Aspartame: Effect on Lunch-time Food Intake, Appetite and Hedonic Response in Children

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Two experiments were conducted, each with 20 healthy 9-10-year-old children. After an overnight fast, subjects were given a standardized breakfast at 0830 hrs, the treatments at 1030 hrs, and a lunch containing an excess of foods at 1200 hrs. Visual analog scales of hunger, fullness, and desire to eat were administered 5 min before and 20 and 85 min after treatment. Lunch-time food intake was measured. In experiment 1, either aspartame (34 mg/kg), or the equivalent sweetness of sodium cyclamate, was given in an ice slurry (300 ml) of unsweetened strawberry Kool-Aid with carbohydrate (1.75 g/kg polycose). In experiment 2, drinks (300 ml) contained either sucrose (1.75 g/kg) or aspartame (9.7 mg/kg). In both experiments, significant meal- and time-dependent effects were observed for subjective feelings of hunger, fullness and desire to eat. Treatments, however, did not affect either subjective feelings of appetite or lunch-time food intake. Thus, aspartame consumed without or with carbohydrate, did not affect either hunger or food intake of children when compared with the sweeteners sodium cyclamate and sucrose, respectively.

Aspartame is a high intensity sweetener that is widely used in beverages and food. There are several reasons to expect that its consumption will decrease food intake (Anderson & Leiter, 1988; Anderson et al., 1984). First, its consumption provides the taste of sweetness without the calories contained in nutritive sweeteners such as sucrose, raising the possibility that daily energy intake might be reduced in users. Second, aspartame has the potential to influence food intake more directly due to its constituent amino acid, phenylalanine. Phenylalanine ingestion, in very large amounts, stimulates the release of the gut hormone cholecystokinin, a putative food intake reducing hormone, and influences central nervous system metabolism of the catecholamine neurotransmitters known to be involved in food intake control mechanisms (Anderson, 1988).

A few studies have been conducted to determine the effect of aspartame on food intake of adults immediately following its ingestion in beverages (Blundell et al., 1988; Blundell & Hill, 1986), puddings or jello (Rolls et al., 1986; Rolls et al., 1988) or in

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capsule form (Ryan-Harshman et al., 1987; Anderson & Leiter, 1988). However, there have been only two preliminary reports of studies conducted with children (Anderson et al., 1988; Birch, 1987) despite the fact that children have the highest intake of aspartame expressed per kilogram of body weight (Heybach & Ross, in press).

In addition to the reasons previously described, the effect of aspartame on food intake of children might be affected by two other factors. First, aspartame is often consumed with carbohydrate (e.g. a cake with a diet drink) and it has been hypothesized that this would enhance the impact of phenylalanine on the central nervous system (Wurtman, 1983). Second, young children have a higher energy intake, compared with adults, on a body weight basis, and have been reported to show clearer evidence of caloric compensation for preload consumption (Birch & Deyser, 1986). Thus, it can be hypothesized that their regulatory mechanisms would readily recognize energy deficits caused by the consumption of aspartame containing food products and compensate accordingly at subsequent meals. The purpose of the research described herein was to investigate these two hypotheses.

METHODS

Objectives and Design

Two experiments were conducted. The objective of the first experiment was to compare the effects of consuming a high dose of aspartame or of an equivalent sweetness as sodium cyclamate with carbohydrate on food intake and subjective measures of appetite in children. The treatment consisted of an ice slurry (300 ml) of unsweetened strawberry Kool-Aid (General Foods Inc.) containing carbohydrate (1.75 g/kg polycose), plus either the test dose of aspartame (34 mg/kg) or the equivalent sweetness as sodium cyclamate and amino acids as alanine.

The objective of the second experiment was to compare the effects of aspartame with a common nutritive sweetener (sucrose) on food intake and appetite. In this study, the treatments consisted of a drink (300 ml) of cold unsweetened strawberry Kool-Aid, plus either 1.75 g/kg sucrose, or the equivalent sweetness (9.7 mg/kg) of aspartame.

In each experiment, 20 children, 9–10 years of age were studied in a double-blind crossover design to examine the effects of treatments on food intake (energy and macronutrient selection) at lunch-time, and on subjective ratings of appetite and hedonic response to a sweet taste. These experiments also included selected measures of learning, behavior and mood which are reported elsewhere (Saravis et al., Note 1).

Subjects

Ten female and ten male subjects (9–10 years old) participated in each study (Table 1). Subjects were recruited by word-of-mouth, and through lists of normal control subjects, and by posters placed in area hospitals, a nearby university, Boy Scouts and Girl Guide meetings, libraries and community recreation centers.

The inclusion criteria were as follows: by parental report the children had to be in good health, attending a regular school class, and not have significant learning, emotional or behavioral problems. Children who were reported to have food allergies or restrained eating habits, or who had a family history of phenylketonuria, were not included. In addition, the child’s weight for height had to be between the 10th and 90th percentiles on normal growth charts (adapted from Hamil et al., 1979).
One parent of each child completed an informed consent form, which had been approved by the Human Subjects Review Committees, Hospital for Sick Children and the University of Toronto. At the end of the study, each child received a movie pass in appreciation for his or her participation.

Procedure

Parents who volunteered were interviewed by telephone according to a semi-structured interview protocol designed to elicit information about the inclusion criteria. If a child appeared to meet these criteria, an appointment was made for the child and parent to come to the Hospital for Sick Children for a screening session.

During the screening session, the study was explained to the child and parent as a study of the taste of various sweeteners and that it involved the sweetener aspartame. The child's physical measurements were then taken. To reduce the child's initial apprehension on the first day of testing, the child was taken to the testing rooms and made familiar with the various tasks.

The study was conducted primarily in a laboratory equipped with an observation room and video equipment. A research kitchen was used to prepare the food for the study and a separate office was used for all individual testing.

Each child participated in two morning sessions, held on non-consecutive days within 1 week, in groups of two to four subjects. Parents were reminded that the children were not to eat after 2000 hrs the night before each session. On the two study session days, at approximately 0815 hrs, the children were brought to the Hospital for Sick Children by their parents or by taxi. They were trained in the use of the visual analog scales (VAS). At 0830 hrs they were given a standardized breakfast, which consisted of cereal (28 g), 2% milk (188 mg), and orange juice (100 ml) for a total of 244 kcal and a distribution of 72% carbohydrate, 14% fat and 15% protein.

Between 0850 and 1025 hrs the children were engaged in card and board games. At 1030 hrs each child was given a drink: Treatment A in one session and Treatment B in the other session. In order to minimize order effects, treatment was randomly assigned, with half of the sample receiving the order A–B and the remainder receiving B–A. Both the experimenters and the subjects were blind to treatment order.

At 1200 hrs lunch was provided. The composition of the lunch was based on foods acceptable to all the children as identified by the parents from a list of foods that the children liked. Each subject was served an individual tray containing three kinds of sandwiches [peanut butter (35 g), peanut butter (35 g) and jam (26 g), roast beef (60 g), each with two slices of white bread (55 g/slice)], two cartons (250 ml) of 2% milk, eight celery sticks (58 g), one medium apple (179 g), one medium orange (165 g), and eight chocolate chip cookies (88 g). Available for addition to the sandwiches were three 5 g
packs of butter, three 5 g packs of margarine and mustard (15 g). Regular mayonnaise (38 g) was provided as a dip for the celery sticks. The food on the tray was weighed before and after serving.

The subjects were told that they could eat as little or as much as they liked, but were instructed not to exchange food from their trays. They were supervised during the meal. The session ended at approximately 1230 hrs.

**Dependent Variables**

**Food intake and selection**

Following each session, the total number of calories consumed and per cent of protein, carbohydrate and fat were calculated. The macronutrient composition of all luncheon foods was determined from food composition tables. Because the foods served were those known to be of relatively constant composition, with the possible exception of the fat content of the beef, and the same products were used through the experiment, it was assumed that differences in food composition determined from tables rather than direct analysis would not contribute substantially to within subject variation in intake on test versus control days. Therefore, chemical analysis of the food was not conducted.

**Visual analog scales**

Six times during each morning the children were asked to taste a 10 ml sample of 20% sucrose solution (not ingested). Immediately afterwards, they rated their perception of the solution's intensity and pleasantness. In addition levels of hunger, desire to eat, and fullness were rated 5 min before and 20 min after breakfast, the mid-morning drink, and lunch. Ratings were quantified by placing a pencil mark along a horizontal 100 mm line as a response to the following questions: how sweet is the drink (not at all to very, very sweet), how much do you like this drink (very, very much to not at all), I am hungry (not at all to starving), I want to eat (tons of food to nothing) and I am full (not at all to stuffed).

**Data Analysis**

**Food intake and selection**

For each dependent variable, a three-way analysis of variance with repeated measures was conducted, with sex and treatment order as independent variables and the treatments as the repeated measure (Winer, 1971). Where the effect of sex or treatment order was not significant the analysis was then collapsed over the variable(s).

**Visual analog scales**

The data for each scale were analyzed separately. First, ratings were plotted and analyzed as a function of time, in order to determine whether they varied with time and nutritional state. Second, to look at change in perception as a result of treatment, a repeated-measures analysis of variance was conducted, with sex and treatment order as independent variables. Where the effect of sex or treatment order was not significant, the analysis was then collapsed over the variable(s). The repeated measures were the post-treatment ratings obtained after 20 and 85 min, expressed as a percentage of the ratings obtained 5 min before consumption of the drinks (baseline), in the two treatment conditions. Finally, to be able to compare the results with those of previous
studies, four planned comparisons were conducted. These comparisons tested the significance of differences between the post-treatment ratings (after 20 and 85 min) and the appropriate baseline rating in the two treatment conditions.

RESULTS

Experiment 1

Food intake and selection

There was no difference due to the addition of either aspartame or cyclamate to carbohydrate on food intake and macronutrient selection at lunch-time (Table 2).

<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
<th>Cyclamate</th>
<th>F(1,19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal)</td>
<td>867 (64)</td>
<td>879 (61)</td>
<td>0.05</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>14.4 (0.9)</td>
<td>14.2 (0.9)</td>
<td>0.06</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>36.9 (1.2)</td>
<td>35.6 (1.0)</td>
<td>1.07</td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>46.9 (1.1)</td>
<td>48.0 (1.3)</td>
<td>1.02</td>
</tr>
</tbody>
</table>

* Mean (standard error).

Visual analog scales

Ratings of hunger \(F(5,80)=19.66, \ p<0.01\), desire to eat \(F(5,80)=29.81, \ p<0.01\) and fullness \(F(5,80)=41.28, \ p<0.01\), but not ratings of sweetness intensity \(F(5,80)=1.53\) or pleasantness of sucrose solution \(F(5,80)=1.69\), fluctuated with time and nutritional state during the morning (Figure 1). These meal- and time-dependent effects demonstrate the sensitivity of the measures and the ability of the children to use the visual analog scales appropriately.

Treatment did not significantly affect ratings of intensity \(F(1,16)=0.17\), or pleasantness \(F(1,16)=0\) of the 20% sucrose solution nor ratings of hunger \(F(1,16)=1.60\), desire to eat \(F(1,16)=2.40\) or fullness \(F(1,16)=3.69\) when the changes from baseline VAS (5 min pretreatment) at 20 or 85 min post-treatment were analyzed by two way ANOVA.

The changes in the VAS and the results of specific post-hoc comparison by paired t-test are shown in Table 3. The aspartame treatment was associated with reduced intensity of the 20% sucrose solution at 20 min \(t(19)=-2.26, \ p<0.05\) and with increased ratings of hunger at 85 min \(t(19)=3.41, \ p<0.01\). Rated desire to eat increased \(t(19)=6.14, \ p<0.01\) and fullness ratings decreased \(t(19)=4.25, \ p<0.01\) 85 min after the cyclamate treatment.
Table 3
Effect of aspartame or sodium cyclamate with carbohydrate on visual analog scales

<table>
<thead>
<tr>
<th>Scale</th>
<th>Intensity</th>
<th>Pleasantness</th>
<th>Hunger</th>
<th>Desire to Eat</th>
<th>Fullness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspartame</td>
<td>-13.2 (5.8)</td>
<td>-0.7 (4.5)</td>
<td>15.0 (4.4)</td>
<td>4.1 (4.4)</td>
<td>2.9 (5.2)</td>
</tr>
<tr>
<td>Cyclamate</td>
<td>-5.1 (2.7)</td>
<td>-5.0 (4.1)</td>
<td>5.3 (5.5)</td>
<td>5.3 (5.5)</td>
<td>4.5 (6.0)</td>
</tr>
</tbody>
</table>

* N = 20. Values reported are Mean (standard error) for changes from baseline in mm on the 100 mm VAS. Changes from baseline were analysed by paired t-test. *p < 0.05; † p < 0.01.
Experiment 2

Food intake and selection

There were no differences in food intake and macronutrient selection at lunch-time of children who consumed drinks with either sucrose or aspartame (Table 4).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Aspartame</th>
<th>Sucrose</th>
<th>F(1,19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal)</td>
<td>777 (58)</td>
<td>765 (67)</td>
<td>0.04</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>15.2 (1.2)</td>
<td>15.2 (0.9)</td>
<td>0.06</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>37.9 (1.6)</td>
<td>38.4 (1.2)</td>
<td>0.09</td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>48.8 (1.7)</td>
<td>48.3 (1.1)</td>
<td>0.11</td>
</tr>
</tbody>
</table>

*Mean (standard error).

Visual analog scales

Meal- and time-dependent fluctuations were observed for ratings of stimulus intensity \([F(5,80)=5.38, p<0.01]\), hunger \([F(5,80)=47.88, p<0.01]\), desire to eat \([F(5,80)=46.67, p<0.01]\) and fullness \([F(5,80)=35.06, p<0.01]\), but not for ratings of hedonic response \([F(5,80)=0.78]\) to sucrose (Figure 2). The effect of treatment was not statistically significant for ratings at 20 and 85 min of sweetness intensity \([F(1,16)=1.71]\), pleasantness of the sucrose solution \([F(1,16)=0.92]\), hunger \([F(1,16)=0.92]\), desire to eat \([F(1,16)=0.97]\), or fullness \([F(1,16)=0.87]\). Furthermore, the interactions of treatment and time of rating were not significant.

The mean change in the VAS at 20 and 85 min compared to baseline and the statistical significance of these changes by paired t-test analysis are shown in Table 5. After the aspartame treatment the rated intensity of the 20% sucrose solution was decreased at both 20 \([t(19)=-2.19, p<0.05]\) and 85 \([t(19)=-2.10, p<0.05]\) min, hunger ratings increased \([t(19)=2.88, p<0.01]\) at 85 min, and desire to eat increased \([t(19)=2.56, p<0.05]\) at 85 min. After the sucrose treatment, the only statistically significant change in the VAS was for hunger, which was increased 85 min later \([t(19)=2.36, p<0.05]\).

Discussion

Although the results of this study were primarily negative, they contribute to placing a perspective on the effect of aspartame and possibly other high intensity sweeteners on feeding behavior of children. These experiments failed to demonstrate an unique effect of aspartame when compared with other sweeteners as controls, either when consumed with carbohydrate or alone, on lunch-time food consumption of children. The results of experiment 1 suggest that carbohydrate does not potentiate any neurochemical effect of aspartame above and beyond that possibly occurring with
FIGURE 2. Experiment 2: Visual analog scales for stimulus intensity, hunger, desire to eat and fullness of children 5 min before (b) and 20 min after (a) breakfast (B), test drinks (D), and lunch (L).

TABLE 5
Effect of aspartame or sucrose drinks on visual analog scales

<table>
<thead>
<tr>
<th>Scale</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Intensity</td>
<td></td>
</tr>
<tr>
<td>Aspartame</td>
<td>-9.6 (4.4)*</td>
</tr>
<tr>
<td>Sucrose</td>
<td>2.2 (5.3)</td>
</tr>
<tr>
<td>Pleasantness</td>
<td></td>
</tr>
<tr>
<td>Aspartame</td>
<td>2.7 (2.6)</td>
</tr>
<tr>
<td>Sucrose</td>
<td>-2.3 (2.5)</td>
</tr>
<tr>
<td>Hunger</td>
<td></td>
</tr>
<tr>
<td>Aspartame</td>
<td>6.0 (4.0)</td>
</tr>
<tr>
<td>Sucrose</td>
<td>-4.8 (5.7)</td>
</tr>
<tr>
<td>Desire to Eat</td>
<td></td>
</tr>
<tr>
<td>Aspartame</td>
<td>4.8 (3.3)</td>
</tr>
<tr>
<td>Sucrose</td>
<td>-5.5 (4.5)</td>
</tr>
<tr>
<td>Fullness</td>
<td></td>
</tr>
<tr>
<td>Aspartame</td>
<td>-3.6 (3.4)</td>
</tr>
<tr>
<td>Sucrose</td>
<td>-0.8 (5.7)</td>
</tr>
</tbody>
</table>

*N = 20. Values reported are mean (standard error) and show changes from baseline in mm on the 100 mm VAS. Changes from baseline were analysed by paired t-test. *p<0.05, **p<0.01.
other combinations of carbohydrate and sweetness. Experiment 2 provides evidence that children are not sensitive to a caloric deficit and do not make appropriate energy intake adjustments within a meal 90 min after consumption of beverages differing by 200–240 kcal.

In Experiment 1, a single dose of aspartame was given in an amount (34 mg/kg) initially estimated at the 90th percentile of consumption if aspartame replaced all added sugar in the diet. This intake was 85% of the acceptable daily intake in Canada and 70% of the acceptable daily intake in the United States. The test dose was given with an intake of carbohydrate (1.75 g/kg) known to elicit a strong insulin response (Jenkins et al., 1978). For this reason, the hypothesis that aspartame consumed with carbohydrate would provoke untoward neurochemical responses (Wurtman, 1983) was tested in children under conditions which represent levels of aspartame usage 25 times higher than currently consumed by Canadian children who use products containing aspartame (Heybach & Ross, in press) and with carbohydrate intakes of 50–60 g, higher than would probably occur with the consumption of a carbohydrate snack (e.g. a piece of cake contains approximately 40 g carbohydrate).

The addition of either aspartame or sodium cyclamate with alanine and polycose to a 300 ml ice slurry of Kool-Aid produced a very sweet slurry, which was, however, consumed with no difficulty within 5 min by the children. When asked, they did not indicate knowledge of the composition of the slurry. Although planned comparisons (Tables 3 and 5) showed statistically significant changes from baseline in some of the VAS, there was no consistent pattern of effect. For example, aspartame increased hunger, whereas cyclamate increased desire to eat and decreased satiety rating at 85 min (Table 3). Thus, while the planned comparisons must be interpreted cautiously, they do not show any fundamental difference in effect of high intensity sweetener on perception of hunger and satiety. Furthermore, the absence of any physiological significance of these changes in VAS due to treatment is demonstrated by the similarity of food intake and selection at lunch-time by the two groups.

Even though the high dose of aspartame was not encapsulated, the results of Experiment 1 are consistent with that of experiments conducted in adults where a lack of responsiveness of systems regulating meal-time food intake to very high intakes of aspartame was demonstrated (Ryan-Harshman et al., 1987; Anderson & Leiter, 1988). No effect of very large doses, approximately 15 to 150 mg/kg, taken in pill form, was found on either lunch-time food intake or on subjective feelings of hunger, mood and arousal in adult male subjects. Thus, the lack of effect of a high dose of aspartame observed in adults may not have been due to the separation of sweet taste from its ingestion.

It is also unlikely that the lack of effect of aspartame consumed with carbohydrate would be explained by the duration of the interval between treatment and the lunch-time meal. In adults plasma phenylalanine is at a maximum between 30 and 120 min after an oral load, and the maximal neurochemical effect, if it occurs would be expected at this time (Ryan-Harshman et al., 1987). It is for this reason that neurobehavioral measures were made between 30 and 90 min after treatment and food intake after 90 min.

The failure of the children to show any differential response in either VAS ratings or energy intake to the average intake of 210 kcal in the sucrose drink compared with the 1 kcal in the aspartame drink (consumed in 2-3 min) was surprising and in contrast to information available from studies in adults (Blundell & Hill, 1986; Blundell et al., 1988). Adults show a decrease from baseline in VAS of hunger and desire to eat after
consuming glucose solutions (188 kcal), whereas they show an increase from baseline if aspartame is consumed at the usual concentrations found in beverages.

Time of administration of the treatment might explain its lack of effect on lunch-time food intake in experiment 2. The time of measurement of food intake was dictated by the time course of response in plasma amino acids after aspartame ingestion. However, this may have meant that signal arising from the ingestion of calories had passed in 90 min. The amount of sucrose given was 50–60 g, equivalent to that in 500 ml of soft drinks, which in adults raises blood glucose and insulin levels substantially by 10–30 min although both return to baseline by 90–120 min. In support of this hypothesis are the data of Birch & Deysher (1986). Young children, 2.5–5 years of age, adjusted lunch-time food energy intake to compensate for 110 calorie differences in the content of puddings given 25–30 min earlier. These data are consistent with our observation that both the breakfast of 244 kcal and the lunch of an average of 800 kcal were sufficient to cause marked changes in the VAS 20 min later. It is surprising, however, that hunger ratings did not reflect the differences of 200–240 kcal in energy content of the drinks 20 min earlier (Table 5), suggesting the possibility that children are less sensitive to caloric differences in the form of drinks than in solid foods. Clearly, the effect of both time of administration and quantity of sucrose consumed in relation to meal-time needs to be examined further before conclusions can be made about the effect of sucrose vs. aspartame on food intake of children.

The decrease in ratings of intensity but not pleasantness of a 20% sucrose solution after aspartame compared with that following sodium cyclamate or sucrose is in contrast to the data reported by Blundell & Hill (1986). In their studies which utilized adult subjects, pleasantness but not intensity of a sucrose solution was reduced to a greater extent after aspartame than after glucose. It is difficult to explain why aspartame creates a stronger negative alliesthesia (decreased perceived pleasantness of sweetness) in adults but not in children. These data might suggest however, that aspartame does not create in children the paradoxical effect of decreased alliesthesia but enhanced hunger noted in adults.

It might be argued that children are not able to complete VAS in a quantitative manner which is consistent with their actual feelings of hunger and satiety. This argument does not hold up, however, as shown by the results of the VAS completed before and after the breakfast and lunch-time meals. Meals consistently decreased desire to eat and hunger, and increased satiety by statistically measurable amounts. Thus, VAS are useful tools for such evaluations in children, as well as in adults.

Finally, these results do not provide data relevant to the question of the role of sweetness per se in influencing subjective measures of appetite or food intake in children. To determine if sweetness alone is a factor, another treatment group of vehicle alone (e.g. polycose in Experiment 1 or water in Experiment 2) should have been included (Blundell et al., 1988). This was not done for several reasons, but primarily because the hypothesis being tested required a comparison of sweeteners and as a result a double blind experiment. This, plus the large number of children utilized as the sample, based on statistical considerations, led to priority being placed on the comparative evaluation rather than extending the participation of each child. Therefore, while the results show that aspartame is not unique in influencing measures of appetite or food intake in children under the design of these experiments, they do not allow one to offer any conclusion on the effect of consuming a sweetener compared with a non-sweet control.
In summary, aspartame, whether consumed without or with carbohydrate, did not affect either hunger or food intake of children when compared with the sweeteners sodium cyclamate and sucrose.

REFERENCE NOTE


REFERENCES


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