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Effects of Aspartame Consumption on Cognitive Function

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EFFECTS OF ASPARTAME CONSUMPTION ON COGNITIVE FUNCTION

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This thesis, submitted by Fang Ye in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

Glenda Lindseth

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This thesis meets the standards for appearance, conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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ABSTRACT

The FDA estimates that 35% of Americans regularly consume aspartame, an artificial sweetener used in diet drinks and other sugar-free food items. Some anecdotal reports indicate the substance has been associated with health, behavioral, and cognitive concerns. The FDA and other regulatory agencies indicate it is safe for use up to 50mg/kg/day. They further advise individuals with metabolic phenylalanine disorders not to consume this product. This conflicting advice has caused confusion for consumers and practioners. Therefore, the purpose of this study was to examine the effects of aspartame consumption on cognitive functioning of healthy adults.

Orem's theory of Self-Care guided this descriptive, clinical study. The effect of dietary aspartame consumption on cognitive function of study participants was monitored and analyzed for participants consuming weighed food intakes for 16 days.

This study tested the hypothesis that cognitive

functioning is poorer when participants' dietary intake of aspartame is higher. The sample population was comprised of 180 randomly selected ethnically-diverse 18 to 40 year old healthy adults recruited through a midwestern university. Instruments used for measurement included a Demographic Questionnaire, Weighed Food Intakes, Kearney and Fleischer's Exercise of Self-care (alpha= .80), the Sternberg Item Recognition Test (r =.95), and the Vandenberg Mental Rotation Test (KR-20=.88).

Depending on the cognitive task (the Vandenberg Mental Rotation Test), results indicated that cognitve function was significantly better (p=.03) when participants consumed less aspartame (<1000mg/day) than those who consumed more (≥1000mg/day).

The relevance of these results is that healthcare professionals need to be aware of dietary factors that can maximize cognitive function and promote quality of life for their clients.

CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

A healthy lifestyle is essential for health promotion and disease prevention. Proper dietary intake is one of the key factors for living healthily. Although dietary intakes have been well-recognized as a significant contributor to "health," people do not pay much attention to what they eat and "Americans consume much more sugar than they need" (Stadler & Essa, 2001, p.3). According to the Federal Continuing Survey of Food Intakes (1994-1996), the average American consumes an amount of sugar substitutes equivalent to 20 teaspoons of sugar per day – equal to about 80 grams of sugar (Henkel, 2004). The Food and Drug Administration (1987) estimates 35% of Americans regularly consume aspartame, which is one of the most widely-used sugar substitutes. Used as an artificial low-calorie sweetener, aspartame has undergone numerous studies regarding safety issues since its approval by the FDA in 1981. Some anecdotal reports indicate aspartame has been associated with health, behavioral, and cognitive function; and about two-thirds of these

symptoms were neurobehavioral in nature (Butchko & Stargel, 2001). The FDA (2004) and other food regulatory agencies indicate that aspartame may be safe for use up to 50mg/kg/day. Based on this conflicting information, it seems important to determine what amount of aspartame consumption would be considered safe for general use.

Purpose

The purpose of our study was to examine the effects of aspartame consumption on cognitive function of healthy adults, testing the hypothesis that cognitive functioning was poorer when participants' dietary intakes of aspartame were greater.

Significance of the Study

The effects of aspartame and its metabolic breakdown products (phenylalanine, aspartic acid, and methanol) have been investigated in general populations as well as in subgroups. Along with these concerns, rising safety issues related to aspartame consumption have been reported in studies, such as the onset of brain tumors and seizures, headaches, allergies, behavioral changes, and changes in cognitive function (European Scientific Committee on Food [ESCF], 2002). Among these studies, researchers have been increasingly paying attention to the effects of aspartame on cognitive function. Over the

years, it has been hypothesized that aspartame could have an effect on human cognition (Wurtman, 1985). However, a number of studies show that there are no direct effects indicated in tests by administrating single doses of up to 60mg/kg/day (Lieberman et al, 1988; Lapierre et al., 1990; Pivonka & Grunewald, 1990; Stokes et al., 1991; Stokes et al., 1994).

Lapierre et al. (1990) conducted a clinical study among ten healthy adult volunteers with administration of a single dose of aspartame (15 mg/kg body weight in capsules). Changes in mood, cognitive function, and memory were tested after aspartame administrations. The researchers of this study reported that no detectable differences were found between aspartame and placebo despite of significant increases in plasma phenylalanine levels after aspartame administration. Changes in mood were also tested by Pivonka and Grunewald in young women following aspartame-containing beverages consumption (1990). However, Pivonka and Grunewald concluded that no significant mood changes were observed following aspartame consumption compared to water. Moreover, the effects of chronic aspartame consumption were also tested among pilots by Stokes et al. (1994). However, no significantly declined cognitive performance observed

among study participants following chronic dosing of aspartame.

However, the results of these studies can be debated, since single dosing administrations do not reflect typical aspartame consumption patterns. Consequently, it suggests a more scientifically-designed, well-controlled clinical study to further evaluate the safe dosing issue.

This proposed study provided in-depth analysis of the safety of aspartame consumptions among healthy adults based upon more typical dietary intakes. Therefore, it was essential for individuals to consume food wisely and in a manner considered to be "healthy."

Review of Literature

Aspartame's Role in the Diet

Aspartame, a dipeptide (L-aspartyl-L-phenylalaline methyl ester) used as a nonsugar sweetener, was discovered in 1965 and approved by the U.S. Food and Drug Administration in 1981 as safe for use in a wide range of food products. Today, aspartame is found in approximately 6000 products, including soft drinks, chewing gums, gelatins, puddings, frozen desserts, yogurt, some pharmaceutics, and many other products (Calorie Control Council, 2004). It is chemically broken down into three

metabolic components (aspartic acid, phenylalanine, and methanol) in the body by hydrolysis of intestinal esterases (American Dietetic Association, 1998). Since it was approved by the FDA in 1981, aspartame has been used in thousands of products for more than 25 years, and the amount of demand for aspartame use has been increasingly rising from 8.4 million pounds in 1986 to 17.5 million pounds in 1992 (American Dietetic Association, 1998).

As it is increasingly being used as a general-purpose sweetener, aspartame has been harshly criticized for its safety issues, including (1) the possible methanol toxicity; (2) the increased plasma concentrations of phenylalanine and aspartic acid in the brain; (3) the potential neuroendocrine alterations associated with elevated concentrations in the brain; and (4) a hypothesized connection between aspartame and epilepsy and brain malignancy (ESCF, 2002). These safety issues related to aspartame and its breakdown metabolic components have been studied in children and general human populations (ESCF, 2002). Shortly after heavy worldwide marketing of aspartame, numerous scientific studies were conducted to investigate these safety issues through clinical and laboratory research. According to

the report by Calorie Control Council (2004), aspartame has been considered to be safe in more than 200 studies, including studies by the U.S. Food and Drug Administration (FDA). However, this investigator cannot find the primary sources of the 200 studies stated above. Despite the safety statement about aspartame by regulatory agencies, however, there were many anecdotal reports of health effects related to aspartame consumption (Hull, 1999). In a report by the FDA (1995), numerous consumer complaint reports were received and 11% were considered serious. Given that 11% of the reports were considered serious, it seems there is a need for further investigation.

Aspartame Consumption and Evidence of No Significant Effects on Cognition

The increased recent interest in the safety of aspartame has prompted investigators to explore whether there is a link or not between aspartame consumption and neurological effects as well as cognitive function. It has been hypothesized that aspartame might have the potential for affecting neurotransmitter levels in the brain since it is believed that a source of phenylalanine from dietary consumption of aspartame-containing products would increase phenylalanine concentrations in the brain.

Wurtman (1985) further suggested that the increased level of phenylalanine in the brain may disturb the balances in monoaminergic neurotransmission, thereby, resulting in effects on cognition, behavior, and physiological functions. The hypothesis has been tested in a number of animal and clinical studies. Although effects on neurotransmitter levels were noted based on some acute and repeat-doses of administration at high doses in animal studies, there were no statistically significant and reproducible effects (Dailey, et al., 1991; Reilly & Lajtha, 1995).

Furthermore, Spiers et al. (1998) conducted a clinical research study to examine the aspartame effects on neuropsychologic and neurophysiologic functioning. Each study participant was administered one of three treatments aspartame, sucrose, or placebo. The authors concluded that large daily doses of aspartame had no effects on neuropsychologic, neurophysiologic, or behavioral functioning in healthy young adults, and stated that aspartame is safe for the general population (Spiers et al., 1998). Another clinical study conducted to measure the neuropsychiatric effects of aspartame among healthy volunteers indicated that there were no significant differences between aspartame and the placebo

found in measures of sedation, hunger, headache, reaction-time, cognition, or memory at any given time during this study after ingestion of a single dose of aspartame (Lapierre et al., 1990).

Regardless of numerous negative research findings of aspartame studies, it is believed that there are still some questionable issues left for further evaluation due to a variety of anecdotal reports and debatable research methodology (Hull, 1999).

Aspartame Consumption and Evidence of Significant Effects on Cognition

Although aspartame has shown little or no behavioral effect in most studies, Conners et al. (1986) stated that activity observed following administration of sucrose or fructose was less than after aspartame. Conners et al. (1986) further reported that the improvement in attention might be considered declined because of aspartame. Another research study has also been conducted on preschoolers who were treated with aspartame compared to glucose, sucrose, and saccharin. Following administration, their activities were observed (Kruesi, et al., 1985). A significant decline of motor activity was observed after aspartame administration, while other

behavioral measures did not demonstrate significant differences (Kruesi, et al., 1985).

Moreover, the U.S. Centers for Disease Control (1984) reviewed 517 cases of consumer adverse reaction complaint reports and concluded that 28% of the cases showed adverse reactions, such as headache, dizziness, mood changes, insomnia, nausea and vomiting, etc., occurred after aspartame-containing product consumption (Butchko & Stargel, 2001).

A recent study conducted in rats by Christian, et al. (2004) reported that rats administered with aspartame in the drinking water for three or four months showed a significant increase in time when performing T-maze activity. Potts et al. (1980) also reported that when aspartame was administered as 9% of the diet for thirteen weeks, altered learning behaviors were observed in male rats.

Although there were no clinical studies to demonstrate the effects of aspartame consumption on poor neurobehavioral or cognitive function, some anecdotal reports have been presented to the FDA indicating adverse reactions associated with potential effects of consuming aspartame-containing products, for example, headache, dizziness, mood changes, nausea and vomiting, etc. (FDA,

view of the studies' conclusion discrepancies based on industry- and non-industry-sponsored research investigations, a more thorough and well-controlled study may be needed to generate a more scientific conclusion for the use and safety of aspartame consumption.

Aspartame and Health Status

Although aspartame has been investigated for many health-related problems, there are not many studies done in healthy adults related to their health status, such as physiological measures—respiration, pulse, blood pressure, blood glucose, body weight, or temperature. One laboratory study conducted by Kiritsy and Maher (1986) reported that animals with aspartame administration could induce high blood pressure due to increased levels of phenylalanine concentrations in the blood and brain. Contrary to the findings of Kiritsy and Maher's study, Leon et al. (1989) concluded that there were no persistent changes in vital signs (including temperature, respiration, blood pressure, and pulse) in participants consuming aspartame for 24 weeks.

Theoretical Framework

Orem's Theory of Self-Care guided this descriptive, clinical study. Our study examined the effects of participants' aspartame consumption on the dependent

variable, that is, cognitive function. Orem's Theory of Self-Care has been widely used in nutrition studies (Owasoyo, et al, 1992; Lindseth and Lindseth, 1995). Self-care is defined as a significant factor for maintaining a high quality of life. Self-care agency is the capability of allowing patients to distinguish factors that need to be controlled to facilitate better regulation of their functioning and development (Orem, 1995). Self-care involves use of knowledge in order to promote health and a high-quality of life. Since self-care is a learned, goal-oriented activity, it was thus measured in our study to determine each participant's capabilities and determine the effectiveness of dietary changes intended to promote management of people's functioning and quality of life.

Research Questions

1. To what extent was cognitive function affected by higher aspartame consumption (≥ 1000 mg/day) from dietary intake in comparison with lower dietary aspartame consumption (< 1000 mg/day)?
2. What was the relationship among cognitive function scores, dietary aspartame consumption, demographics, and health status in healthy participants?

Definitions

The definitions were used in the study as follows:

1995). This indicates a demand for further investigation for its safe use.

Discrepancies among Studies

The European Scientific Committee on Food (ESCF) concluded that here were no significant effects of aspartame consumption noted on behavior, mood, or EEG profiles, or cognitive function, even with elevated phenylalanine levels in the brain in long- and short-term clinical studies in either the general populations or sensitive individuals (2002). However, an analysis of 164 studies, including 90 non-industry-sponsored and 74 industry-sponsored studies, reviewed by Ralph Walton, Chairman of The Center for Behavioral Medicine and Professor of Clinical Psychiatry at Northeastern Ohio Universities College of Medicine, concluded that there were many questions left related to human safety. Of these 164 studies, among 90 non-industry-sponsored studies, 92% found one or more problems associated with aspartame. Among 74 industry-sponsored studies, 100% stated that there were no problems found (Aspartame Toxicity Information Center, 1996). However, this investigator was not able to evaluate these one hundred sixty-four studies as mentioned above due to the lack of available primary sources reviewed in Walton's report. In

Cognitive function was defined as enabling users "to transform a (prescribed) task into an activity (effective task)" and was "experimentally elicited by interpreting the deviations between the task and user activity in terms of role, context, and resources" (Boy, 1998, p. 266-267). These resources included user-based (e.g., knowledge and skills) and task-based (e.g., procedures) functions (Boy, 1998). Cognitive function was operationally measured for our study using the Vandenberg Mental Rotation Test (MRT) and Sternberg Item Recognition (SIR) Test.

Vandenberg Mental Rotation Test presented participants with a series of problems in which they were given a geometric figure as a target item and a row of four geometric figures as distracters, and the task was to select two of the four distracter items which is the same as the target items. The participants needed to complete 20 questions within 6 minutes to earn a maximum score of 40 on the test. MRT had a score of Kuder - Richardson internal consistency .88 and a test-retest reliability .83 when tested for reliability (Vandenberg & Kuse, 1978).

Sternberg Item Recognition Test was used to test short term memory. For this test, a computer was used to present stimuli on a monitor and participants were given a

short list of items (typically digits), and they responded to each trial as quickly as they could, and the computer recorded their responses for approximately ten milliseconds. The coefficient for test-retest reliability for SIR test was ≥ .95 (Sternberg, 1966).

Assumptions

1. Individuals might not have been aware of how much aspartame they consumed in their daily lives since aspartame is increasingly used in almost 6,000 products.

Limitations

1. This is a secondary analysis. Therefore, this investigator had no control of variables because data was collected after participants' dietary intakes.
2. This is a secondary analysis. Therefore, this investigator had no control of the study groups and control group since all data was gathered after dietary treatments.

Summary

Although a number of studies showed that there was little or no direct effects of aspartame consumption on neurobehavioral or cognitive function, as discussed above, the question is still left to be discussed further due to the debatable study methodology and the

credibility of study conclusions. Further study needs to test consumer reported adverse reactions associated with aspartame consumption since some study results are still controversial. Overall, the purpose of the study was to examine the effects of aspartame consumption on the cognitive function of healthy adults.

CHAPTER II

METHODOLOGY

Introduction

The purpose of our study was to examine the effects of aspartame consumption on cognitive function of healthy adults, testing the hypothesis that the cognitive functioning was poorer when participants' consumption of dietary aspartame intakes were greater.

This chapter focuses on the methodology employed in our study. The study population, sample, study design, data collection methods and procedures, instrument reliability and validity, data analysis, and the protection of human subjects are addressed in this chapter.

The research questions of our study were the following:

1. To what extent was cognitive function affected by higher aspartame consumption (≥ 1000 mg/day) from dietary intake in comparison with lower dietary aspartame consumption (< 1000 mg/day)?
2. What was the relationship among cognitive function

scores, dietary aspartame consumption, demographics, and health status in healthy participants?

Population and Sample

The sample population was comprised of 180 randomly selected ethnically-diverse 18 to 40 year-old healthy adults recruited through a midwestern university. The criteria for inclusion were as follows: (a) 18 to 40 years of age; (b) capacity to read, understand, and speak English; and (c) enrollment in a midwestern university.

Study Design

Orem's Theory of Self-Care guided this clinical study using a descriptive, correlational study design. Each participant served as his or her own control when participating in the study. Amounts of aspartame consumption by each participant were calculated by a registered dietitian based upon the amount of aspartame contained in food products provided by the manufacturers. The data were recorded and analyzed from weighed food intakes for 16 days for comparison of cognitive testing mean scores on aspartame consumption.

Data Collection Methods/Procedures

This is a secondary analysis based upon the following clinical study which included food treatments.

A registered dietitian and the study investigators were consulted about the dietary treatments. The purpose and details of the study were explained to the anticipating participants at an arranged meeting and questions were also answered by the researchers. Participants who signed the study consent forms completed questionnaires and had measurements taken for demographics, self-care agency, and anthropometrics. Participants were randomly selected for the study. The participants met with the research team a week before treatments. On the treatment weeks, each participant was instructed to consume only the food and beverages provided for the study; moreover, the participants were instructed to complete questionnaires on a daily basis about that food consumption. The importance of compliance with the treatment plan was also addressed.

Dietary intakes were controlled in terms of what and how much was consumed. On the weeks of treatment, a weighed scheduled meal was given to each participant for 16 days (three 4-day dietary treatments). A weighed food record was well-recognized as the most precise method for measuring individuals' food intakes according to Gibson (1990). Food portions were measured based upon individuals' kilocalories per day using indirect metabolic

calorimetry, and portion sizes were weighed before and after consumption. Beverages, such as juices and milk, were given to the participants with no limited amount as part of their meals. The participants' preferences of beverages were taken into account for their daily caloric intakes. However, only water and non-caloric drinks in addition to fluids provided at meals were issued and the amount of caffeine was carefully controlled in the study because of its potential effects on cognitive function with no more than 200 mg per day. Snacks were also issued to participants to take home for consumption between the evening meal and before midnight.

Meals were brought by the researchers or research assistants directly to each participant and served in a private study dining room at the university. Food preparation was completed with the consultation and under the guidance of a dietitian, and the researchers or research assistants confirmed that each meal was prepared properly before serving the participants. Amounts of aspartame were mainly analyzed for its potential effects on cognitive function.

Instrumentation and Reliability & Validity

This is a secondary analysis of the clinical study - "Nutritional Effects on Cognition and Flight Performance."

Demographics. A Demographic Questionnaire was completed by each participant, including place of residence, age (in years), education (in years), marital/social living status, employment status, and ethnic identification.

Anthropometric measurements. Serial weights and weight-for-height measures were recorded, and body mass indices (BMI) were further calculated for each participant. The components of reliability for anthropometric measures were studied in both male and female participants from the Second National Health and Nutrition Examination Survey (NHANES II). The anthropometric measurements for our study (weight and height) had reliabilities greater than 0.97 (Marks, et al., 1989). Body weights were taken twice for each participant using a Cardinal-Detecto balance beam scale, at the beginning and at the end of each study week. Height was measured and recorded on the first visit by using an *Accu-stat* wall-mounted height board. BMIs, a ratio of weight for height based upon the measurement of each participant on admission, were calculated in accordance with the Quatelet Index (kg/m^2) (Gibson, 1990). In addition, serial weight was monitored to determine if the participant was considered underweight or overweight at

the beginning of the study and as a baseline for monitoring weight gains or losses during the study.

Health assessment data. The data of health status assessment modified from Doenge's Health Assessment Checklist (1989) was collected and recorded for each participant. The checklist consisted of nine factors, including history of chronic systemic disease such as heart disease, hypertension, respiratory insufficiency, diabetes; metabolic or GI disorders; and urinary or neurological disorders. To control for these disorders, data were eliminated if disorders from these systems are an interfering factor.

Dietary treatments. Weighed food intakes were used to calculate each participant's dietary aspartame intakes from their meals, by using the Food Processor-Genesis System to analyze a variety of extensive nutrients based on the U.S. RDA. Indirect calorimetry was used to determine the appropriate calorie levels, rather than BMI and activity levels. Confounding relationships between food process and food borne illnesses were controlled through closely monitored food distribution practices.

Self-care agency. Self-care agency was measured to determine the participants' abilities to take care of themselves with the reliability of Kearney and Fleischer's

Exercise of Self-Care Agency (alpha = .80) (Whetstone, 1986).

Cognitive Function Tests. Two psychometric measures, the MRT and the SIR test, were used to assess participants' cognitive functions. The MRT instrument presented participants with a series of problems in which they were given a geometric figure as a target item and a row of four geometric figures as distracters, and the task was to select two of the four distracter items which were the same as the target items. The participants needed to complete 20 questions within 6 minutes with a maximum score of 40 on the test. A Kruder-Richardson internal consistency coefficient was .88 when testing reliability of the Vandenberg Test of Mental Rotation (Vandenberg & Kurse, 1978). The SIR test was used to test short term memory. For this test, a computer was used to present stimuli on a monitor and participants were given a short list of items (typically digits), and they responded to each trial as quickly as they could, and the computer recorded their responses for approximately ten milliseconds. The coefficient of test-retest reliability for short term memory testing was ≥ .95 (Sternberg, 1966).

Data Analysis

The study data was analyzed by using the Statistical Package for Social Science (SPSS). The SPSS Explore Procedure (2006) was utilized to screen data and to test for normality and homogeneity of variance. Demographic data was analyzed in our study in regards to each study participant, including the following: (a) the age; (2) the years of education received; (c) the body mass index; (d) the self-care agency score. The frequencies were evaluated for responses to the measures of dietary aspartame intakes, demographics, health status, and cognitive function. These data were analyzed by descriptive and inferential statistics. An alpha level of .05 was the criterion for significance.

Descriptive statistics and correlations were used to analyze the effects of dietary aspartame consumption by the participants when comparing their cognitive function levels during treatment measures. All data were quantified for analysis. Our study was conducted in accordance with the methods discussed above to examine the effects of aspartame consumption on cognitive function by using the descriptive and correlational statistics.

Protection of Human Subjects

The Institutional Review Boards of the university and the U.S. Army Biomedical Research Human Use Committee reviewed and approved the study regarding ethical considerations for the human subjects in the study. The researchers of our study also clearly explained to participants that the study was totally voluntary and all collected data will remain confidential and only the summative and collective results will be reported. Each participant was also assured that there was no way in which she/he could be identified.

The findings of our study would help healthcare professionals as well as each individual in the society to better understand the dietary aspartame consumption. This information would benefit both healthcare providers and the consumers as well.

CHAPTER III

DEMOGRAPHICS

Introduction

The purpose of our study was to examine the effects of aspartame consumption on cognitive function of healthy adults, testing the hypothesis that the cognitive functioning was poorer when participants' dietary intakes of aspartame were greater.

This chapter focuses on the demographic characteristics of the sample used in our study.

The research questions of our study were the following:

1. To what extent was cognitive function affected by higher aspartame consumption (≥ 1000 mg/day) from dietary intake in comparison with lower dietary aspartame consumption (< 1000 mg/day)?
2. What was the relationship among cognitive function scores, dietary aspartame consumption, demographics, and health status in healthy participants?

The Statistical Package for the Social Sciences (SPSS) program was utilized to analyze the result

obtained in our study, and significance was set at the .05 level.

Demographic Characteristics

Demographic data were analyzed in our study in regards to each participant as follows: (a) the age; (2) the years of education received; (c) the body mass index; (d) the self-care agency score. Ages of the study participants ranged from 18 to 40 years old. The analysis of the demographic characteristics of the study participants revealed that the mean age was 20.6 years with a standard deviation of 2.0. The average education years of the study participants was 13.6, and the standard deviation of education years was .98. The mean body mass index of the participants was 24.8 with a standard deviation of 3.5. The self-care agency mean scores of the study participants were 127.2, and the standard deviation was 13.7. These demographic data are illustrated in Table 1.

Table 1

Means and Standard Deviations for Demographics, Health Status, and Self-Care Agency Data (n=176)

Variable	SD	Mean
Demographics of the sample		
Age (Years)	20.6	2.0
Education (Years)	13.6	.98
Health Status of the Participants		
Body Mass Index (BMI)	24.8	3.5
Self-care Agency (Scores)	127.2	13.7

CHAPTER IV

RESULTS AND ANALYSIS

Introduction

The purpose of our study was to examine the effects of aspartame consumption on cognitive function of healthy adults, testing the hypothesis that the cognitive functioning was poorer when participants' dietary intakes of aspartame were greater.

This chapter discusses the statistical analysis used and results obtained in our study.

The research questions of our study were the following:

1. To what extent was cognitive function affected by higher aspartame consumption (≥ 1000 mg/day) from dietary intake in comparison with lower dietary aspartame consumption (< 1000 mg/day)?
2. What was the relationship among cognitive function scores, dietary aspartame consumption, demographics, and health status in healthy participants?

The Statistical Package for the Social Sciences (SPSS) program was utilized to analyze the results

obtained in our study and significance was set at the .05 level.

Research Question 1

The first research question was to examine to what extent cognitive function was affected by higher aspartame consumption (≥ 1000 mg/day) from dietary intake in comparison with lower dietary aspartame consumption (< 1000 mg/day).

Of 180 study participants, 95 consumed aspartame equal to or greater than 1000 mg per day, and 78 consumed aspartame less than 1000 mg per day from their dietary intakes. Table 2 shows the amount of aspartame contained in some common products and its toxicity levels based on 50mg/kg/d = toxic.

Vandenberg Mental Rotation Test Mean Scores and Aspartame Consumption

The MRT score differences of the participants were compared for aspartame consumption. The MRT scores were based upon measures of dietary aspartame intakes. The mean MRT cognition score of study participants who consumed aspartame equal to or greater than 1000 mg per day was 14.8 with a standard deviation of 6.0, and the mean MRT score of study participants who consumed aspartame less than 1000 mg per day was 16.7 with a standard deviation of

5.6. With the MRT measure, a higher score indicates better cognitive performance.

Statistically significant differences for Table 3 were based upon an analysis of the amount of aspartame consumption from food. The MRT scores were significantly different with mean scores of 14.8 (± 6.0) and p=.03 when aspartame consumption equal to or greater than 1000 mg per day. The mean scores of cognitive measures are shown in Table 3, which illustrates between-subjects differences for the dietary aspartame intakes of the participants when using t-test analysis.

Table 2

Aspartame Equivalents

Aspartame Equivalents(1000mg)	Servings 54.5kg Female	FDA defined toxicity *
Carbonated drinks (12 oz)	5.56	15.15
Yogurt (8 oz)	8.06	21.99
Powdered soft drinks (12 oz)	8.33	22.73
Gelatin dessert (4 oz)	10.53	28.71
Fruit drinks - 10% fruit juice	14.29	38.96
Ice cream (4 oz)	20.00	54.55
Pudding (4 oz)	40.00	109.09
Chewing gum - 1 stick	142.86	389.61
Vitamins - 1 Multivitamin	250.00	681.82
Breath mints - 1 mint	666.67	1,818.18

*Based on 50 mg/kg/d = Toxic

Sternberg Item Recognition Mean Scores and Aspartame Consumption

T-test analysis was utilized to examine the SIR score differences of study participants for their dietary aspartame consumptions. Mean SIR scores were 731.9 (± 190.5) when aspartame consumption was equal to or greater than 1000 mg per day compared to 730.9 (±144.0) while aspartame consumption was less than 1000 mg per day. The SIR scores were based on measures of aspartame intakes from food. The between-subjects differences for the dietary aspartame intakes of the participants were analyzed by using a t-test. T-test analysis of effects of aspartame consumption showed no significant differences in scores using the SIR test as illustrated in Table 4.

Table 3

Comparison of MRT Mean Scores and Aspartame Consumption

Variable	Aspartame < 1000 mg/day		Aspartame ≥ 1000 mg/day			
	Mean	SD	Mean	SD	t	p
Cognitive Measures						
Vandenberg Mental Rotation Scores	16.7	5.6	14.8	6.0	2.13	.03

NS Significance*: p= <.05
n= 169

Table 4

Comparison of SIR Test Mean Scores and Aspartame Consumption

Variable	Aspartame < 1000 mg/day		Aspartame ≥ 1000 mg/day			
	Mean	SD	Mean	SD	t	p
Cognitive Measures						
Sternberg Item Recognition Scores	730.9	144.0	731.9	190.5	.04	NS

NS Significance*: p= <.05
n= 169

Research Question 2

The second question examined by our study was what the relationship among cognitive function scores, dietary aspartame consumption, demographics, and health status in healthy participants was.

Pearson's Correlations were used to examine this relationship. Based upon Pearson Correlations, no significantly correlated relationships were indicated among dietary aspartame consumption and body weight, blood pressure, respirations, body temperature, glucose, self-care agency and the SIR test; however, it shows that aspartame was inversely correlated with the MRT. The MRT also had an inversely correlated relationship with the

SIR test. The self-care agency scores also inversely correlated with the participants' measures for respiration, body weight, SIR scores, and MRT scores. Table 5 shows some significant intercorrelational variables for healthy adults in our study.

Table 5

Intercorrelations of Effects of Aspartame Consumption on Cognitive Function Scores with Demographic and Health Status Variables

	1	2	3	4	5	6	7	8	9
1. Aspartame	1.0								
2. Respiration	.15	1.0							
3. Temperature	.12	.07	1.0						
4. Blood Pressure	-.01	-.04	.01	1.0					
5. Weight	.02	-.03	.02	-.06	1.0				
6. Random Glucose	-.13	.09	-.02	-.03	.05	1.0			
7. Sternberg Test	-.01	.06	-.10	-.06	-.03	.07	1.0		
8. Vandenberg Test	-.18*	-.13	.08	.09	.15	.01	-.23**	1.0	
9. Self-Care Agency	.14	-.21*	.01	-.00	-.17*	.01	-.21**	-.16*	1.0

Effects of Aspartame Consumption on Physiological Changes

Physiological measures (respiration and pulse) of the study participants were also compared for differences based on aspartame consumptions. The respiration scores

were significantly different (p = .04) when comparing aspartame consumption equal to or greater than 1000 mg per day, which had a mean score of 22.4 (± 15.96), to aspartame consumption less than 1000 mg per day, which had a mean score of 18.6 (± 6.95). However, T-test analysis did not find significant effects of aspartame consumption on pulse measure as indicated in Table 6.

Table 6

Comparison of Physiological Changes Mean Scores and Aspartame Consumption

Variable	Aspartame < 1000 mg/day		Aspartame ≥1000 mg/day			
	Mean	SD	Mean	SD	t	p
Physiological Measures						
Respiration	18.6	6.95	22.4	15.96	2.05	.04
Pulse	82.8	14.7	82.1	14.99	.32	NS

NS Significance*: p= <.05
n= 169

CHAPTER V

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The purpose of our study was to examine the effects of aspartame consumption on cognitive function of healthy adults, testing the hypothesis that cognitive function was poorer when participants' dietary intakes of aspartame were greater.

This chapter briefly summarizes study results followed by a discussion and then a section on study conclusions. Recommendations for education, practice, and research suggested by our study are also given.

The research questions of our study were the following:

1. To what extent was cognitive function affected by higher aspartame consumption (≥ 1000 mg/day) from dietary intake in comparison to lower dietary aspartame consumption (< 1000 mg/day)?
2. What was the relationship among cognitive function scores, dietary aspartame consumption, demographics, and health status in healthy participants?

Summary

Our study examined the effects of dietary aspartame consumption among study participants. It also tested the statistical relationships among cognitive function scores, dietary aspartame consumptions, demographics, and health status. The MRT and the SIR test were used to assess the extent to which cognitive function scores were affected by dietary aspartame consumption of study participants.

180 subjects participated in our study. Of these participants, 95 consumed dietary aspartame intakes equal to or greater than 1000 mg per day, and 78 consumed less than 1000 mg per day.

T-test analysis found statistically significant differences (t = 2.13, p =.03)in the MRT scores among participants who consumed equal to or more than 1000 mg of aspartame per day in their diet when compared to participants who consumed less than 1000 mg per day. A t-test analysis did not find statistically significant differences in the SIR scores among study participants who consumed equal to or more than 1000 mg per day in their diet when compared to participants who consumed less than 1000 mg per day.

Pearson's Correlations were used to examine the relationships among cognitive function scores, aspartame consumption, demographics, and health status in healthy participants. Using the Pearson's correlation coeffecient, aspartame correlated significantly with the MRT ($r = -.18$, $p = .05$), which negatively correlated with the SIR test; however, a significant correlation between the SIR test with dietary aspartame consumption was not indicated. A Pearson's correlation test did not indicate significant relationships among dietary aspartame consumptions, body weight, blood pressure, respiration, body temperature, serum glucose, and self-care agency.

Dorothea Orem's Self-care Deficit Theory was used as the theoretical framework to guide this clinical study. Lack of knowledge about healthy dietary consumption is viewed as a self-care deficit. Therefore, healthcare professionals could help people overcome this deficit by providing appropriate education about healthy diets as well as healthier lifestyles.

Discussion

A major finding of this clinical study showed significant differences in cognitive function when comparing higher dietary aspartame consumption to lower dietary aspartame consumption using the MRT. This finding

seems to reflect an earlier hypothesis that aspartame might have the potential for affecting neurotransmitter levels in the brain since it is believed that dietary consumption of aspartame-containing products could increase phenylalanine concentrations in the brain (Wurtman, 1985). Wurtman (1985) further suggested that the increased level of phenylalanine in the brain may have an impact on the balances in monoaminergic neurotransmission, consequently resulting in effects on cognition, behavior, and physiological function. The hypothesis was tested in a number of animal and clinical studies.

Similar to the results of our study using the MRT, a recent study conducted in rats by Christian et al. (2004) found that rats treated with aspartame (250mg/kg/day) in the drinking water for three or four months showed a significant increase in time when doing T-maze performance. This may suggest a possible effect of long-term aspartame consumption on memory. However, the finding of this animal study did not reflect the results of the SIR test in our study. In addition, altered learning behaviors were found in male rats with aspartame administration as 9% of the diet for thirteen weeks (Potts et al., 1980).

One study reported that when observing children's activities following administration of 1.25mg/kg of sucrose or fructose activities were less than after aspartame consumption (Conners et al., 1986). It appears that aspartame might play a major role in increasing children's activity if the sugars are considered reference points. The researchers of this study further reported an improvement in attention among children with the sugars compared to the subgroup of thirteen children with aspartame administration. Conners et al., therefore, suggested that aspartame might be claimed to cause the decline in attention activity.

Another study has also been conducted on 32 preschoolers with administration of 30mg/kg of aspartame, were observed in comparison with glucose, sucrose, and saccharin (Kruesi, et al., 1985). When activity was observed in these children, a decline in motor activity, considered significantly less active in these preschoolers, was noted after aspartame administration, while other behavioral measures did not show significant differences (Kruesi, et al., 1985). The authors of this study, therefore, concluded that the behavioral effects of acute aspartame consumption, if present, were viewed as subtle. They further pointed out that children

considered relatively "slowing down" following aspartame consumption had higher "internalizing" scores on the 11 Achenbach Child Behavior Checklist than children without "slowing down" did.

It is interesting to note that in our study the SIR test did not confirm Wurtman's hypothesis. The score differences of our study participants were compared for aspartame consumption; however, there were no significant effects of aspartame consumption on the SIR test. This finding concurs with the result of a clinical research study conducted by Spiers et al. (1998). Forty-eight volunteers participated in the study, and each participant was treated with one of three treatments of aspartame, sucrose, or placebo. The authors concluded that large daily doses of aspartame had no significant effects on neuropsychologic, neurophysiologic, or behavioral functions in healthy young adults, although plasma phenylalanine concentrations were increased during aspartame treatment (Spiers et al., 1998).

This finding is also consistent with the results of a research study by Lapierre et al. (1990). In this study, the neuropsychiatric effects of aspartame were monitored among ten healthy volunteers using visual analog scales, arithmetic test score, and brake-pedal

reaction timer measures. The study results indicated that there were no significant differences between aspartame and the placebo detected in measures of reaction-time, cognition, or memory at any time during the study following a single dose of aspartame ingestion (Lapierre et al., 1990). Similar results were also reflected in other clinical investigations. For example, in one study, thirteen pilots were tested by using SPARTANS cognitive test. The authors reported that aspartame ingestion was not detrimental to impairment in skills essential for cognitive performance, and that performance was not degraded to any measurable degree (Stokes et al., 1991).

A number of research studies were also carried out on children and potentially sensitive individuals to test whether aspartame consumption was related to cognitive and behavioral changes. Individuals diagnosed with PKU, depression, Parkinson's disease, Attention Deficit Disorder(ADD), epilepsy or other suspected seizures were studied. There were no effects observed in children regarding behavior, mood, or learning when aspartame was consumed at a single dose and multiple doses for up to two weeks (Saravis, et al., 1990; Shaywitz et al., 1994). However, individuals with PKU must be restricted in their phenylalanine intakes from all food resources, including

aspartame (Butchko & Stargel, 2001). The FDA (2004) further advises these individuals not to consume this product.

Treatment-related longer-term effects were also not noted in children with ADD (Shaywitz et al., 1994). The same results were also indicated in a study of preschool children described as sugar sensitive by their parents (Wolraich, et al., 1994).Although effects on neurotransmitter levels were noted based on some single and repeat-doses of aspartame administration at high dose levels in animal studies, Dailey et al. (1991) and Reilly and Lajtha (1995) stated there were no statistically significant and reproducible effects. Similar results were also reported in studies with administration of single doses of up to 60mg/kg/day (Lieberman et al, 1988; Lapierre et al., 1990; Pivonka & Grunewald, 1990; Stokes et al., 1991; Stokes et al., 1994). The results of these studies can be debated, however, since single dosing administrations do not reflect chronic aspartame consumption.

Using correlational coefficients, there were no correlational relationships among dietary aspartame consumption, health status, and physiological measures, such as body temperature, weight, blood pressure,

respirations, and random glucose. Although in our study a significant relationship between dietary aspartame consumption and body physiological changes such as blood pressure and body temperature was not indicated, a study conducted by Kiritsy and Manor (1986) concluded that the neurochemical changes produced by aspartame could lead to significant changes in blood pressure. In this laboratory study on rats, Kiritsy and Maher (1986) reported that animals receiving aspartame injections could induce hypertension because of increased levels of phenylalanine in the blood and brain. They further pointed out that elevated levels of phenylalanine could be hydrolyzed to tyrosin in the liver, which can lead to blood pressure changes.

In our study, physiological measures (respiration and pulse) were compared for differences between participants who consumed dietary aspartame intakes of equal to or more than 1000 mg per day and who consumed less than 1000 mg per day in our study. There were statistically significant differences ($p=.04$) in the mean respiration scores when comparing the two groups. This finding is not consistent with the results of the study by Leon et al. (1989), who concluded that there were no persistent changes in vital signs (including temperature,

respiration, blood pressure, and pulse) in participants consuming aspartame for 24 weeks. No significant differences were found when measuring the effects of dietary aspartame consumption on pulse in our study of healthy adults. Yet, over 1% of all claims reported to the FDA were consequential respiratory symptoms associated with aspartame consumption. It is believed that aspartame could have an impact on certain neurotransmitters in the brain which influence the respiratory center (Aspartame Consumer Safety Network, 1996).

Another interesting finding of our study was that Self-care Agency had significantly inverse correlation with respiration, body weight, the SIR test and the MRT. As described by Orem (1995), self-care agency was an acquired ability to meet an individual's needs of self care. Orem (1995) further pointed out that the capability of doing self-care was determined by individuals when they were engaged in activities. Due to limited research study references in the literature, it is recommended that further study may be considered when investigating the potential impact of self-care agency on human beings' capability of performing activities in their daily lives.

Conclusions

To summarize, the findings of our study seem to support the hypothesis that aspartame may be related to cognitive function as evidenced by aspartame consumption equal to or greater than 1000 mg per day based upon the MRT. However, these findings are preliminary, and much work needs to be done to further substantiate the results of our study. Given all of the above and our own findings, however, we are skeptical about reports that aspartame may be related to neuropsychological and neurologic symptoms. Further investigations are necessary to clarify this important issue.

It seems that a large amount of aspartame consumption might have an impact on human being's cognitive function in the long-run. Healthcare professionals should assist people to overcome a self-care deficit and allow them to further establish healthier self-care activities.

Recommendations

Recommendations were made for practice, education, and research based upon the results obtained in this clinical study.

Practice and Education

Information provided by our study will help to increase healthcare professionals' knowledge base about the role of the artificial sweetener -- aspartame in common food products. Because of increasing use of aspartame in food products, it will be beneficial to educate individuals regarding the potential risks for health problems and potential benefits for eating healthier. Although debate on aspartame products has been controversial for many years, it may still be possible that individuals might not be aware of potential risks related to large amount of aspartame consumption.

Our study found that the large amount of aspartame consumption (equal to or greater than 1000 mg per day) significantly decreased individuals' abilities to perform on the MRT. Although the results were not statistically significant on the SIR test, it still poses a caution about what people eat. These study findings suggest that people should be aware of the amount of aspartame consumption in daily food intakes, especially less than 1000 mg per day, since people could easily drink five or six cans of carbonated drinks per day without noticing, which approximately equal to 1000 mg of aspartame. These issues are also education related since knowledge of

research findings should be translated to clinical practice and public healthcare education. Therefore, without research findings translated from the "bench to bedside," clinical practice cannot be modified to provide high-quality care for people.

Research

In conducting our study, several areas of further research were suggested. Healthcare professionals should be aware of new research findings related to practice and education in order to provide more thorough and current knowledge to people. As healthcare providers, we also need to utilize Orem's Theory to assist people to meet their self-care demands.

Recommendations for further research include the following:

1. Replication of our study with tighter control of variables, such as participants with and without long-term dietary aspartame consumption.
2. Replication of our study involving more diverse population samples, such as including the elderly and the adolescent population.
4. A study comparing control group, placebo group, and treatment group on the consumption of aspartame food products.

5. Replication of our study following study participants' cognitive function for a longer period of time.

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