfast promotes a stronger sensation of hunger and later, an increase in energy consumption.

Subjects and Methods

Subjects

Sixteen healthy young adult women were recruited from the university community of the Federal University of "Triângulo Mineiro" (UFTM). Inclusion criteria were the following: age between 18-30 years, female sex, and stable body weight (less than a 10.0% change) for the last 3 months. Exclusion criteria were a diagnosis of type I or II diabetes mellitus, use of antipsychotic drugs and/or other medications that interfere with appetite, allergy or intolerance to foods used in the study, being pregnant, or nursing.

The general study design was explained to the participants before beginning of the investigation. In order to minimize the

possibility of interference with the evaluations of hunger and satiety, with the amount of sugar used to sweeten drinks and with food consumption, the subjects were not informed about the specific objective of the study before all data were collected. They were informed that the general objective of the study was to assess the effect of sugar consumption on cognitive skills, with distraction tests (logic exercises) being applied along the study. The study, with the above described design, was approved by the Research Ethics Committee of UFTM.

Study protocol

The participants were instructed to fast overnight for 8 h before their participation in the study. In the morning when they arrived at the laboratory, they were submitted to anthropometric assessment (measurements of height and weight and calculation of BMI- Body Mass Index) and then received a standardized test meal (breakfast) consisting of 200 ml of passion fruit juice, 60 ml of coffee and 1 unit (50 g) of French bread with 5 g of margarine. The 2 drinks were offered with no sugar added so that the participants would sweeten them ad libitum with sugar. The women were instructed to consume the entire breakfast offered.

The sugar container that was offered to subjects as the source of sugar to sweeten their drinks was weighed both before and after its use by each individual subject. The amount of sugar added to the drinks was calculated as the difference in the weight of the container. The raw material for the drinks and the way they were prepared, as well as the utensils used for their presentation, were standardized. Then, the women were instructed not to eat or to drink anything (except water) after breakfast until the lunchtime.

For the ad libitum lunch, which was served 3 h after breakfast, participants were offered pasta with tomato sauce and were instructed to eat until they felt fully satisfied. This dish was chosen because of its practical preparation and because of the great familiarity of the general population with it. The recipe and preparation were standardized. The nutritional composition of the pasta with tomato sauce was (in 100 g): 102.0 kcal, 3.1 g of protein, 21.6 g of carbohydrate, and 0.4 g of lipid.

Energy consumption was assessed based on the variation between the amount of pasta portioned (initial and final weight of the serving dish where the pasta with tomato sauce was arranged) and the leftovers on the plate. The above weights were measured using a Micheletti portable digital scale with 5 kg capacity and 1 g precision without the knowledge of the participant, so that she would not feel intimidated or embarrassed, and would not change her food consumption. In order to calculate the energy intake of the participants, a computerized nutrient calculation system was used (DietPro, version 5.1).

Anthropometric evaluation

The measurements were performed by a trained professional according to standardized techniques [14]. Body weight, in kg,

was measured with a portable Philco® scale of the platform type with a maximum capacity of 200 kg and precision of 0.1 kg. Height, in meters, was measured with a portable Alturexata stadiometer, consisting of a vertical rod with 0.5 cm graduations.

The BMI (kg/m^2) was calculated for the classification of nutritional status using the cut-off points recommended by the WHO [15].

Subjective measurements of hunger and satiety using visual analogue scales and food consumption

For the assessment of hunger, satiety, and desire to eat, the participants were asked to fill out previously validated visual analogue scales (VAS) [16,17]. Participants were asked to rate their levels of hunger ("How hungry do you feel at this moment?"), satiety ("How full does your stomach feel at this moment?"), and desire to eat ("How strong is your desire to eat at this moment?") using these scales, presented one at a time. Subjects marked their rating on a 100 mm line anchored at 0 ("I am not hungry/satiety at all"; "I have no desire to eat at all") and 100 ("I have never been more hungry/satiety"; "I have never been more desire to eat").

These evaluations were performed by the participants before consuming the test breakfast (basal time-0 min), repeated immediately after the end of the meal (15 min) and at 30 min intervals over a total period of 3 hours (30, 60, 90, 120, 150 and 180 min). After receiving the ad libitum meal, the participants were again asked to fill out the VAS.

Furthermore, at the end of the ad libitum meal the participants were asked to fill out the visual analogue scales for the evaluation of the familiarity and palatability of the food, with the following questions: "How much do you like pasta with tomato sauce?" and "How delicious is this pasta?" The scales were applied to determine whether these variables influenced food consumption.

Statistical analysis

For data analysis, the participants were divided into 2 groups according to the median quantity of sugar used to sweeten the breakfast drinks (below and above the median) and all parameters studied were compared between these 2 groups.

Data are reported as mean ± SD (standard deviation). The nonparametric Mann-Whitney test was used for comparison of the groups at each time point and the Spearman test was used to determine the correlations between the variables of interest. The level of significance was set at 5% ($P < 0.05$).

Results

Sample characterization

The study was conducted on 16 women with a mean age of

Table 1. Anthropometric data and sugar consumption of both groups of women enrolled in the study

Variables	Group 1 (n = 7)	Group 2 (n = 9)
Age (yrs)	20.6 ± 3.8	23.4 ± 4.2
Weight (kg)	60.3 ± 6.7	66.0 ± 13.6
BMI (kg/m^2)	22.0 ± 2.3	25.1 ± 4.8
Sugar consumed at breakfast (g)	14.0 ± 3.9	23.4 ± 4.5*

Data are reported as mean ± SD. * $P = 0.0002$.

22.4 ± 4.1 yr and a mean BMI of 23.7 ± 4.1 kg/m^2. Most women (68.7%) were currently enrolled in, or had completed their studies at the university.

The participants were divided into 2 groups according to median sugar consumption (20 g): Group 1 (n = 7): sugar consumption below the median and Group 2 (n = 9): sugar consumption equal to or higher than the median. No differences in age, weight or BMI were observed between groups (Table 1).

Sugar consumption and sensation of hunger, satiety and desire to eat

The mean amount of sugar used to sweeten the drinks at breakfast by Groups 1 and 2 was 14.0 ± 3.9 g and 23.4 ± 4.5

g, respectively, with the difference being statistically significant ($P = 0.0002$).

The evaluation of the perceptions of satiety and of the desire to eat showed no difference between groups at any of the time points studied. However, the sensation of hunger was significantly greater for Group 2 than for Group 1 at 30 min (8.0 ± 8.1 mm vs 1.0 ± 2.3 mm, respectively) and at 180 min, which corresponded to the preprandial period (80.9 ± 20.1 mm vs 49.0 ± 27.0 mm, respectively), with no differences being observed at the other time points (Fig. 1).

There was a positive and significant correlation between the amount of sugar consumed at breakfast and the sensation of hunger during the preprandial period (180 min) (r = 0.52, $P = 0.04$), whereas no significant correlations were observed between these variables at the other time points.

In addition, a positive correlation was observed between the amount of sugar consumed at breakfast and the amount of pasta consumed at lunch (r = 0.75, $P = 0.0008$).

Ad libitum consumption of pasta

In agreement with the greater sensation of hunger reported by Group 2 at preprandial time (180 m after breakfast), the mean
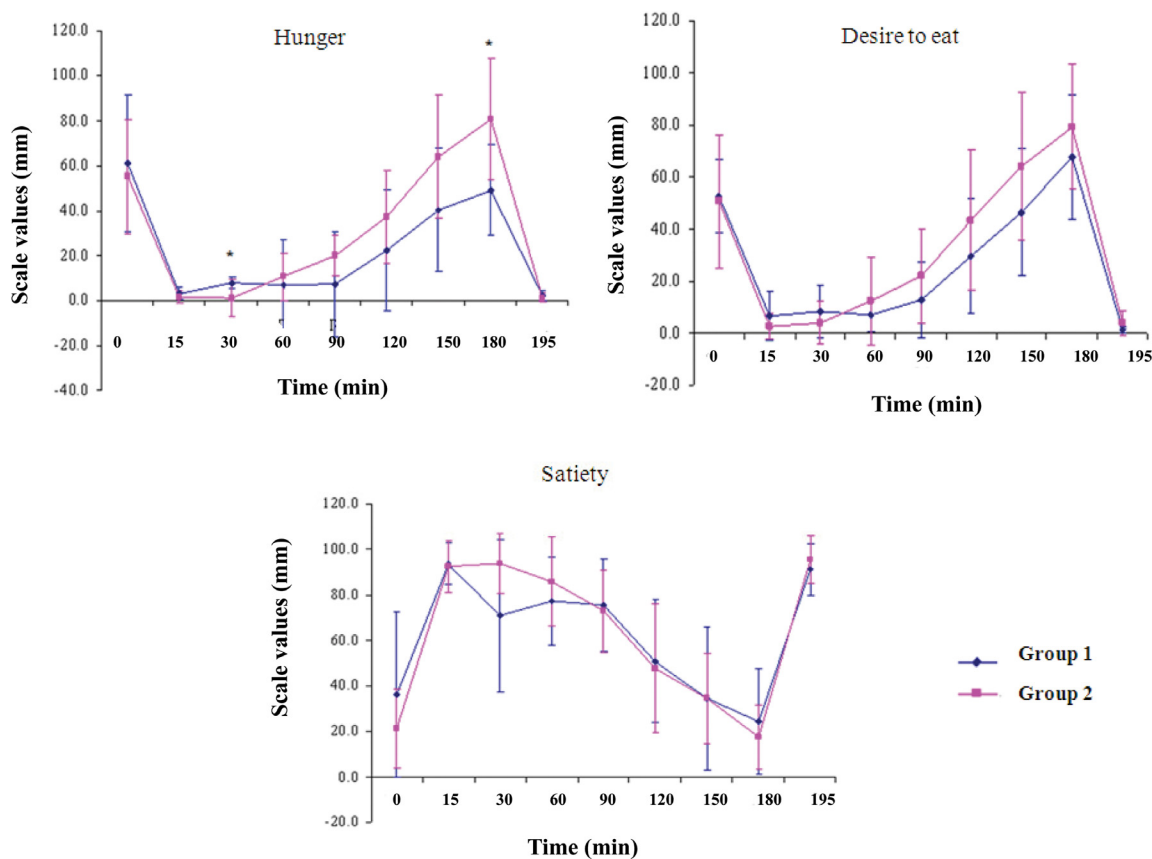

Fig. 1. Perceptions of hunger, desire to eat, and satiety in both groups during the period of evaluation. * $P < 0.005$

consumption of pasta at lunch was significantly greater in this group than in Group 1 (389.9 ± 129.7 mm vs 256.0 ± 68.6 mm, respectively, $P = 0.002$), corresponding to a mean energy intake of + 166.2 kcal.

Based on the scales used to assess the familiarity of the food, Group 1 showed 94.1 ± 12.5 mm and Group 2, 85.4 ± 18.0 mm. In the scale for the evaluation of palatability of the pasta, the means for Groups 1 and 2 were 93.0 ± 11.7 mm and 92.2 ± 10.9 mm, respectively. No differences were observed between groups in any of these evaluations.

Discussion

The results of the present study confirmed our initial hypothesis that a greater consumption of sugar at breakfast would generate a greater sensation of hunger during the preprandial period compared to the group consuming less sugar, which leads to greater ad libitum consumption of food.

In the present study, we observed a positive correlation between the amount of sugar consumed at breakfast and a sensation of hunger during the preprandial period, and also with the quantity of pasta consumed at lunch. These findings support the notion that more stable blood glucose levels are associated with a reduction of appetite [18]. Foods with a higher GI, such as drinks sweetened with sugar, are rapidly digested and absorbed and provoke a rapid increase in blood glucose, a fact that exacerbates hunger and favors hyperphagia, since these foods are unable to stimulate the mechanisms of satiety [12]. Considering that sugar is a food with a high GI, the results obtained in the present study may be related to a higher rate of glucose release promoted by this GI, which generates a fall in glycemia levels as a short-term rebound effect, triggering central signals of hunger stimulation, and favoring greater food intake.

It has been suggested that foods with both a high and a low GI have an impact on satiety, with foods with a lower GI having greater and longer-lasting satiety-inducing effects [19]. One of the main mechanisms of action of this positive effect on foods with a low GI on satiety and on food intake is related to their greater fiber content; this generates lower digestion and absorption rates (helping to delay the rate of glucose, and consequently of insulin, release), which favor increased satiety [20-22].

In a study of adult women (mean age: 39.2 ± 0.7 years), Furchner-Evanson et al. [23] observed that the satiety index was greater and serum insulin and glycemia levels were lower after the intake of a snack with a low sugar content and a greater fiber content. However, in contrast to the present study, they did not observe an impact on later ad libitum food consumption. Other authors observed positive effects of foods with a low GI on satiety and on the desire to eat in women [24,25], although they did not assess the impact of this greater satiety on food consumption.

The greater sensation of hunger during the preprandial period,

which favored a greater energy intake at lunch (+ 166.2 kcal) which was detected in the present study, supports the data reported by Warren et al. [26], who also observed a sensation of preprandial hunger and a greater energy consumption at lunch after a breakfast with a high GI compared to a breakfast with a low GI (+ 145.0 ± 54.0 kcal vs + 119.0 ± 53.0 kcal, respectively) regardless of the sex or weight of the participating adolescents.

The results of the present study are particularly important because they support the growing body of evidence that GI may play a role in the prevention and treatment of excess body weight by modulating hunger and short-term food consumption. Studies evaluating the long-term impact of GI on hunger and food consumption are necessary now.

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