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Neurobehavioral Effects of Aspartame Consumption

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Abstract

Despite its widespread use, the artificial sweetener aspartame remains one of the most controversial food additives, due to mixed evidence on its neurobehavioral effects. Healthy adults who consumed a study-prepared high-aspartame diet (25 mg/kg body weight/day) for 8 days and a low-aspartame diet (10 mg/kg body weight/day) for 8 days, with a 2-week washout between the diets, were examined for within-subject differences in cognition, depression, mood, and headache. Measures included weight of foods consumed containing aspartame, mood and depression scales, and cognitive tests for working memory and spatial orientation. When consuming high-aspartame diets, participants had more irritable mood, exhibited more depression, and performed worse on spatial orientation tests. Aspartame consumption did not influence working memory. Given that the higher intake level tested here was well below the maximum acceptable daily intake level of 40–50 mg/kg body weight/day, careful consideration is warranted when consuming food products that may affect neurobehavioral health.

Keywords

aspartame; cognition; neurobehavioral effect; depression; spatial orientation; memory; food additive; sweetener

Aspartame is an artificial sweetener found in over 6,000 food items, and millions of American adults and children consume aspartame each day (Butchko & Stargel, 2001; Thomas, 2005; Whitehouse, Boullata, & McCauley, 2008). Aspartame was first approved by the US Food and Drug Administration (FDA) for limited use in solid food in 1981; it was approved as a general sweetener in 1996 (US Food and Drug Administration (FDA), 2006). The World Health Organization (2004) and food regulatory authorities in Canada (Mortelmans, Van Loo, De Cauwer, & Merlevede, 2008) and Europe (Lean & Hankey, 2004) consider excessive intakes of aspartame as dosages above the acceptable daily intake

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(ADI) of 40 mg/kg body weight/day. The US FDA has set the ADI of aspartame at 50 mg/kg body weight/day (US FDA) and upholds the safety of aspartame consumption except for individuals with phenylketonuria, who should avoid using aspartame because phenylalanine is a metabolite.

Despite its widespread use, aspartame remains one of the most controversial food additives (Magnuson, 2010). Although some researchers have proposed that aspartame metabolites are responsible for adverse effects, such as headache, compromised memory, mood changes, and depression, others have not identified adverse effects of aspartame consumption. The purpose of this study, therefore, was to examine the neurobehavioral effects of consuming diets with higher (25 mg/kg body weight/day) and lower (10 mg/kg body weight/day) amounts of aspartame.

Pathophysiology of Aspartame Intake

Once ingested, aspartame is metabolized to yield aspartic acid, phenylalanine, and methanol (Humphries, Pretorius, & Naudé, 2008). Phenylalanine is involved in neurotransmitter regulation, and aspartic acid is an excitatory neurotransmitter (Caballero & Wurtman, 1988). Altered neurotransmitter regulation can result in neurobehavioral disturbances. Some researchers have reported substantial increases in phenylalanine and aspartic acid, and subsequently reduced dopamine and serotonin production, following aspartame ingestion (Humphries et al., 2008; Rycerz & Jaworska-Adamu, 2013), which suggests aspartame metabolites may be responsible for neurobehavioral changes (Ekong, 2009).

Aspartame also compromises the blood–brain barrier, increasing its permeability and altering concentrations of catecholamines, such as dopamine, in the brain. Thus, aspartame ingestion may have a role in the pathogenesis of certain mental disorders (Humphries et al., 2008). Such claims have been refuted, however, by authors citing the high-aspartame concentrations needed for detrimental effects (Fernstrom, 2009).

Aspartame and Cognition

Recent reports comparing consumption of aspartame and sucrose sweeteners have raised questions regarding the relationship between aspartame consumption and cognitive function. For example, Konen et al. (2000) surveyed 90 university students who considered themselves either chronic aspartame users or non-users. The students completed nutrition surveys and memory questionnaires, in which they rated their perceived forgetfulness in the previous 6 months. Compared to non-users, the aspartame users reported longer memory lapses. In a randomized double-blind study of 80 healthy young adults, Sunram-Lea, Foster, Durlach, and Perez (2002) reported better spatial memory, word recall, and reaction times in subjects who consumed drinks sweetened with 25 mg of glucose than in those who consumed a drink sweetened equally with aspartame. Harte and Kanarek (2004) also reported similar results when 14 healthy smokers drank 8 oz of a beverage containing either sucrose or aspartame and then chewed gum with or without nicotine. Although nicotine had no effect on the participants' memory and attention performance, those who consumed beverages with sucrose performed better on spatial memory and attention tasks than those

who consumed beverages sweetened with 100 mg of aspartame (Harte & Kanarek, 2004). In these two studies, the effects may have been positive effects of sucrose rather than negative effects of aspartame, and aspartame and sweetener doses were administered only once and were the same regardless of body weight.

In contrast, in a double-blind study of 36 college students, attention and reaction times of participants did not differ among those who consumed a single can (250 ml) of Red Bull© energy drink, Red Bull© Sugar-Free (containing aspartame) energy drink, or a caffeine- and calorie-free placebo drink, and were tested once after drink consumption and again 1–10 days later (Gendle, Smucker, Stafstrom, Helterbran, & Glazer, 2009). As in previous studies, aspartame was given in a single dose that was not based on body weight.

Aspartame and Headaches

Although there are theoretical links between aspartame and headaches, evidence is limited. Dietary triggers may affect phases of the migraine process by influencing catecholamine and neuronal pathways (Millichap & Yee, 2003). In a review of evidence, large doses of aspartame (900 to 3,000 mg/kg body weight/day) were reported to trigger or exacerbate headaches in individuals susceptible to migraines (Sun-Edelstein & Mauskop, 2009). Migraine as an allergic response to formaldehyde was proposed by Jacob and Stechschulte (2008), who found that in five patients reporting a history of migraines after aspartame consumption, patch-tests showed all had an allergic reaction to formaldehyde, an aspartame byproduct. Despite counseling to avoid formadehyde- containing products, however, three of the five participants reported migraine recurrence when assessed 8–12 weeks later. In a randomized, double-blind, crossover study of 18 participants (aged 18–65 years), Van den Eeden et al. (1994) reported no significant differences in headache length or intensity after consumption of aspartame (30 mg/kg body weight/day) or placebo when aspartame was administered over four 7-day sessions after an initial week of placebo administration.

Aspartame, Mood, and Depression

The role of aspartame in depression and mood has been studied with mixed results. When 40 participants with depression and 40 participants without depression were given aspartame (30 mg/kg body weight/day) or confectioners' sugar (Walton, Hudak, & Green-Waite, 1993) in a randomized, double-blind, crossover trial over 20 days with two 3-day washout periods and two 7-day treatment sessions and self-reported symptoms, the study was stopped by the institutional review board after only 13 participants completed the trial, due to the severity of adverse reactions in the depressed participants who consumed aspartame (Walton et al., 1993). In contrast, when 133 women of normal weight (Reid, Hammersley, Hill, & Skidmore, 2007) and 53 overweight women (Reid, Hammersley, & Duffy, 2010) blinded to treatment condition who consumed standard doses of aspartame or sucrose-sweetened beverages over 4 weeks and completed a daily 10-item visual analog scale to measure mood, there were no differences in mood between those who drank aspartame-sweetened and sucrose-sweetened soft drinks.

The conflicting reports of the neurobehavioral effects (cognition, mood, depression, and headaches) of aspartame consumption may be due to study design issues including use of single doses of aspartame, placebo, or a sugar-based treatment, followed by a one-time assessment, without calculating dosages according to body weight or participant energy requirements, or only estimating dose by retrospective dietary recall. No reports were found of indirect calorimetry to determine individual energy needs and portion sizes. We sought to control for these design limitations by using a crossover design and more rigorous measures to compare the neurobehavioral effects of consuming diets with high (25 mg/kg body weight/day) and low (10 mg/kg body weight/day) amounts of aspartame.

Methods

Study Design

A double-blinded repeated-measures within-subjects study design was used to determine differences in cognition (spatial orientation and working memory), mood, depression, and headaches following consumption of high and low amounts of aspartame. The participants served as their own controls. They were monitored while consuming aspartame-containing meals and during neurobehavioral assessments (cognition, mood, and depression tests). Both the participants and the research staff were blinded to the aspartame content of the foods served, and only the principal investigator and study dietitian knew the amounts of aspartame served to the participants during the study interventions.

A random assignment of the diets was used to avoid an error of variance for possible systematic effects of order (S. Sternberg, personal communication, February 23, 2010). Each participant ate a diet that consisted of pre-weighed aspartame-containing foods. Participants consumed three meals and two snacks per day for 8 days during the dietary treatment periods. A pilot study with the same design was conducted 4 months before the full study, allowing the investigators to examine the psychometric properties of the study instruments and test the protocols.

After each dietary treatment session, participants entered a 2-week washout period, in which they resumed their usual diets, and then crossed over to the other treatment diet. No study foods were given to the participants during the washout period.

Sample Recruitment and Selection

Study protocols were reviewed and approved by the University’s Institutional Review Board and the US Army Human Research Protection Office. The study was funded by the US Army Peer Reviewed Medical Research Program in response to a funding priority for nutrition research in its request for applications. Although some members of the military participated because of their interest in the project, most participants were not military, and this was not a requirement for project funding.

To recruit participants with similar cognitive abilities, the investigators solicited participation from eligible university students in their third semester of study, during the first 2 weeks of a course. The investigators approached 305 students in nine sections of the same course. The researcher read a script to the potential research participants. To avoid undue influence and

feelings of coercion by the perspective participants, classroom instructors did not participate in the solicitation process. All potential participants received a full description of the study, consent forms, and the opportunity to ask questions about the study before giving consent. Researchers explained that participation in the study was strictly voluntary. Students were told that not all participants who gave consent to participate would be assessed to verify they met the eligibility requirements.

Borenstein, Rothstein, and Cohen's "Power & Precision" software (2001) was used to calculate a sample size based on a plan for repeated-measures analysis. The potential effects of the dietary interventions were determined from information gathered in a preliminary study of dietary intakes with a similar population (Lindseth et al., 2011). Other studies using the Sternberg Item Recognition Test (1966) to measure working memory calculated a medium effect size of .25 to .30 (Lindseth et al., 2011; Lupien, Gillin, & Hauger, 1999). With a statistical power of .80, alpha of .05, and effect size of .30 with a planned "medium" effect, an estimated sample size of 30 participants who would receive both treatments was calculated.

Eighty-seven students gave consent to participate. Thirty participants were randomly selected who met the inclusion criteria of being healthy young adults between 20 and 40 years old enrolled during the first 2 weeks of their third semester of academic study at a Midwestern university who could read, understand, and speak English and agreed to consume only study foods and beverages prescribed by the research project for the 4 weeks of dietary interventions.

Complete data sets were available for 28 participants. Statistical power for a sample of 28 participants was recalculated at .72. According to Cohen (1988), a statistical power of .72 is on the lower end of the acceptable range (.70 to .90) depending on resources and the critical nature of study outcomes.

Anthropometric Measurements

Each participant was weighed at the beginning and end of each treatment week using a *Detecto*© balance beam scale, while an *Accustat Genentech*© wall-mounted height board was used to measure height. Body mass indices and weight-to-height ratios were calculated using the participant's measurements in accordance with the Quetelet Index (kg/m^2) (Gibson, 1990). Reliabilities of similar anthropometric (weight and height) measurements have been reported as >.97 (Marks, Habicht, & Mueller, 1989).

Health Assessment and Physiological Measures

The health of each participant was recorded using a modified Health Assessment Checklist (Doenges, Geissler, & Moorhouse, 1989). Data included each participant's history of chronic systemic diseases, such as heart disease, hypertension, respiratory insufficiency, and diabetes; metabolic or gastrointestinal disorders; and urinary or neurological disorders, including headaches. A registered nurse completed a current medication history and measured each participant's temperature, pulse, and respiratory rate. The principal investigator, a nurse researcher, screened participants for symptoms that could compromise performance on study measures.

Cognitive Function Tests

The Vandenberg MRT—The Vandenberg MRT (Vandenberg & Kuse, 1978) was chosen to measure spatial visualization, the ability to mentally manipulate two-dimensional and three-dimensional figures. The spatial visualization process occurs within the visual-spatial sketchpad, a working memory component of the brain that retains information about what we see and is used for temporary storage and manipulation of spatial and visual information (Baddeley, 1996; Baddeley & Hitch, 1974). This measure had been previously used for evaluating spatial cognitive ability in naval aviators, a group similar in age to this study sample (Gordon & Leighty, 1988).

Participants are presented with a series of 20 problems, each including a target geometric figure and a row of four geometric figures as distracters. The task is to select the two distracter items that are the same as the target item for as many questions as possible within 6 minutes. Possible test scores range from a minimum of zero to a maximum of 24, with 24 being the best. The originators reported a Kuder–Richardson internal consistency reliability coefficient of .88 and test-retest reliability of .83 (Vandenberg & Kuse, 1978). Concurrent validity was established based on a correlation of $r = .60$ ($p < .01$) between scores on the Vandenberg MRT and the Primary Mental Ability Spatial Relations Subtest (Voyer et al., 2006).

Sternberg Item Recognition Test—The Stern-berg Item Recognition Test (1966) was used to test working memory. Stimuli are presented on a computer monitor, and the participants are given a short list of items (digits or alphabetical letters) from which to identify initial stimuli. The participants are instructed to respond to each trial as quickly as possible, and the computer records their response times. Total scores can range from 250 to 1,100 ms, with 250 ms being a quicker response time. The internal consistency (Cronbach alpha coefficient) was .92 in a study of pilots of similar age to the participants in this study (Lindseth, Lindseth, Petros, Jensen, & Caspers, 2013) and in this study was .89. The original test-retest reliability alpha coefficient for the Sternberg Item Recognition Test was .96 (Sternberg, 1966). Construct validity for this test was established by determining its relationship with measures of interference control (e.g., identifying digits that were not in the memory set; Jonides & Nee, 2006).

Depression and Mood Measures

Depression was measured using Zung's Self-Rating Depression Scale (SDS) to quantify affective, psychological, and somatic symptoms (Zung, Richards, & Short, 1965). The 20-item scale was developed from interviews of patients with depressive symptoms (Zung et al., 1965; Zung, 1986). Participants' responses are scored on a scale of 1 (least severe depressive symptoms) to 4 (most severe depressive symptoms); the total scores can range from 20 (least depressed) to 80 (most depressed). The Cronbach alpha reliability of the Zung SDS was .85 in a sample of 415 undergraduate students (Campbell, Maynard, Roberti, & Emmanuel, 2012) and was .91 in this study. Concurrent validity for the Zung SDS was established in a sample of 152 patients based on a correlation coefficient of .70 between the Zung SDS and MMPI Depression Scales (Zung, 1965). The Zung SDS (1965) has been found to be a

sensitive measure of the severity of clinical depression (Biggs, Wylie, & Ziegler, 1978; Passik et al., 2000; Zung et al., 1965).

Zung's (1965) Irritability Subscale was used to quantify affective mood symptoms such as crying spells, fatigue, psychomotor agitation, and irritability. Responses on the five-item irritability subscale range from 1 (least severe irritability symptoms) to 4 (most severe irritability symptoms); total scores can range from 5 (least irritable) to 20 (most irritable). The Zung's Irritability Subscale had an internal consistency of .78 in 2,187 undergraduate students (Sakamoto, Kambara, & Tanno, 2001). The Cronbach alpha in our study was .86.

Dietary Intervention

Participants received high-aspartame meals (25 mg/kg body weight/day) and low-aspartame meals (10 mg/kg body weight/day) for 8 days in each treatment period. Study meals were prepared under the supervision of the research dietitian using standardized recipes and exact portion sizes. Food and beverage intakes were weighed by research staff to within one-tenth of an ounce. Weighed food and beverage intakes are considered to be the most precise method to measure food consumption (Gibson, 1990).

To prevent neurobehavioral effects due to nutrient deficiency or unplanned nutrient reactions, food servings were calculated to meet nutritional recommendations of the US Recommended Dietary Allowances (RDA; Food & Nutrition Board, 1998). Each participant received a diet that met his or her required energy needs (in kilocalories) while consuming the assigned aspartame-containing foods and beverages. Indirect calorimetry, the gold standard for assessing participants' energy expenditure, was used in determining portion sizes for the study meals (Gibson, 1990).

The dosages of aspartame were based on results of previous research. Because Walton's (1993) study was stopped early by the Institutional Review Board due to the severity of adverse reactions to aspartame consumption in depressed participants, we chose to use a 25 mg aspartame dosage rather than the 30 mg dose in that study. Also, 25 mg/kg body weight/day of dietary aspartame was considered to be equivalent to the amount of aspartame needed to replace the highest amount of carbohydrates normally consumed in a day (Butchko et al., 2002; US FDA, 1981, 2006). Based on this work, 25 mg/kg body weight/day of aspartame was established as a safe "high" amount of aspartame for our study. The "low" dose of 10 mg/kg body weight/day of aspartame was selected because previous studies showed that 10 mg/kg body weight/day of aspartame did not significantly increase blood plasma aspartate concentrations (Stegink et al., 1987; Stegink & Filer, 1996). The modest aspartame amounts also enabled the taste of the aspartame within the study foods to be less noticeable. A variety of foods containing aspartame were served to further ensure that taste preference would not be a factor. Examples of foods high in aspartame that were served included jellies and syrups, puddings, gelatins, ice cream, beverages, and desserts. Table 1 lists the typical servings of high-aspartame foods for a treatment day.

Beverages were an important component of the study diet and included water or non-caloric drinks with controlled caffeine, and beverages containing energy (kilocalories) such as juices and milk. To avoid confounding effects, caffeine intake was controlled. Individuals with a

history of moderate caffeine intake consumed no more than 100 mg of caffeine per day. Participants could consume as much water as they desired. All water and beverage intake was measured and recorded to the nearest one-tenth of a fluid ounce.

Dietary Intervention Procedures

This study was performed in an on-campus study dining room within walking distance of classes and residence areas. The study dining room was a separate part of a large dining facility used by all students. During an initial meeting of the participants with the study dietitian, eating times were coordinated with the participants based upon their class and work schedules. The first meal of the day was served at 6:30 a.m., and the last meal of the day was served at 6:30 p.m.

Foods and beverages were served to participants by a research team member. Participants were asked to consume all foods and beverages provided. The importance of strict compliance in consuming only the study foods and beverages was emphasized.

Snacks and beverages were provided in the evening. Each participant was given a container to carry the snacks for later consumption. Participants were instructed to return the next day with the food and beverage packaging in their containers so research staff could determine whether all foods had been eaten. Each day the participants were also asked to verify in writing that no other foods or beverages had been consumed during the previous 24 hours.

Data Collection Procedures

Participants who consented to be in the study were contacted by telephone or e-mail to meet with the researcher. At this meeting, participants were reassured of their right to refuse to participate in the study, and that they could discontinue the study at any time without prejudice. Participants were assured that study responses would remain confidential and that results would be reported as summarized aggregate data. They were then asked to complete initial demographic and health assessment questionnaires.

Two weeks before study treatments, indirect calorimeter measures were obtained, and anthropometric measurements and health assessments were completed. An educational session was held to inform the participants of the importance of dietary compliance to ensure the accuracy of the study results. To ensure willingness to consume study foods and beverages, participants completed a food habit questionnaire. If a participant indicated they would not eat the prescribed foods, they were advised not to participate. Participants were again instructed that they must eat only the food and beverage items assigned for the study treatments.

Cognition, depression, and mood (irritability) testing was performed within 2 hours after consumption of the last study meal of each dietary treatment session. Cognitive testing was administered by a clinical psychologist and completed in a quiet testing room. Symptoms of potential illnesses were assessed by the nurse researcher throughout the treatment schedule so possible confounding factors would not be confused with the effects of aspartame. Participants received $125 in compensation for completing the study.

Data Analysis

ESHA Food Processor Software was used to analyze the aspartame content and nutrient values of the weighed foods and beverages consumed by each participant (ESHA Research, 2010). This nutrition analysis system was selected because of its capability to analyze the specific food and beverage intakes for an extensive list of nutrients.

All study data were analyzed using the Statistical Package for Social Sciences (SPSS) software. Data (including the nutrient analyses) were entered twice to eliminate possible data entry errors. The SPSS Explore Procedure was used to screen the data, to visually examine the distribution of values among the groups, and to test for normality and homogeneity of variance. Frequencies were tabulated for the demographic and anthropometric data. Food intake data from each of the 8 days of high-aspartame consumption and 8 days of low-aspartame consumption were analyzed to evaluate the effects of aspartame consumption on the study variables.

The depression and mood data, spatial orientation data, and working memory data were analyzed by descriptive statistics, repeated-measures analysis of variance, and paired *t*-tests. The level of significance for this study was set at $p = .05$. Kazdin's (2002) definition was used for determining clinical significance: A participant was considered to exhibit a clinically significant neurobehavioral effect when the mean cognition, depression, or irritability score was two standard deviations outside of the mean score for normal functioning.

Results

Demographic Characteristics

The mean age of the study participants was 20.8 years ($SD = 2.5$). The average number of years of education was 13.4 ($SD = 1.0$), and the mean body mass index was 24.1 ($SD = 3.5$).

Effects of Aspartame Consumption on Cognition

Based on Vandenberg MRT scores, spatial orientation scores were significantly better for participants after their low-aspartame intake period than after their high intake period (Table 2). Two participants had clinically significant cognitive impairment after consuming high-aspartame diets.

Within-subject differences in Sternberg Item Recognition scores (working memory) at the two measurement points were not significant. After consuming high-aspartame diets, two participants (different individuals than those with spatial orientation difficulties) experienced clinically significant impaired working memory scores.

Effects of Aspartame Consumption on Mood and Depression

Participants were significantly more depressed after they consumed the high-aspartame diet compared to when they consumed the low-aspartame diet (Table 2). After consuming the high-aspartame diet, 3 of the 28 participants (different individuals from those who experienced either form of cognitive impairment) had a depression score of over 49,

indicating mild to moderate clinical depression. After consuming the low-aspartame diet, all 28 participants had depression scale scores within the normal range (Zung, 1986). Participants' scores on Zung's Irritability Subscale showed significantly more irritability after consuming the high-aspartame diet.

Effects of Aspartame Consumption on Headaches

Only one participant reported a headache; no difference in headache incidence between high- and low-aspartame intake periods could be established.

Discussion

Healthy young adult participants scored lower on spatial orientation tests after 8 days on a high-aspartame diet than they did after the same period on a low-aspartame diet, supporting previous evidence of neurobehavioral effects of aspartame (Wurtman, 1983, 1987). Harte and Kanarek (2004) also reported that participants who drank sucrose-sweetened beverages performed better on spatial memory and attention tasks than those who consumed aspartame-sweetened beverages. In another study, recall, reaction time, and spatial memory scores were better among those who consumed glucose compared to aspartame-sweetened beverages (Sunram-Lea et al., 2002). However, working memory, as measured by Sternberg's Item Recognition Test, did not differ in our participants, as found by Brandt, Sunram-Lea, and Qualtrough (2006) when comparing the impact of aspartame and glucose on memory.

A high dose of aspartame caused more irritability and depression than a low-aspartame dose consumed by the same participants, supporting earlier study findings by Walton et al. (1993), whose work was not completed because of adverse reactions in some of the vulnerable study participants. The amount of aspartame served to participants in Walton's study was 30 mg/kg body weight/day, which was only slightly higher than the amount in our high-aspartame diet. Additionally, three participants in our study scored in the clinically depressed category while consuming the high-aspartame diet, despite no previous histories of depression. These results contrast with another study, in which mood did not differ significantly when overweight women consumed a beverage sweetened with aspartame or a sucrose-sweetened beverage over a 5-week period and self-reported prospective food and drink intake, mood, and daily activities in 2-hour increments (Reid et al., 2010). Headaches were rare in our sample, so we were unable to support or refute those of Jacob and Stechschulte (2008), who proposed a link between aspartame and migraine based on a clinical case study of six individuals.

Limitations of our study included the small homogeneous sample, which may make it difficult to apply our conclusions to other study populations. Also, our sample size of 28 participants resulted in a statistical power of .72, which is on the lower end of the acceptable range. A washout period before the baseline assessments and using food diaries during the between-treatment washout period to verify that aspartame was not consumed would have strengthened the design.

Conclusions

Aspartame intake affected certain aspects of neurobehavioral performance. Spatial orientation was weaker and irritability and depression were more frequent after high-aspartame consumption than low aspartame consumption when subjects served as their own controls. Furthermore, seven participants experienced clinically significant neurobehavioral conditions following the higher level of aspartame consumption. A diet high in aspartame did not influence working memory or headaches.

Investigators who previously had explored the neurobehavioral effects of aspartame consumption did not control the effects of non-study food and beverage intakes in their participants' diets or administered single-dose treatments, such as aspartame-sweetened beverages or capsules, followed by cognition, mood, and/or depression testing. Our study represents an advance over this previous work. Nonetheless, because there are relatively few clinical studies of the neurobehavioral aspects of short-term aspartame consumption and the results of these are conflicting, additional research is warranted to assess the safety of aspartame consumption and its implications for health.

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Table 1

Typical Food and Beverage Servings for a High-Aspartame (25 mg/kg/day) Diet for a 54 kg Female

Foods and Beverages Containing Aspartame	Portion Size	Aspartame (mg)
Breakfast		
Sugar-free fruit juice	10 oz.	116
Sugar-free yogurt	8 oz.	160
Lunch		
Sugar-free gelatin	4 oz.	100
Sugar-free lemonade	12 oz.	120
Snack/beverage		
Diet soda	20 oz. bottle	325
Dinner		
2 scoops (4 oz.) sugar-free ice cream	8 oz.	100
1 glass sugar-free fruit punch	12 oz.	120
Evening snack beverage		
Diet soda	20 oz. bottle	325
Total:		1,364

Notes. Aspartame values may vary depending upon brands. The dosage administered is half the 50 mg/kg body weight/day set as the acceptable daily intake by the US Food and Drug Administration (US FDA, 2006).

Table 2

Within-Subject Differences in Neurobehavior Scores After High and Low Aspartame Intake (N = 28)

Variable	*M*	*SD*	Paired *t*-test	*p*
Spatial orientation				
High-aspartame	14.1	4.2	2.4	.03 *
Low-aspartame	16.6	4.3		
Working memory				
High-aspartame	730.0	152.7	1.5	N.S.
Low-aspartame	761.1	201.6		
Mood (irritability)				
High-aspartame	33.4	9.0	3.4	.002 **
Low-aspartame	30.5	7.3		
Depression				
High-aspartame	36.8	7.0	3.8	.001 **
Low-aspartame	34.4	6.2		

* $p < .05$.

** $p < .01$.