CORRELATION BETWEEN THE SUCROSE CONCENTRATION AND GLYCEMIC LOAD OF FOODS USED IN FOOD FREQUENCY QUESTIONNAIRES: AN EXPLANATION FOR THE PUTATIVE ROLE OF DIETARY SUCROSE IN LUNG CARCINOGENESIS?

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To the Dean of the Graduate School:

I am submitting herewith a thesis written by Roberto Gonzalez entitled "Correlation between the Sucrose Concentration and Glycemic Load of Foods used in Food Frequency Questionnaires: An Explanation for the Putative Role of Dietary Sucrose in Lung Carcinogenesis?" I have examined this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Nutrition.

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ABSTRACT

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CORRELATION BETWEEN THE SUCROSE CONCENTRATION AND GLYCEMIC LOAD OF FOODS USED IN FOOD FREQUENCY QUESTIONNAIRES: AN EXPLANATION FOR THE PUTATIVE ROLE OF DIETARY SUCROSE IN LUNG CARCINOGENESIS?

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Researchers have investigated how dietary intake affects lung cancer risk. The literature indicates that sucrose may potentially play a role in lung cancer carcinogenesis. This study examined the sucrose content and glycemic load of foods commonly found in seven food frequency questionnaires (FFQs) to investigate if a correlation exists between these two variables. Values for sucrose concentration and glycemic load were obtained by carrying out an extensive review of the literature using databases such as PubMed, AGRICOLA, and the United States Department of Agriculture's Standard Release series. Correlational analysis was carried out. The findings indicate that there is a statistically significant relationship between the sucrose concentration of the foods commonly found in FFQs and their glycemic loads, $r = 0.31$, $p < .001$. This indicates that the putative role of dietary sucrose in the incidence of lung cancer is supported.

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CHAPTER I

INTRODUCTION

Chronic diseases such as diabetes, heart disease, and cancer, have become widespread as the world has modernized. Western cultures, particularly, have seen a tremendous increase in the incidence of some chronic diseases. Dietary factors may be causally related to this increased incidence. Research on the factors causally involved in cancer has received great attention due to the huge impact that the disease has on patients, patients' families, and on society in general. Lung cancer, in particular, has been the subject of much research due to the fact that smoking is very prevalent in the United States and other Westernized countries, and the fact that this disease has a poor prognosis. The possible impact of nutritional factors on lung cancer incidence has been overshadowed by the focus on the use of tobacco as a causal agent. The role of nutrition in the development of lung cancer should be investigated because many people who use tobacco do not get lung cancer, while many people who do develop lung cancer do not smoke or use tobacco products. Thus smoking is not the sole determinant of who will or will not develop lung cancer. Other determinants, which include diet, may also play a role. Also, the diets of smokers may be different from those of nonsmokers, making this a cofounder when quantifying the contribution of smoking to cancer incidence. It is important to research factors that increase the risk of smokers' getting lung cancer as many people who smoke have great difficulty in quitting, and research may lead to

nutritional interventions. These interventions may decrease a smoker's chance of getting lung cancer.

Lung Cancer

Lung cancer is just one of the many types of cancers that affects millions of people worldwide. At the end of the 20th century lung cancer became one of the world's leading causes of preventable death (Alberg & Samet, 2003). Smoking has been known to be the key cause of most lung cancers for some time. Although tobacco use throughout history has been well known and documented in many cultures, the present pandemic of lung cancer followed the introduction of manufactured cigarettes with addictive properties, which resulted in a new pattern of sustained exposure to the lungs of inhaled carcinogens. Case-control studies taking place as early as the 1950's in Britain and the United States showed that there was a strong association between cigarettes and the risk of lung cancer. By 1964 there was enough evidence to support a conclusion by the United States Surgeon General that cigarette smoking caused lung cancer (Alberg & Samet).

Today lung cancer is still a very serious and deadly form of cancer, and with an ever-growing population of smokers it will continue to be a prominent form of cancer. It has been estimated that about 23% of adults in the United States were current smokers during the period between 1999–2001. About 46% of these smokers reported smoking less than 15 cigarettes per day, while 39% said that they smoked 15 to 24 cigarettes per day (Stat Bite, 2004). These numbers represent a large portion of the population of the United States. It has been shown that the risk for lung cancer among cigarette smokers increases with the duration of smoking and the number of cigarettes smoked per day.

This observation has been made repeatedly in cohort and case-control studies over time (Alberg & Samet, 2003). With one quarter of the population reporting that they smoke, and one-third of these smokers smoking greater than 15 cigarettes per day it seems that lung cancer will continue to be a key concern for public health officials for some time to come.

Lung Cancer and Nutrition

Other risk factors for lung cancer may include dietary factors, such as macronutrients, micronutrients, and non-nutrients. Studies focusing on the role of nutrition in the development of lung cancer have focused on the intake of various foods or micronutrients to ascertain if any of these can help in the prevention of this disease. Studies attempting to find a preventative or causal link between nutrients and lung cancer date as far back as the 1970's.

The first four major studies on lung cancer and nutrition were conducted during the mid to late 1970's. These studies found that a higher consumption of green and yellow vegetables or foods high in vitamin A approximately halved the risk of developing lung cancer (Koo, 1997). These initial studies were the foundation for much of the research into the role of diet in the development of lung cancer carried out in the 1980's and 1990's. Other investigators who carried out research on the role of diet and the prevention of cancer also demonstrated that increased consumption of carotenoids is associated with a reduced risk of lung cancer (ATBC, 1994; Koo, 1997; Omenn et al., 1996a). The findings of these studies led to the development of several studies trying to

discover the relationship of the various dietary forms of vitamin A and lung cancer incidence.

A few examples of other nutrients and foods that have been investigated as being preventive against the development of lung cancer include vitamin C, selenium, fat/cholesterol intake, vitamin E, and soy products. At times the conclusions from some of the studies on nutrition and lung cancer are actually contradictory. A Swedish study for example found a tendency for an increased risk of lung cancer related to milk consumption, and this was due to a significantly increased risk for adenosquamous cell carcinoma. Two studies from Norway found contradictory data, and actually showed in a follow-up study on 168 cases of lung cancer, milk was found to be a protective factor (Axelsson & Rylander, 2002).

Macronutrients appear to have not been as widely studied as micronutrients in the development of lung cancer, although the role of sucrose, a carbohydrate, has been studied, albeit on a limited basis. Sucrose, or table sugar, is widely used in the food industry, and is a source of empty calories. Sucrose also occurs naturally in some foods, particularly fruits. A Uruguayan case-control study, designed to determine the relationship between lung cancer and fat consumption, indicated that the consumption of desserts rich in sucrose might lead to an increased risk of developing lung cancer. The authors hypothesized that foods rich in sucrose enhance hyperinsulinemia, which has also been suggested as a risk factor for other cancers, including colon cancer (De Stefani et al., 1997). The authors concluded that it remains to be determined whether sucrose is a risk factor for lung cancer, after controlling for energy and fat intake.

Problem Statement

There is epidemiological evidence that dietary sucrose may increase the risk of developing lung cancer. Evidence from epidemiological studies carried out with other forms of cancer suggests a causal role in lung carcinogenesis for diets having a high glycemic load. There is, therefore, a need to determine whether the putative causal role of dietary sucrose in lung cancer carcinogenesis may be mediated as the result of an increased dietary glycemic load. This in turn may stimulate hyperinsulinemia, a stimulus to cellular proliferation. Because food frequency questionnaires (FFQs) are used in conjunction with nutrient databases in epidemiological studies, the correlation between sucrose concentration and glycemic load could be studied using foods commonly used in FFQs.

Null Hypothesis

There will be no correlation between the sucrose concentration and glycemic load of foods used in food frequency questionnaires.

CHAPTER II

REVIEW OF LITERATURE

Non-Smoking Risk Factors for Lung Cancer

Second-hand smoke, also known as passive smoking, is the involuntary inhalation of tobacco smoke by nonsmokers. Exposure to second-hand smoke has also been shown to increase the risk of developing lung cancer. It has been estimated that there are some 3,000 deaths annually in the United States that can be accredited to passive smoking (Alberg & Samet, 2003). The National Research Council reviewed epidemiological evidence and concluded that nonsmoking spouses who were married to cigarette smokers were about 30% more likely to develop lung cancer than nonsmoking spouses who were married to nonsmokers, and that the relationship was biologically plausible. Almost one fourth of lung cancer cases among never-smokers were estimated to be attributed to exposure to passive smoking (Alberg & Samet).

Lung and bronchus cancers were the most important cause of cancer mortality during the 1990s. It is estimated that approximately 28% of all cancer-related deaths during that decade were related to lung or bronchus cancer. Approximately 90% of those deaths have been attributed to smoking (Gargiullo, Wingo, Coates, & Thompson, 2002).

There are also other possible factors that can contribute to the development of lung cancer. Although smoking and second hand smoking are the most commonly seen causes of lung cancer other causal agents have been identified. Radon for example is one

of the substances found to be a carcinogenic agent in lung cancer. It has been hypothesized that exposure to radon was a cause of lung cancer in underground miners. Thus, radon may be classified as an occupational respiratory carcinogen. Today radon in indoor environments is considered to be a significant cause of lung cancer (Alberg & Samet, 2003). There are other occupational carcinogens that can lead to the development of lung cancer. Occupational causes of lung cancer also include exposure to arsenic, asbestos, chromates, chloromethyl ethers, nickel, polycyclic aromatic hydrocarbons, radon progeny, and other agents (Alberg & Samet). It is estimated that 4,000 to 6,000 deaths a year from lung cancer may be attributable to exposure to asbestos (Omenn et al., 1996a). Both outdoor and indoor pollution have also been linked to the development of lung cancer. In some developing countries, exposure to fumes from cooking stoves and fires has been associated with lung cancer risk. Indoor air may also contain several carcinogens including radon, asbestos, and cigarette smoke (Alberg & Samet).

Nutritional Studies and Lung Cancer

Beta-carotene was one of the first compounds to be investigated in the prevention of lung cancer. There was special interest in beta-carotene because of its potential role as an antioxidant and its possible role in preventing lung carcinogenesis. With initial support form cohort and case-control studies associating the consumption of beta-carotene with a reduced risk of developing lung cancer various studies were initiated to test the use of high levels of beta-carotene in hopes that it might reduce death rates from lung cancer and possibly other causes (Koo, 1997). These studies included two of particular interest.

One named the ATBC (alpha-tocopherol beta-carotene) Cancer Prevention Study, and another named the beta-carotene and retinol efficacy trial or CARET.

The ATBC study was a Finnish study that indicated that beta-carotene might actually have adverse effects in lung cancer. This study was conducted with 29,133 adult male smokers. The participants were divided into one of four treatment groups. Participants received either alpha-tocopherol (50 mg per day) alone, beta-carotene (20 mg per day) alone, both alpha-tocopherol and beta-carotene, or placebo. Alpha-tocopherol was supplied as synthetic dl-alpha-tocopherol acetate, and beta-carotene was supplied as synthetic beta-carotene (ATBC, 1994). Participants in this study were followed for a time period of five to eight years. During the course of this study 876 new cases of lung cancer were diagnosed. This study revealed that there was no reduction in the incidence of cancer observed in the group receiving only alpha-tocopherol. The group receiving the β-carotene had an 18% higher incidence of lung cancer, and an 8% higher total mortality rate than those who did not take the supplement (Koo, 1997). The study found no evidence of an interaction between alpha-tocopherol and beta-carotene with respect to the incidence of lung cancer. The authors concluded that they could not find any reduction in the incidence of lung cancer among male smokers after five to eight years of dietary supplementation with alpha-tocopherol or beta-carotene. In fact, the results of this trial raised the possibility that these supplements may have harmful as well as beneficial effects with respect to lung cancer.

The CARET study, conducted in the United States, was initially started in 1983. This study also attempted to decipher the effect that beta-carotene may have on lung

cancer incidence. This study was designed to test the combination of 30mg beta-carotene and 25,000 IU retinyl palmitate (vitamin A) taken daily versus a placebo in 18,314 men and women at high risk of developing lung cancer. It was hypothesized that beta-carotene and vitamin A may have a favorable effect through complementary molecular actions. The CARET intervention was stopped 21 months early in January of 1996, as there was no clear evidence of benefit and substantial evidence of possible harm of the supplementation with beta-carotene (Omenn et al., 1996b). The authors concluded that those CARET participants who were receiving the combination of beta-carotene and retinyl palmitate received no chemopreventive benefits and actually had an excess lung cancer incidence and mortality. This study showed that there were 28% more lung cancers and 17% more deaths in the active intervention group of the study, that is those who were receiving the combination of beta-carotene and retinyl palmitate (Omenn et al. 1996a). These results were consistent with the findings of the Finnish ATBC study. The CARET study indicates that individuals at high risk of developing lung cancer, such as current smokers or asbestos-exposed workers, should be discouraged from taking supplemental beta-carotene, and the combination of beta-carotene with vitamin A (Omenn et al. 1996b).

Glycemic Index and Glycemic Load

The concept of the glycemic index (GI) was first proposed during the early 1980s by David Jenkins and colleagues. The GI rates foods relative to either 50 g of glucose or 50 g worth of carbohydrate as white bread, for their ability to raise blood glucose concentrations post prandially, that is 2-3 hours past dosing, for a given carbohydrate

intake, which is usually 50 g. The GI compares how a food item raises blood glucose levels compared to the test food, which is glucose or white bread. The GI is defined as the area under the 2-hour glucose curve of a test food expressed as a percentage of the appropriate mean of the glucose tolerance test value (Jenkins et al., 1981). Thus GI may be a way to measure the body's potential insulin response to various foods. The GI of foods can be affected by various factors that include a food's fiber content, moisture content, cooking method, and a food's particle size. Fat and protein also appear to affect the GI of foods. A significant negative relationship is seen between fat and protein content of the foods and the glycemic index (Jenkins et al.).

The glycemic load (GL) of a food is used to show a combination of quality as well as quantity of carbohydrates consumed, and thus it is a measure of dietary insulin demand. Thus the GL of a typical serving of food is the product of the amount of available carbohydrate in that serving and the GI of the food. The international table of GI and GL determines GL by multiplying the available carbohydrate per serving and the food's GI value with glucose as the reference food (Foster-Powel, Holt, & Brand-Miller, 2002). Many studies appear to prefer using the GL to just the GI to determine if there is a relationship between sucrose and carbohydrate intake and various cancers. Because of its ability to quantify the amount of sucrose and carbohydrate intake the GL does appear to be a better measure of intake and insulin demand.

Sucrose, Other Refined Carbohydrates, and Cancers

Many studies have tried to unravel if any relationship exists between carbohydrate and sucrose intake and increased risk of various cancers. These studies focusing on

cancer and its interaction with refined carbohydrate link the putative causal role of dietary sucrose to its ability to augment the overall dietary GI and GL. GI and GL are two indices that reflect a food's ability to raise blood glucose levels.

One study of particular interest that used the GI and GL to test for cancer risk was conducted in Italy. This case-control study on colorectal cancer was designed to determine if a high GI or GL increases the risk of developing colorectal cancer. The authors used a 77-item food frequency questionnaire (FFQ) to assess the participants' habitual diet, energy intake, as well as typical consumption of foods and food groups (Decarli et al., 1996). Intake patterns were used to calculate a daily GI and GL for each individual. Daily levels of GI and GL were then broken into quintiles for which odds ratios and the corresponding 95% confidence intervals were derived. The authors found that colorectal cancer risk increased with an increase in GI and GL. Odds ratio for the highest versus lowest quintile of GI was 1.7; 95% Confidence Interval (CI): 1.4-2.0, and for GL was 1.5; 95% CI:1.5-2.2. (Franceschi et al., 2001). Colon cancer had higher odd ratios with 1.9 for both GI and GL in the highest quintile than for rectal cancer, which had odd ratios of 1.4 and 1.5 respectively. It was concluded that a diet that increases glycemic response is involved in the etiology of cancers of the colon-rectum, particularly of those, which arise from the colon. It was suggested that the positive associations observed between GI and GL and colorectal cancer were amongst the strongest reported to that time for any dietary factor, and were consistent in different strata of age, sex, and various risk covariates (Franceschi et al.).

Another Italian study was designed to determine if either the intake of carbohydrate or sucrose intake was associated with the risk of developing breast cancer. The main basis for the hypothesis was that diet may affect breast cancer risk, based on the ecological observation that breast cancer rates are up to six times higher in Western countries than in countries whose population does not follow the typical western diet. The western diet is characterized by high intakes of animal products and refined carbohydrate foods (Key, 2001). The authors of this study also used a 78-item FFQ item to determine the dietary habits of participants during the two years prior to cancer diagnosis (Augustin et al., 2001). The authors collected data on total energy intake, the average weekly frequency of consumption of foods or food groups (Augustin et al.). After adjusting for suspected risk factors, a direct association emerged for breast cancer risk and GI. The association for GL with breast cancer was apparently stronger in postmenopausal women. The risk of developing breast cancer was related to consumption of refined carbohydrate foods with typically high GI values, while the consumption of pasta, a medium GI food, did not affect the risk of breast cancer regardless of menopausal status (Augustin et al.).

Another study involved the use of GI and GL to determine the risk of consumption of higher GI and GL foods with increased risk for pancreatic cancer. Previous studies had suggested that glucose intolerance and insulin resistance played a role in pancreatic carcinogenesis; dietary factors that increased postprandial plasma glucose levels were hypothesized to have a direct impact on the risk of developing pancreatic cancer. Given that high GI and GL have been observed to be associated with the risk of diabetes, heart disease, and lipid levels in the cohort, the researchers chose to

examine these variables in the study. The researchers used a FFQ to determine average frequency of intake over the previous year for a specified serving size of each food on the questionnaire, and then calculate GI and GL for each participant (Michaud et al., 2002). The researchers found that among participants there was no consistent trend when examining the association between carbohydrate intake and the risk of pancreatic cancer. After controlling for a number of risk factors, the researchers observed a 53% increase in risk of pancreatic cancer for women in the highest quintile of glycemic load intake as compared to women in the lowest quintile. However the increase was not statistically significant nor was it monotonic across quintiles. The research did find that dietary GL, GI, and fructose intakes were statistically significantly associated with the risk of pancreatic cancer among women who were overweight and sedentary but not among women who were lean and physically active (Michaud et al.).

Digestion and Metabolism of Sucrose and Other Sugars

Sucrose, or table sugar, is a major component of many foods. This dietary carbohydrate is found naturally in plants. Sucrose is also added to many foods and comes from commercially grown sugar cane and sugar beets. Sucrose is a disaccharide resulting from the covalent bond formed between glucose and a fructose molecule. The resultant disaccharide is named α-D-glucopyranosyl-(1→2)-β-D-fructofuranoside (Stipanuk, 2000). The metabolism of sucrose begins when it reaches the small intestine. The enzyme sucrase found along the brush border region of the small intestine hydrolyzes sucrose into glucose and fructose (Marieb, 1998). A similar process is used by the body to metabolize two other common sugars, maltose and lactose, which are also commonly found in many

foods. Maltose is the disaccharide formed from the covalent bond between two glucose molecules. Maltose is hydrolyzed by the enzyme maltase in the small intestine. Lactose or milk sugar is the disaccharide that results from the boding of a molecule of galactose with a molecule of glucose. Lactose is hydrolyzed into its founding molecules by the enzyme lactase (Marieb).

After this initial digestion process, the resultant monosaccharides are then absorbed by the enterocytes of the brush border. A special sodium glucose transporter, or SGLT1, is used for the uptake of glucose and galactose from the intestinal lumen into the enterocyte. Fructose is absorbed into the enterocyte by the brush border membrane protein GLUT5, which effectively transports luminal fructose and functions independently of sodium (Stipanuk, 2000). Uptake and accumulation of these monosaccharides occurs allowing them to enter the enterocyte. The monosaccharides exit down a concentration gradient into the extracellular milieu beneath the enterocyte layer, from which these can then enter the capillary beds of the portal system (Stipanuk). The digestion and absorption of sugars officially ends in the small intestine because the colon does not secrete digestive enzymes. Resident colonic bacteria though do break down and metabolize some residual complex carbohydrates and some sugars (Marieb, 1998).

The liver plays the main role in the metabolism of the monosaccharides. The metabolic pathways used for the metabolism of the monosaccharides are very complex and use many different cellular processes, many of which originate in the liver. The glycolic pathway is the major cellular level process of breaking down glucose for energy. This process is used to form adenosine triphosphate, or ATP, which is an organic

molecule, that stores and releases chemical energy for use in body cells. Fructose and galactose are normally first converted to glucose by the liver before they enter the general circulation. These molecules may also be converted into intermediates of glycolysis (Stipanuk, 2000). The glycolic pathway is the main, but not the only, way we make and store the energy needed to carry out even the most basic of life processes.

When carbohydrates are available in greater quantities than needed to meet energy needs, thus excess glucose, for example, can be converted into glycogen in the skeletal muscle, the heart, and the liver. This glycogen can then be broken down into glucose at a later time when blood glucose levels need to be raised. Excess glucose can also be converted into triglycerides in the adipose tissue (Marieb, 1998). Hence excess carbohydrates and sugars can be a major cause of overweight and obesity.

Food Frequency Questionnaires

FFQs are widely used in many epidemiological studies including those that study the role of diet in the development of different cancers. They are integral tools used to determine the typical intake of foods and supplements used by study participants. FFQs can be created to suit a researcher's particular needs, hence a great variety of FFQ have been developed over the years.

FFQs can vary greatly in terms of the number of food items that are incorporated into them. FFQs may also question a participant about what specific foods he or she consumes on a regular basis while others, like the Harvard University FFQ, will ask if certain foods are consumed and if so in what quantities are they consumed. Some FFQs have been developed to be self administered by the study participant, while others are to

be administered through an interview by a researcher or research assistant (Molag et al, 2007). Differences in the development of FFQs, variations in design, and FFQ characteristics, could ultimately affect reported intakes. Because of these possibilities FFQs are regularly tested for validity and reliability. By testing a FFQ for validity and reliability the researcher will be able to assure that their FFQ is actually measuring what the researcher wants to be measured and that the FFQ will do so in a predictable manner (Molag et al.).

FFQs are very useful tools but having to create a FFQ from scratch could be an overwhelming and time consuming task for a researcher. One of the negative aspects of creating a brand new FFQ is that a researcher would also have to be concerned with getting his or her new FFQ validated. One option that researchers have is to modify a preexisting FFQ that has already been validated. A very valuable aspect of FFQs is that a person can use an already existing FFQ as the framework for new modified FFQ. If a researcher has a specific research interest, or has a specific population, age group, he or she is targeting by using a preexisting FFQ they can save valuable time, effort, and money. (Shatensteini et al., 2005)

Case-Control Studies

A case-control study is a type of study used in research that attempts to find what characteristics place people at risk for certain conditions. Case-control studies begin with the selection of cases, or participants that have a given condition that is being studied. A researcher will then choose a group of participants to be part of the control group. The control group is defined as those members of the study that do not have the condition that

is being studied. This group is chosen strictly for use as a comparison group. In case-control studies researchers look into the study subjects' history to try to determine if the case and control groups have different histories of exposure or if a group has the presence of any specific characteristics that might have placed them at higher risk for developing the condition being studied. In case-control studies the generated data are used to derive an odds ratio to show the probability that an exposure may have caused a certain condition (Portney & Watkins, 2000).

Case-control study may be useful for some researchers because finding subjects is usually relatively easy. Case-control studies are also useful for analyzing conditions and disorders that take years to develop. Other studies, for example longitudinal studies, could require years to identify participants who developed the condition. Whereas in a case-control study a researcher could use subjects that already have the condition, and compare the cases to controls, so saving years or even decades worth of research. (Portney & Watkins, 2000).

Investigators frequently use case-control studies in their nutrition-based research. FFQs are often used in these studies to see what kinds of foods and nutrients are and were consumed by participants. FFQs used in conjunction with nutrient databases are used to analyze the foods consumed by the participants in these studies. The data can show the makeup and quantity of different macronutrients and micronutrients that are present in the participants' diets. The generated data can be used to find differences in intake patterns. Researchers can then use the data to conclude what macronutrients or micronutrients can help prevent or reverse certain conditions.

Relative Risk, Odds Ratio, and Calculations

The term odds ratio (OR) is used in case-control studies to estimate the relative risk for certain conditions. Relative risk (RR) is a measure, which indicates the likelihood that someone who has been exposed to a risk factor will develop the condition, as compared with one whom has not been exposed. In case-control studies RR cannot be used because researchers cannot accurately calculate cumulative incidence, because subjects are purposefully chosen based on the presence of absence of disease. Hence researchers cannot determine the rate of incidence of the disease (Portney & Watkins, 2000).

RR is often used in cohort studies that follow subjects for months or even decades. A randomized clinical trial where participants are randomly allocated to the exposure or no exposure group, also know as the no treatment group, is an example of these studies. These studies attempt to show if a relationship exists between specific exposures or characteristics and specific conditions. These studies establish if an association exists and the strength of that association. If an association does exist it is said that the specific exposure represents a risk factor. RR is defined as the ratio of incidence of disease among those who have been exposed to a risk factor compared to the incidence of disease among the unexposed. RR is calculated as follows:

$$RR = CI_E / CI_O = [\, a / (a + b) \,] / [\, c / (c + d) \,]$$

Where (a) represents those who have the disease and were exposed, (b) represents those who do not have the disease and were exposed, (c) represents those who have the disease and were not exposed, and (d) represents those who do not have the disease and were not exposed. CI_E represents the cumulative incidence estimate for the exposed group and CIO represents the cumulative incidence estimate for the unexposed group. The numbers generated from the use of this equation give us an estimate of the risk a person has to a certain condition if they are exposed to a risk factor (Portney & Watkins, 2000).

OR is an estimate of relative risk and is calculated as follows:

$$OR = [\, a / c \,] / [\, b / d \,] = ad / bc$$

OR can then be calculated from the data that is generated from case-control studies. For example if the rate of the disease among the exposed (a) was 4, and the rate of no disease among the exposed (b) was 3, and the rate of the disease among the not exposed (c) was 147, and the rate of the no disease among the not exposed (d) was 542, OR would be calculated as follows:

$$OR = ad / bc = [\, (4)\,(542) \,] \;/\; [\, (3)\,(147) \,] = 4.92$$

This means that the odds of having the disease among the exposed are almost five times greater for those who have the risk factor than for those who do not (Portney & Watkins, 2000).

CHAPTER III

MATERIALS AND METHODS

The process of selecting foods for possible inclusion in this study was based on a review of seven FFQs commonly used in the United States. The FFQs included in this study include that used by Dr. Walter Willett at Harvard University, which was used for the Nurses Health Study (Willett et al., 1985). The FFQ used by the Department of Epidemiology at the University of Texas M.D. Anderson Cancer Center (MDACC) was also used (Borrud, McPherson, Nichaman, Pillow, & Newell, 1989). The FFQs used in this study also included the Southwest FFQ from the University of Arizona, the Fred Hutchinson Cancer Research Center FFQ, the Health Habits and History Questionnaire, the National Health and Nutrition Examination Survey III FFQ, and the FFQ used for the Hawaii and Los Angeles Cohort Study (Thompson & Byers, 1994). A food or food category had to be present in at least 50% of all FFQs to have been included in this study. Analysis to determine which foods from these FFQ were eligible for inclusion in this study was performed using Microsoft's Excel program.

Values for the sucrose concentration as well as the GI and GL were obtained by carrying out an extensive review of the literature using databases such as PubMed, AGRICOLA, and the United States Department of Agriculture's (USDA) Standard Release Editions 17-21. When values could not be located, a recipe analysis will be

carried out. For the calculation of GI and GL, a weighted method was used. The equation to calculate the weighted glycemic index is as follows:

$$^{n}\Sigma_{i=1}\, GI_i \times CHO_i \,/\, ^{n}\Sigma_{i=1}\, CHO_i$$

Where GI_i is the glycemic index of the $food_i$, and CHO_i is the carbohydrate content of the $food_i$ (in grams). Correlational analyses will be carried out, and a p-value of less than or equal to 0.05 will be considered statistically significant.

CHAPTER IV

RESULTS

Foods that were to be used in this study were selected from seven of the major FFQs that are available to researchers. The foods and categories that are listed below in Table 1 and Table 2 appear as they are listed in the FFQs used in this study. Table 1 is a list of the foods that were determined to be eligible for analysis and inclusion into this study. Foods had to have been included in at least 50% of the FFQs to be included in this study. Table 1 also indicates in which FFQs foods were not included. Table 2 lists the foods that were determined to be ineligible for analysis and inclusion into this study because they were not included in at least 50% of FFQ, along with a listing of the FFQs in which these foods were included.

For the tabulation of the values for parameters of interest, 119 foods were selected. Table 3 shows a summary of the individual foods that were analyzed and included in this study. Foods are arranged according to their Nutrient Databank numbers (NDB). Please note that there are foods listed in Table 1 who were eligible for inclusion into this study but were not analyzed and do not appear in Table 3. These foods including meats, fish, butter, certain salad vegetables, avocados, different cheeses, cream, wine and eggs were not included in final analysis because they do not have GI or GL values. These foods have little or no carbohydrate making it difficult to test for GI and GL. Even if eaten in large amounts they would not be likely to induce a significant rise in blood glucose (Foster-Powel, Holt, & Brand-Miller, 2002). Please note that miso soup is

included in the ineligible list yet was still included in the final analysis. Miso soup with white rice was still included in the study analysis in order to substitute for a MDACC FFQ food item.

Table 4 shows the correlational analysis for sucrose and glycemic load per serving.

Table 1

Summary of FFQ Foods and Food Categories Deemed Eligible for Analysis

Food (NDB Food category)	Percentage of FFQs having food	FFQs in which food was not included
Milk, skim (1)	100%	Not applicable
Milk, 1 or 2% (1)	100%	Not applicable
Milk, whole (1)	100%	Not applicable
Cream (1)	83%	NHNES
Non-dairy whitener (1)	83%	NHNES
Frozen yogurt, sherbet, or non-fat ice cream (1)	100%	Not applicable
Ice cream (1)	100%	Not applicable
Flavored yogurt (1)	100%	Not applicable
Yogurt or flavored yogurt with Nutrasweet (1)	50%	HLA, SW, NHNES
Cottage or ricotta cheese (1)	100%	Not applicable
Cream cheese (1)	100%	Not applicable
Other cheese (America, Cheddar, etc.) (1)	100%	Not applicable
Butter (1)	100%	Not applicable
Eggs, whole with yolk (1)	83%	HLA
Margarine (4)	100%	Not applicable
Mayonnaise, regular (4)	100%	Not applicable
Salad dressing (4)	100%	Not applicable
Chicken or turkey with skin (5)	100%	Not applicable

Table 1 (Continued)

Summary of FFQ Foods and Food Categories Deemed Eligible for Analysis

Food (NDB Food category)	Percentage of FFQs having food	FFQs in which food was not included
Chicken or turkey without skin (5)	100%	Not applicable
Liver, chicken or turkey (5)	83%	HLA
Chowder or cream soups (6)	83%	NHNES
Beef or pork hotdogs (7)	100%	Not applicable
Chicken or turkey hotdogs (7)	100%	Not applicable
Salami, bologna (7)	100%	Not applicable
Processed meats (sausage, kielbasa) (7)	100%	Not applicable
Cold breakfast cereal (8)	100%	Not applicable
Cooked oatmeal or oat bran (8)	100%	Not applicable
Other cooked cereal (8)	100%	Not applicable
Raisins(9)	67%	HHQ, NHNES
Prunes (9)	67%	HHQ, NHNES
Bananas (9)	100%	Not applicable
Cantaloupe (9)	100%	Not applicable
Avocado (9)	83%	NHNES
Applesauce (9)	67%	SW, NHNES
Fresh apples or pears (9)	100%	Not applicable
Apple juice or cider (9)	100%	Not applicable

Table 1 (Continued, 2)

Summary of FFQ Foods and Food Categories Deemed Eligible for Analysis

Food (NDB Food category)	Percentage of FFQs having food	FFQs in which food was not included
Oranges (9)	100%	Not applicable
Orange juice (9)	100%	Not applicable
Grapefruit (9)	100%	Not applicable
Grapefruit juice (9)	100%	Not applicable
Other fruit juice (9)	100%	Not applicable
Strawberries (9)	100%	Not applicable
Berries (9)	100%	Not applicable
Peaches, apricots, plums (9)	100%	Not applicable
Pork as main dish (10)	100%	Not applicable
Bacon (10)	100%	Not applicable
Beef, pork, or lamb as mixed dish (10, 13)	100%	Not applicable
Tomatoes (11)	100%	Not applicable
Tomato juice (11)	83%	HLA
Tomato sauce (11)	50%	HLA, FH, SW
Ketchup or red chili sauce (11)	83%	FH
Salsa, picante or taco (11)	50%	HLA, FH, HHHQ
String beans (11)	100%	Not applicable
Broccoli (11)	100%	Not applicable

Table 1 (Continued, 3)

Summary of FFQ Foods and Food Categories Deemed Eligible for Analysis

Food (NDB Food category)	Percentage of FFQs having food	FFQs in which food was not included
Cabbage or cole slaw (11)	100%	Not applicable
Cauliflower (11)	100%	Not applicable
Brussels sprouts (11)	100%	Not applicable
Carrots, raw (11)	100%	Not applicable
Carrots, cooked (11)	100%	Not applicable
Corn (11)	100%	Not applicable
Peas or lima beans (11)	100%	Not applicable
Mixed vegetables (11)	100%	Not applicable
Dark orange squash (11)	100%	Not applicable
Eggplant, zucchini or other summer squash (11)	100%	Not applicable
Yams or sweet potato (11)	100%	Not applicable
Spinach, cooked (11)	100%	Not applicable
Spinach, raw (11)	100%	Not applicable
Kale, mustard, or chard greens (11)	100%	Not applicable
Iceberg or head lettuce (11)	100%	Not applicable
Romaine or leaf lettuce (11)	100%	Not applicable
Celery (11)	50%	HHHQ, SW, NHNES
Green peppers (11)	83%	HHHQ

Table 1 (Continued, 4)

Summary of FFQ Foods and Food Categories Deemed Eligible for Analysis

Food (NDB Food category)	Percentage of FFQs having food	FFQs in which food was not included
Other vegetables (11)	100%	Not applicable
Onions(11)	67%	HLA, NHNES
Potatoes, baked boiled or mashed (11)	100%	Not applicable
Other nuts (12)	83%	HHHQ
Hamburger, lean or extra lean (13)	83%	SW
Hamburger, regular (13)	83%	SW
Beef or lamb as main dish (13)	100%	Not applicable
Liver, beef calf or pork (13)	83%	HLA
Cola, low calorie (14)	83%	FH
Cola, regular (14)	100%	Not applicable
Hawaiian punch, lemonade (14)	83%	HHHQ
Beer, regular (14)	100%	Not applicable
Beer, light (14)	100%	Not applicable
Red wine (14)	100%	Not applicable
White wine (14)	100%	Not applicable
Liquor, whiskey, gin, etc. (14)	100%	Not applicable
Herbal tea (14)	50%	FH, HHHQ, NHNES
Tea (14)	100%	Not applicable

Table 1 (Continued, 5)

Summary of FFQ Foods and Food Categories Deemed Eligible for Analysis

Food (NDB Food category)	Percentage of FFQs having food	FFQs in which food was not included
Coffee with caffeine (14)	100%	Not applicable
Tuna, canned (15)	100%	Not applicable
Shrimp, lobster (15)	100%	Not applicable
Dark meat fish (Mackerel, Salmon, Sardines) (15)	50%	FH, HHHQ, NHNES
Other fish (Haddock, Halibut) (15)	100%	Not applicable
Peanuts (16)	100%	Not applicable
Peanut butter (16)	100%	Not applicable
Beans or lentils, baked or dried (16)	100%	Not applicable
White bread (18)	100%	Not applicable
Dark bread (18)	100%	Not applicable
Bagels, English muffins, or rolls (18)	100%	Not applicable
Muffins or biscuits (18)	100%	Not applicable
Tortillas (18)	100%	Not applicable
Pancakes or waffles (18)	67%	HHHQ, NHNES
Crackers, Triscuits, Wheat Thins (18)	67%	HHHQ, SW
Cookies (18)	100%	Not applicable
Brownies (18)	67%	FH, SW
Doughnuts (18)	100%	Not applicable

Table 1 (Continued, 6)

Summary of FFQ Foods and Food Categories Deemed Eligible for Analysis

Food (NDB Food category)	Percentage of FFQs having food	FFQs in which food was not included
Cake (18)	100%	Not applicable
Pie (18)	100%	Not applicable
Sweet roll, coffee cake other pastry (18)	100%	Not applicable
Corn bread or muffins (18)	83%	HU
Popcorn (19)	100%	Not applicable
Pretzels (19)	50%	FH, HHHQ, SW
Pure chocolate bar (Hershey's, M&M's) (19)	100%	Not applicable
Mixed candy bar (Snickers, Reeses) (19)	100%	Not applicable
Candy without chocolate (Mints, Lifesavers) (19)	67%	HLA, NHNES
Jams, jellies, preserves (19)	83%	NHNES
Potato or corn chips (19)	100%	Not applicable
Brown rice (20)	67%	FH, SW
White rice (20)	67%	FH, SW
Pasta (spaghetti, noodles) (20)	100%	Not applicable
Noodle casseroles (20)	83%	HU
Mixed mexican dishes (tacos, tostadas) (21)	67%	HU, HHHQ
Chicken or turkey sandwich (21)	83%	SW
Fish, breaded (21)	100%	Not applicable

Table 1 (Continued, 7)

Summary of FFQ Foods and Food Categories Deemed Eligible for Analysis

Food (NDB Food category)	Percentage of FFQs having food	FFQs in which food was not included
Pot pie (22)	50%	HU, FH, NHNES
Pizza (21)	100%	Not applicable

Note. FFQ = Food Frequency Questionnaires, NDB = Nutrient databank number, HU = Harvard University Food Frequency Questionnaire, HLA = Hawaii and Los Angles Cohort Study Food Frequency Questionnaire, FH = Fred Hutchinson Cancer Center Research Center Food Frequency Questionnaire, HHHQ = Health Habits and History Questionnaire, SW = Southwestern Food Frequency Questionnaire: University of Arizona, NHNES = National Health and Nutrition Examination Survey III Food Frequency Questionnaire.

Table 2

Summary of FFQ Foods and Food Categories Deemed Ineligible for Analysis due to Inadequate Inclusion in FFQs

Food (NDB Food category)	Percentage of FFQs having food	FFQs in which food was included
Tofu or soybeans (16)	33%	HU, HLA
Egg Beaters or egg whites (1)	33%	HU, HHHQ
Other grains (bugler, kasha, couscous) (18)	17%	HU
Oat bran added foods (18)	33%	HU, HLA
Miso soup	17%	HLA
Coffee drinks, cappuccino, café latte (14)	33%	HLA, FH

Note. FFQ = Food frequency questionnaire, NDB = Nutrient databank number, HU = Harvard University Food Frequency Questionnaire, HLA = Hawaii and Los Angles Cohort Study Food Frequency Questionnaire, FH = Fred Hutchinson Cancer Center Research Center Food Frequency Questionnaire, HHHQ = Health Habits and History Questionnaire.

Table 3

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
1	Milk, whole	01077	0	31	5	2	SR21
2	Milk, nonfat	01085	0	31	5	2	SR21
3	Soup, lentil	06037	0.39	50	8	4	Li 2002
4	Soup, split pea	06050	0.65	60	11	7	Li 2002
5	Sausage, smoked link pork and beef	07074	0	28	3	1	SR21
6	All Bran cereal	08001	13.2	44	66	29	SR21
7	Cheerios cereal	08013	4.02	74	67	50	SR21
8	Cornflakes	08020	4.06	81	83	67	SR21
9	Bran flakes	08029	17.3	63	63	40	BFT
10	Froot Loops cereal	08030	44.35	69	87	60	SR21
11	Grapenut cereal	08038	0	71	70	50	SR21
12	Raisin Bran cereal	08060	0.17	61	63	39	SR21

Table 3 (Continued)

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
13	Rice Krispies, Kellogg's	08065	8.32	82	87	72	SR21
14	Frosted corn flakes	08069	35.62	55	87	50	SR21
15	Whole Grain Total, General Mills	08077	12.3	76	73	56	SR17
16	Cream of wheat	08103	0.03	66	11	7	SR21
17	Quick oats	08121	0.25	66	10	7	SR21
18	Shredded wheat cereal	08147	0.55	75	67	50	SR21
19	Apple, raw	09003	2.07	38	13	5	SR21
20	Apple juice, unsweetened	09016	1.26	40	9	4	SR21
21	Apricots, raw	09021	5.87	45	9	4	SR21
22	Apricots, dried	09032	7.89	31	47	14	SR21
23	Banana, raw	09040	2.39	52	20	10	SR21
24	Blueberries, raw	09053	0	53	9	5	SR21

Table 3 (Continued, 2)

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
25	Cherries, raw	09063	0.8	42	12	6	SR21
26	Figs, dried	09094	0.07	61	43	26	SR21
27	Grapefruit, raw	09112	3.51	25	11	3	SR21
28	Grapefruit juice	09123	2	48	8	4	BFT
29	Grapes, raw	09131	0.1	46	15	7	BFT
30	Kiwi, raw	09148	0.15	53	12	6	SR21
31	Mango, raw	09176	8.27	51	14	8	Li 2002
32	Cantaloupe	09181	4.35	67.5	6	4	SR21
33	Nectarines, raw	09191	4.87	43	7.5	3	SR21
34	Orange, raw	09200	3.9	42	9	4	BFT
35	Orange juice	09209	3.1	52	9	5	BFT
36	Peach, raw	09236	4.76	42	9	4	SR21

Table 3 (Continued, 3)

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
37	Pear, raw	09252	0.78	38	9	3	SR21
38	Pears, canned in juice	09254	0.6	43	11	4	SR21
39	Pineapple, raw	09266	5.99	59	11	6	SR21
40	Plums, raw	09279	1.57	39	10	4	SR21
41	Plums, dried (prunes)	09291	0.15	29	55	16	SR21
42	Raisins, seedless	09298	0.45	64	73	47	SR21
43	Strawberries, raw	09316	0.47	40	3	1	SR21
44	Watermelon, raw	09326	1.21	76	5	4	SR21
45	Pineapple juice	09409	1.53	46	14	6	SR21
46	Beets, raw	11080	8.5	64	9	6	BFT
47	Carrots, raw	11124	3.59	30	8	2	SR21
48	Green peas, raw	11304	4.99	48	9	4	SR21

Table 3 (Continued, 4)

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
49	Potato, mashed instant	11383	0	85	13	11	SR21
50	Tomato juice, with salt	11540	0.25	31	3	1	SR21
51	Potato, baked with skin	11674	0.4	64	20	13	SR21
52	Lima beans, immature canned	11717	1.13	32	19	6	SR21
53	Corn, sweet yellow boiled	11770	1.73	54	21	11	SR21
54	Sweet potato	11875	2.98	70	21	15	SR21
55	Cashews, dry roasted	12585	5.6	25	18	4	BFT
56	Beer, regular	14003	0	66	3	2	SR21
57	Lemon lime soda, Sprite	14145	0.65	58	11	7	SR21
58	Cola, with caffeine	14148	0	58	10	6	SR21
59	Cranberry juice cocktail	14242	0	60	13	8	SR21
60	Gatorade	14460	0.92	78	6	5	SR21

Table 3 (Continued, 5)

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
61	Fish, portions and sticks preheated	15027	0.59	38	19	7	SR21
62	Baked beans	16006	4.8	46	13	6	SR21
63	Kidney beans, raw	16029	1.85	28	17	5	SR21
64	Chickpeas, mature canned	16058	0.44	28	20	6	Li 2002
65	Cowpeas, mature canned	16064	0.90	46	20	9	BFT
66	Peanuts, roasted	16090	3.8	14	12	2	BFT
67	Refried beans	16103	0.46	38	12	4	SR21
68	Pinto beans, mature boiled	16343	0.34	39	17	7	SR21
69	Multi-grain bread (included whole-grain)	18035	0	57	43	24	SR21
70	Cake, chocolate	18046	26.6	38	47	18	BFT
71	Bread, rye	18060	0	50	40	20	Li 2002
72	White bread, commercial	18069	0	70	47	33	SR21

Table 3 (Continued, 6)

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
73	Chocolate chip cookies	18159	27.06	43	64	28	SR21
74	Saltine crackers	18228	0	74	68	50	SR21
75	Doughnut, cake	18250	9.1	76	47	36	BFT
76	English muffin	18258	0	77	47	36	SR21
77	Rolls, french	18349	0.1	73	53	39	BFT
78	Rolls, hamburger	18350	0	61	50	31	SR21
79	Tortilla, corn	18363	0.55	52	48	25	SR17
80	Tortilla, flour	18364	0.05	30	52	16	SR17
81	Waffle, frozen ready to eat	18403	3.24	76	37	28	SR21
82	Bagel	18406	0.1	70	50	35	BFT
83	Cheese crackers, cheese filling	18927	3.09	54	59	32	SR21
84	Pancakes	18936	0.16	71	43	31	SR21

Table 3 (Continued, 7)

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
85	Corn chips, plain	19003	0.54	63	52	33	SR21
86	Extruded cheese puffs/twists	19008	0.19	74	52	38	SR21
87	Popcorn, air popped	19034	0.72	65	55	36	SR21
88	Pretzels, hard plain salted	19047	0.12	83	67	55	SR21
89	Ice cream, vanilla	19095	11.5	61	26	16	BFT
90	Milk chocolate candies	19120	46.6	43	56	34	BFT
91	Snicker's Bar	19155	31.48	51	58	30	SR17
92	Chocolate pudding	19183	15.47	47	16	7	SR21
93	Honey	19296	0.89	55	72	40	SR21
94	Maple syrup	19353	56.28	54	67	36	SR21
95	Granola bar, with chocolate chips	19404	16.51	62	64	40	SR21
96	Potato chips	19411	0.5	56	42	23	BFT

Table 3 (Continued, 8)

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
97	Dark chocolate	19903	36.39	23	52	12	SR21
98	Buckwheat groats, roasted	20010	0.4	45	20	9	SR21
99	Rice, brown cooked	20037	0.35	55	22	12	SR21
100	Rice, white cooked	20045	0.1	64	24	15	BFT
101	Spaghetti, cooked	20321	0.09	49	27	13	SR21
102	Pizza, with cheese	21049	0.1	60	27	16	BFT
103	Pizza, with cheese, meat, and vegetables	21050	0.1	30	22	7	BFT
104	French fried potatoes	21138	0.2	64	20	13	SR21
105	Chicken nuggets	21229	0.15	46	16	7	SR21
106	Cheese burger, McDonalds	21233	0.24	66	16	11	SR21
107	Chicken soft taco, Taco Bell	21262	0.34	42	19	7	SR21
108	Bean burrito, Taco Bell	21264	0.47	39	23	9	SR21

Table 3 (Continued, 9)

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
109	Supreme pizza, Pizza Hut	21276	0	36	24	9	SR21
110	Grilled chicken sandwich, McDonalds	21402	0.44	66	22	14	SR21
111	Beef pot pie	22529	0.32	45	22	9	SR21
112	Lasagna, with meat and sauce	22915	0.5	47	12	6	SR21
113	Rice bowl with chicken	22958	3.5	41	22	9	SR21
114	Snicker's Marathon, energy bar	25016	14.27	43	50	22	SR21
115	Powerbar	25017	0.52	56	65	36	SR21
116	Tortilla chips, plain	25028	0.97	63	67	42	SR21

Table 3 (Continued, 10)

Summary of FFQ Foods Used in this Study

Food No.	Food	NDB Number	Sucrose (g/100g)	GI	Available CHO (g/100g)	GL (Per 100g)[a,b]	Source
117	Chili, with beans	MDACC Recipe #4	0.64	7	8	6	Appendix
118	Macaroni and cheese	MDACC Recipe #9	0.09	64	1	12	Appendix
119	Miso soup with rice[c]	MDACC Recipe #10	0.09	61	26	16	Appendix

Note. [a]Glycemic index with glucose as reference food, [b]Source for glycemic index and glycemic load values are Foster-Powell, Holt, & Brand-Miller, 2002 and Atkinson, Foster-Powell, & Brand-Miller, 2008, [c]Due to a lack of glycemic load for miso soup as the M.D. Anderson recipe is written, a recipe for miso soup and rice was used as a substitute. Source of miso soup and rice is Sugiyama, Tang, Wakai, & Koyama, 2003. FFQ = Food frequency questionnaire, Food No. = Food number, NDB = Nutrient databank number, GI = Glycemic index, CHO= Carbohydrate. GL = Glycemic load, SR17 = Standard Release 17, SR21 = Standard Release 21, BFT = British Food Tables, Li 2002 = (Li, Andrews, & Pehrsson, 2002). MDACC = M.D. Anderson Cancer Center Food Frequency Questionnaire.

Table 4

Correlation Analysis for Sucrose and Glycemic Load Per Serving

	Sucrose (g)	Glycemic load per serving
Sucrose		
Pearson Correlation	1.000	.310**
Significance (2-tailed)	.	.001
N	119	119
Glycemic load per serving		
Pearson Correlation	.310	1.000
Significance (2-tailed)	.001	.
N	119	119

Note. ** Correlation is significant at the 0.01 level (2-tailed).

It is important to note that Table 4 shows that when correlation analyses was carried out the p-value for the correlation between sucrose and glycemic load per serving was less than 0.05. It has been established that if the p-value of the correlation was less than or equal to 0.05 the correlation would be considered statistically significant. Because the p-value was less than or equal to 0.05 there is a statistically significant relationship between the sucrose concentration and the glycemic load per serving in the foods commonly found in FFQ's that were used in this study. The Pearson correlation was equal to .310. With a statistically significant p-value of .001 and a Pearson correlation of .310, the null hypothesis can be rejected.

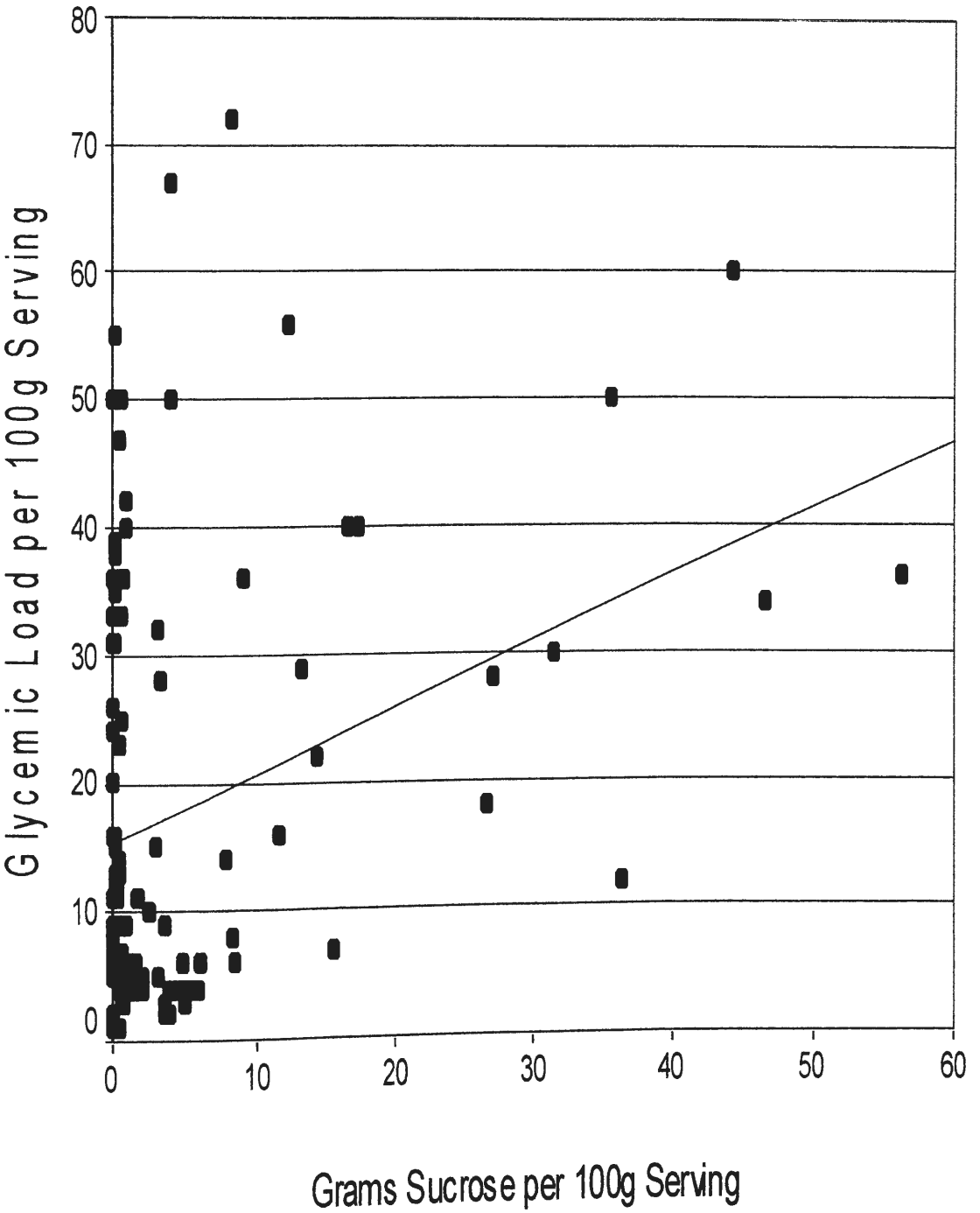

Figure 1. Scatter plot that shows the relationship between glycemic load and sucrose concentration per 100g serving size for the foods selected for this study. Diagonal line depicts the linear relationship between these variables.

CHAPTER V

DISCUSSION

The results of this study show that there is a statistically significant relationship between the sucrose concentration and the glycemic load in foods commonly used in FFQ's that were examined in this study. Statistical analysis using correlational analyses was used and it was established that the null hypothesis, that is, there will be no correlation between the sucrose concentration and glycemic load of foods used in FFQs, can be rejected. The findings indicate that there is a relationship between the sucrose concentration of the foods commonly found in FFQ's and their GL, $r = 0.31$, $p < .001$. (The relationship is plotted in Figure 1). This indicates that the putative role of dietary sucrose in the incidence of lung cancer is supported.

Sucrose concentration in foods used in this study varied greatly. The actual range of values for sucrose ranged from 0 g sucrose/100g, which includes foods like milk, sausage, saltine crackers, rye bread, and cola with caffeine, all the way up to 56.28 g sucrose/100g for maple syrup. The GL values for foods used in this study also varied greatly. The range of values for GL per 100 g serving ranged from a low of GL= 1, which includes sausage, raw strawberries, and tomato juice with salt, to a high of GL= 72 for Rice Krispies cereal. Other high GL foods include hard pretzels (GL= 55), Whole Grain Total (GL= 56), and corn flakes (GL= 67).

Examining the foods in this study that have higher concentrations of sucrose helps to a show a possible explanation for the study's findings. Some of the foods with the highest sucrose concentrations include milk chocolate candies (46.6 g sucrose/100 g), Fruit Loops cereal (44.35 g sucrose/100g), frosted corn flakes (35.62 g sucrose/100 g), Snicker's bar (31.48 g sucrose/100g), chocolate chip cookies (27.06 g sucrose/100g), and bran flakes (17.30 g sucrose /100g). One of the common links that some of these foods share is that they are made with, or include, milk chocolate. Snicker's bar was chosen to represent various other types of chocolate candy bars, which could include Twix, Reese's Cups, Milky Way Bars, and other brand name chocolate covered bars. These products all have very similar ingredients, and are grouped together in some of the FFQ's. Milk chocolate is a highly processed and heavily sweetened form of chocolate. The chocolate chip cookies have 27.0 g sucrose/100g and a GL of 28, the Snicker's bars have 31.5g sucrose/100g and a GL of 30, and the milk chocolate candies have 46.6 g sucrose/100g and have a GL of 34. These heavily sweetened foods would be expected to have high GL values. Many of these foods are high in fat content though, which would be thought to help lower the GL. The chocolate chip cookies, for example, have 23.31 g fat/100g, the Snicker's bar have 23.85 g fat/100g, and the milk chocolate candies have 29.66 g fat/100g. These foods may be high in fat but they have little to no fiber or protein which are known to also decrease GL (Jenkins et al., 1981). Their high carbohydrate content and high sucrose levels tend to favor the increase in GL values. It is evident from these three foods that GL increases as sucrose content increases.

The cereals previously mentioned are good examples to show how increasing sucrose content can increase a food's GL. The sucrose values for these cereals are 17.3 g sucrose/100g for bran flakes, 35.62g sucrose/ 100g for frosted corn flakes, and 44.35g sucrose/100g for Froot Loops. Their GLs are 40, 50, and 60 respectively. Bran flakes has a lower GL because they have less sucrose, and because they are high in fiber (13 g fiber/100g) which reduces GL. Frosted corn flakes and Froot Loops show how the increase in sucrose can affect the GL even if there is extra fiber in the food item. Froot Loops (3.1 g fiber/100g) have 1.3 more grams of fiber than frosted corn flakes (1.8 g fiber/100g), but they have 9 extra grams of sucrose, which helps to increase the GL of the cereal, even though the extra fiber is present.

These foods also share the trait that they are representative of many foods that have high sucrose content in that as the sucrose content increases the foods tend to be more refined. This is very obvious when these cereals are considered. Bran flakes have the lowest sucrose content and GL (17.3 g sucrose/100g, GL= 40), frosted flakes have higher sucrose and GL (35.62 g sucrose/100g, GL= 50), and finally Froot Loops have the highest sucrose content and GL (44.35 g sucrose/100g, GL=60). As sucrose content and GL increase the refinement of the foods is more obvious. Bran flakes have more fiber and are much less refined than both other cereals. Frosted flakes are more refined than bran flakes and have a sugar coating added. Froot Loops are further refined as they are made up of finer powered corn that is mixed with sugar and formed, and the cereal is then sugar coated. Because the Froot Loops are composed of finer more ground materials GL will also increase, as it is known that smaller particle size increases a food's GL.

Epidemiological studies have investigated the role that sugars and GL may play in cancer. In one cohort study it was reported that an increased risk of colorectal cancer was associated with an increased GL (RR= 2.85), and with an increased intake of fructose, one of the two carbohydrate moieties of sucrose, with a RR= 2.09. There was no effect of sucrose on the risk of developing colorectal cancer (Higginbotham et al., 2004). In another cohort study, it was reported that an increased risk of pancreatic cancer in women who were both overweight and sedentary was associated with and increased GL (RR= 2.67), and that an increased risk of pancreatic cancer was associated with a high fructose intake (RR= 1.57). There was no effect of sucrose on the risk of pancreatic cancer (Michaud et al., 2002). Thus, the effect of simple carbohydrates on the development of cancer appears to vary from cancer to cancer.

Two case-control studies carried out in Uruguay have reported an increased risk of developing lung cancer associated with the consumption of dietary sucrose (OR= 1.55) and sucrose-rich desserts (OR= 2.52) (De Stefani et al., 1997; De Stefani, Deneo-Pellegrini, Mendilaharsu, Ronco & Carzoglio, 1998). Neither study reported GL. In the future studies on the role of carbohydrates in the development of lung cancer should determine GL as well as intake of simple carbohydrate. There is one animal study whose results agree with epidemiologic findings, such as these, in regards to the role that sucrose may play in cancer. A Japanese animal study found an association between a high sucrose diet and tumor growth. The study found that animals fed a high sucrose diet had an increased rate of tumor growth and higher elevations in biological markers of

tumor growth than did mice who were fed a low fat and low sucrose diet (Kimura & Sumiyoshi, 2007).

Findings from this study suggest that an increased dietary GL may mediate the putative causal role of dietary sucrose in lung cancer carcinogenesis. This role was suggested by statistical analyses that showed, through correlation analysis, that a statistically significant relationship does exist between the sucrose concentration and the GL per serving of the foods commonly found in FFQ's that were used in this study. The literature review has shown that there are several studies that have suggested a possible link between increased sucrose consumption and increased risk for cancer. This correlational study can conclude that there is a correlation between the sucrose content and GL of foods used in FFQs, but could not determine if sucrose itself causes the increased risk of lung carcinogenesis. It is possible though to speculate as to why a high sucrose intake could increase a person's risk for lung cancer carcinogenesis. It is possible that an increased intake of sucrose may in itself be secondary to other factors that can increase risk for lung cancer carcinogenesis. If antioxidant rich foods such as vegetables and fruits are replaced in a diet with highly refined sweets and sweet drinks that are high in sucrose a person may be increasing his or her risk by lacking beneficial and potentially cancer preventing antioxidants in their diet. Increased sucrose intake may also be a contributing factor to overweight and obesity that are known risk factors for cancer.

Limitations

The study sample used in this research project was moderately sized with a total of 119 of the most commonly used foods from FFQs being analyzed. Some FFQs may

have less food in them than were analyzed for this study, but some FFQ may have many more foods than that used in this study. Some of the FFQs contained mixed food items such as certain soups, stir-fries, lasagna, and casseroles. This study had 22 mixed foods within the analyzed data, which equates to 18.5% of foods analyzed being mixed foods. This may not be representative of all FFQ. This study is also limited to the FFQ's that were examined in order to select the foods for this research. There are many more FFQ's in existence and in use that were not analyzed in this study. Because those FFQ's may vary in the number and variety of foods generalizations from the findings of this study will not necessarily apply to them.

CHAPTER VI

CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

The most important finding and implication of this study is that we can conclude that the sucrose concentration of foods in commonly used FFQ's is associated with GL. Case control studies exploring the role of carbohydrates in the development of lung cancer should involve the determination of GL as well as sucrose intake. Sucrose may play a role in lung cancer carcinogenesis through increasing the GL of diets. Further research is needed to determine if a direct relationship exists between glucose intake and increased risk for lung carcinogenesis. Many studies have hinted at the possible relationship or role of sucrose in lung cancer carcinogenesis, but they have not performed much research into this important subject. Studies must be performed to see if higher intakes of sucrose or if lifestyles associated with high intakes of refined sugars is a culprit in lung carcinogenesis.

It is also important to note that further research and development of databases of the nutrient composition of foods is needed. When recipe analysis cannot be conducted because there are missing values for even the most common foods, further nutrient analysis is indicated. This is especially true in the amount of common foods for which there are values missing in the USDA's Standard Release Nutrient Database.

Further development of GI and GL tables is also needed. Many common foods have no recorded value for GI or GL. Even though the most current version of the international table of GI and GL values contains almost 1900 different foods, more research and the development of newer tables is needed. In the future, it would be valuable for researchers to determine the GI and GL values for many more of the common foods found in today's modern supermarket. Newer FFQ's could ask participants for brand product information and more in depth tables will help to facilitate nutrition research and analysis.

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APPENDIX A

Recipe Analysis

Table 5

Recipe Analysis M.D. Anderson FFQ Recipe: Chili Made With Beans

Ingredient	NDB	Sucrose (g/ 100 g recipe)[a]	Carbohydrate (g/ 100 g recipe)[b]	Source
Regular ground beef	23558	0	0	SR21
Onions, raw	11282	0.07	0.68	SR21
Celery, raw	11143	0.005	0.12	SR21
Chili powder	02009	0.003	0.19	SR21
Salt, table	02047	0	0	SR21
Tomatoes, stewed	11533	0.006	1.85	SR21
Tomato sauce, canned	11549	0.038	0.8	SR21
Beans, kidney canned	16034	0.52	4.36	SR21
Totals		0.642	8.0	

Note. [a]Grams of sucrose calculated per 100 grams of cooked recipe. [b]Grams of carbohydrate calculated per 100 grams of cooked recipe. FFQ = Food frequency questionnaire. NDB = Nutrient databank number. SR21 =Standard Release 21

Table 6

Recipe Analysis M.D. Anderson FFQ Recipe: Macaroni and Cheese

Ingredient	NDB	Sucrose (g/ 100 g recipe)[a]	Carbohydrate (g/ 100 g recipe)[b]	Source
Macaroni, cooked	20100	0.38	13.02	SR21
Margarine, regular	04610	0	0	SR21
Wheat flour, white	20081	0.0029	1.24	SR21
Salt, table	02047	0	0	SR21
Milk, 2%	01079	0.0036	1.64	SR21
Cheese, cheddar	01009	0.039	0.21	SR21
Bread crumbs, dry	18079	0	2.79	SR21
Eggs, chicken whole	16034	0.0043	0.028	SR21
Totals		0.0878	18.928	

Note. [a]Grams of sucrose calculated per 100 grams of cooked recipe. [b]Grams of carbohydrate calculated per 100 grams of cooked recipe. FFQ = Food frequency questionnaire. NDB = Nutrient databank number. SR21 =Standard Release 21

Table 7

Recipe Analysis M.D Anderson FFQ Recipe Substitute: Miso Soup with Rice[a]

Ingredient	NDB	Sucrose (g/ 100 g recipe)[b]	Carbohydrate (g/ 100 g recipe)[c]	Source
Water, municipal	14429	0	0	SR21
Rice, white cooked	20045	0.0875	22.48	BFT
Miso	16112	0	3.64	SR21
Totals		0.875	26.12	

Note. [a]Source of miso soup and rice is Sugiyama, Tang, Wakai, & Koyama, 2003.[b]Grams of sucrose calculated per 100 grams of cooked recipe. [c]Grams of carbohydrate calculated per 100 grams of cooked recipe. FFQ = Food frequency questionnaire. NDB = Nutrient databank number. SR21 =Standard Release 21, BFT = British food tables.