

THE RELATIONSHIPS AMONG ARTIFICIAL SWEETENER CONSUMPTION,  
BODY WEIGHT AND CALORIC INTAKE

by

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(ABSTRACT)

The relationships among artificial sweetener consumption, body weight, and energy intake were examined using a rat model and a survey of college students. The rats were divided into four treatment groups and one control group (n=10 per group). Group 1 was provided with a 10% sucrose solution; group 2, a 50% sucrose solution; group 3, a 0.05% aspartame solution; and group 4, a 0.25% aspartame solution. All groups were provided with rat chow and water ad libitum. Analysis of variance (ANOVA) and Duncan's multiple range test were used to evaluate the data from the rat study. No differences existed among the groups for weight gain or total energy intake. Differences did exist among the groups for solution and food intake with the two groups given sucrose consuming the greatest amount of sweetened solution and the least amount of food. In the survey of college students, the human subjects' gender, perception of their weight, weight status, dieting status, weight consciousness, weight change over a one year period, and total caloric intake/ total energy expenditure were examined in relation to their consumption of diet soda and packets of table top artificial sweeteners.

Chi-square approximation was used to evaluate the data from the human portion of the study. Relationships existed among reported artificial sweetener consumption and weight consciousness, dieting status, self perception of weight, weight status, and reported total caloric intake/total energy expenditure for females. Weight conscious females (as measured using the Drive for Thinness Scale) consumed significantly greater amounts of artificial sweeteners than non weight conscious females (p 0.01). Those females asked reportedly were dieting to lose weight consumed significantly greater amounts of artificial sweeteners. Females who perceived themselves to be overweight consumed greater amounts of artificial sweeteners than those who perceived themselves to be at their ideal body weight with those who perceived themselves to be underweight consuming the least amount among the three groups (p 0.01). Females whose actual body weights were ideal and overweight consumed significantly greater amounts of artificial sweeteners than those whose body weights were underweight (p 0.01). Females whose caloric intakes were greater than 90% of their energy expenditure consumed significantly less diet sodas than females whose caloric intakes were less than 90% of their energy expenditure. No differences existed between these groups for table top artificial sweetener intake. No relationship between artificial sweetener consumption and the preceding variables existed for the males. Relationships did not exist between reported artificial sweetener consumption and reported weight change over a one year period for either females or males.

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## Chapter 1

### INTRODUCTION

Excess body weight is both a common and serious problem faced by an estimated 34 million Americans (Van Itallie, 1985). Approximately 12.4 million persons in this group were estimated to be moderately to severely obese (Van Itallie, 1985). Although definitions of the terms "overweight" and "obesity" vary, most authorities define overweight as a body weight of more than ten percent above ideal body weight and obesity as a body weight of more than twenty percent above ideal body weight (Whitney and Cataldo), 1983). Other authorities on the subject of obesity and weight control have defined obesity according to three categories: mild obesity (20 to 40 percent above ideal body weight), moderate obesity (40 to 100 percent above ideal body weight) and severe obesity (greater than 100 percent above ideal body weight). Measuring percent body fat is a less often used alternative to body weight. Measures of percent body fat are used to describe body composition in terms of the adipose tissue mass relative to total body mass. Only indirect methods are available for determining percent body fat in vivo. Underwater weighing is considered to be the most reliable method of determining percent body

fat. Skinfold calipers are a more convenient but less accurate method of body fat measurement (Yuhas et al., 1986).

Media messages present conflicting information for the overweight/obese person who wants to lose weight. The food industry invests many advertising dollars into the sale of food products. For every dollar the Surgeon General and researchers spend to examine the causes of obesity, one hundred dollars is spent by the food industry to entice people to eat fattening foods (Liebman, 1982). Many consumers want to eat calorically dense foods but without the resulting weight gain. The overweight person will often turn to quick weight loss gimmicks despite the Food and Drug Administration's actions against such products for unsubstantiated claims (Willis, 1982).

For the overweight person trying to lose weight, human nature may be the problem. Human beings seem to be born with an innate predilection for sweet foods (Woteki et al., 1982; Cleave, 1974). The human preference for sweet foods may have been an evolutionary development designed to prevent humans from eating bitter tasting plant foods that were poisonous (Alfin-Slater et al., 1987). Today, people may not necessarily benefit from this protective mechanism. Sugar often is found in association with high fat foods and together these two foods can contribute to excessive weight

gain. Sugar consumption in 1980 was estimated at 128 pounds a year per person (Lecos, 1981).

Sugar has been associated with a number of health problems and diseases such as dental caries, atherosclerosis, and diabetes. While sugar is known to contribute to the incidence of dental caries, its link as a cause of other diseases is unsubstantiated. However, many government agencies and other associations including the American Heart Association and the Select Committee on Nutrition and Human Needs of the U.S. Senate have cautioned against the exaggerated use of sugar (Cleave, 1974).

The love for sweet foods coupled with the desire for thinness has led consumers to search for a non-caloric (or very low calorie) artificial sweetener. The food industry has developed several artificial sweeteners over the years. The three major artificial sweeteners that are or were available for consumer use are cyclamate, saccharin and, most recently, aspartame (Lecos, 1981).

Despite social pressure to be thin, low calorie foods, artificial sweeteners, and new research into the causes of obesity, many Americans remain obese. Secondary to the health problems associated with obesity, obese people in the United States are conceived of as being unattractive, undesirable, stupid, and lazy (Wadden and Stunkard, 1985). Approximately 90 percent of the persons who successfully

lose weight often regain much or all of the weight initially lost in as little as 18 months (Simonson and Heilman, 1983).

Reduction in the consumption of simple sugars is often advocated in the treatment and prevention of obesity. Artificial sweeteners can provide the sweet taste in food and beverage products without the concomitant caloric contributions of glucose based sweeteners. It seems reasonable to conclude that artificial sweeteners can aid in weight loss by replacing sugar in the diet. However logical this conclusion may appear, the relationship between artificial sweeteners and body weight remains controversial. The safety of artificial sweeteners was examined extensively to gain the approval of the FDA, however, few data exist on the efficacy of the use of artificial sweeteners as aids in weight loss (Porikos and Van Itallie, 1984). Blundell and Hill (1986) have questioned the physiological effects of aspartame on the mechanisms of appetite control.

#### Purpose of Research

The purpose of this research was to determine if the replacement of dietary sucrose with the artificial sweetener aspartame results in a physiological drive to overeat and a subsequent weight gain in animals. An additional purpose was to determine if the use of artificial sweeteners in humans is associated with low body weights and also to

examine some of the characteristics of the persons who use large amounts of artificial sweeteners.

This research project was composed of two experiments that examined the relationship between artificial sweeteners and body weight. The first study utilized a rat model to study the physiological effects of the artificial sweetener aspartame on appetite and weight gain independent of the psychological factors often encountered in human studies.

The second experiment utilized a sample drawn from a group of college students to study the association of self reported artificial sweetener use and weight status (below, above or within ideal body weight range). The chosen method was that of a questionnaire to determine each subject's self reported usage level of artificially sweetened products which was then compared to the subject's own perception of his/her weight and also to the subject's actual weight status as measured by the researcher. The major users of artificial sweeteners identified according to gender, weight status, self-perception of weight, diet status, self-reported caloric intake, and degree of the subject's psychological drive for thinness. The second experiment was designed to examine artificial sweetener use in humans who were in control of and aware of their intake of artificial sweeteners as opposed to the exclusively physiological

effects of artificial sweetener use examined in the first experiment.

### Research Questions

The following research questions were addressed in the study:

\*When aspartame is used to replace sugar in the diet do male weanling rats display an increase in total energy intake?

\*When aspartame is used to replace sugar in the diet do male weanling rats show an increased weight gain?

\*Do college age women tend to use artificial sweeteners more than do college age men?

\*Do persons who are dieting use artificial sweeteners more than do those who do not diet (determined by the subject's response to the question "Are you on a diet at this time?")?

\*Do persons who are more weight conscious (as defined by a score of 15 or greater on the "Drive for Thinness Scale") use artificial sweeteners more than those who are not weight conscious?

\*Is the use of artificial sweeteners associated with weight loss (defined as a self reported loss of five pounds or more over a one year period)?

\*Do overweight (10% or greater than ideal body weight) people use artificial sweeteners more than do those of ideal body weight or underweight status (10% or less than ideal body weight)?

\*Is the use of artificial sweeteners associated with the maintenance of ideal body weight (defined as a self reported weight fluctuation of less than five pounds over the past year)?

\*Do persons whose caloric intake is low (at least 10% below their total energy expenditure) use artificial sweeteners more than those whose caloric intake is within or above 10% of their TEE?

#### Justification of Methods

The Drive for Thinness (DFT) scale was the method chosen to measure the subjects' degree of concern with their weight (Appendix A, item #7). The DFT scale is a subscale of the Eating Disorders Inventory (EDI) which is an instrument used to evaluate the psychological

characteristics indicative of the eating disorders anorexia nervosa and bulimia (Garner et al., 1982a). The EDI is made up of eight subscales each of which is internally consistent and valid. The validity of the instrument was tested by several means. Anorectic patients were differentiated from normal female controls using a cross-validation procedure. The validity of the subscales was determined by examining the congruence between clinicians' ratings of the patients' subscale traits and their scores on the individual subscales (Garner et al., 1982b).

The Eating Attitudes Test (EAT), which has been used to identify cases of anorexia nervosa in high risk groups such as weight preoccupied professional dance students, and young, female college students (Garner and Garfinkel, 1979), was also given to 55 female college students who had completed the EDI. The DFT score was the subscale of the EDI most highly correlated with the total EAT score (Garner et al., 1982c).

The formats of the DFT scale and the EAT are similar. Respondents rate items by choosing among the following responses: "always," "usually," "often," "sometimes," "rarely," or "never". Beginning at either "always" or "never" (depending upon the keyed direction) a score of 3 is assigned to the response, a 2 is assigned to the immediately adjacent response, a 1 is assigned to the next response and

the next three responses (the "least anorexic") receive a score of 0. A score of 15 or greater is associated with an excessive concern with dieting, weight, and the pursuit of thinness (Garner et al., 1982d).

The determination of actual body weight categories (underweight, overweight, ideal weight) among the subjects was based on the nomograph method of assessing body weight developed by Thomas et al. (1976). This method utilizes the body mass index (BMI) which is the ratio of weight/height<sup>2</sup> to assess relative body mass in adults. The BMI is presented in the form of a nomograph (Appendix B) for facilitated use in clinical settings. The scale presents relative weight as a continuous variable while showing the ranges of weight considered desirable in life insurance studies.

Skinfold measures to access percentage of body fat were not utilized in this study since the BMI has been found to correlate well with skinfold measurements (Yuhas et al., 1986, and Thomas et al. 1976). Error can occur easily in skinfold measurements if the site of the measurement is improperly located, if the skinfold is held incorrectly, or if the caliper is improperly manipulated (Yuhas et al., 1986).

A three day diet record was used to measure the average food intake of the subjects. If discrepancies in reporting food intake occur, such as overweight individuals

underreporting to a greater extent than normal-weight individuals, then the results of the study could be altered. Lissner and coworkers (1989) conducted a study to determine if overweight women underreport their food intake to a greater extent than do normal-weight women. The subjects were 63 women on a continuum of body weight. The subjects ate all of their meals at a metabolic unit and their energy intake was measured by the researchers. The subjects kept three to five day food journals. The journals were analyzed for energy intake using food composition tables. The intake calculated from the food journals and from the observed intake were compared. There was no evidence from this study that the overweight subjects under-reported their intake as compared to the normal-weight subjects. The researchers concluded that information of dietary intake obtained from overweight women is no less accurate than that obtained from normal-weight women.

Myers et al. (1988) also conducted a study that examined the possibility of the overweight person underreporting self recorded food intake when compared to the normal-weight person. Forty female college students were observed as they ate a lunch meal at the school cafeteria. The students were asked to complete a 24-hour recall of their food intake the following day. Their observed intake was compared to their intake as determined

from the 24-hour recall. Although there were large variations in the accuracy of the self-reported intakes as compared to the observed intake with a significant amount of overreporting, no differences in the accuracy of self-reported intake were found between the normal weight and the overweight participants (Myers et al., 1988).

## Chapter 2

### REVIEW OF LITERATURE

#### Problems Associated with Obesity

Many major diseases, including hypertension, atherosclerosis, type II diabetes, and some types of cancer are associated with obesity (Bray, 1985). Other health complications that also may be linked with obesity are hepatic steatosis, gallbladder disease, pulmonary function impairment, endocrine abnormalities, obstetric complications, stress on weight bearing joints, gout, cutaneous disease, proteinuria, increased hemoglobin concentration, and possible impairment of the immune system (Bray, 1985). The social and psychological consequences of being obese as well as the desire of many to be thin must also be recognized and considered when studying obesity. Young women and adolescent girls are at particular risk in developing psychological eating disorders such as bulimia and anorexia nervosa due to society's negative attitude towards the obese. Indeed, the prevalence of these eating disorders demonstrates the fear of obesity among American women and young girls (Wadden and Stunkard, 1985).

### Obesity and Mortality Rates

Researchers began to examine the relationship between body weight and mortality before the turn of the century when American life insurance companies began using such data to adjust their premiums. Most life insurance actuaries at this time felt that persons who were thin should pay higher premiums for their life insurance due to the prevalence of tuberculosis as a major cause of death and its association with low body weight (Keys, 1980). However the actuaries began finding in the early 1900's that, according to their death claims, the highest mortality rates occurred among their heaviest policy holders (Keys, 1980).

Indeed, it is now generally accepted knowledge that persons who are 20% percent or more overweight (clinically defined as obese), especially at younger ages, have a tendency to die younger than do average-weight persons (Simopoulos and Van Itallie, 1984). The 1979 Build Study researchers demonstrated that mortality increased at increasing degrees in men whose weight was greater than 15% above the average weight of the sample population. Lower mortality rates were found among men who were 5% to 15% above and below the average weight increasing again in men who were 15% or more below average (Simopoulos and Van Itallie, 1984). The American Cancer Society conducted a

follow-up study from 1959 to 1973 in which mortalities were analyzed according to variations in weight (corrected for height) from the average sample population weight. The group which demonstrated the lowest mortality rate was the group of subjects who were of average weight and 10-20% below average weight. Men and women who were 30-40% higher than average had mortality rates almost 50% higher than the average and slightly below average group. The mortality rate was 90% higher among those who were 40% or more above average weight. Coronary heart disease was the major cause of death among the overweight (Lew and Garfinkel, 1979).

Researchers with the Framingham Heart Study have examined participants biennially since 1949. Several of these researchers published a study in the late 1970's examining the relationship between the incidence of cardiovascular disease and obesity (Simopoulos and Van Itallie, 1984; (Hubert, 1984). The researchers found that persons at either extreme of the relative weight distribution - either underweight or overweight - had mortality rates well above the average (Hubert, 1984). It was clearly shown that obesity in the Framingham men and women was a consistent long-term predictor of cardiovascular disease especially among the younger subjects (Hubert, 1984).

### Health Complications of Obesity

The evidence of a direct relationship between the risk of coronary heart disease and obesity is found by some to be consistent and substantial (Van Itallie, 1979) while others find the evidence to be inconsistent (Barrett-Connor, 1985). Thus the subject remains controversial and under much study. Consistent evidence does exist supporting the relationship between obesity and several risk factors for heart disease.

Hypertension, defined as a 160 mmHg or higher systolic blood pressure and/or a 95 mmHg or higher diastolic blood pressure, is more prevalent among the overweight population (Bray and Teague, 1980). For overweight American adults aged 20 to 75 years the relative risk of hypertension is threefold that of their non-overweight counterparts (Van Itallie, 1985). For the 20-45 overweight age group, the risk of hypertension is 5.6 times greater than for non-overweight Americans in the same age group (Van Itallie, 1985).

Total serum cholesterol is another risk factor of coronary heart disease which is known to be higher in the obese person than the non-obese person. Hypercholesterolemia, defined as 240 mg/dl of plasma cholesterol, was 1.5 times more prevalent in overweight Americans aged 20-75 years than for their non-overweight counterparts. For overweight Americans aged 20-45 years, the relative risk of hypercholesterolemia

is 2.1 times that of their non-overweight counterparts (Van Itallie, 1985).

It is primarily from epidemiologic studies that the relationship between obesity and atherosclerosis has been examined by researchers (Barrett-Connor, 1985). Keys (1980) reviewed 13 studies and found only one which showed a definite relationship between obesity and coronary heart disease while Larsson et al. (1981) reviewed 37 studies and interpreted the majority as demonstrating an increased risk of coronary heart disease with obesity. Hubert (1984) reviewed 10 studies and interpreted six of these as showing a positive relationship between obesity and coronary heart disease. It is possible that the macronutrient content of the diet rather than body weight may be the atherogenic factor responsible for the positive relationship between obesity and heart disease (Van Itallie, 1985). Diets higher in fat (particularly saturated fats) may raise serum cholesterol which is a risk factor in atherosclerosis and may also be associated with obesity (Van Itallie, 1985).

The evidence supporting the role of obesity in type II diabetes mellitus is overwhelming. Type II diabetes is known to be more prevalent in persons who are obese and in obese populations (Bennett, 1981). In the type II diabetic, the severity of the symptoms is often lessened with weight

loss. In some diabetics, weight loss alone can completely alleviate the symptoms of the disease.

Diseases of the digestive tract have been shown to be associated with obesity. Digestive disease, particularly of the gallbladder, was second only to diabetes to be adversely affected by excess weight. The increased risk of gallbladder disease may be due to increased cholesterol production and secretion (Bray, 1985). Hepatic function also may be impaired in the obese (Bray, 1985). In 25% to 35% of obese patients, fatty infiltration was found to occur in more than half of the hepatocytes (Mavrelis, et al., 1983).

Obese patients often suffer from abnormalities in pulmonary function (Rochester and Enson, 1974). Higher metabolism of the obese at rest, extra weight on the chest and abdomen and abnormal function of the respiratory muscles can all contribute to the pulmonary problems of the obese (Bray, 1985).

Excessive body weight before and during pregnancy can have negative effects on the course and outcome of the pregnancy. The frequency of toxemia, hypertension and prolonged labor are significantly increased in obese pregnant women. Obese women are also more likely to experience abnormal labor, including oxytocin infusion and caesarian section, due to their excess weight (Bray, 1985).

### Psycho-social Problems of Obesity

Although the health risks associated with obesity are of primary concern, the emotional consequences must also be considered. Children as young as six years of age show evidence of strong prejudice against obese persons (Wadden and Stunkard, 1985). Researchers showed that many persons in this country are strongly prejudiced against the obese regardless of age, gender, race or socioeconomic status (Allon, 1979). Six-year old children have been documented as describing silhouettes of an obese child as "lazy", "dirty", "stupid", "ugly", "cheats", and "lies" (Wadden and Stunkard, 1985). Children, adults, and even the obese rate line drawings of obese children as the least likable even when compared to drawings of handicapped and disfigured children (Wadden and Stunkard, 1985) .

Prejudices against the obese can affect these persons from childhood and into the adult years. Canning and Mayer (1966) found that obese high school students were accepted into higher ranking colleges at a lower rate than were their equally qualified normal-weight peers. Similar occurrences were found in the work force by Wadden and Stunkard (1985).

Although the prevalence of obesity is approximately equivalent in men and women (Wadden and Stunkard, 1985), women are more likely to perceive themselves as being overweight than are men (Creager et al., 1984). In a study

done by Gray (1977), almost half of the college undergraduates examined misperceived their body image: females generally perceived themselves as heavier and males generally perceived themselves as lighter than their actual weight.

Storz and Greene (1983) studied the interrelationship between body weight and body image in 203 adolescent girls. The majority of the subjects were either within or under the average weight range, yet the researchers found that most of the subjects wanted to lose weight. The subjects also chose line drawings of figures that were smaller than their actual figure as the ideal. Davis (1985) found similar results in a study conducted with 91 female college students. The majority of the subjects in this study perceived the ideal figure as being more ectomorphic than self. Davis concluded that the college females in this study desired to be thinner than the self-perceptions of their bodies.

Garner et al. (1980) demonstrated changes in the Western culture's standard for the ideal female figure over a twenty year period. Height and weight data were gathered from Playboy centerfolds and Miss America Pageant contestants from 1959 through 1978. The authors also examined the number of articles related to dieting and weight loss found in six popular women's magazines from 1958 through 1978. From the results of both the Playboy

centerfolds and the Miss America Pageant contestant studies, the researchers found a definite trend toward decreasing body weights over the 20 year time span. This represents a shift in the ideal standard of beauty and not a population trend in average weights. The number of diet articles in magazines reflected a trend toward thinness as well. The yearly mean from 1959 to 1968 was 17.1 articles related to dieting; this increased to 29.6 for the period 1969 to 1978 which was a significant increase ( $p < 0.001$ ). The results of this study strongly support the hypothesis of a gradual cultural trend toward a thinner ideal body size for women. This societal expectation for thinness may increase the risk for the development of serious eating disorders.

Negative attitudes towards excessive weight seem to affect young females more than any other group. Misperceptions of body weight and the desire to be thinner are dangerous in young girls and women often rendering them vulnerable to anorexia nervosa and bulimia. Creager et al. (1984) found bulimia to be a prevalent disorder among high school girls and recognized the possible influence of societal expectations for thinness to be a contributing factor in the development of this disorder.

### Dietary Intake and Obesity

Obesity is a complex issue that cannot be explained by the simple reasoning that the overweight individual overeats. Genetics, fat cell number and size, physical activity, and behavioral characteristics all interact with dietary factors to affect an individual's weight status (Stunkard, 1980). While it is well accepted that obesity is more prevalent in populations with higher caloric intakes, a correlation between individual caloric intake and obesity has not been conclusively demonstrated (Rolland-Cachera and Bellisle, 1986).

Spitzer and Rodin (1981) reviewed research that examined the relationship between caloric intake and weight status in humans. From this review, they concluded that overweight individuals do not consume a greater number of calories than do normal weight individuals. However, they also concluded that the relationship between caloric intake and weight status of the individual may be more evident in more naturalistic studies as opposed to laboratory studies. Also, most subjects that are examined in these studies are in a static state of obesity (weight maintaining) rather than in a dynamic state (weight gaining) (Spitzer and Rodin, 1981).

Kulesza (1982) evaluated the dietary intake of 100 obese and 50 non-obese women. The obese women were

identified as either being in the dynamic phase of obesity (having a weight gain of at least 10% in the last year) or being in the static phase of obesity. The women in the dynamic phase of obesity were found to have an average daily intake of 480 kilocalories greater than the women in the static phase of obesity. No differences in average daily caloric intake were found between the women in the static phase of obesity and the non-obese women. The researcher concluded that this study supports the view that energy intake above the body's requirements can lead to the development of obesity. However, a caloric intake above the body's needs may not be necessary to maintain an elevated body weight (Kulesza, 1982).

Several studies have shown that sugar intake in the form of a solution can contribute to obesity in animals. Faust and coworkers (1978) found that adult male rats fed a sucrose solution along with rat chow over a five month period gained 38% more weight than did the controls fed only rat chow. Both adipocyte size and number were found to have increased in the sucrose fed rats.

Kanarek and Hirsch (1977) also found that adult male rats fed a sucrose solution along with rat chow gained a greater amount of weight than did chow only controls. Over a 125 day period, the sucrose fed rats consumed 20% more calories and gained 43% more weight than did the controls.

High sucrose diets have been shown to result in a greater storage of body fat in animals as compared to a high starch diet. This may be due to an enhanced transport of sucrose from the intestine into the bloodstream resulting in elevated insulin levels which promote the storage of sucrose as adipose tissue (Reiser and Hallsfrisch, 1977).

### Sweeteners

Attaining the thin ideal is difficult for many persons due to their fondness for foods high in fat and sugar. Throughout history, humans have sought sweet tasting foods. By the 14th century, sugar was being refined and was considered to be a delicacy. Today, sugar is commonplace and consumption in the U.S. is high. According to the United States Department of Agriculture (USDA) the per capita consumption of refined sugar, corn syrup, and corn sugar increased from 122 pounds in 1970 to 128 pounds in 1978 (Lecos, 1981). More recently, sugar has been associated with negative consequences such as tooth decay and obesity (Cleave, 1974), spurring the food industry to develop and market artificial sweeteners that mimic the taste of sugar without containing the corresponding caloric value. Although sucrose and other sweeteners are not nutritionally required by the human body, few people are willing to do without some sort of sweetening agent in their

diet. Artificial sweeteners may not only satisfy the need for sweets in the average diet but also may be useful in promoting adherence to therapeutic diets. Artificial sweeteners can be useful in maintaining the diet of diabetics - many of whom are unwilling to eliminate sweeteners from their diet but must severely limit glucose based sweeteners to prevent severe health consequences (Horwitz and Bauer-Nehrling, 1983)

#### Non-Glucose Sweeteners

Non-glucose sweeteners can be divided into two categories: nutritive and non-nutritive. Cyclamate and saccharin are the two major non-nutritive sweeteners and only saccharin is a legal food additive in the United States. Discovered in 1879 and originally used as an antiseptic and food preservative, saccharin was the dominant artificial sweetener for more than 60 years (Lecos, 1981). Cyclamate replaced saccharin in popularity during the 1950's and 1960's. Saccharin-cyclamate blends produced a highly accepted sweetness that was well perceived in soft drinks. Thus, the two sweeteners became widely used during this time period. Before the ban of cyclamate in 1970, production had reached a peak in 1969 of 21 million lb/year in the United States (Inglett, 1984). The popularity of saccharin was demonstrated in 1977 when the FDA proposed the banning of

saccharin in response to various studies which showed that the substance caused bladder tumors in rats. Public outcry was so great in response to the proposed ban (the FDA alone received 100,000 complaints) that a moratorium was imposed, permitting the continued sale and use of saccharin. While saccharin is still in use today, warning labels on food products containing the substance are required (Cleave, 1974).

Saccharin is derived from naphthalene or naphtha and is approximately 300 times sweeter than sucrose. Saccharin is absorbed slowly in the gut and is quickly excreted by the kidneys; it is not metabolized by the body's cells (London, 1988). Although some researchers have shown saccharin in large amounts causes bladder cancer in animals, no epidemiological evidence exists linking bladder cancer in humans to saccharin use (American Dietetic Association, 1987). At this time, most studies support the safety of saccharin for human consumption with the possible exception of its consumption by pregnant women (London, 1988). The American Medical Association (AMA) supports the use of saccharin since evidence of bladder cancer in humans caused by saccharin use is lacking. However the AMA does recommend continued evaluation of any adverse health effects caused by saccharin consumption (Council on Scientific Affairs, 1985). The saccharin molecule is fairly stable and can therefore be

used in a wide variety of food and beverage products including baked goods (Alfin-Slater et al., 1987).

Nutritive, non-glucose sweeteners include sugars and sugar alcohols such as fructose, sorbitol and xylitol. These compounds can be useful in some diabetics who maintain normal blood glucose levels because the initial metabolism of these sugars does not require insulin (Horwitz, 1983). However, the caloric value of these sweeteners is the same as that of glucose or sucrose therefore the obese person would not benefit from their use.

#### Aspartame

The newest non-glucose sweetener on the market is aspartame which is classified as a nutritive sweetener because it is metabolized by the cells of the body (Horwitz, 1983). Originally produced by G.D. Searle and Co., Skokie, Il., aspartame has achieved a great deal of popularity in the past few years. Like cyclamate, aspartame also was discovered by accident. James M. Schlatter, a Searle chemist, was searching for an inhibitor of the gastrointestinal secretory hormone, gastrin, for use in ulcer treatment. Aspartame, one of the intermediates of the compound the scientist was preparing, was being heated in a flask with methanol when the mixture spilled onto the

outside of the flask. Some of the powder got onto Dr. Schlatter's fingers which he later licked when picking up a piece of paper. Noticing the intensely sweet flavor of the substance on his fingers, he identified it as aspartyl-phenylalanine methyl ester (Inglett, 1984).

Aspartame is a dipeptide containing the amino acids phenylalanine and aspartic acid with a methyl group esterified to the carboxyl group of phenylalanine (Horwitz, 1983). Aspartame has a sucrose-like sweetness which blends well with other food flavors but since it is generally 150 to 200 times sweeter than sucrose it can be added to foods in much smaller amounts than sucrose with a concomitant reduction in calories (Inglett, 1984). The sweetness of aspartame in comparison to sucrose is inversely related to the concentration of sucrose. That is at 3% sucrose, aspartame has 215 times the sweetness of sucrose but only 133 times the sweetness at a sucrose concentration of 10% (Janssen and Heigden, 1988).

The sweet taste of aspartame is dependent on each component of its structure: aspartic acid alone is tasteless or slightly sour; phenylalanine is bitter in taste; the methyl ester compound is tasteless. The L-configuration is also required for sweetness, other stereoisomers being weakly bitter. All of these components

must be present in the proper configuration in order for the compound to be perceived as sweet (Inglett, 1984).

In appearance aspartame is a white powder with no detectable odor (Horwitz, 1983). The solubility of aspartame is dependent on the pH and temperature of the solution. It is more soluble in warm than cold solutions and more soluble in acid than neutral solutions (Horwitz, 1983). Aspartame is stable in its dry form at temperatures up to 40 degrees celsius but in solution it decomposes at a gradual rate to its diketopiperazine form, losing its sweetness. Aspartame is most stable in solutions with a pH of 3.9 to 4.3 (Horwitz, 1983).

#### Metabolism of Aspartame

Unlike saccharin which is absorbed into the bloodstream and quickly excreted by the kidneys, aspartame is metabolized by the cells. After aspartame ingestion, the methyl group is hydrolyzed by intestinal esterases yielding methanol. The remaining dipeptide is apparently absorbed and digested as dipeptides resulting from dietary protein digestion (Mazur, 1984; Tokey and Heizer, 1986). A significant amount of the Asp-Phe dipeptide may be transported intact from the lumen into the cell where it is hydrolyzed in the cytosol (Mazur, 1984).

Ranney et al. (1976) conducted a study in which <sup>14</sup>C labelled aspartame and the separate labelled compounds were given to animals by gastric intubation and to humans by oral dose. The metabolism of aspartame was compared to that of its separate moieties. The researchers found that aspartame was completely hydrolyzed in the gut to yield its constituent compounds: methanol, aspartic acid, and phenylalanine. Humans and animals were found to metabolize the aspartame in a similar fashion. The compounds derived from aspartame were found to follow the pathway characteristic of each component. Methanol was oxidized to carbon dioxide, aspartate was converted to carbon dioxide via the tricarboxylic acid cycle and phenylalanine was used to maintain body proteins either as phenylalanine or as tyrosine (Ranney, 1976).

#### The Safety of Aspartame

On March 5, 1973, G.D. Searle petitioned the FDA to approve aspartame as a sweetener for table use. Searle funded an independent research team to review their own data on the safety of aspartame. Fears that aspartame might cause brain damage, mental retardation, neuroendocrine damage and brain neoplasms were raised. Although the FDA approved aspartame for use on July 15, 1981, many still question the safety of this substance (Lecos, 1981).

The methanol moiety of the aspartame compound has caused some concern due to its potential ocular toxicity (London, 1988). Methanol is metabolized into formaldehyde (catalyzed by alcohol dehydrogenase) which is then oxidized into formic acid (Tephly et al., 1984). Formic acid is the compound responsible for the blindness resulting from methanol poisoning (London, 1988). However, the amount of methanol consumed from one can of aspartame sweetened soda is equal to the amount of methanol found in a banana so the concerns over the methanol moiety are unfounded (London, 1988).

The aspartate moiety of aspartame seems to have little effect on the overall aspartate ingestion of the average person (London, 1988). If aspartame were to replace the average person's daily sucrose intake on a sweetness basis, the average intake of aspartate would be 1.3-4.9 mg/kg with a maximum of 9.8-15.2 mg/kg (Stegink et al., 1988). Total aspartate intake among persons of age 15 is 170 mg/kg and of age 34 is 80 mg/kg per year (London, 1988).

Despite aspartame's seemingly safe metabolism in the human body, the safety of this compound is still questionable due mainly to high plasma levels of phenylalanine after ingestion. Both phenylalanine and aspartate are neurotoxins however only phenylalanine levels are elevated after aspartame ingestion (Pardridge, 1986).

Concerns with the phenylalanine moiety of aspartame include the possibility that aspartame ingestion may affect the neuroendocrine regulatory system and may contribute to brain damage and possibly brain tumors in rats. The normal range for plasma phenylalanine is 6-12 micromoles/dl and the toxic threshold is 100 micromoles/dl (including infants) and 50 micromoles/dl for pregnant women (Stegink and Baker, 1971). Stegink and coworkers (1988) examined the effect of aspartame ingestion on plasma amino acid concentrations. Eight adult subjects ingested 32 ounces of an aspartame sweetened beverage at two-hour intervals. Plasma amino acid concentrations were then measured throughout a six-hour period. The researchers concluded that plasma aspartate levels remained unaffected by aspartame ingestion. Plasma phenylalanine levels were significantly higher ( $p < 0.05$ ) than baseline values, however the levels did not exceed normal postprandial values at any time.

Many extensive studies have shown that high doses of aspartame are well tolerated, however it is important to estimate a probable range of intake to ensure public safety. Roak-Foltz and Leveille (1984) estimated approximate aspartame intake using a menu approach and the typical aspartame level for each food. They found that the estimated intake of aspartame would result in a 10% increase in phenylalanine intake; a 4% increase in aspartic acid

intake; and an added methanol exposure of 75 mg. The researchers concluded that these increases were insignificant in comparison to intake of these compounds from other sources. The Council on Scientific Affairs (1985) has officially stated that aspartame is safe for the general population excluding those with homozygous phenylketonuria or other individuals who may need to control phenylalanine consumption.

Much of the fear that aspartame ingestion causes neurological symptoms (particularly headaches), seizures, and other medical problems is based on isolated, anecdotal evidence. Novick (1985) sites a case in which a patient had been consuming 36 to 44 ounces of a saccharin containing soft drink for six years and then switched to an aspartame containing soft drink for ten weeks before presentation. The patient visited her physician after several nontender deep nodules appeared initially on her thighs and then elsewhere on her legs. Several trials of aspartame elimination and resumption in the patient's diet (with no other dietary changes) revealed that the patient's granulomatous panniculitis was aspartame-induced. The pathogenic mechanism of the panniculitis was not clear, however it was suspected that toxic metabolites of aspartame and their large consumption may have caused the condition.

Wurtman (1985) sites three cases in which consumption of large amounts of aspartame containing soft drinks (ranging from 1 to 4 quarts) was associated with seizures. Although aspartame contains the amino acid phenylalanine, it lacks other neutral amino acids found in dietary proteins which compete for uptake into the brain. Brain phenylalanine levels may then increase and affect catecholamine or serotonin synthesis possibly causing seizures (Wurtman, 1983).

The most common complaint associated with aspartame ingestion has been the increase of headaches. Schiffman et al. (1987) conducted a double blind study in which subjects who reportedly had headaches after the ingestion of aspartame containing products were tested with both aspartame and a placebo. The authors found that the placebo and the aspartame (30 mg per kilogram of body weight) treatments did not differ in the subsequent incidence of headache.

#### Artificial Sweeteners and Weight Reduction

Assuming that aspartame and other artificial sweeteners are safe food additives, their benefits to certain subpopulations, such as the obese and the diabetic, must be considered. The efficacy of aspartame as a tool in weight reduction has not been examined to a great extent (Porikos and Van Itallie, 1984). The lack of research may be due to the

difficulty of isolating aspartame as a causal or contributing factor to weight loss or maintenance.

Few studies on other non-caloric sweeteners and weight reduction have been undertaken however, Friedhoff and associates (1971) did examine this subject. The researchers conducted a study to assess the effects of the substitution of an artificially sweetened solution for a sucrose solution on food consumption and weight in laboratory animals. Three groups of mice (n=10) were fed solid food ad libitum. The water bottles of each group of mice contained a sucrose solution, a non caloric sweetener solution of equal sweetness to the sucrose solution, or water. Weight change and food consumption were measured over a 23 day period. No differences were found to exist among the groups for weight change. The sucrose group consumed significantly less food than did the sweetener or the control group ( $p < 0.02$ ). The sweetener group did not differ from the control group for food intake. The authors concluded that the ingestion of the sucrose solution by the mice may have caused an appetite depressing effect reflected in the failure of the mice in that group to gain weight. The researchers also concluded that the ingestion of non-caloric beverages may be compensated for by the ingestion of calorie containing solid food. The researchers cautioned that the findings in this animal study are not necessarily applicable to the human.

McCann et al. (1956) examined the use of low calorie sweeteners in two groups of obese people and found no relationship between artificial sweetener consumption and weight loss. Group 1 consisted of 147 obese subjects who were part of a follow up study for a weight loss program. Almost half (49%) of the subjects were using or had used non-caloric sweeteners. Their weights before the weight reduction program and after three years (the time of the follow up study) were tabulated. No significant difference in weight loss was found to exist between users and non-users of non-caloric sweeteners. Group 2 consisted of 100 subjects who had recently begun a weight reduction program. Of the 100 subjects, 33 were identified as users of non-caloric sweeteners. The subjects were not evaluated on actual weight loss due to the short period of time they had been on the weight loss program. Eleven of the 33 subjects who used non-caloric sweeteners felt that the products helped them to lose weight while the remaining 22 felt that they had either gained weight or remained at the same weight. However, in this study the palatability of the artificial sweetener was apparently a factor in the study's results. Only 26% of the subjects who used artificial sweeteners reported liking the taste of these products.

A more recent study was done by Parham and Parham (1980) in which the researchers examined the effects of

saccharin use on sugar consumption among 166 healthy college students. The researchers conducted a survey which consisted of background questions, a 24-hour recall, and a report of frequency of the intake of various sweeteners. The association between the use of saccharin and caloric intake, sugar intake, and weekly servings of sweets was then determined by Pearson correlation coefficients. The authors found a positive correlation between saccharin use, reduced total caloric intake, and reduced weekly servings of sweets. However, the researchers concluded that while saccharin is "mildly beneficial to healthy consumers who are watching their weight or trying to limit their sugar intake" saccharin is not necessarily an essential component of weight loss, maintenance, or dietary sugar reduction.

Knopp and coworkers (1976) conducted a study in which 55 overweight subjects, with a mean age of 19.3 years, were put on a calorically restricted eating plan. The subjects were given gelatin capsules of either aspartame or a lactose placebo on a double blind, randomized basis. The aspartame dose was 2.7 g/day. Mean weight loss at the end of the 13 week study was not significantly different between the two groups. The plasma levels of the glucoregulatory hormones, insulin and glucagon, were also examined. Aspartame dosage was not found to increase the secretion of either plasma glucagon or insulin.

Porikos and Van Itallie (1984) conducted a series of studies in a controlled laboratory setting. The researchers studied the energy intake of volunteers eating foods sweetened with sucrose or aspartame. The authors' objective was to determine whether persons maintain their usual level of energy intake when aspartame covertly replaced part of their caloric intake. In study 1 obese subjects were fed a conventional sucrose-containing diet on days 1-3 and 10-15. On days 4-9 the energy diluted diet containing aspartame was fed. During the first three days on the aspartame diet, energy intake averaged 77% of the baseline intake. During the next 3 days energy intake increased by an average of 310 kcal/day which was 86% of the baseline. The authors recognized the fact that a longer term study was needed to examine further changes in energy intake.

The second study conducted by Porikos and Van Itallie (1984) involved subjects of normal body weight (within 10% of desirable body weight). The design was similar to that of study 1 but was doubled in length of time. The substitution of aspartame produced a significant decrease in energy during the first 3 day period (76% of the baseline level). During the second 3 day period of aspartame substitution intake increased by 354 kcal/day. The adjustment stabilized at 85% of the baseline intake.

The third study conducted by the same authors followed the same design as the second study however both normal weight and obese subjects were tested. The obese and the normal weight subjects both showed a significantly decreased energy intake while on the aspartame-sweetened diet.

The authors concluded that people do not regulate their energy intake precisely and that when the conventional sucrose diet was replaced by an aspartame diet persons tend to stabilize their intake at 85% of the baseline. It must be pointed out that since the incorporation of aspartame into the diet was covert, the psychological influence of taking in a sugar analogue was not a factor. Persons may use the intake of low calorie food or beverage products as an excuse for the higher intake of other more fattening foods.

Blundell and Hill (1986) proposed that artificially sweetened food and beverage products serve two purposes in the diet: to increase the palatability of foods and to reduce the caloric value of these foods. The researchers hypothesized that artificial sweeteners distort the information used by the appetite regulatory control mechanisms consequently increasing feelings of hunger and motivation to eat.

The researchers examined the effects of aspartame on appetite control in 95 male and female volunteers aged 18 - 22. Changes in perceived sweetness of sucrose solutions

were quantitated after a glucose load. This effect was then compared to the effect after an aspartame load of equivalent sweetness. Changes in appetite motivation were also measured. The glucose load decreased motivation to eat and increased feelings of fullness as was expected when compared with the control (a water load). The aspartame load did not suppress appetite ratings and in some of the volunteers actually increased appetite ratings when compared with the control ( $p < 0.05$ ). The volunteers reported feelings of "residual hunger" associated with the aspartame load.

Blundell and Hill (1986) concluded that aspartame may cause ambiguous signals to appetite control centers in the body and may consequently increase caloric intake. They hypothesized further that this disturbance of the psychobiological information has the potential to cause a loss of appetite control especially in susceptible individuals. Artificial sweeteners do not necessarily fulfill all of the psychobiological roles of sugars such as suppression of appetite and may therefore impede weight loss in individuals attempting to lose weight (Blundell and Hill, 1986).

## Chapter 3

### METHODOLOGY

#### Design - Experiment 1

Fifty weanling male rats were randomly assigned to one of five treatment groups. Each group of ten rats was given standard laboratory rat chow and water ad libitum. In addition, four of the treatment groups were given a sweetened solution of either aspartame or sucrose at a designated weight by volume concentration. Treatment group 1 was given a 10% sucrose solution in addition to the chow and water. Treatment group 2 was given a 50% sucrose solution. Treatment groups 3 and 4 were given solutions of 0.05% aspartame and 0.25% aspartame, respectively.

The sweetness of aspartame is known to be 180 to 200 times sweeter than sucrose; therefore, the sweet solutions in treatment groups 1 and 3 were equally sweet as were the solutions in groups 2 and 4. The lower of the two sweetness levels is equal to the sweetness of diet drinks. Treatment group 5 was not offered any type of sweet solution in addition to the chow and water and therefore was the control group.

## Procedure

Upon arrival the rats were weighed and placed in numbered metal cages with food and water provided. The rats were allowed to become acclimated to their environment for a period of three days before the treatments began. The rats were randomly separated into five groups such that the average weights of each group were approximately equal. (App. E) Each of the groups was then assigned a treatment number 1-5. The laboratory room in which the rats were placed was environmentally controlled for temperature (72°C) and for light (12 hours of "daylight" and 12 hours of "night").

After the acclimation period, each of the treatment groups was given a graduated bottle of 25 ml of the appropriate solution. The bottles were marked 10S, 50S, 05A, and 25A to prevent errors when refilling the bottles. The amount of solution consumed by each rat was recorded daily, and the bottle was then refilled with the appropriate solution to the 25 ml mark. Food was measured by the following method: each rat had its own bag of food which was labeled with the rat number and treatment. Each rat was fed from its own bag as was necessary. Each bag was weighed at the beginning of the study and at the end of the study (which included any food left in the dish) and the difference was taken to determine the total amount of food consumed by each rat over the 28-day period. Spillage of

rat chow was measured when the food bowls were refilled and subtracted from the chow intake. Water consumption was recorded when water levels became low and the bottles were refilled. Total caloric intake was determined by the recorded amount of sucrose solution intake (4 kilocalories/gram of sucrose) and the amount of food intake (4 kilocalories/gram of rat chow). Since the caloric value of aspartame is negligible no kilocalories were calculated from those sweetened solutions.

The rats were weighed on the first day of treatment on a calibrated scale to obtain initial weight and were weighed three times a week thereafter until the day of sacrifice when their final weight was measured. At the end of the 28 day period, the rats' final weights were measured. Each rat was lightly anesthetized and a blood sample was drawn by cardiac puncture after which each rat was sacrificed by the administration of carbon dioxide.

### Statistical Analysis

The data were analyzed using the Statistical Analysis System (SAS). Analysis of variance (ANOVA) procedures were used to determine if differences existed among the treatment groups for the previously listed variables. The following dependent variables were tested for differences across the five groups: total weight gain (grams), total food

consumption (grams), total water consumption (milliliters), and total food energy intake (kilocalories). The dependent variable total solution consumption (milliliters) was tested for differences among the four treatment groups. The level of probability was noted an alpha level of 0.05.

Duncan's multiple range test was used to determine which group means were significantly different at a probability level of 0.05. The test was conducted on groups 1 through 5 for the dependent variables of total food consumption and total water consumption to determine where differences among the groups existed. The test was conducted on groups 1 through 4 for the dependent variable of total test solution consumption to determine where among the groups differences existed.

## Methodology Experiment 2

### Sample

The sample was drawn from college students enrolled in two sections of a freshman level nutrition course which is a requirement for several majors and is also a popular elective among a large variety of majors and all class levels. The professor for the course agreed to award bonus points to students who participated in the study. The researcher visited each section of the class to explain what would be expected of the participants. The students then signed up for appointments that were scheduled at five minute intervals over a time span of 2 1/2 weeks. Of the total 280 students who participated in the study 122 were male and 158 were female. The age range was 18 to 34 years with an average age of 20.5.

### Strategies for Data Collection

Data were collected using a questionnaire designed for the study (Appendix A). The students provided demographic data (age, gender, ethnic background). The students were then asked to state how they perceived their present weight (overweight, underweight, or neither). The students were then asked to complete the "Drive for Thinness Scale" as question 7 of the questionnaire (Appendix A) which is used

to identify persons with an excessive concern with dieting and a preoccupation with weight (see "Justification of Methods") A score of 15 or over on the DFT scale is considered abnormal. The students were also asked to state if they were dieting at the present time. The remaining questions were designed to quantitate the students' use of food and beverage products which contained artificial sweeteners.

Weight and height were measured by the researcher using a platform beam scale. The students' total energy expenditure and average caloric intake also were recorded. These values were calculated by the students for a required class project in which the students were instructed on keeping a three day food intake record and then using food composition tables to determine the caloric value of the food. The students were instructed to record all foods eaten over a three day period that included at least one weekend day and then the average of these three days was used to determine their average caloric intake (ACI) per day. Each student's three day diet recall was reviewed by the graduate teaching assistant (GTA). The GTA based this review on the detail of the description for the consumed foods and appropriate measures of these food. The record was then given back to the student. If the information on

the food record was unsatisfactory the student was instructed on the required corrections.

Total energy expenditure (TEE) was also calculated by each student for the class project. This value was determined by the following formula: Total Energy Expenditure (TEE) = Basal Metabolism + Energy expenditure + Thermic Effect of Food (Appendix E)

### Procedure

The platform scale was not moved during the study and a screen was placed in front of the scale to provide the students with privacy while their height and weight were measured. Accuracy of the scale was checked at the beginning of the study using a ten kilogram weight and was rechecked each day that data collection took place.

The questionnaires were numbered sequentially from 001 to 300. Two consent forms (Appendix F) were attached to each questionnaire - one for the student's own records and the other for the researcher. After completion of the questionnaire the students were asked to remove their shoes, any heavy jackets and hats and step onto the scale for measurement. Weight was recorded to the nearest tenth of a kilogram. The student was then asked to stand up straight and to look straight ahead. Height was measured by adjusting the moveable arm on the scale so that it touched

the top of the head. Height was then recorded to the nearest half centimeter.

### Statistical Analysis of Research Questions

The data were analyzed for the total sample and also for males and females separately.

\* Analysis of Variance (ANOVA) was used to determine differences between female and male usage of artificially sweetened products.

\* The chi-square test was used to determine if a relationship existed between gender and being on a diet.

\* Differences between male and female scores on the Drive for Thinness (DFT) scale were determined by ANOVA.

\* The chi-square test was used to determine if a relationship existed between sex and DFT scores considered to be high or low.

\* ANOVA was used to determine if differences existed between high and low DFT scorers and their use of aspartame.

\* ANOVA was used to determine if differences existed between people on or not on a diet and their use of artificially sweetened products.

\* The chi-square test was used to determine if a relationship existed between actual weight (classified by above, below, or at ideal body weight) and use of artificially sweetened products.

\* The chi-square test was used to determine if a relationship existed between subjects' perception of their weight and their use of artificially sweetened products.

Chapter 4  
RESULTS AND DISCUSSION  
Experiment 1

Results

The mean, standard deviation, and range for each of the dependent variables for each treatment group and for the control group are summarized in Appendix A. All of the rats survived and remained healthy throughout the 28 day test period; therefore each treatment group is complete with  $n=10$ .

Group 4 (0.25% aspartame) and group 3 (0.05% aspartame) had the greatest average weight gain at 201.4 gm, followed by group 1 (10% sucrose) at 200.4 gm, group 2 (50% sucrose) at 195.4 gm and group 5 (control) at 189.5 gm). No significant differences were found among the groups for weight gain ( $p<0.5612$ ) (Appendix B).

Results for food, water, and solution intake are given in Table 1. Groups 1 and 2 consumed a significantly lower amount of food than did groups 3, 4, and 5. Group 3 consumed the greatest average amount of food at 593.85 gm, followed by group 5 (570.70 gm), group 4 (549.80 gm), group 1 (435.00 gm) and group 2 (365.60). The differences among the groups for food intake were statistically significant at  $p<0.05$  (Table 1).

TABLE 1

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 Total Food, Water, and Solution Intakes of Animals
 

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<u>Treatment</u>	<u>*Food (g)</u>	<u>*Water (ml)</u>	<u>*Soln (ml)</u>
10% Sucrose	435.00a	401.30a	1050.55a
50% Sucrose	365.60a	425.50a	499.50b
0.05% Asptm	593.85b	757.90b	220.35c
0.25% Asptm	549.80b	694.10b	301.05c
Control	570.70b	960.70c	---

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\*(Means within a column of the same letter are not significantly different at  $P < 0.05$ )

Group 5 (the controls) consumed the greatest average amount of water (960.70 ml) compared to the other four groups. Groups 3 and 4 differed from the other groups with water intakes of 757.90 ml and 694.10 ml, respectively. Groups 2 and 1 consumed the least amount of water (425.50 ml and 401.30 ml, respectively). The differences among the groups for water intake were statistically significant at  $p < 0.05$  (Table 1).

Group 2 consumed the greatest number of kilocalories at 2461.4 followed by group 3 (2365.8 kcals), group 5 (2282.8 kcals), group 4 (2202.2 kcals) and group 1 (2160.2 kcals). These differences were not statistically significant ( $p < 0.2221$ ) (Appendix B).

Group 1 consumed the greatest average amount of its sweetened test solution (1050.5 ml of the 10% sucrose solution). The 50% sucrose solution intake of group 2 averaged 499.5 ml. Groups 3 and 4 consumed the least amount of their sweetened test solutions (0.05% aspartame and 0.25% aspartame solutions) with intakes of 220.3 ml and 301.0 ml, respectively. The differences between groups 1 and 2 were statistically significant at  $p < 0.05$  (Table 1). Groups 3 and 4 differed significantly from groups 1 and 2 ( $p < 0.05$ ) but did not differ from one another (Table 1).

The total fluid intake (water and sweetened solution) of groups 2 through 5 were approximately the same (925.0 ml,

978.2 ml, 995.1 ml, and 960.7 ml, respectively). Group 1 consumed a higher level of total fluids due to the high intake of the 10% sucrose solution.

### Discussion

Although groups 1 and 2 consumed significantly less food than groups 3, 4, and the control group, the total kilocalorie intake did not differ significantly among the groups (Appendix F). As indicated by a significantly greater sweetened solution intake, the caloric intake of the sucrose groups was increased by consumption of calories from the sweetened solution. The animals appeared to have reduced their food intake proportionately to the amount of calories ingested from the sucrose solution. There was a significant difference between the solution and food intake of the 10% sucrose group and 50% sucrose group. Although the 10% sucrose group consumed a greater amount of total solution, the caloric density of the 50% solution was greater, thus equalizing the caloric intake. The total fluid intake of treatment groups 2 through 5 was approximately the same. Group 1 consumed a greater amount of total fluid (1451.8 ml) due to the high level of 10% sucrose solution consumption (Table 1). The animals demonstrated a preference for the 10% sucrose solution over water and over the other sweetened solutions.

The food intake of groups 3 and 4 was significantly greater than that of groups 1 and 2 but did not differ from the control group. Since aspartame does not contribute energy to the diet, the animals in the aspartame groups consumed the same as the controls. Animals on a laboratory diet have been shown to maintain a relatively consistent level of energy intake (Kissileff and Van Itallie, 1982).

Appetite regulation involves several complex mechanisms that interact in ways not completely understood by leading researchers. (Stunkard, 1980) Multiple peripheral factors (such as endocrine hormones, gastrointestinal hormones, and the hedonic qualities of food) send messages to the central satiety system in the central nervous system (Morley and Levine, 1985). The majority of the research in the area of appetite regulation has been done in animals. The glucostatic theory of appetite control may explain in part the results of this study (Oomura, 1976). The glucostatic theory suggests that the levels of plasma glucose and insulin may be major regulators of the appetite. Porte and Woods (1981) have suggested that increased plasma insulin levels suppress food intake by serving as a signal to the feeding center in the central nervous system.

The rats in groups 1 and 2 may have received signals initiated by plasma glucose levels that inhibited their food intake. The rats in the aspartame and control groups may

not have received these signals and consequently consumed greater amounts of food to equalize their caloric intake with that of the sucrose groups. Although the artificial sweetener aspartame may provide similar hedonic qualities to the diet as sugar, it may not replace all of its qualities, in particular the appetite suppressing effects that sugar may provide.

The rats in groups 3 and 4 consumed significantly less of the sweetened solutions (even though the two levels of sweetness were supposedly identical for sucrose and aspartame) than did the rats in groups 1 and 2 (Table 1). Sclafani and Abrams (1986) recently conducted a study in which the preference of rats for aspartame was studied. The researchers found that rats show only a weak preference for aspartame over water. The results of this study do not agree with those of Sclafani and Abrams. The rats in both groups 3 and 4 did not show any preference for the aspartame sweetened solutions over water. The rats in groups 3 and 4 in this study may have perceived the solution differently than the rats in groups 1 and 2 as shown by their low intake of sweetened solution.

While the results of this experiment agree with the findings of Kissileff and Van Itallie (1982) supporting energy regulation in the animal model, extrapolation to humans must be done with caution. The ability of laboratory

animals to regulate energy intake is dependent upon the type of diet (rat chow vs. the "supermarket diet") being fed. Sclafani and Springer (1976) showed that when laboratory rats were fed an ad lib "supermarket" diet of cookies, chocolate, marshmallows, peanut butter, cheese, and other highly palatable foods, the animals gained 269 percent more weight than the controls fed a laboratory diet. Since most humans have access to a variety of palatable foods it is difficult to assess the other appetite mechanisms that may be affecting energy regulation.

The use of artificial sweeteners to replace sucrose in the diet does not appear to reduce food consumption in male weanling rats as sucrose does. The rats in groups 1 and 2 appear to have reduced their intake of food when compared to the control group due to the ingestion of kilocalories from the sucrose solution. The rats in groups 3 and 4 did not adjust their food intake when compared to the control group. Animal data cannot necessarily be extrapolated to humans. Humans consume a varied diet as previously discussed. The psycho-social factors involved such as eating due to social pressures, desire to reduce caloric intake to decrease or control weight, and eating due to emotional factors like stress and boredom must also be addressed when human eating behavior is examined. For example, humans may use artificial sweeteners as an excuse to consume more high

calorie foods in the diet. Conversely, artificial sweeteners may fulfill a psychological need for sweet foods without the excess calories of caloric sweeteners thereby helping to reduce energy intake and body weight. The psychological desire to be thin or to lose weight also may be a factor in the use of artificial sweeteners and energy balance in the human model.

## RESULTS AND DISCUSSION

### Experiment 2

#### General Characteristics of the Subjects

Two hundred and eighty students completed the questionnaire and were measured for weight (in kilograms) and height (in centimeters). One hundred fifty-eight of the total subjects were female (56.4%); 122 of the total subjects were male (43.6%). Two hundred forty-six (87.9%) of the subjects were caucasian; 23 were black (8.2%). The remaining 11 subjects (3.9%) were non-whites and non-blacks. The average age of the subjects were 20.5 years with an age range of 18 to 34 years.

Of the total sample, 72 subjects (25.7%) reportedly used no products containing Nutrasweet. Seventy-eight subjects (27.9% of the total sample) reportedly used Nutrasweet products "sometimes". The remaining 130 subjects (46.4% of the total sample) answered "yes" when asked if they use products containing Nutrasweet.

#### The Relationship between Gender and Use of Artificial Sweeteners

The mean intake of diet soda among the female subsample was 13.1 ounces per day with a range of 0.0 to 72.0 ounces. The mean intake of diet soda among the male subpopulation

was 7.3 ounces per day with a range of 0.0 to 60.0 ounces. This difference between males and females was statistically significant ( $p < 0.01$ ) (Table 2).

The mean intake of packages of artificial table top sweeteners among the female subsample was 0.80 packets per day with a range of 0.0-9.0 packets. The mean intake of packages of artificial table top sweeteners among the male subsample was 0.21 packets per day with a range of 0.0-3.0 packets (Table 2). Males and females differed significantly ( $p < 0.01$ ) for consumption of artificial table top sweeteners.

The female subjects consumed significantly greater amounts of artificially sweetened sodas and table top artificial sweeteners (Table 2) than did the male subjects. Few data exist on artificial sweetener consumption patterns of college age persons; however, Morgan and coworkers (1985) examined soft drink consumption patterns of the United States population using data from the 1977-78 Nationwide Food Consumption Survey (NFCS). The researchers assessed the consumption patterns of both regular and artificially sweetened soft drinks and found that 35-44 year-old women had the highest percentage of diet soft drink consumption. The women in the 17-18, 19-24, and 25-34 year-old age groups consumed greater amounts of diet soft drinks than their male counterparts. The greater diet soft drink consumption among

Table 2

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 Artificial Sweetener Consumption  
 of Males and Females
 

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Sweetener Consumption	Females n=158	Males n=122
*Diet Soda Consumption (ounces/day)	13.1 <sub>a</sub>	7.3 <sub>b</sub>
*Table Top Artificial Sweetener Consumption (packets/day)	0.8 <sub>a</sub>	0.2 <sub>b</sub>

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(Means in the same row with different letters are significantly different at  $p < 0.01$ )

females when compared to males may be due to a greater preoccupation with weight and thinness among the female population. Males in the 19-24 and 25-34 year old age groups were found to have the largest mean intake of regular sodas (Morgan et al., 1985).

The data collected on the consumption of other artificially sweetened food or beverage products is not presented here for several reasons. The frequency of overall consumption of these products was very small (Appendix H). The majority of the subjects reported no consumption of these products. Also, measurement of serving sizes was impossible to quantitate since the questionnaire format was that of a food frequency test.

#### The Relationship between Dieting and Use of Artificial Sweeteners

The question "Are you on a diet?" was asked to identify those subjects who were pursuing weight loss by restricting their caloric intake. Thirty-four of the 280 subjects answered "yes" to this question. Of the female sample, 128 were reportedly not on a diet (81.0%); 30 were on a diet (19.0%). Of the male sample, 118 (96.7%) were reportedly not on a diet while 4 (3.3%) were on a diet. The number of females on a diet was significantly greater than the number of males on a diet ( $p < 0.01$ ). This is consistent with the

findings of other researchers. According to Neuman and Halvorson (1983), women comprise 95% of the members of formal diet programs in the United States.

Those subjects who identified themselves as being on a diet consumed significantly greater amounts of diet sodas ( $p < 0.01$ ) than those not on a diet. Among females, those who identified themselves as being on a diet were found to consume significantly ( $p < 0.01$ ) greater amounts of diet sodas (20.6 ounces/day) than those females who identified themselves as not being on a diet (11.4 ounces/day). No difference was observed between dieting and non-dieting female subjects for the consumption of table top artificial sweeteners (Table 3).

It is recognized that the wording of the question "Are you on a diet?" may have been misleading since not all diets are designed for weight loss (diabetic diets for example). However, the researcher was present and available to clarify any questions concerning the survey while all of the subjects were participating in the study. Any confusion caused by this question would have been appropriately addressed by the researcher at that time.

#### Relationship between DFT Score and Artificial Sweetener Use

On the "Drive for Thinness Scale", the mean score for males was 1.33 (SD +/- 2.2) with a range of 0 to 12. For

Table 3

Dieting Status and Diet Soda Consumption for Females	
<u>Dieting Status (n=158)</u>	<u>*Mean Diet Soda Consumption (ounces/day)</u>
Dieting Females (n=30)	20.6 <sub>a</sub>
Non-Dieting Females (n=128)	11.4 <sub>b</sub>

\* (Means with different letters are significantly different at  $p < 0.01$ )

females the mean score was 5.8 (SD +/- 6.3) with a range of 0 to 21. These differences between males and females were found to be significant upon testing by ANOVA ( $p < 0.01$ ) (Table 4).

Females were found to be more likely to have an abnormally high score (15 or greater) on the Drive for Thinness (DFT) scale ( $p < 0.01$ ). This is not a surprising finding since females are believed to be more preoccupied with weight than are males (Miller et al., 1980; Garner et al., 1980). When females with abnormal DFT scores (15 or greater) were compared with females with low DFT scores (0-14) for consumption of diet soda (Table 5) the subjects with high scores were found to consume significantly greater amounts of diet soda than those females with low scores ( $p < 0.01$ ). No significant differences were found in the consumption of table top sweeteners between the two groups. As with females who dieted, the subjects with a higher drive for thinness may use the artificially sweetened food and beverage products as a method of calorie reduction and consequent weight loss.

The findings from the "Drive for Thinness" scale and the "Are you on a diet?" question indicate that the major users of diet sodas are females who are dieting and/or who score abnormally high on the DFT scale. Within the female subsample, those with a greater concern with their weight,

Table 4

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Gender and Drive for Thinness Score

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DFT Score	*Gender	
	Female (n=158)	Male (n=122)
0-14	83.5% <sub>a</sub> (n=132)	100.0% <sub>b</sub> (n=122)
15+	16.5% <sub>a</sub> (n=26)	0.0% <sub>b</sub> (n=0)

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\* (Averages in the same row with different letters are significantly different at  $p < 0.001$ )

Table 5

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Drive for Thinness Score and Diet  
Soda Consumption for Females

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<u>DFT Score (n=158)</u>	<u>*Mean Diet Soda Consumption (ounces/day)</u>	<u>Packets</u>
0-14 (n=132)	11.4 <sub>a</sub>	
15+ (n=26)	21.7 <sub>b</sub>	

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\* (Means with different letters are significantly different at  $p < 0.01$ )

as shown by a high DFT score and those who indicated that they are dieting, used the greatest amounts of diet soda.

The Relationship among Perceived Weight, Weight Status and the Use of Artificial Sweeteners

One hundred fifty-six of the subjects (55.7%) perceived themselves as being neither underweight nor overweight. Of the females, 84 (53.2%) perceived themselves as being neither underweight nor overweight (Table 6). This finding contrasts the findings of a study conducted by Miller and associates (1980). The researchers questioned undergraduate students between the ages of eighteen and twenty-three regarding body image and found that 32 out of the 46 women (70%) perceived themselves as being overweight. For the male subsample, 72 (59%) perceived their weight as neither underweight nor overweight. This finding is fairly consistent with the Miller et al. study where 11 of the 22 men surveyed (50%) perceived themselves as being of normal weight. For all the subjects, 28 perceived themselves as being underweight (10.0%). Of the female subpopulation, 9 perceived themselves as underweight (5.7%). For the males, 19 perceived themselves as underweight (15.6%). Ninety-six subjects of the total sample (34%) perceived themselves as overweight. For the females, 65 (41.1%) perceived themselves as overweight. For the males, 31

Table 6

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 Females vs. Males for Perception of Weight, Weight Wish,  
 and Actual Weight
 

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<u>Perception of Self</u>	<u>% Total (n=280)</u>	<u>% Females (n=158)</u>	<u>% Males (n=122)</u>	<u>*p-value</u>
Overweight	34.3%	41.1%a	25.4%b	p=.008
Underweight	10.0	5.7a	15.6b	p=.008
Neither	55.7	53.2a	59.0a	p=.335
<u>Weight Wish</u>				
Lose	56.4%	68.4%	41.0%b	p=.000
Gain	16.4	5.7a	30.3b	p=.000
Neither	27.2	25.9a	28.7a	p=.685
<u>Weight Status</u>				
Overweight	43.9%	34.8%a	55.7%b	p=.001
Underweight	28.6	36.7a	18.1b	p=.001
Neither	27.5	28.5a	26.2a	p=.668

(Means in the same row with different letters are significantly different at P 0.01)

\* p-value for Fisher's exact test of equality of "% of females" & "% of males" in each row

(25.4%) perceived themselves as overweight. The gender of the subject was found to have a significant effect on their perception of body weight with females more likely to perceive themselves as being overweight than males ( $p < 0.01$ ). This finding is consistent with the findings of other researchers (Miller et al., 1980; Moss et al., 1984; Garner and Garfinkel, 1980).

Of the total sample, 158 subjects (56.4%) wished to lose weight. For females, 108 wished to lose weight (68.4%). For males, 50 wished to lose weight (41%). For all subjects, 76 wished to remain at their present weight (27.1%). For females, 41 wished to remain at their present weight (26.0%). For males, 35 wished to remain at their present weight (28.7%).

For all subjects, 46 wished to gain weight (16.4%). For females, nine wished to gain weight (5.7%). For males, 37 wished to gain weight (30.3%). Gender was found to have a significant effect on the subjects' weight wish with females more likely to wish to lose weight than males ( $p < 0.01$ ). It is interesting to note that even though the majority of the subjects (55.7%) perceived themselves as being neither underweight nor overweight, the majority of the subjects (56.4%) wanted to lose weight. Although the subjects did not perceive themselves as being overweight they still wished to be at a lower body weight. This

finding may be a result of the cultural trend toward thinness described by Garner et al. (1980). Although average body weights have not changed, society's expectations of the ideal body weight and shape may have a greater influence on the populace than actual body weight trends.

The relationship between artificial sweetener use and weight perception was significant for females at  $p < 0.01$  (Table 7). As the perceived weight among females increased, the consumption of diet sodas and table top artificial sweeteners increased. The females who perceived themselves as being underweight ( $n=9$ ) consumed an average of 0.2 ounces of diet soda and no packets of table top artificial sweeteners a day. Those females who perceived their weight as being "neither overweight nor underweight" ( $n=84$ ) averaged 11.9 ounces of diet soda and 0.6 packets of artificial sweetener a day. This was a significantly greater amount of consumption ( $p < 0.01$ ) than the females who perceived themselves as being underweight. The females who perceived themselves as being overweight ( $n=65$ ) consumed significantly greater average amounts ( $p < 0.01$ ) of both diet soda (17.4 ounces/day) and packets of artificial sweeteners (1.2 packets/day) than each of the previous groups. The relationship between artificial sweetener use and weight perception was not found to be significant for males (Table 8).

Table 7

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Weight Perception and Artificial Sweetener Consumption  
Among Females

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<u>Weight Perception (n=158)</u>	<u>*Mean Diet Soda Consumption (ounces/day)</u>	<u>*Mean Table Top Artificial Sweetener Consumption (packets/day)</u>
Underweight (n=9)	0.2 <sub>a</sub>	0.0 <sub>a</sub>
Ideal Weight (n=84)	11.9 <sub>b</sub>	0.6 <sub>b</sub>
Overweight (n=65)	17.4 <sub>c</sub>	1.2 <sub>c</sub>

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\* (Column means with different letters are significantly different at  $p < 0.01$ )

Table 8

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 Weight Perception and Artificial Sweetener Consumption  
 Among Males
 

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Weight Perception (n=122)	*Mean Diet Soda Consumption (ounces/day)	*Mean Table Top Artificial Sweetener Consumption (packets/day)
Underweight (n=19)	7.7	0.1
Ideal Weight (n=72)	6.1	0.2
Overweight (n=31)	10.0	0.3

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\*(Chi-Square test for relationship among variables not significant)

The mean female weight was 60.17 kg (SD +/- 8.40) with a range of 45.10 kg to 91.90 kg. (Appendix G) The mean female height was 165.80 cm (SD +/- 7.60 cm) with a range of 147.00 cm to 190.50 cm. The mean male weight was 78.44 kg (SD +/- 13.01) with a range of 57.40 kg to 131.40 kg. The mean male height was 178.99 cm (SD +/- 6.35 cm) with a range of 161.50 cm to 198.00 cm. For the males, 55.7% were classified, using "body mass index", as overweight, 18.1% as underweight, and 26.2% as neither underweight nor overweight. For the females, 34.8% (n=55) were classified as overweight, 36.7% (n=58) as underweight, and 28.5% (n=45) as neither underweight nor overweight.

The relationship between artificial sweetener consumption and weight status was found to be significant for females at  $p < 0.01$  (Table 9). The females in the "underweight" category consumed an average of 7.9 ounces of diet soda and 0.5 packets of table top artificial sweeteners a day. The females in the "ideal body weight" category consumed a significantly greater amount of both products than did the females in the "underweight" category ( $p < 0.01$ ). They consumed an average of 16.9 ounces of diet soda and 0.7 packets of table top artificial sweeteners a day.

The females in the "overweight" category consumed an average of 15.5 ounces and 1.2 packets of table top

Table 9

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Actual Weight and Artificial Sweetener Consumption  
Among Females

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<u>Actual Weight (n=158)</u>	<u>*Mean Diet Soda Consumption (ounces/day)</u>	<u>*Mean Table top Artificial Sweetener Consumption (packets/day)</u>
Underweight (n=58)	7.9 <sub>a</sub>	0.5 <sub>a</sub>
Ideal Weight (n=45)	16.9 <sub>b</sub>	0.7 <sub>b</sub>
Overweight (n=55)	15.5 <sub>b</sub>	1.2 <sub>b</sub>

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\* (Column means with different letters are significantly different at  $p < 0.01$ )

artificial sweeteners a day. They differed significantly for consumption from the "underweight" group ( $p < 0.01$ ) but not from the "ideal body weight" group (Table 9). The relationship between artificial sweetener consumption and weight status was not significant for males (Table 10). Males at ideal weight or overweight did not consume more artificial sweeteners than underweight males.

The female subjects' consumption of artificial sweeteners was influenced by both perceived weight and by actual weight whereas the male subjects' consumption of artificial sweeteners was not influenced by either perceived or actual weight. Females may use artificial sweeteners to lower caloric intake and thereby reduce weight whereas men may not be using these products for the same purpose. The males were not as concerned with their weight, as shown by their "Drive for Thinness" scores, which may be related to their comparatively low diet soda and table top artificial sweetener consumption. Those males who did consume artificial sweeteners were not influenced by either their perceived weights or their weight status. This may indicate that men who want to control their weight (41.0% wanted to lose weight, 28.7% wanted to maintain weight) may pursue weight loss or maintenance by other means such as increased activity. Also, it simply may be an indication that the

Table 10

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Actual Weight and Artificial Sweetener Consumption  
Among Males

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<u>*Actual Weight (n=122)</u>	<u>*Mean Diet Soda Consumption (ounces/day)</u>	<u>*Mean Table Top Artificial Sweetener Consumption (packets/day)</u>
Underweight (n=22)	7.9	0.1
Ideal Weight (n=32)	8.1	0.3
Overweight (n=68)	7.6	0.2

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\*(Chi Square test for relationship among  
variables not significant)

males are less concerned about their caloric intake than the females.

As perceived weight increased among the females, the consumption of both diet sodas and packets of artificial sweeteners increased. Differences were significant among all three groups (Table 7). How the females felt about their weight was related to their consumption of artificial sweeteners. The subjects who saw themselves as underweight may not have felt it necessary to use artificially sweetened products since weight gain was not a concern. The subjects who perceived themselves as being at their ideal weight may have been using artificial sweeteners to maintain their present weight and avoid weight gain. The subjects who perceived themselves as overweight consumed the greatest amount of artificial sweeteners as compared to the other two groups. This group may have been using the artificial sweeteners to either deter weight gain or aid in weight loss by reducing their caloric intake.

As weight status increased, only the underweight group consumed significantly less artificial sweeteners than the other weight status groups for females (Table 9). As with weight perception, this may show that the female subjects at greater body weights use artificial sweeteners to try to control their weight.

It is interesting to note that weight perception had a greater influence on the artificial sweetener consumption of the females (Table 7) than did their actual weight (Table 9).

### The Relationship between TEE, TCI and Artificial Sweetener Use

The mean total average energy expenditure (TEE) for the female subsample was 1874.8 kcals (SD =/- 309.7) with a range of 1161.0 to 3937.0 (Appendix G). The mean total average caloric intake (ACI) was 1671.4 (SD +/- 676.5) with a range of 584.0 to 4190.0. The mean ACI/TEE difference for females was - 203.3 kcals (SD +/- 561.5) with a range of -1324.0 to 1866.0 kcals.

The mean total average energy expenditure for the male subsample was 2712.3 kcals (SD +/- 443.9) with a range of 1505.0 to 4995.0. The mean total average caloric intake was 2516.4 kcals (SD +/- 1020.3) with a range of 1009.0 to 6300.0 kcals. The mean ACI/TEE difference for males was -95.9 kcals (SD +/- 882.9) with a range of -2127.0 kcals to 2784.0 kcals.

The relationship between average caloric intake/total energy expenditure (ACI/TEE) and artificial sweetener consumption was significant at  $p < 0.01$  for diet soda consumption of females (Table 11). The relationship between ACI/TEE and table top artificial sweeteners was not significant for females (Table 11). Females whose ACI/TEE was greater than 90% consumed an average of 8.7 ounces of diet soda and 0.4 packets of table top artificial sweeteners

Table 11

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Artificial Sweetener Use and Average Caloric Intake/Total  
Energy Expenditure for Females

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*Caloric Intake Energy Expenditure (n=140)	*Mean Diet Soda Consumption (ounces/day)	*Mean Table Top Artificial Sweetener Consumption (packets/day)
>90% (n=57)	8.7 <sub>a</sub>	0.4 <sub>a</sub>
<90% (n=83)	15.5 <sub>b</sub>	0.9 <sub>a</sub>

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\* (Column means with different letters are significantly different at  $p < 0.01$ )

a day. Females whose ACI/TEE was less than 90% consumed an average of 15.5 ounces of diet soda and 0.9 packets of table top artificial sweeteners a day. The relationship between ACI/TEE and artificial sweetener consumption was not significant for the males (Table 12).

The consumption of artificially sweetened sodas may help females reduce their caloric intake 10% or more below their total energy expenditure. These results are similar to those of Porikos and Van Itallie (1984) in which the subjects whose sugar intake was replaced by artificial sweeteners maintained a lower caloric intake than those whose sugar intake was not replaced.

These results seem somewhat inconsistent with the other findings of the study. The female subjects whose weight status was "ideal weight" or "overweight" consumed the greatest amounts of diet soda and packets of artificial sweeteners. Also, a trend toward weight gain appears to exist among the female subjects consuming the greatest amounts of diet soda (this is discussed in the following section). However, those subjects with the greater caloric deficit may not necessarily have lower body weights since other factors, such as a person's basal metabolism, are important determiners of body weight. Therefore, the use of diet sodas may have aided the subjects in maintaining a

Table 12

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Artificial Sweetener Use and Average Caloric Intake/Total  
Energy Expenditure for Males

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<u>*Caloric Intake Energy Expenditure (n=106)</u>	<u>*Mean Diet Soda Consumption (ounces/day)</u>	<u>*Mean Table Top Artificial Sweetener Consumption (packets/day)</u>
>90% (n=54)	7.1	0.3
<90% (n=52)	6.9	0.1

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\* (Chi Square test for relationship among variables not significant)

greater caloric deficit without concomitant weight loss. The total energy expenditure is a rough estimate, calculated using a formula by the subjects themselves. It is difficult to determine the accuracy of the subjects' energy expenditures.

#### The Relationship between Weight Change and Artificial Sweetener Consumption

The mean total weight change over a one year period was +1.9 pounds (SD +/- 4.7) (Appendix G). For females, the mean weight change was +1.8 pounds (SD +/- 4.5). The mean weight change for males was +2.0 pounds (SD +/- 5.0).

The results for weight change and artificial sweetener consumption for females are shown in Table 13. Females who reported losing more than five pounds over the past year consumed an average of 9.5 ounces of diet soda and 1.5 packets of table top artificial sweeteners per day. Those who reported no weight change consumed an average of 11.2 ounces of diet soda and 0.6 packets of table top artificial sweeteners per day. Females who reportedly gained five pounds or more over the past year consumed an average of 15.7 ounces of diet soda and 0.8 packets of table top artificial sweeteners per day. No relationship was shown to exist between weight change and artificial sweetener consumption for females.

Table 13

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Weight Change and Artificial Sweetener Consumption  
Among Females

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<u>*Weight Change (pounds) (n=155)</u>	<u>*Mean Diet Soda Consumption (ounces/day)</u>	<u>*Mean Table Top Artificial Sweetener Consumption (packets/day)</u>
Loss >5 (n=18)	9.6	1.5
No Change (n=69)	11.2	0.6
Gain >5 (n=68)	15.7	0.8

---

\*(Chi-Square test for relationship among variables  
not significant)

The results for weight change and artificial sweetener consumption for males are shown in Table 14. Males who reported losing five pounds or more over the last year consumed an average of 8.2 ounces of diet soda and 0.1 packets of artificial sweeteners per day. Those who reported no weight change consumed an average of 8.3 ounces of diet sodas and 0.2 packets of artificial sweeteners per day. Males who reported gaining five pounds or more over the past year consumed an average of 6.3 ounces of diet soda and 0.3 packets of artificial sweeteners per day. The relationship between weight change and artificial sweetener consumption for males was not significant.

The results agree with those of McCann et al. (1956). These researchers found no significant difference between the weight loss of subjects in a weight loss program who used noncaloric sweeteners and those who did not use artificial sweeteners.

While the differences among the females for diet soda consumption and weight change were not significant ( $p < 0.08$ ), there did seem to be a trend toward greater consumption among the females in the group that gained weight. This finding could be related to an observation by Grunewald (1985) in which chronic or periodic dieters were more likely to be obese. The greater use of diet sodas among those who

Table 14

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 Weight Change and Artificial Sweetener Consumption  
 Among Females
 

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<u>*Weight Change (pounds) (n=121)</u>	<u>*Mean Diet Soda Consumption (ounces/day)</u>	<u>*Mean Table Top Artificial Sweetener Consumption (packets/day)</u>
Loss >5 (n=17)	8.2	0.1
No Change (n=43)	8.3	0.2
Gain >5 (n=61)	6.3	0.3

---

\*(Chi Square test for relationship among variables  
not significant)

gained weight compared to those who maintained or lost weight may be a reflection of their belief that diet sodas may aid them in weight control. However, diet sodas are most likely not a deterrent to weight loss, but merely a reflection of the weight gain concerns of the individual consuming them. Many researchers agree that artificial sweeteners do not adversely affect weight loss efforts (Parham and Parham, 1980; Knopp et al., 1976; and Kanders et al., 1988).

## SUMMARY

The purpose of this study was to determine if artificial sweetener use is positively associated with weight loss. It is difficult to make conclusive statements regarding a causal relationship between the use of artificially sweetened food and beverage products and weight change or maintenance due to the multiplicity of factors that affect weight fluctuations in humans. From experiment 1 it may be summarized that the laboratory animals carefully regulated their energy intake and compensated for the calorie deficit created by the artificial sweetener by consuming more food.

Relating the findings from animal studies to humans must always be done with caution. It is particularly difficult in this case due to the differences in the nature of the rat diet and the human diet. Psychological factors involved in the eating habits of humans must also be considered when relating animal data to humans. The use of artificial sweeteners in humans involves a number of psychological factors. Many individuals may use the artificially sweetened products to justify the intake of other (possibly high calorie) foods. This could actually cause the individual to gain rather than lose weight depending on the level of increased caloric intake.

Conversely, if the artificially sweetened food or beverage product satisfies a craving for their sucrose analogs, preventing their intake, weight loss may occur.

Other factors that must be examined when the use of artificial sweeteners as weight loss promoters is studied include the amount of sucrose originally consumed in the diet. If sucrose contributes a significant amount of calories to an individual's diet then replacement with artificially sweetened food and beverage analogs is likely to produce weight loss if all other factors remain constant. An individual's efforts in other areas such as diet modification and increased activity levels will also be a determining factor where weight loss occurs. In other words, it is difficult to isolate artificial sweeteners as the sole contributor to weight loss in human beings.

From the data analyzed in this study, certain conclusions can be drawn realizing that each human being is an individual case and must be treated as such. The major users of artificial sweeteners can be identified as females and more specifically as weight conscious females.

Self perception of weight appears to be a strong indicator of artificial sweetener use as well as the actual weight of the individual for females but not for males. This may be a reflection of the degree of societal pressure

put upon females to be thin that is known to be prevalent in western cultures.

Persons who use artificial sweeteners appear to use them to control their caloric intake and possibly their weight although no strong evidence exists supporting the efficacy of artificial sweeteners as weight loss or maintenance promoters. The results of this study do not demonstrate that the use of artificial sweeteners in the diets of college age students promote the gain, loss or the maintenance of body weight. Persons who use artificially sweetened food and beverage products for weight loss purposes should be aware that many other factors contribute to weight status and that these factors may be of greater importance in controlling body weight. Artificial sweeteners may serve to control some of these factors but cannot be relied upon to reduce weight solely upon their inclusion in the diet.

## FURTHER STUDY

There are several recommendations that can be made based upon this study. These recommendations include examining the composition of the diet, the new fat analogs in the diet, and the degree of satisfaction that artificial sweeteners may contribute to persons on calorie controlled diets.

Since artificial sweeteners were developed to replace sucrose based sweeteners in the diet, it would be interesting to examine the extent to which such replacement occurs. In other words, does the use of artificial sweeteners help reduce the consumption of foods sweetened with caloric sweeteners? This could be assessed by the use of a five to seven day food record. Evaluation of the diet for artificial sweetener use by the researcher using the diet record would provide more accurate information on their consumption. With the development of the artificial fats such as Olestra and Simplesse, a similar study could be conducted (when these become commonly used among the population). These "fake fats" are promoted as dietary fat replacers, implying that they may aid in weight loss. The use of these products should be studied to determine their possible impact on food consumption and body weight.

Finally, it is recommended that studies be conducted designed to assess changes in compliance on reducing diets with the addition of artificial sweeteners. It is possible that persons on specific weight loss regimes may benefit from artificial sweeteners by increased dietary satisfaction and compliance.

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APPENDIX A  
DATA COLLECTION FORM FOR EXPERIMENT 2

Name \_\_\_\_\_  
 Section 9:00\_\_\_ 2:00\_\_

Please answer the following questions as completely possible. Results are completely confidential. Your name will be removed from the questionnaire after your TEE and 3 day average caloric intake are recorded on the data sheet. Thank you for your cooperation.

### QUESTIONNAIRE

1. age\_\_\_
2. sex: female\_\_\_ male\_\_\_
3. Ethnic background:
  - caucasian\_\_\_
  - black\_\_\_
  - oriental\_\_\_
  - other\_\_\_
4. At the present time do you consider yourself to be:
  - Overweight\_\_\_\_\_
  - Underweight\_\_\_\_\_
  - Neither\_\_\_\_\_
5. At the present time do you wish to :
  - gain weight\_\_\_
  - lose weight\_\_\_
  - maintain weight\_\_\_\_\_
6. One year ago I weighed \_\_\_\_\_ lbs.

7. Please answer the following questions according to the scale:

A=always U=usually O=often S=sometimes R=rarely N=never

A U O S R N  
 ( ) ( ) ( ) ( ) ( ) ( )

( ) ( ) ( ) ( ) ( ) ( )

1. I eat sweets and carbohydrates without feeling nervous.
2. I think about dieting.

- ( ) ( ) ( ) ( ) ( ) ( )
- ( ) ( ) ( ) ( ) ( ) ( )
- ( ) ( ) ( ) ( ) ( ) ( )
- ( ) ( ) ( ) ( ) ( ) ( )
- ( ) ( ) ( ) ( ) ( ) ( )

- 3. I feel extremely guilty about overeating.
- 4. I am terrified of gaining weight.
- 5. I exaggerate or magnify the importance of weight.
- 6. I am preoccupied with the desire to be thinner.
- 7. If I gain a pound, I worry that I will keep gaining.

8. Are you on a diet at this time?  
 yes \_\_\_  
 no \_\_\_

If yes, are you on a particular diet program? .  
 yes \_\_\_  
 no \_\_\_

Please identify the diet you are on if you answered yes to the previous question.

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9. Do you consume food or beverage products that contain the artificial sweetener NutraSweet? (see list under question #12)

Yes \_\_\_  
 No \_\_\_  
 Sometimes \_\_\_

10. Approximately how much diet soda (of any variety) do you consume per day? (1 can = 12 oz.)

\_\_\_\_\_ ounces per day

11. Approximately how many packets of artificial table top sweeteners (such as "Equal" or "Sweet n Low" do you consume per day?

\_\_\_\_\_ packets per day

12. How often do you consume any of the following products (leave the space blank if you never consume a product)?

1. once a day
2. more than once a day
3. once a week
4. 3 to 4 days a week
5. once a month

Sugar-Free Hot Cocoa Mix (such as ALBA, Carnation, Kroger, Nestle, Swiss Miss) \_\_\_\_\_

Sugar-Free Gelatin Dessert (such as JELL-O Brand or Kroger sugar free gelatin dessert) \_\_\_\_\_

Sugar-Free Instant Pudding (such as JELL-O Brand or Kroger sugar free instant pudding) \_\_\_\_\_

Sugar-Free popsicles or fudgesicles (such as Crystal Light Bars, Sugar free fudgesicles/popsicles) \_\_\_\_\_

Sugar-Free Instant Coffees/Teas (such as Crystal Light fruit teas, General Foods sugar free International Coffees, Kroger sugar free tea mix, Lipton sugar free tea/fruit tea mix) \_\_\_\_\_

Sugar-Free Instant Breakfasts (such as Carnation Instant Breakfast No Sugar Added) \_\_\_\_\_  
 @

Sugar-Free Chocolate Milk Maker (such as Swiss Miss) \_\_\_\_\_

Sugar-Free Powdered Soft Drinks (such as Sugar Free Country Time Drink Mix, Sugar Free Drink-Aid, Sugar Free Kool-Aid, Kroger Light Drink Mix) \_\_\_\_\_

Sugar Free Shake Mixes (ALBA '77 High Calcium Shake) \_\_\_\_\_

Artificially Sweetened Cereals (such as Sun Flakes) \_\_\_\_\_

Do Not Write Below this Line: Beth will complete this section

1. TEE \_\_\_\_\_
2. Average calorie intake \_\_\_\_\_
3. Height \_\_\_\_\_ cm
4. Weight \_\_\_\_\_ kg

APPENDIX B

NOMOGRAPH FOR ASSESSING WEIGHT STATUS, EXPERIMENT 2

NOMOGRAPH FOR BODY WEIGHT

NOMOGRAPH FOR BODY MASS INDEX (KG/M<sup>2</sup>)

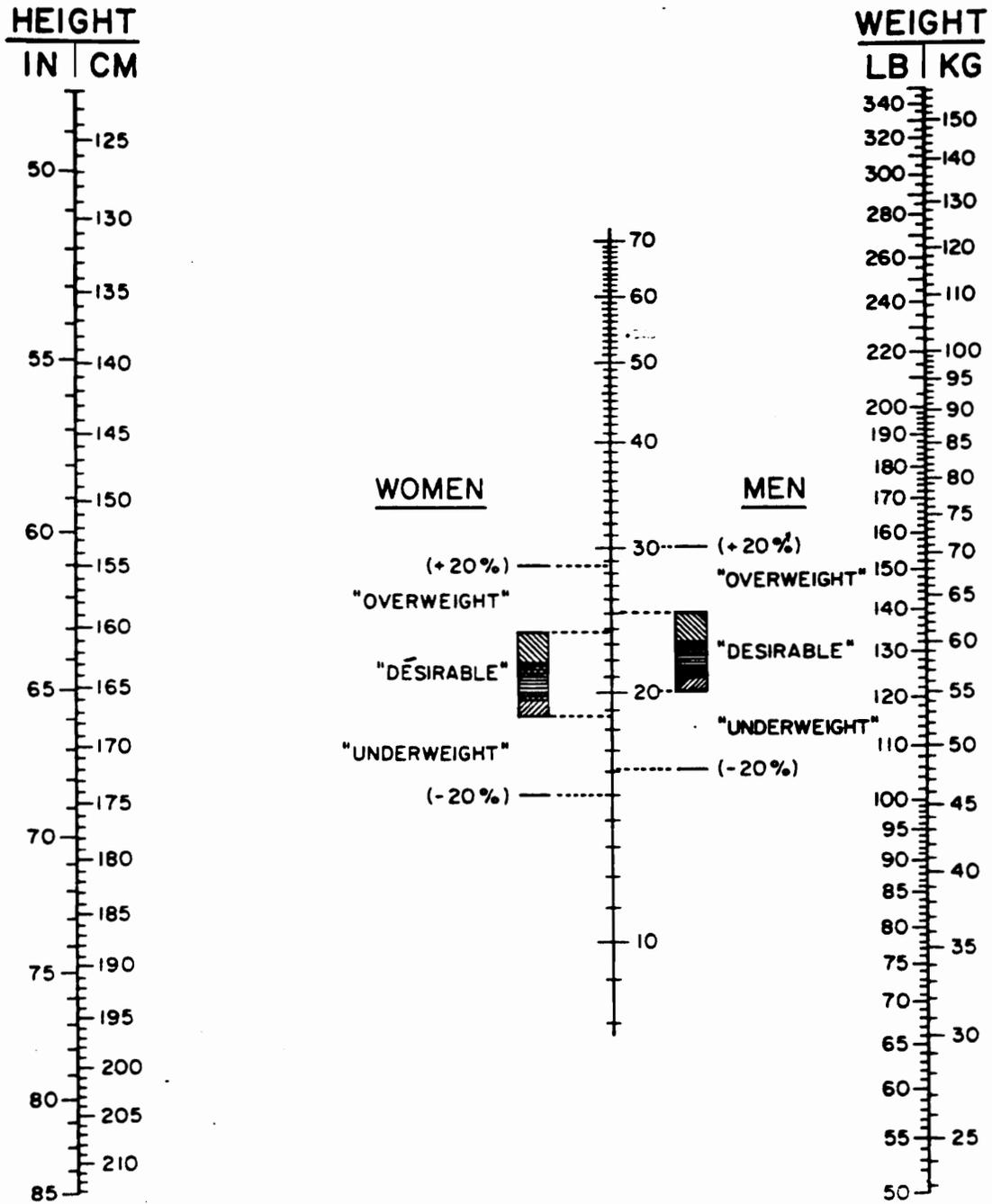


FIG. 1. The ratio weight/height<sup>2</sup> is read from the central scale. The ranges suggested as "desirable" from life insurance data (1, 2) must be interpreted with clinical judgment regarding relative skeletal and muscle mass, as explained in the text.

APPENDIX C

TEE FORMULA, EXPERIMENT 2

Estimating your TOTAL ENERGY EXPENDITURE (TEE). Complete this section by filling in the blanks below. (An example estimation is on the next page.)

- A. Estimate the energy you spend on basal metabolism by using the figure 1.0 kcal per kilogram per hour (for men) and 0.9 kcal (for women) and then multiply by 24 hours. Estimate your basal metabolism using your desirable weight not your actual weight. Estimate your desirable weight using the tables on pages 234 and 235 of your text.

Basal Metabolism \_\_\_\_\_ kcal

- B. Estimate the energy you spend on physical activities by using the following guidelines. For sedentary (mostly sitting activity - a professor), take 20 percent of the energy spent on basal metabolism (A). For light activity (a student), take 30 percent. For moderate activity (a nurse), take 40 percent. Or for heavy work (a roofer), use 50 percent or more.

Activity \_\_\_\_\_ kcal

- C. Estimate the energy spent on metabolizing food as 10 percent of your 3 day average caloric intake.

Thermic Effect of Food (TEF) \_\_\_\_\_ kcal

- D. Now add these three figures together.  $A + B + C =$  (TEE) Total Energy Expenditure \_\_\_\_\_ kcal

APPENDIX D  
CONSENT FORM, EXPERIMENT 2

## CONSENT FORM

This study is being conducted to identify the users of food and beverage products sweetened with aspartame and to examine aspartame's association with weight gain, loss, or maintenance. Your participation in this study would be greatly appreciated. You will be asked to complete the attached questionnaire and to have your weight and height measured. All information will be completely confidential. Your name will be stricken from the questionnaire after your TEE and 3 day average intake are recorded from your project. Only a number (used for analysis purposes) will remain on the questionnaire. After signing both consent forms, please keep one copy for your own records and place the other copy in the envelope marked CONSENT FORMS.

Thank you for your cooperation.

I have read the above information and I agree to participate in this project.

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SIGNATURE

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DATE

APPENDIX E  
DATA FROM EXPERIMENT 1

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Values for Dependent Variables for  
Animal Treatment Groups and Controls

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n=10

Variable	Mean	Standard Deviation	Range
TREATMENT 1 (10% sucrose)			
WEIGHT (gm)	200.4	8.3	190.0-211.0
FOOD (gm)	435.0	112.6	126.0-516.0
WATER (ml)	401.3	128.1	205.0-608.0
SOLN (ml)	1050.6	235.2	610.0-1274.0
KCAL	2160.2	413.1	1013.6-2447.6
TREATMENT 2 (50% sucrose)			
WEIGHT (gm)	195.4	17.6	159.0-216.0
FOOD (gm)	365.6	57.1	271.0-469.0
WATER (ml)	425.5	134.5	217.0-627.0
SOLN (ml)	499.5	74.3	357.0-583.0
KCAL	2461.4	178.6	2218.0-2836.0
TREATMENT 3 (0.05% aspartame)			
WEIGHT (gm)	201.0	21.5	173.0-232.0
FOOD (gm)	593.8	70.9	485.0-704.5
WATER (ml)	757.9	161.2	451.0-944.0
SOLN (ml)	220.3	113.5	120.5-418.0
KCAL	2365.8	282.1	1940.5-2818.3
TREATMENT 4 (0.25% aspartame)			
WEIGHT (gm)	201.4	16.8	180.0-241.0
FOOD (gm)	549.8	103.4	401.0-745.0
WATER (ml)	694.1	140.3	389.0-926.0
SOLN (ml)	301.0	151.0	130.0-657.0
KCAL	2202.2	414.1	1607.6-2986.6
TREATMENT 5 (Control)			
WEIGHT (gm)	189.5	25.6	155.0-237.0
FOOD (gm)	570.7	54.6	501.0-649.0
WATER (ml)	960.7	144.1	675.0-1180.0
SOLN (ml)	---	---	---
KCAL	2282.8	218.5	2004.0-2596.0

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APPENDIX F

ANOVA PROCEDURE FOR DEPENDENT VARIABLES, EXPERIMENT 1

Analysis of Variance Procedure  
(ANOVA)  
for Experiment 1

Dependent Variable	Mean	ANOVA Sum of Squares	F Value	P>F
Weight	197.6	1071.6	0.7	0.561
Food	503.0	385300.1	13.9	0.001
Water	647.9	2223516.0	27.5	0.001
Kcals	2294.5	596271.9	1.5	0.222
Soln	517.9	4196145.0	57.9	0.001

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APPENDIX G  
DATA FROM EXPERIMENT 2

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 Data Collected from Student Questionnaire
 

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VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
AGE (yrs)	280	20.6	1.6	18.0	34.0
DFT	280	3.8	5.4	0.0	21.0
ARTIFICIAL SWEETENER USE:					
DIET SODA (12 oz./day)	280	0.9	1.2	0.0	6.0
PACKS/day	280	0.5	1.3	0.0	9.0
OTHER (servings/day)	280	0.1	0.3	0.0	1.5
TOTAL (Servings/day)	280	1.5	2.1	0.0	12.5
TEE (kcal)	246	2235.6	558.2	1161.0	4995.0
ACI (kcal)	246	2078.6	962.1	584.0	6300.0
HT (cm)	280	171.5	9.6	147.0	198.0
WT (kg)	280	68.1	14.0	45.1	131.4
LAST WT (kg)	276	66.3	13.5	40.8	117.9
WT CHANGE (kg)	276	1.9	4.7	-16.5	18.1

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Data Collected from Questionnaire  
for Females

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Variable	N	Mean	Standard Deviation	Minimum Value	Maximum Value
AGE (yrs)	158	20.3	1.8	18.0	34.0
DFT	158	5.8	6.3	0.0	21.0
ARTIFICIAL SWEETENER USE:					
DIET SODA (12 OZ/day)	158	1.1	1.4	0.0	6.0
PACKS/day	158	0.8	1.6	0.0	9.0
OTHER (servings/day)	158	0.1	0.3	0.0	1.5
TOTAL (servings/day)	158	2.0	2.4	0.0	12.5
TEE (kcal)	140	1874.8	309.7	1161.0	3937.0
ACI (kcal)	140	1671.4	676.5	584.0	4190.0
HT (cm)	158	165.8	7.6	147.0	190.5
WT (kg)	158	60.2	8.4	45.1	91.9
LAST WT (kg)	155	58.5	7.8	40.8	86.2
WT CHANGE (kg)	155	1.8	4.5	-16.5	17.6

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Data Collected from Questionnaire  
for Males

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Variable	N	Mean	Standard Deviation	Minimum Value	Maximum Value
AGE (yrs)	122	20.9	1.3	18.0	25.0
DFT	122	1.3	2.2	0.0	12.0
ARTIFICIAL SWEETENER USE:					
DIET SODA (12 oz. /day)	122	0.6	1.0	0.0	5.0
PACKS/day	122	0.2	0.6	0.0	3.0
OTHER (servings/day)	122	0.1	0.3	0.0	1.5
TOTAL (servings/day)	122	0.9	1.3	0.0	6.0
TEE (kcal)	106	2712.3	443.9	1505.0	495.0
ACI (kcal)	106	2516.4	1020.3	1009.0	6300.0
HT (cm)	122	179.0	6.3	161.5	198.0
WT (kg)	122	78.4	13.0	57.4	131.4
LWT (kg)	121	76.5	12.6	49.9	117.9
WT CHANGE (kg)	121	2.0	4.9	-16.5	18.0

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AGE DISTRIBUTION

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AGE	FREQUENCY	PERCENT	PERCENT
18	24	8.6	8.6
19	37	13.2	21.8
20	73	26.1	47.9
21	82	29.3	77.1
22	47	16.8	93.9
23	11	3.9	97.9
24	3	1.1	98.9
25	1	0.4	99.3
28	1	0.4	99.6
34	1	0.4	100.0

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DISTRIBUTION BY SEX

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SEX	FREQUENCY	PERCENT
FEMALE	158	56.4
MALE	122	43.6

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DISTRIBUTION BY ETHNIC GROUP

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ETHNIC GROUP	FREQUENCY	PERCENT	CUMULATIVE PERCENT
CAUCASION	246	87.9	87.9
BLACK	23	8.2	96.1
ORIENTAL	5	1.8	97.9
OTHER	6	2.1	100.0

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APPENDIX H

FOOD FREQUENCY DATA - EXPERIMENT 2

FOOD FREQUENCY DATA FOR CONSUMPTION OF FOOD AND BEVERAGE  
PRODUCTS CONTAINING ARTIFICIAL SWEETENERS (EXCLUDING  
DIET SODAS AND TABLE TOP ARTIFICIAL SWEETENERS)

<u>PRODUCT</u>	FREQUENCY OF CONSUMPTION FOR TOTAL SAMPLE					
	<u>Never</u>	<u>Once/ Month</u>	<u>Once/ Week</u>	<u>3-4 Days/ Week</u>	<u>Once/ Day</u>	<u>&gt;1/ Day</u>
Sugar-Free Hot Cocoa Mix	270	4	0	0	6	0
Sugar-Free Gelatin	274	3	0	0	3	0
Sugar-Free Instant Pudding	276	3	0	0	1	0
Sugar-Free Popsicles	272	1	2	0	5	0
Sugar-Free Instant Coffee/Tea	228	15	20	0	17	0
Sugar-Free Instant Breakfast	275	3	0	0	2	0
Sugar-Free Chocolate Milk Maker	278	1	0	0	0	1
Sugar-Free Powdered Soft Drinks	237	8	18	0	17	0
Sugar-Free Shake Mixes	278	1	1	1	0	0
Artificially Sweetened Cereals	270	3	0	0	7	0

## VITA

Elizabeth M. Kitchin was born on February 1, 1964 in Atlanta, GA. Ms. Kitchin attended James Madison University in Harrisonburg, VA and graduated with a Bachelor's Degree in Dietetics in May 1986. She subsequently began working towards her graduate degree in Human Nutrition and Foods at Virginia Polytechnic Institute and State University. Ms. Kitchin plans to complete her graduate degree in the summer of 1990. She presently works as a clinical nutritionist at the University of Tennessee Medical Center in Knoxville, Tennessee where she specialized in patient counseling and in community nutrition education. She plans to take the registration exam for dietetics in October, 1990.