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Impact of Whole Grain Consumption Compliance on Gluten Sensitivity and Bowel Health

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Abstract

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by

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

While many health benefits have been associated with increased whole grain consumption, current researchers have not considered if the consumption of whole grains in currently recommended or higher amounts actually leads to health problems, specifically to a correlated increase in gluten sensitivity. The purpose of this study was to determine if diets high in whole grains or those that met the recommended daily intake of whole grains help minimize or increase gluten sensitivity, and when whole grains are consumed as recommended if they cause more harm than good. The theoretical basis for this quantitative, cross sectional design was the precaution adoption process model, allowing for the examination of preventive behaviors as a series of cognitive steps over time. Individuals ($N = 5,746$) from the National Health and Nutrition Examination Survey 2007 to 2012 were assessed for daily intake of whole grains before and after the release of the 2010 Dietary Guidelines for Americans, and from 2007 to 2010 for bowel health and sensitivity to whole grains. SAS correlations and regression analysis at $p < .05$ were analyzed. There was an increase in whole grain intake by 7.4% and in bowel sensitivity with 50% reporting increases in gas, but more data are needed to determine exact amounts that caused these increases in symptoms. Understanding the complete picture, policy makers and others will be more informed about current recommendations and the way that Americans eat, as well as if changes are needed for the future.

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Chapter 1: Introduction to the Study

Introduction

The link between celiac disease and gluten containing products and many whole grains (barley, wheat, rye, and to a lesser degree oats) is clearly defined and documented in the literature. However, a newer diagnosis of exclusion problem known as gluten intolerance and its connection to gluten and whole grain consumption is not clearly documented in the literature. Gluten sensitivity is the diagnosis given to patients when diseases, such as celiac disease and irritable bowel disease, for which there are diagnostic tests come up negative but the problem persists. Prior research states that whole grains should be avoided in individuals who have diagnosed celiac disease and gluten intolerance. For example, Brown (2012) found that celiac disease has increased four-fold since 1950 when studying diagnosed cases of celiac disease over time. However, recently there has been increased pressure to consume whole grains through various media and nutrition outlets, as a way to get healthier and help prevent chronic comorbidities like diabetes and hypertension. Gluten-free diets are also a trending topic due to the increase in celiac disease (Gaesser & Angati, 2012).

The Academy of Nutrition and Dietetics (AND), the National Institutes of Health (NIH), and the United States Department of Agriculture (USDA) have recommendations and guidelines for dietary requirements, activity levels, and various food groups and portions (AND, 2013; NIH, 2005; USDA, 2011). However, this does not mean that Americans follow these guidelines and recommendations or that these foods are healthful and readily available. Gidding et al. (2009) pointed to the modernization and

industrialization of the food consumed in the United States and the manner in which it is disbursed as having serious impacts on obesity and disease levels. Increasing public concern for gluten, its impact on health, and its potential for gluten sensitive issues and bowel disease has led to an increase in the availability of gluten free foods (it is now a 2.6 billion dollar industry; Beck, 2011). These are two of the primary issues concerning the AND recommendations to eat more whole grains, but the increased public concern for consuming wheat and other whole grain gluten containing products highlights another movement to be healthy, counter to the gluten-free movement but with potential health costs. The current study will help identify important components in the American diet that are advertised as healthy and beneficial but that have also contributed to the increase in celiac disease as noted by Brown (2012). This research has the potential to inform researchers of future studies about whole grains and the recommendations for consumption, increase the popularity of the gluten-free diet, and change the way many Americans view their health through dietary changes. It also may influence dietary changes leading to lower morbidity and mortality rates that are linked in some literature to the consumption of whole grain products like wheat and barley.

In this chapter, I outline the background information and significance of the topic of increased gluten sensitivity as related to increased whole grain consumption and provide brief justification for the topic. I also provide the hypothesis I am examining, research questions, and a list of definitions.

Background

Gluten as a dietary debate has moved to the forefront over the past decade.

According to Sapone et al. (2012), the average daily gluten intake is between 10 and 20 grams, with some individuals consuming as much as 50 grams daily. The variety of known and newly discovered disorders that center around the consumption of gluten, including celiac disease, wheat allergies, gluten ataxia, bakers asthma, dermatitis herpetiformis, wheat-dependent exercise-induced anaphylaxis, and general gluten sensitivity, have grown over the past 10 years and created a rise in demand for gluten-free products. This demand is characterized by a 28% growth in gluten-free food demand on the market, resulting in $2.6 billion in gluten-free food sales from 2005 to 2011 (Sapone et al., 2012). The growth in both the incidence and prevalence of gluten related disorders as well as the food industry's development of gluten-free products due to the demand as illustrated by Sapone et al. (2012) demonstrate the importance of determining the causes of this phenomenon by examining the American diet.

A study conducted by Carroccio et al. (2012) examined wheat sensitivity using patients with Irritable Bowel Syndrome (IBS) and celiac disease as controls. The researchers found that over the course of 10 years, from 2001 to 2011, two distinct groups emerged, wheat sensitive and IBS. The nonceliac wheat sensitive group showed biological markers of positive serum assays for IgG/IgA antigliadin and cytometric basophil activation, similar to patients with celiac disease. Additionally, eosinophil infiltration of the duodenal and colon mucosa, which results in inflammation of tissues and a distinct immune response, was seen in the nonceliac wheat sensitive group. Carroccio et al. (2012) showed that gluten sensitivity is a real and potentially serious disorder that is prevalent and can be tracked over time. While these research findings

contribute to the increased knowledge and understanding of underlying mechanisms that gluten intolerance is a real disorder, additional research is needed to identify and understand how dietary factors link to the problem, including nonspecific wheat sources, which most likely include whole grains. Understanding how whole grain foods impact gluten intolerance and potentially contribute to the problem is of interest to this research and is important to informing the literature.

Problem Statement

As part of a achieving a healthy diet, current guidance for intake of total grain is to consume at least half of all grains as whole grains and to increase whole grain intake by replacing refined grains with whole grains (USDA, 2011). This recommendation varies by age, gender, and physical activity level and for most adults ranges from 6 oz equivalents (3 whole grains) for 2,000 calories to 10 oz equivalents (5 whole grains) for 2,800 or more calories per day (USDA, 2012). In response to dietary recommendations, the U.S. marketplace has evolved to include more whole grains, particularly in the past 5 years. Direct to consumer advertising now advertises food products such as General Mills cereals as containing several sources of whole grains as a part of a balanced diet. Coupled with studies that link consumption of whole grains, specifically grains such as oats and barley to a decrease in low density lipoprotein (LDL) levels, whole grain consumption of foods like oats and barley can reduce the risk of heart disease (Harris & Etherton, 2010) and potentially the risk of other diseases as well. Therefore, whole grain consumption by American consumers and the impact on health is important to consider.

While many health benefits have been associated with increased whole grain

consumption, researchers have not considered if the consumption of whole grains in currently recommended or higher amounts actually leads to health problems, and more specifically, if this increased consumption leads to a correlated increase in gluten sensitivity. To this topic, Biggs and Parsons (2009) conducted a study examining the impact of increased whole grain consumption on chicks and found a significant increase in the size of the gizzard. The gizzard is responsible for the grinding up of grains to make them easier to digest in chickens, and its increased size indicated a physiological response to higher whole grain consumption. While the study did not specifically identify this as a positive or negative issue, the increase in size suggests that the digestive system worked harder to digest whole grain food sources.

Authors of another study suggested that whole grains undergo equal to or less fermentation than their degraded counterparts (Hernot, Boileau, Bauer, Swanson, & Fahey, 2008). Fermentation occurs as a result of anaerobic digestive processes that allow for the production of short-chain fatty acids (SCHFA) and is an important part of protecting people from chronic diseases and colon cancer. A difference in fermentation shows that whole grains are not necessarily better for SCHFA production as previous studies have claimed (Hernot et al., 2008). This could in part be due to the genetic engineering of crops. Bioengineering of crops in recent years has been designed to better meet recommended daily allowances of certain types of phytonutrients (Mattoo, Shukla, Fatima, Handa, & Yachha, 2010) to include those found naturally in whole grains. While genetically modified food is cheaper to produce, and in general the public tolerates a 5% genetic modification of the food they regularly consume (Rousu, Huffman, Shogren, &

Tegene, 2004), not all genetic modifications are associated with health benefits. In particular, there are concerns about the allergen additions or substitutions to these crops that make them less tolerable. For example, there is documented evidence that celiac disease has increased four-fold since 1950 (Kasarda, 2013). Celiac disease is an autoimmune reaction to the consumption of gluten.

The available literature reviewed provides no explanation for the phenomenon of gluten intolerance. Biesiekiersk et al. (2011) determined that nonceliac related gluten intolerance does exist, but the mechanism that triggers the intolerance is not really known. In this study, individuals fed diets with gluten experienced identifiable symptoms of gluten intolerance as compared to those fed placebos, but the exact source or type of gluten food was not explicitly noted. The unknown aspects that have led to an increased incidence of celiac disease and increased but unexplainable gluten sensitivity underscore the importance of finding the cause or causes of this phenomenon. The genetic modification of crops that has occurred over the past several years provides a potential clue with the heightened concern of allergen introduction into the modified form of many grains in the American diet. The encouragement to include whole grains in the daily diet and at specific amounts could explain these noted occurrences in people who follow those recommendations and further study is warranted.

The mechanisms through which gluten impacts the digestive tract are clear. However, the information on the benefits and risk of increasing consumption of whole grains is contradictory and requires further investigation. The primary research available examines only how whole grains are beneficial to one's health. However, there are

missing pieces on the potential negatives associated with that consumption. With a rise in gluten sensitivity and awareness of the problem, the role that whole grains play in that increase has not been explored.

Purpose

The purpose of this study was to determine if diets high in whole grains or those that meet the recommended daily intake of whole grains help minimize or increase gluten sensitivity. This is a longitudinal, quantitative study using a secondary source of data (NHANES). Data from the National Health and Nutrition Examination Survey (NHANES) for the years 2007 to 2012 were used to examine adults ages 20 and older, allowing for analysis of dietary trends over time. This was important to determine if the more recent emphasis on incorporating whole grains into the diet impacts (a) the amount or frequency of whole grain consumption and (b) bowel health (the variable this study uses to measure gluten sensitivity). Moreover, the results of the study will help people determine what sources of whole grains increase gluten sensitivity and in what amounts if any/at all.

Research Questions

1. Is there an increase, defined as a 5 to 10% increase or higher, in whole grain consumption by adults 20 and older after the release of the 2010 dietary guidelines (2010-2012) compared to prior to the release of the 2010 guidelines (2007-2010)?
2. Does an increase in whole grain consumption by adults 20 and older result in increased gluten sensitivity or bowel problems?

3. Is consumption of whole grains by adults 20 and older equivalent to and at half of the 2010 dietary guidelines recommendation linked to increased gluten sensitivity and changes in bowel health and intolerance (as indicated by increased bowel problems)? And if so, for what percentage range or amount in grams of whole grain wheat is there a noted difference?

Hypotheses

$H1_0$: There is no or limited increase (less than 5%) in whole grain consumption by adults in the United States after the release of 2010 dietary guidelines.

$H1_a$: There is an increase of at least 5% in whole grain consumption by adults in the United States after the release of 2010 dietary guidelines.

$H2_0$: The increase consumption of whole grains has not resulted in an increase in gluten sensitivity and related bowel symptoms.

$H2_a$: The increase in consumption of whole grains has resulted in an increase in gluten sensitivity and related bowel symptoms in adults ages 20 and older.

$H3_0$: Individuals who meet or exceed the recommended daily consumption of whole grains show no significant bowel symptoms, noted by no increase in bloating, gas, and loose stools.

$H3_a$: There are bowel health changes and responses, noted by increase in bloating, gas, and loose stools as a result of any consumption of whole grains, but the frequency of reported incidences of bloating, gas, and loose stool are greater in those who meet or exceed the recommended daily amount.

Conceptual Basis for Study

Increased consumption of whole grains is something that many people are aware of as an important step in adopting a healthier lifestyle and decreasing the incidence of diseases. However, there is the potential problem that increased consumption over time could lead to gluten sensitivity. In light of both of these scenarios, people may or may not be aware of the impact eating whole grains has on their health in good or bad ways. Once they discover the potential health benefits or drawbacks of this consumption, they may or may not decide to change how they eat. They will then maintain what they are doing currently or change what they are doing based on this new awareness.

It is therefore important to view this subject through a relatively new theory called the precaution adoption process model. The National Institutes of Health (2005) described the precaution adoption process model (PAPM) as a model that describes the seven step process from the unawareness state of an issue or problem to the awareness and adoption or maintenance of a health behavior. There are seven key constructs of this model: being unaware of the issue, being unengaged by the issue, being undecided about acting, deciding not to act, deciding to act, acting, and maintenance. Individuals' unawareness of the potential negative impacts of consuming whole grains, since they are regularly reported as beneficial, leads to individuals either acting by changing dietary habits based on new knowledge and maintaining that change in behavior or action or continuing to do what they have been doing, because they are not engaged by the issue. This theory provides an explanation as to why people might have changed their diets to incorporate whole grain foods over the past 4 years. Additionally, it can potentially

explain an increase in gluten sensitivity, should that be found.

This theory also explains changes made by individuals based on information that links dietary behaviors with certain diseases. An example of this type of behavior change is illustrated by Gold et al. (2011) who found text messages about sexually transmitted infections (STI) sent to individuals ages 16 to 29 resulted in increased knowledge and the action of increased testing for STIs. Attention bias and motivational states significantly influence responses that this theory examines. Attention bias requires messages about diet to be personally relevant to impact or change behavior, and the plan for one's health and nutrition moving forward dictates the impact of the new information due to individual motivational states (Jensena et al., 2012).

Nature of the Study

The study was longitudinal and quantitative in nature, with the primary data source being NHANES data from 2007 through 2012. NHANES surveys 5,000 individuals annually across the United States using self-administered and professionally administered questionnaires. For this study, I targeted adults, ages 20 and older, since age limits are not set for the bowel health and nutrition questions, and I used specific dietary survey questions related to whole grain and general grain consumption. I compared reported whole grain consumption and bowel problems/issues as a primary indicator of gluten sensitivity. Study variables included types and amounts of grain consumption, overall dietary consumption of whole grain food sources and bowel health variables.

Significance

AND, the NIH, and the United States Department of Agriculture all have

recommendations and guidelines for dietary requirements, activity levels, and various food groups and portions (AND, 2013; NIH, 2005; USDA, 2011). However, this does not mean that Americans follow these guidelines and recommendations or that these foods are healthfully and readily available. Gidding et al. (2009) pointed to the modernization and industrialization of the food consumed in the United States and the manner in which it is disbursed as having serious impacts on obesity and disease levels. Increasing public concern for gluten, its impact on health, and its potential for gluten sensitive issues and bowel disease has led to an increase in the availability of gluten free foods (it is now a 2.6 billion dollar industry; Beck, 2011). This illustrates two primary issues regarding the AND recommendation to eat more whole grains and the increased public concern for consuming wheat and other whole grain gluten containing products. This research will help identify important components in the American diet that are healthy as well as those that contribute to the increase in celiac disease. This research has the potential to further increase the popularity of the gluten-free diet and change the way many Americans view their health through dietary changes. This also has the potential to lower morbidity and mortality rates that are linked in some literature to the consumption of whole grain products like wheat and barley.

Definitions

Celiac disease: An autoimmune disorder of the small intestine that occurs in genetically predisposed people of all ages from middle infancy onward. Symptoms include chronic diarrhea, failure to thrive (in children), and fatigue, but these may be absent, and symptoms in other organ systems have been described (Fasano, 2012).

Gliadin: A fraction of the gluten protein that is found in wheat and rye and to a lesser extent in barley and oats. Its solubility in diluted alcohol distinguishes it from another grain protein, glutenin. Those with celiac disease are sensitive to this substance, and it is excluded from their diet (Fasano, 2006).

Gluten: A mixture of insoluble plant proteins occurring in cereal grains, chiefly corn and wheat, used as an adhesive and as a flour substitute (Fasano, 2012).

Gluten sensitivity: A nonallergic and nonautoimmune condition in which the consumption of gluten can lead to symptoms similar to those observed in celiac disease or wheat allergy with symptoms include bloating, abdominal discomfort or pain, and diarrhea, and might present extraintestinal symptoms including muscular disturbances and bone or joint pain (Canani et al., 2011).

Immunoglobin A: The class of antibodies produced predominantly against ingested antigens, found in body secretions such as saliva, sweat, and tears, and functioning to prevent attachment of viruses and bacteria to epithelial surfaces (Fasano, 2012).

Irritable bowel syndrome: A common intestinal condition characterized by abdominal pain and cramps, changes in bowel movements (diarrhea, constipation, or both), gassiness, bloating; nausea, and other symptoms. There is no cure for IBS. Much about the condition remains unknown or poorly understood; however, dietary changes, drugs, and psychological treatment are often able to eliminate or substantially reduce its symptoms (Canani et al., 2011.)

Paracellular: Transfer of substances between cells of an epithelium (Fasano,

2006).

Phytonutrients: Organic components of plants that are thought to promote human health but are not essential for sustaining human life. Examples of sources of these include fruits, vegetables, grains, legumes, nuts, and teas (Mattoo et al., 2010).

Polyphenols: A chemical that acts as an antioxidant in the body that protects cells and body chemicals from free radical damage (Mattoo et al., 2010).

Wheat allergy: A rare allergy that typically presents itself as a food allergy but can also be a contact allergy resulting from occupational exposure to wheat and involves immunoglobulin E and mast cell response (Canani et al., 2011).

Zonulin: Protein that modulates the permeability of tight junctions between cells of the wall of the digestive tract (Fasano, 2012).

Operational Definitions

Gluten containing foods: Hot or cold cereals, whole grains, whole grain breads, and white bread.

Gluten sensitivity: An increase or worsening of bowel health symptoms including diarrhea, more frequent gas and bloating, and greater frequency of bowel movements that consist of leakage.

Notable or significant: For the purposes of this study, this is defined as a change of 5% or greater.

Whole grains: Hot or cold cereals, foods listed under the whole grains question in NHANES, whole grain breads, brown rice, and popcorn. More broadly, this includes food made from wheat, rice, oats, cornmeal, barley, or another cereal grain containing the

entire grain kernel (MyPlate, 2011).

Worse: For purposes of this study, a change of 5% or greater in bowel health responses where the frequency of the response to any bowel health question with a negative response increases.

Assumptions/Limitations

The population sampled through NHANES is a representative sample of the United States population and presents a broad and generalizable sample for data analysis. In this study, I also assumed that the self-reported data were accurate, but self-reported data are in itself a limitation. Self-reported data have the limitations of selective memory, event recall that does may not match what is being asked or the time that is being asked about, exaggeration of the truth, lying to protect the perception of the person reporting the data, and incorrect associations or correlations of events or actions and outcomes. The Hawthorne effect is an additional concern when dealing with surveys that are administered by individuals (Fricker & Schonlau,2002). This is the tendency of people to act atypically when they know they are being observed. All of the data used in this study relied on self-reports and therefore have all of these limitations.

Additional limitations of this study include the type of available data and how it compares to what is being studied. There are no specific questions in the NHANES survey that ask about gluten sensitivity or account for the specific source of whole grains. However, the questions pertaining to food consumption do ask if the rice consumed was brown or white and ask specifically about whole grains excluding white bread; the questions pertaining to cereal consumption ask what kind of cereal is typically consumed.

For purposes of this study, it is therefore assumed that the whole grains discussed in the context of the survey contain gluten, the corresponding bowel symptoms analyzed are indicative of gluten sensitivity, and the questions being used are sufficient to adequately determine dietary correlations with symptoms of and therefore actual gluten sensitivity.

Validity is always a serious concern with survey designed research studies. However, the concerns of comparative validity are easier to rectify with NHANES, since the study is conducted every year. While this study is looking at change over time in consumption and corresponding bowel symptoms, there are several years of previous data available to check and make sure that the dietary and bowel questions do not deviate significantly from one year to the next and that the reporting is therefore relatively accurate or consistent.

Due to limited funding from the Centers for Disease Control and Prevention, the data collected are not geographically representative or reflective of the different demographics of individuals sampled and are only good for national conclusions. In this, I study examined national trends that make this general limitation of NHANES less applicable. In addition, another limitation of NHANES data related to the geographic distribution is that the same samples are not surveyed every year. Geographic irregularities from year to year make for less than ideal conditions for tracking changes over time. This is a slight issue with this study as it examines whole grain consumption over a period of time, tracking for an increase. This study compares food consumption to the corresponding years of bowel health questions. The actual examination for increases from year to year based on individual question responses is a smaller component of

supportive evidence to the study when compared to the conclusions being reached by the actual comparison of the bowel and nutrition questions.

Summary

This study will determine if there is a link between reported whole grain consumption and bowel symptoms indicative of gluten sensitivity. There is research evidence that suggests increases in celiac disease and that gluten sensitive disorders other than celiac disease do exist. The rise in popularity of gluten free foods as well as whole grain foods requires examination of potential causes. Although the mechanism in the intestines that results in gluten sensitivity is not well understood, connections between diet and intestinal sensitivity can be made.

Chapter 2: Literature Review

Introduction

Recommendations for a healthy diet and lifestyle currently include consuming at least 6oz of whole grains daily and up to 10oz depending on the amount of calories consumed (USDA, 2012). In response to these recommendations, the U.S. marketplace has evolved to include more whole grains. Direct to consumer advertising now advertises food products, such as General Mills cereals as containing several sources of whole grains as a part of a balanced diet. Studies that show correlations between certain whole grains decreasing LDL cholesterol and reductions in heart disease and risk for developing cardiovascular issues direct consumers toward whole grains as part of a preventative diet (Harris & Etherton, 2010). Therefore, whole grain consumption by American consumers and the impact on health is important to consider.

However, the potential negative aspects of consuming whole grains, such as increased gluten sensitivity have not been fully researched. Understanding both the healthy aspects, as well as potential negative health impacts of whole grains is very important in understanding dietary needs. To this topic, Biggs and Parsons (2009) conducted a study examining the impact of increased whole grain consumption on chicks and found a significant increase in the size of the gizzard as a direct response to consumption of whole grains. While the authors did not specifically identify this as a positive or negative issue, the increase in size suggests that the digestive system worked harder to digest whole grain food sources.

Fermentation occurs as a result of anaerobic digestive processes that allow for the

production of SCHFA and is an important part of protecting people from chronic diseases and colon cancer. Hernot et al (2008) have suggested that whole grains undergo equal to or less fermentation than their degraded counterparts. A difference in fermentation shows that whole grains are not necessarily better for SCHFA production as previous studies have claimed. This could in part be due to the bioengineering of crops. Bioengineering of crops in recent years has been designed to better meet recommended daily allowances of certain types of phytonutrients (Mattoo et al., 2010) to include those found naturally in whole grains. While genetically modified food is cheaper to produce, and in general, the public tolerates a 5% genetic modification of the food they regularly consume (Rousu et al., 2004), not all genetic modifications are associated with health benefits. In particular, there are concerns about the allergen additions or substitutions to these crops that make them less tolerable. Genetic modification can result in everything from increases in vitamins to increases in gluten and protective toxins naturally produced by crops.

There is documented evidence that celiac disease has increased four-fold since 1950 (Kasarda, 2013). The available literature provides no explanation for this phenomenon. Biesiekiersk et al. (2011) determined that nonceliac related gluten intolerance does exist, but the mechanism that triggers the intolerance is not really known. In this study, individuals fed diets with gluten experienced identifiable symptoms of gluten intolerance as compared to those fed placebos, but the exact source or type of gluten food was not explicitly noted. The unknown aspects that have led to an increased incidence of celiac disease and increased, but unexplainable gluten sensitivity underscores the importance of finding the cause or causes of this phenomenon. The

genetic modification of crops that has occurred over the past several years provides a potential clue with the heightened concern of allergen introduction into the modified form of many grains in the American diet. The encouragement to include whole grains in the daily diet and at specific amounts could explain these noted occurrences in people who follow those recommendations and further study is warranted.

The purpose of this study is to determine if diets high in or those that meet the recommended daily intake of whole grains help minimize or increase gluten sensitivity. Study data were from the NHANES, allowing for analysis of U.S. dietary trends over time. This is important to determine if the more recent emphasis on incorporating whole grains into the diet impacts (a) the amount or frequency of whole grain consumption and (b) bowel health. Moreover, the results of the study will help people determine what sources of whole grains increase gluten sensitivity and in what amounts if any/at all.

In Chapter 2, I present a comprehensive background about gluten, nutrition, gluten sensitive or intolerant diseases, and the physiological mechanisms behind how gluten is digested in the body. This chapter addresses the potential reasons why gluten intolerance is increasing, how food manufacturing and practices contribute to the problem, and the response to the gluten-free trends in diet. I additionally explain the theoretical lens through which the subject is being viewed and why this approach is appropriate.

Literature Search Strategy

There were several techniques used in finding the literature for this topic. The search started with a basic nutritional search of databases provided by the online Walden

University library, Google Scholar, and general queries to nutritional websites, such as the Centers for Disease Control, the National Whole Grains Council, and the USDA. These websites were a wealth of information, but not specifically for the topic. I used search word queries including *gluten intolerance, gluten sensitivity*, and *negative impacts of whole grains*. The search strategy was then broadened to include illnesses that result in gluten-associated problems, such as celiac disease, irritable bowel disease (IBD), and wheat allergies. This led to the next search strategy and a creation of a section on gut microbes and digestive properties. Searches included phases such as *gut microbes and gluten, celiac disease and gut microbes*, as well as specific searches for the names of *gut flora*. Key concepts were also included as search topics including *frequency of bowel movements, viscosity of the stool*, and *diarrhea*. These search terms were used in conjunction with previous search terms, such as *whole grains, dietary related, gluten*, and *digestion*.

Aside from searching specific websites and article topics, credible academic blogs were used to find scholarly articles as well as potential authors for which to search on the subject. There are numerous nutritional blogs with cited articles that led to other scholarly articles via citations and links. Additional searches on bowel health that covered the past several years, but were limited to those studies from 2008 to the present, using NHANES elicited more information and useful articles. As well as simple search terms such as *gluten, gliadin, IBD*, and *digestion,* all elicited helpful articles. However, simply searching whole grains and digestion or disease did not return helpful articles. Over 600 articles were found using the various search strategies. Abstracts eliminated the relevance

of around 350 articles because the subject matter was not pertinent to the topic being studied as they examined elements not under consideration, mostly diabetes. The 80 articles that were selected all contained what was pertinent to the topic and search strategy. The articles were then synthesized and incorporated into the paper with articles being eliminated because they were not necessary, were repetitive, or did not turn out to be contributory to the literature review.

Theoretical Framework

Precaution Adoption Process Model

The NIH (2005) depicted the PAPM as a model that describes the seven step process from the unawareness state of an issue or problem to the awareness and adoption or maintenance of a health behavior. Increased consumption of whole grains is something that many people are aware of as an important step in adopting a healthier lifestyle and decreasing the incidence of diseases. However, there is the potential problem that increased consumption over time could lead to gluten sensitivity. In light of both of these scenarios, people may or may not be aware of the impact eating whole grains has on their health in good or bad ways. Once they discover the potential health benefits or drawbacks of this consumption, they may or may not decide to change how they eat. They will then maintain what they are doing currently or change what they are doing based on this new awareness. Jensena et al. (2012) illustrated this using awareness of folate in individual's diets. Certain categories of people were more aware and responsive to changing behaviors to increase folate in their diets due to factors such as age and pregnancy. Regardless, presenting the information to the individuals under study did raise awareness

and produced some level of action. The action was more pronounced in those who really felt the impact of the message due to a personalizing factor (age or pregnancy).

The inundation with commercial advertisement for the importance of eating whole grains and the increase in consumer products advertising as "whole grain" products is likely to have impacted the diet of the individuals surveyed by NHANES. This theory is relevant and applicable to the research questions of this study. It allows for the explanation as to why people might have changed their diets to incorporate whole grain foods over the past 6 years with the increase in whole grain food products available mentioned previously. This is because they may have a specific health concern that has prompted them to act on this information, such as diabetes or heart disease. Additionally, it would potentially explain an increase in gluten sensitivity, should that be found. The explanation flows from the examination of bowel health as related to dietary consumption of whole grains. This PAPM also explains the changes to other forms or types of diets based on information that links them with certain diseases, which allows for different explanations for dietary and disease changes. In this case, a link between reported experienced symptoms in relation to the types of food consumed leads to greater self-awareness of individuals and how food impacts their health and bowel symptoms. The answer to each research question allows subsequent, more specific research questions to be answered. Examining these questions through the PAPM shows progression of awareness and why that may lead individuals to make the dietary choices they make.

Key Variables/Concepts

The USDA has guidelines for basic whole grain consumption for adults and

children. This recommendation varies by age, gender, and physical activity level, and for most adults ranging from 6 oz equivalents (3 whole grains) for 2,000 calories to 10 oz equivalents (5 whole grains) for 2,800 or more calories per day (USDA, 2012). However, the average adult does not meet the recommendations for whole grain consumption. Zanovec, O'Neil, Cho, and Nicklas (2010) determined that adults aged 19 to 50 years old consumed an average of 0.63 servings of whole grains on a daily basis. Based on the minimum recommendation of three servings daily, adults on average barely consume one-fourth of the daily advisable amount.

While many Americans do not meet the recommendations, both the availability and intake of whole grains has progressively increased since 2000. The Whole Grains Council (2012) reported a 1,960% increase in the amount of whole grain products available to the public from 2000 at 164 grain based products on consumer shelves to 2011 at 3,378. Despite the fact that Americans do not eat the daily suggested amount of whole grains daily, the amount taken in has steadily increased, by 20% from 2005 to 2008 based on self-reported data (Whole Grains Council, 2012). Whole grain consumption is encouraged for its potential health benefits.

For purposes of this study, whole grain is based on the American Whole Grain Council (WGC) and American Association of Cereal Chemists (AACC) definition. This is also the standard American definition of what a whole grain food is, should contain, and defines different processing aspects of the grain. The WGC and AACC defined a whole grain as “the intact, ground, cracked or flaked caryopsis whose principal anatomical components–the starchy endosperm, germ and bran–are present in the same

relative proportion as they exist in the intact caryopsis" (as cited in Aman & Frolich, 2010, p. 2). This definition is important as it differentiates the qualities of the grain and does not include or reference fiber as a necessary component of the definition, as fiber can be added to foods in the form of things like inulin. Therefore, different whole grains can be defined as whole grains without regard to fiber content.

Grain consumption undoubtedly has health benefits. Kim and Jo (2011) determined that Koreans who ate diets rich in grains lowered their risk for contracting metabolic syndrome as adults. Furthermore, Borneo and Leon (2012) determined that dietary fiber, inulin, beta-glucan, resistant starch, carotenoids, phenolics, tocotrienols, and tocopherols are the components in whole grains that enhance the disease fighting characteristics of whole grains. Additionally, whole grain consumption is linked with reductions in hypertension, type II diabetes, stroke, and obesity (Borneo & Leon, 2012).

Many researchers support the benefits of whole grain consumption as well as its importance for digestion and overall health. However, not all whole grains are equal in their beneficial capacities, so grouping them all together and stating that they all contribute to the reduction of morbidity and mortality levels from certain diseases is inaccurate. Vitaglione, Napolitano, and Fogliano (2008) conducted a study examining the antioxidant capacity of several different types of whole grains. They determined that only those grains that contained bran contributed to the slow-release health benefits commonly associated with generalized whole grain benefits. These antioxidant capabilities of certain grains and lack of those in other grains directly impact the effect grains have on cholesterol. This, in turn, alters the capacity of whole grains as a general category to

mitigate morbidity and mortality rates related to cardiac problems.

Fundamentally, fiber consumption is an important part of diets in order to aid in the prevention of diseases such as cardiovascular disease and diabetes. More importantly are the potential benefits of the dietary consumption or artificial consumption of fiber (using fiber supplements like Metamucil or fiber one) as it relates to overall bowel health and assists in the treatment of certain gastrointestinal illnesses. Slavin, Savarino, Diaz, and Fotopoulos (2009) suggested that soluble fiber helps regulate the digestive system, including the prevention of constipation and diarrhea as well as the regulation of irritable bowel disease. The fiber that confers these benefits is primarily ingested through plant foods such as fruits and vegetables. There is an important distinction between soluble and insoluble fiber and their respective benefits. Soluble fiber is the fiber that is fermented in the small intestine and forms short-chain fatty acids that aid in cell proliferation and differentiation within epithelial cells (Slavin et al., 2009). Conceptually this is important as it is part of the essential process of digestion as it relates and contributes to overall bowel health. Additionally, the idea that it is generally soluble fiber that confers these benefits and protections against comorbid conditions highlights the importance of differentiation between whole grains and fiber contained by those grains (and other fruits and vegetables) as the beneficial portion of the food versus the potentially harmful portion of the grains.

Currently, one of the primary mechanisms for increasing fiber intake is through its ingestion in cereals. Dietary guidelines recommend ingesting 14 grams of fiber for every 1,000 calories consumed, but the average American consumes only roughly half of this

daily (Vuksan et al., 2008). Fiber is important for fecal bulk and water concentrations in feces, as a preventative measure and treatment for diarrhea. Vuksan et al. (2008) conducted a study to determine what impacts the increase in soluble and insoluble dietary fiber has on intestinal health, fecal bulk, and comfort levels of the digestive tract and found that an increase in both types of fiber results in minimal to no discomfort and increased stool frequency and bulk. The indications of this study are two-fold: They offer insight into how to improve intestinal mobility with minimal discomfort and indicate a serious problem with the American diet as it relates to bowel health through a lack of consumption of adequate amounts of fiber. With variables being examined having to do with loose stools, frequent bowel movements, and symptoms of diarrhea, the lack of appropriate or recommended fiber consumption indicates that people would tend not to have regular bowel movements and the bowel movements would be smaller allowing for clear indications of bowel health issues as related to diet.

IBS as with many other digestive diseases is helped by the elimination of irritating and aggravating foods from the diet. Symptoms of IBS, gluten intolerance, celiac disease and other similar diseases are caused by any of the following factors: visceral hyperactivity, gastric intestinal motility disturbances, sugar malabsorption, gas-handling disturbances, and abnormal intestinal permeability (Yoon, Grundmann, Koepp, & Farrell, 2011). These are the primary factors that lead to the discomfort and intestinal symptoms experienced by sufferers. Yoon, et al. (2011) indicate that a primary cause of these intestinal symptoms has to do with the ingestion of certain types of carbohydrates, more specifically those found in cereals and packaged and/or baked goods. An important

differentiation made by the Yoon et al. (2011) study deals with fiber and the source of the fiber consumed and how it helps or exacerbates symptoms. Dietary fiber, which is supposed to be helpful for healthy bowel function, caused symptoms such as bloating and abdominal discomfort, while fruit and vegetables as the primary source of the necessary fiber resulted in no bloating and discomfort. This distinction is important as a mechanism by which certain types of food can be detrimental to the bowel with or without disease and food as a source of symptoms of food intolerance.

Gluten and its Role in Digestion

The evolution and changes of vertebrate digestive system tolerances progress with the changing diet and available food sources of vertebrates. Vertebrates have a gut immuno-chemical make-up that allows the microbiota in the intestines to adapt. Immunoglobin A (IgA), which is an antibody pivotal in mucosal immunity, is the primary mechanism through which this gut adaptation occurs in vertebrates and allows for alteration of microbes in the intestinal tract (Ley, Lozupone, Hamady, Knight, & Gordon, 2009). IgA is involved with mucosal immunity and lower levels lead to immune system problems. These various adaptations are a product of genetics, food availability, and the people who cohabitate with one another. The divergence from invertebrates and continued changes and adaptations to the environment and food sources impacts the body's ability to digest and tolerate gluten.

Gluten sensitivity, unlike celiac disease, is rooted in several factors that can determine the severity of the reaction and overall disorder. Brown (2012) states that gluten sensitivity can be a result of genetic food modifications, gluten being used as a

food additive, pesticide use on crops, and environmental factors leading to an increase in gluten sensitive cases. Gluten sensitivity tends to have a much slower onset of symptoms than celiac disease. Celiac disease can also have neurological symptoms, whereas gluten sensitivity does not. Neurological indicators of celiac disease can include any of the following neurological disorders: ataxia, neuropathy, encephalopathy, and myopathy (Hadjivassiliou et.al , 2010). These symptoms are possible in patients with gluten intolerance, but are much less likely statistically than in patients with celiac disease (Hadjivassiliou et.al , 2010). This is another way physicians can differentiate between the two health problems to make a more concrete diagnosis.

The general symptoms of gluten sensitivity or intolerance often occur after ingesting food containing gluten, when the body attempts to digest the food. The primary symptoms that will be the focus of this study include: bloating, gas, abdominal pain or discomfort, constipation, and diarrhea. However, it is important to note, that as with celiac disease, there are some less-common symptoms of gluten intolerance. Pietzak (2012) asserts that weight loss, nutrient malabsorption resulting in malnutrition, joint pain and arthritis, and dental problems are also other symptoms associated with gluten intolerance. These symptoms arise as a result of the gluten as it interacts with gut microbia, epithelial cells resulting in changes, and triggered inflammatory responses in the digestive system.

Gliadin is one of the primary triggers for negative gut responses in individuals with gluten intolerance. Studies in rats have determined the following mechanism: intestinal exposure to gliadin triggers a zonulin-dependent increase in intestinal

permeability, which in turn allows antigens from food to interact with lamina propria (Sapone et. al., 2012). Zonulin impacts intestinal permeability to food molecules. There is an internal intestinal reaction that is triggered through the gliadin-zonulin reaction, starting with Interleukin 15. Interleukin 15 triggers a stress response from epithelial cells in the gut lining and this stress results in a transformation of intraepithelial lymphocytes, making them" natural killer" cells (Bernardo, Garrote, Ferbabdez-Salazar, Riestra, & Arranz, 2007). These natural killer cells cause enterocyte apoptosis and increase the epithelial permeability causing the related intestinal discomfort often associated with gluten intolerance.

Whole Grain Consumption and Bowel Health

Determining the impact of whole grains on digestive health is difficult as many articles do not differentiate between whole grain impacts and dietary fiber impacts on bowel health. Slavin (2010) states that there are several studies that have been conducted on individual types of fiber that comprise whole grains, but virtually no studies on the actual impact of whole grains on gut health. Additionally, it is important to understand what the American diet view of whole grains is and what the actual content of products labeled whole grain contain. Dixit, Azar, Gardner, and Palaniapp (2011) determined that in the United States products labeled as whole wheat flour are diluted with other types of flour and that process that many of these flours undergo, even when labeled "whole", performs acts that the digestive tract would normal have to undertake reducing feelings of fullness that would otherwise occur. There are important distinctions between the processed whole grains and ancient whole grains for dietary benefits and consumption.

Ancient minimally processed grains are recommended over any wheat or grain product that must be processed in order to maximize health benefits and minimize negative impacts.

Bowel health is not a total measure of dietary intake, as it is also influenced by medications, physical activity level, stress, fluid and type of fluid intake, and hormones. However, the type of bowel movements and frequency can be examined in light of these other details to determine how certain dietary patterns impact bowel health. Whole grains have been shown to increase fecal bulk and frequency of bowel movements (Slavin, 2010). However, it is the size of the particles in addition to the type of whole grain ingested that determines the overall impacts on bowel health. Fecal bulk can be increased by a ratio of 5 to 1 to a ratio of 1 to 1 depending on the whole grain ingested and the types of fiber contained in that whole grain (Slavin, 2010). These differences are a product of both the type of fiber and the size of the whole grains. The larger the whole grain, the larger the fecal bulk produced and vice versa, because the larger particles have trouble being fermented in the gut and permeating the gut wall. In addition, butyrate produces the most short-chain fatty acids, so the other types of short-chain fatty acids, including propionate and acetate, are less common products of gut fermentation and are produced as a result of less gut beneficial fibers.

Whole grains are described as being largely beneficial in reducing the likelihood of many chronic diseases. Short chain fatty acids are the primary immunological reason for intestinal health and the promotion of feelings of satiety, but whole grains are not the only or primary source of these important intestinal fatty acids. Butyrate is the primary

short-chain fatty acid in the intestine that confers beneficial protective mechanisms including: regulating the transport of transpithelial fluid, decreasing inflammation of the mucosal membranes, helps aid in the defense barrier within the epithelial layer, and aids in intestinal motility (Canani et. al, 2011). Foods that contain this short-chain fatty acid are generally high in amylose and include fruits, vegetables, and whole grains, where the beneficial part in these foods is the dextrin and cellulose.

Short-chain fatty acids have been used therapeutically for people who suffer inflammatory bowel disease and sepsis to reduce inflammation. Researchers have confirmed that oral ingestion of butyrate and dietary fiber in supplemental medicinal form reduced symptoms associated with inflammatory bowel disease, through decreased inflammation in the intestines caused by the short-chain fatty acids (Vinolo, Rodrigues, Nachbar, & Curi, 2011). This furthers the idea that it is not necessarily the whole grain that confers the beneficial properties, but rather the fiber that confers benefits. Fiber can be consumed through fruits and vegetables, indicating that whole grains specifically are not the only or more precisely the primary dietary aid in preventing and controlling co-morbid conditions, it is the fiber contained in these foods.

DNA damage to colonic cells is an important area of interest when examining potential benefits of whole grain diets and high fiber diets. Conlon et al. (2012) and Bajka et al. (2010) both demonstrated that high amylose diets, when the source of amylose is maize, conferred protection against DNA damage to colon cells and reduced contractile activity in the colon allowing for better water and mineral absorption in rats. These findings are important to dietary attempts to prevent colon cancer in humans. Diets high

in amylose from maize and protein were found to confer the most benefits (Conlon et al. 2012). Other whole grain sources were tested in these studies including wheat, but it was the amylose generated from a vegetable source that conferred the greatest benefit.

Gut Microbes and the Role of the Large Intestine

There are a variety of microbes and bacteria in the human intestinal or gut system that impact the way in which humans eat, what they can and cannot eat, and how they respond, digestively speaking, to the consumption of food. Humans, like many other mammals, have a unique digestive system that relies on bacterial recognition and bacterial-epithelial cell responses which can result in immune responses. It is the immune system that is able to differentiate between tolerable foods and sensitive foods via Microbe-Associated Molecular Patterns (Possemiers et. al, 2009). These pathways are what result or mitigate inflammatory processes associated with gluten-sensitive diseases.

The majority of the gut permeation that results when gluten sensitive individuals consume gluten containing products occurs in the large intestine. Food particles travel rather quickly though the stomach and small intestines and the majority of waste production and consolidation from the digestive tract occurs in parts of the colon. Short-chain fatty acids are important in the process of digestion and when examining intestinal permeability. Acetate, propionate and butyrate are the three primary short-chain fatty acids that impact intestinal health and by extension immune function; these three fatty acids are formed from carbohydrate and protein fermentation in the gut (Jacobs, Gaudier, van Duynhoven & Vaughan, 2009). Butyrate has been shown to protect the colon from cancer in animal studies. It is the proper fermentation of these short chain fatty acids that

is thought to promote healthy intestinal function.

Polyphenols have varying impacts on intestinal microbial metabolites. Jacobs et al. (2009) found that vegetarian fecal water samples show inhibition of COX-2 protein levels, which helps prevent intestinal inflammation. However, all of the food that is consumed has varying impacts on intestinal microbial levels and interactions with metabolites. It is important to understand the types of tests available to check certain levels and make determinations about changes or differences in microbe or metabolite levels in fecal matter as related to the intestines for individuals exhibiting gluten-associated disorders. For instance, fecal samples from individuals with both ulcerative colitis and Crohn's disease had lower levels of butyrate, acetate, methylamine, and TMA (trimethylalamine) suggesting changes to the microbial composition of the gut (Jacobs et al. 2009). Alterations in gut levels of various microbes that are impacted by different foods being consumed clearly impact intestinal health in both beneficial and harmful ways.

It is important to understand the role of diet in microbial concentrations of the large intestine. Celiac disease is an excellent example of how diet impacts gut microbial levels, because it arose as a result of dietary changes and changes in grains (Sanz, 2010). Therefore, understanding what impacts gluten, grains, and gluten-free food choices have on digestion and intestinal bacterial composition leads to a better understanding of the positive and negative aspects of dietary changes from a microbial and physiological perspective. A study of the effects on gluten-free diets on intestinal microbial concentrations and immune response stated disruption of the sensitive balance between

the host and its intestinal microbiota (dysbiosis), ….might encourage the overgrowth of expedient pathogens and weaken the host defenses against infection and chronic inflammation via possible alterations in mucosal immunity (Sanz, 2010 p. 135). It is both the internal environment of the intestines and digestive systems and what people put into that environment that work in conjunction to create sensitivities, intolerances, and move microbial homeostasis closer to or farther away from what is considered normal or healthy.

It has been proposed that dietary evolution is a large part of the reason for microbial gut changes over the past decades. However, other medical and technical advances also contribute to the occurrences of these digestive illnesses. These factors have been linked to occurrences of digestive diseases with the phenomenon starting at birth. Cesarean sections, formula feeding rather than breast feeding, vaccinations of baby and mother, personal hygiene practices for both parents and infants, and antimicrobial soaps and cleaners are all considered factors associated with an to increase in digestive related problems. Each of these factors in addition to others impact the types and amounts of gut microbes, especially in infants (Round & Mazmanian, 2009). Additionally, comorbidities that require medication also impact gut floral concentrations. Other immune-related disorders that require treatment (allergies such as asthma for example) result in other immune-related responses that can lead to variations of bacteria levels in the intestines, resulting in the occurrences of intestinal related problems and illnesses (Round & Mazmanian, 2009). Also, there are a number of non-food related issues that result in impact on gut floral levels and overall intestinal health.

Physiology/Digestive Properties of Whole Grains That Contain Gluten

It is important to understand the mechanism through which gluten can cause inflammation as it has implications for grain consumption and gluten intolerance. Fasano (2006) states that gliadin and zonulin acts as signalers and receptors when gluten containing foods are digested. Eating these gluten containing foods results in gliadin activating zonulin, which results in increased intestinal porousness to macromolecules. The resulting release of zonulin occurs in the epithelial cells of the intestine. This mechanism allows for the resulting symptoms of disorders such as gluten sensitivity and celiac disease due to the inflammatory response that is triggered via the above mechanism.

It is important to distinguish gluten sensitivity from celiac disease as the symptoms of each disorder are very similar. However, the symptoms of gluten sensitivity will resolve within days as long as a gluten free diet is implemented and followed. Sapone et al, (2011) determined that similar to celiac disease, but to a lesser extent, intestinal permeability in gluten sensitivity uses paracellular pathways, since it moves in the space between cells not through them, as indicated by increases in urinary lactulose. Urinary lactulose found in urine is a hallmark of the transport through paracellular pathways. Sapone et al. (2011) additionally determined that there is a significant reduction of recruitment/activation of t-cells in gluten sensitive intestines versus the intestines of those with celiac disease. This further illustrates the difference in the two disorders through the lack of autoimmune response.

The autoimmune response elicited in individuals with celiac disease is triggered

by the ingestion of gluten containing foods. Once these foods travel through the digestive system and into the small intestine, the autoimmune response is triggered and measured primarily through bacteria level changes in the intestines and resulting fecal material. Cytokines and chemokines, specifically TNFα, IFNγ and IL-8, induce inflammatory responses in the intestines of individuals with celiac disease (Sanz, 2010). These cytokines and chemokines can be measured in fecal matter and when individuals with celiac disease are placed on gluten free diets, the levels are significantly reduced. One primary difference between individuals who have celiac disease and those who are gluten sensitive involves gliadin. Sabel'nikova (2012) noted that higher than normal levels of AGA or gliadin antibodies, but a lack of autoimmune antibodies are observed. These pathological changes without histological changes are important in differentiating between the two clinical disorders.

It is important to examine the physiological response the body has to digestion and the breakdown of whole grains. Biggs and Parsons (2009) conducted a study examining the impact of increased whole grain consumption on chicks and found a significant increase in the size of the gizzard. The gizzard is responsible for the grinding up of grains to make them easier to digest in chickens and its increased size indicated a physiological response to higher whole grain consumption. Additionally, Hernot et al. (2008) suggest that whole grains undergo equal to or less fermentation than their degraded counterparts (Hernot et al., 2008). Fermentation occurs as a result of anaerobic digestive processes that allow for the production of short-chain fatty acids and is an important part of protecting people from chronic diseases and colon cancer. A difference

in fermentation shows that whole grains are not necessarily better for SCHFA production as previous studies have claimed.

Another important consideration when dealing with gluten sensitivity and disorders, such as celiac disease is whether or not people are actually aware of the problem/issue. Rubio-Tapia, Ludvigsson, Brantner, Murray, and Everhart (2012) determined in an NHANES related study that celiac disease affects one in every 141 Americans. However, what was more interesting was that 29 of the 35 participants in the study were unaware that they had the disorder. These are important considerations when dealing with digestive issues and tolerances. The statistics show that there has been a fourfold increase in celiac disease diagnosis since 1950 (Murray, 2009). However, this current NHANES study illustrates that the problem may be much more prevalent than originally believed.

Gluten Sensitivity and Disorders

There are a number of digestive related disorders that result in gluten sensitivity. Celiac disease, Crohn's disease, and irritable bowel syndrome (IBS) are three of the main digestive disorders that require diets that are specific about gluten-containing food consumption. A great deal of the sensitivity people with these disorders experience has to do with gut fermentation of different types of grains and carbohydrates in general. Lomer (2010) determined that fermentable oligo-, di-, mono-saccharides and polyols when ingested in individuals with Crohn's and irritable bowel syndrome, result in excess bloating and increase colon secretions, which often result in loose stools. This sensitivity is a result of the consumption of simple carbohydrates, like fruits, and more complex

carbohydrates, like whole grains. The lack of removal of the outside of the grains, which makes them whole grains, makes them much more difficult to digest in individuals with these conditions.

The evolution of the body, food sources, and diet are all important factors when examining gluten sensitivity, celiac disease, and diagnostic tests for these changing disorders. Tommasini, Not, and Ventura (2011) determined that wheat products now contain higher concentrations of gluten and are now more readily available than they were previously and that changing epidemiology of gastrointestinal infections are both significantly influential in the manifestations, severity, and physiological changes associated with celiac disease and other gluten related illnesses.

This information has led to changes in the diagnosis of gluten related disorders. Currently, the standard method for diagnosing celiac disease involves detection of serum endomysial (EmA) and transglutaminase 2 (TG2-ab) antibodies to predict damage to the villi in the small intestine, before it occurs. Recent research confirmed that antibodies against deamidated gliadin peptides (DGP-AGA) appear prior to the EmA and TG2-ab antibodies, allowing for even earlier diagnosis of celiac disease and better prediction of intestinal damage (Kurppa et al, 2011). This allows for very early detection and diagnosis of gluten related disorders and damage. Knowing and understanding the damage that gluten can cause to the intestines and the manner in which that damage is signaled helps clinicians assess the risks associated with dietary choices.

Celiac disease and irritable bowel syndrome are two of the primary diseases related to gluten sensitive symptoms. Both disorders are clinically diagnosable, but can

present with a very broad number of symptoms. This, in part, may explain why 71% Americans have celiac disease, but the majority of cases remain undiagnosed, as previously stated (Rubio-Tapia et al. 2012). Many of the patients with a diagnosis of IBS could potentially have celiac disease, but a diagnosis of celiac disease for an individual with IBS overrides the previous IBS diagnosis and the individual is then considered to soley have celiac disease. More importantly though, is that the symptoms that defined celiac disease and IBS are also symptoms that define gluten sensitivity (Verdu, Armstrong & Murray, 2009). While gluten sensitivity is defined using many of the characteristics used to define and diagnose celiac disease and IBS, it does not satisfy all of the necessary criteria to be celiac disease and by definition is not IBS.

Celiac disease additionally, can be associated with a number of co-morbid conditions including Type I diabetes, cancer, and nutrient deficiencies. One of the primary differences between celiac disease and other gluten sensitive disorders like wheat allergies and gluten intolerance is that these two health issues are not associated with other co-morbid conditions, as is celiac disease (Pietzak, 2012). Anyone having one of these disorders should follow a gluten-free diet according to a physician's dietary recommendations. However, gluten impacts and effects the individuals afflicted with each of these disorders differently.

A wheat allergy is similar to other food allergies, with a heavy association to an illness or reaction known as Baker's asthma. Baker's asthma results when wheat is inhaled by someone with a wheat allergy and exhibits similar symptoms to an asthma attack, but wheat allergies are much more easily diagnosable through a simple skin prick

test (Sapone et al, 2012). This is one of the only gluten sensitive related disorders that does not require a diagnosis by exclusion. Many of the other gluten sensitive disorders require the isolation of symptoms and the elimination of certain issues, co-morbid conditions, and immune specific responses to get to a correct diagnosis.

A number of studies have been conducted on mice, which attempt to mitigate the inflammatory impacts on the intestines of inflammatory bowel disease. Round and Mazmanian (2009) determined that not only are mice that are raised in germ-free or sterile environments immune to the gut issues associated with inflammatory bowel diseases, but that if mice (among many other animals) are pre-treated with antibiotics the inflammatory response that is normally present in these sensitive guts is not present. The study used mice that under non-sterile or normal conditions all spontaneously develop a chronic form of colitis. This finding is important for the management of symptoms and diet related problems associated with inflammatory bowel diseases.

Gluten sensitivity or intolerance should not be confused with irritable bowel disease, even though the symptoms are similar. An important distinction between the two is the impact of mental states of individuals with the disorders on the physical symptoms experienced. Kay, Jorgensen, and Jensen (2009) conducted a study that followed patients over the course of five years examining symptoms of irritable bowel disease and found that the disease and its symptoms fluctuate over time and are more tied to psychological factors than any lifestyle components. Gluten sensitivities are triggered by the ingestion of foods that contain gluten, while irritable bowel disease can also be triggered by food as the mental state of the person experiencing the illness plays a key role in the severity and

frequency of symptoms. Additional studies have been conducted to determine what if any influence the placebo effect has on IBD sufferers. One such study by Kaptchuk et al. (2008) determined that in three different placebo treatment scenarios for IBD, the one that had the greatest impact on reducing symptoms and symptom severity revolved around a strong physician-patient relationship based on extra attention and warmth on the part of the physician. Gluten intolerance and symptom management do not show improvement with more positive mental health component.

Summary and Conclusion

The literature on various aspects of the digestive process, diagnosis criteria for bowel and gluten related illnesses and diseases, and control mechanisms is clear about the uncomfortable side-effects of consuming gluten and the intracellular pathways that cause that discomfort. There are a number of issues and problems that occur throughout the digestive process for individuals who have gluten sensitivities. There are also clear variations in the ability of certain diet-related and cognitive treatments for gluten-associated disorders. Distinctions between various types of gluten disorders are also difficult to make, because of the lack of availability of testing for specific disorders. Rather, bowel symptoms are relied on to determine sensitivities with the existence of other symptoms used as determining diagnosis criteria.

Understanding the role of short chain fatty acids and the physiological mechanisms that underpin digestion are key in understanding how foods impact digestive health. The type and composition of the foods that are ingested play important roles in gut fermentation and gut sensitivity to those foods. These physiological digestive

properties are keys to understanding the symptoms related to the digestion of, in the case whole grains and gluten containing foods. The alteration and modification of grains is also an important component to gut fermentation and digestion and potentially helps explain the rise in gluten sensitivity.

Unfortunately, there is no real definitive literature that deals with the benefits or draw-backs of whole grain consumption. The majority of the literature that amplifies benefits of whole grains, actually is discussing the benefits of various types of fiber contained within the whole grains. These same types of fiber can be obtained through fruits and vegetables. This is why it is vital to examine bowel symptoms in light of whole grain consumption and deal with what the dietary recommendations for whole grain consumption and the increase in the consumption has done to bowel health and gluten sensitivity.

Chapter 3: Research Method

Introduction

The goal of this study was to determine if diets high in whole grains or that meet the recommended daily intake of whole grains help minimize or increase gluten sensitivity, based on the bowel symptoms that correlate with gluten sensitivity. Study data were from the NHANES, allowing for analysis of U.S. dietary trends over time. This was important to determine if the more recent emphasis on incorporating whole grains into the diet impacts (a) the amount or frequency of whole grain consumption and (b) bowel health. Moreover, the results of the study will help people determine what sources of whole grains increase gluten sensitivity and in what amounts if any/at all. I targeted adults, ages 20 and older, used specific dietary survey questions related to whole grain and general grain consumption, and compared reported whole grain consumption and bowel problems/issues as a primary indicator of gluten sensitivity.

Research Design and Rationale

Study variables included types and amounts of grain consumption, consumption of gluten-free foods, overall dietary consumption of whole grain food sources, nongrain food sources, and bowel health variables. SAS were used to analyze data. The study was correlational and quantitative in nature, with the primary data source being NHANES data from 2007 through 2012. NHANES uses a stratified, continuous sampling, multistage probability design, and the NHANES data gives a snapshot for a particular time, which makes it easier for comparison. I targeted adults, ages 20 to 99, used specific dietary survey questions related to whole grain and general grain consumption, and

compared reported whole grain consumption and bowel problems/issues as a primary indicator of gluten sensitivity.

Specific NHANES questions pertinent to bowel health and symptoms associated with gluten sensitivity and dietary questions on consumption of foods that are high in fiber and are whole grain products were used to answer the study research questions:

1. Is there an increase, defined as a 5 to 10% increase or higher, in whole grain consumption by adults 20 and older after the release of the 2010 dietary guidelines compared to prior to the release of the 2010 guidelines? (independent variable: 2010 dietary guidelines; dependent variable: whole grain consumption)
2. Does an increase in whole grain consumption by adults 20 and older result in increased gluten sensitivity or bowel problems? (independent variable: daily amount of whole grain consumption; dependent variable: gluten sensitivity illustrated by bowel problems)
3. Is consumption of whole grains by adults 20 and older equivalent to and at half of the 2010 dietary guidelines recommendation linked to increased gluten sensitivity and changes in bowel health and intolerance (as indicated by increased bowel problems)? And if so, for what percentage range or amount in grams of whole grain wheat is there a noted difference?

NHANES questions used for the study are from the bowel health (BHQ) and dietary intake (DTQ) questionnaires. The questions are based on a survey of self-reported

data that do not delve deeply into the "whys" of food consumption. Questions from the BHQ include the following: BHQ010 - Bowel leakage consisted of gas?; BHD050 - How often have bowel movements?; BHQ030 - Bowel leakage consisted of liquid?; BHQ040 - Bowel leakage consisted of solid stool?; BHD050 - How often have bowel movements?; BHQ060 - Common Stool Type; BHQ070 - Had an urgent need to empty bowels?; BHQ070 - Had an urgent need to empty bowels?; and BHQ090 - In past 12 months had diarrhea? Questions pertaining to dietary consumption include the following: DTQ.010 During the past month, how often did {you/SP} eat **hot or cold cereals**?; DTQ.020 During the past month, what kinds of cereal did {you/SP} **usually** eat?; DTQ.210 (During the past month), how often did {you/SP} eat **brown rice** or other cooked whole grains, such as G/Q/U bulgur, cracked wheat, or millet? Do **not** include white rice. (You can tell me per day, per week or per month.); DTQ.200 (During the past month), how often did {you/SP} eat **whole grain bread** including toast, rolls and in G/Q/U sandwiches? Whole grain breads include whole wheat, rye, oatmeal and pumpernickel. Do **not** include white bread. (You can tell me per day, per week or per month.); and DTQ.260 (During the past month), how often did {you/SP} eat **popcorn**? (You can tell me per day, per week or per G/Q/U month.). The variables are already defined within NHANES specific questions and each of the variables has units of measure assigned to them by the survey.

The bowel health questions were compared and analyzed with those pertinent questions from the dietary screener module. The bowel health questions were chosen as common symptoms of gluten intolerance. It was only important to compare these bowel

symptoms with foods that are known as whole grains or are known to contain whole grains but also to foods that can elicit the bowel symptoms for other diseases. Fresh fruits and vegetables cause similar symptoms to gluten intolerance in individuals who have irritable bowel disease. It was important to compare the foods with each bowel symptom to determine if the bowel symptoms are caused by a gluten containing whole grain or something else. These dietary questions are the ones that are isolated to those products containing whole grain foods.

Population and Sample Size

The NHANES database includes a very broad population with varying socioeconomic backgrounds, demographics, ages, sexes, and health statuses. The purpose of the survey is to determine health risks for given demographics, based on disease prevalence and risk factors for developing diseases. The survey includes a comprehensive sample of, on average, 6,059 individuals annually. All of the participants are located in the United States, and for quality purposes, 15 counties participating in the survey are visited every year with different participating counties visited from year to year (NHANES 2009 to 2010).

For this study, data were limited to those individuals who were aged 20+ years, with the sample comprising equal compositions of individuals from each state, ethnicity (such as the whites, Latinos, Blacks, among others), and gender (male and female). Celiac disease tends to affect sexes and ethnicities on given continents (such as North America and Europe) at similar rates. Therefore, an analysis was not done on ethnicity or gender, and those variables were saved for future studies. Additionally, the sample size

was based on NHANES frequency of reporting for bowel health related variables of interest (2007 to 2008, 5,261; 2009 to 2010, 5,276) because that is the smallest sample of people who responded to the questions under examination. This sample size allows adequate analysis of the issue and easy comparison from year to year, since the same sample size is used annually.

Data Source

The NHANES database is designed to be used primarily for quantitative studies. The actual survey includes important health information that is analytically measurable, such as laboratory tests for diseases and dental, medical, and physiological information. Additionally, the survey portion of the database includes questions and information on demographic, socioeconomic, dietary, and health issues. The data are already collected using a standardized instrument that has consistently collected that same information since 1999. Survey tools lend themselves to quantitative data analysis, when examining objective subject matter.

I compared data from NHANES 2007-2008, 2009-2010, and 2011-2012 for the selection of questions related to bowel health and habits such as frequency of bowel movements, viscosity of the stool, diarrhea and data on celiac disease, diet for data on individual grain sources, and data on diet trends (such as gluten-free and whole grain). Some of the questions regarding bowel include

- How often have you had bowel leakages and what is the component of such leakages?

- How often do you usually have bowel movements?
- Have you ever had an urgent need to empty your bowel in the past 12 months?
- Have taken laxatives in the past 30 days? If yes, how many times?

I looked at patterns in the grouping over the past 3 to 5 years of groups of people who have taken the survey for whole grain consumption and bowel issues.

Instrumentation

The tool (NHANES survey) is a major program of the National Center for Health Statistics, an agency under the Centers for Disease Control and Prevention, was established over 50 years ago, and has been revised multiple times in order to meet the emerging needs of the changing population. This was done to capture the most relevant and accurate data possible. Sample weights and populations have also been altered over time as the composition of the United States changed. Sampling fractions were also set to ensure that overall Hispanic populations were appropriately accounted and that the sample size for Mexican-Americans was similar to previous years in order to provide reliable information of the subcategory. For example, for some years children were oversampled. More recently, all Hispanic individuals were oversampled, as opposed to only Mexican-Americans, to ensure that overall, Hispanic populations were accounted for and that the sample size for Mexican-Americans was similar to previous years in order to provide reliable information of the subcategory. Oversampling is performed to make sure equal weights and values are given to certain population subgroupings and individuals as

well as to allow for nationally generalizable data (NHANES, 2009, 2012, 2013).

NHANES uses a stratified, continuous sampling, multistage probability design that has undergone rigorous testing and is available in both English and Spanish. The survey has an excellent reputation and, in addition to the factors already discussed, was chosen for the current study because it provides national estimates of nutritional status and consumption and epidemiological health of the United States population. Moreover, it was designed using Good Clinical Practice guidelines (WHO, 2002).

It is first important to consider and understand that I examined both gluten intolerance and whole grain consumption. The dietary intake questions selected directly address the consumption of whole grains. However, based on findings cited in the literature review, it is important to consider sources of fiber as well as the intake of whole grains because specific types of fiber can mimic the effects of other food sources. I controlled for confounding of this variable through the examination of food sources (whole grains, fruits, vegetables) that could cause the bowel symptoms typical of gluten intolerance and IBS through self-reported data from NHANES. These questions are also important in making a differentiation between how whole grains impact bowel health and how fruit and vegetable fibers impact bowel health, since the literature points to fruits and vegetables as having the same benefits as whole grains without some of the more uncomfortable bowel health side-effects.

The survey does not directly measure celiac disease prevalence, IBS prevalence, or gluten intolerance. There are also no definitive diagnostic tests for IBS or gluten intolerance. Rather, the symptoms of these disorders are what constitute a potential

diagnosis. Gluten intolerance and IBS are diagnoses of exclusion because they cannot be tested for, whereas celiac diseases can, which is why these are commonly misdiagnosed. Specific bowel health questions in conjunction with dietary intake questions allows for the reconciliation between diet and bowel health.

The bowel health questions chosen were related to specific symptoms of gluten intolerance. Common symptoms of gluten intolerance include gas, swelling of the abdomen, bloating, diarrhea, loose watery stools, vomiting, and mild stomach pain. All of these symptoms were assessed through the questions contained within the bowel health portion of the NHANES survey. Some bowel health questions were omitted from this study because they were not relevant to the symptoms of gluten intolerance. Likewise, they did not add or leave out important information that could lead to other medical conclusions regarding whole grain consumption and gluten intolerance.

Procedure

This study was deemed to be one of minimal risk to participants. There was no direct contact between participants and me. I did not perform the collecting and organizing of data by NHANES. I did not obtain or administer the informed consent and did not enroll any participants in the study. This study is, therefore, not considered to be engaged in human subject research under Office for Human Research Protection guidelines. Furthermore, the probability and scope of potential harm or discomfort that was anticipated to be involved in this research study was not greater than that experience in ordinary daily life.

This research was conducted in alignment with the U.S. Department of Health and Human Services (DHHS) regulations 45 CFR § 46.102 and Food and Drug Administration regulations 21 CFR § 50.3 and 56.102 (FDA, 2012). This study was exempt from Institutional Review Board approval due to the provision that any research conducted on preexisting data, records, or documents where no identifiers link the subjects to the data. This data were collected from a preexisting data source that was fully in compliance with DHHS and FDA rules and regulations. Additionally, the protocol and informed consent documents used to collect the original data are in full compliance and approved annually by an Institutional Review Board.

Data Analysis

I analyzed secondary data, generated from a survey designed to randomly select households and individuals to participate using a Primary Sample Units (PSUs) technique, which were chosen from within each strata and defined by geography and minority population factors. This sampling design is slightly complicated and required special attention when making calculations for percentages, estimates, and standard errors. The PSUs created issues of similarity because PSU compositions tend to be more homogeneous, so greater sampling of different PSUs rather than within them is attempted to create a more heterogeneous sample.

SAS was used as it is compatible with the NHANES database and was the statistical program best suited for data analysis of this study. Four years of data can be analyzed as one single group or set of data, which is why 4 years were chosen. The bowel health questions and dietary questions were merged for analysis of the 4 years of data.

Chi-square analysis was performed and correlation coefficients were used to determine if there were correlations between the dietary intake of whole grains and bowel symptoms experienced. In SAS, the PROC SURVEYFREQ procedure is performed to obtain chi-square statistics. The following process was used to compare the bowel health questions with the dietary intake questions: STRATA specifies the strata variable for stratification LUSTER accounts for clustering and is used to specify PSU, which are all PSUs, WEIGHT assigns probability weights to even out the strata and clustering variances and nonresponses, and the WHERE can be used to specify a subpopulation. The WHERE function is not used in this analysis because the overall study and sample is broad across the United States for generalizable results. A table is then generated using the TABLE statement, which illustrates the categorical variables of diet and bowel health.

The chi-square test was the most appropriate for this study as it measures two variables. Chi-square tests were performed for each bowel health question and each dietary question, creating two-way tables to determine the association between whole grain consumption and bowel health. For each question compared in the chi-square table, 1 or 2 degrees of freedom were used, depending on the table and number of variable compared within that table. A probability level of equal to .05 was used for optimal determination of statistical significance. Familywise error is a probability and can result in alpha inflation, meaning that the noted associations were due to chance.

$$\mathrm{FWER} = \Pr(V \geq 1),$$

In order to correct for an increase in alpha inflation, Bonferroni was used post hoc to

ensure that the alpha value remains at .05.

$$\sum_{i=1}^{n} a_i = \alpha$$

This study is based on usual dietary intake. Therefore, random dietary error can lead to weakened estimations of association and lowered statistical powers. Individuals can over or underestimate consumption of certain items creating errors in assessment. Regression calibration was performed for this very reason. Regression calibration uses a best fit line in order to determine adjust point and interval effect estimates that result from, commonly, nutritional measurement errors. It requires known data on observed dependent/independent variable relationships in order to make estimates of other values of the independent variable based on different observations of dependent variables. In the case of this study whole grain consumption and dietary intake are the independent variables and resulting gluten-sensitivity (indicated by bowel health questions) is the dependent variable.

In order to answer the proposed research questions each of the bowel questions were compared individually to the dietary questions. Relationships were determined using chi squared analysis and contingency and correlation coefficients. The contingency coefficient is a measure of the degree of relationship, association of dependence of the classifications in the frequency table, where the larger the value of this coefficient, the greater the degree of association. The maximum value of the coefficient, which was never greater than 1, was determined by the number of rows and columns in the table.

$$C = \sqrt{\frac{\chi^2}{\chi^2 + n}}$$

The following questions were answered using chi squared analysis and correlation coefficients where appropriate:

For the question “Is there a notable increase in whole grain consumption by adults after the release of the 2010 dietary guidelines?” the consumption of whole grains will be directly measured by examining the following dietary questions: DTQ.200 (During the past month), how often did {you/SP} eat whole grain bread including toast, rolls and in G/Q/U sandwiches? Whole grain breads include whole wheat, rye, oatmeal and pumpernickel. Do not include white bread. (You can tell me per day, per week or per month.), and DTQ.260 (During the past month), how often did {you/SP} eat popcorn? (You can tell me per day, per week or per G/Q/U month.). These questions were compared to the same questions using the data sets from 2009 and then the data sets from 2011 to determine if there was a statistical change of 5% or more.

For the questions “Is consumption of whole grain wheat in excess of the 2010 dietary guidelines linked to increased gluten sensitivity and intolerance (as indicated by increased bowel problems)? And if so, for what percentage range or amount in grams of whole grain wheat is there a noted difference?” the results from the previous question will be used for the analysis. Additionally the dietary questions: DTQ.200 (During the past month), how often did {you/SP} eat whole grain bread including toast, rolls and in G/Q/U sandwiches? Whole grain breads include whole wheat, rye, oatmeal and pumpernickel. Do not include white bread. (You can tell me per day, per week or per

month.), and DTQ.260 (During the past month), how often did {you/SP} eat popcorn? (You can tell me per day, per week or per G/Q/U month.) were compared in individual chi squared analysis and using correlation coefficients to the bowel health questions: BHD050 - How often have bowel movements? BHQ030 - Bowel leakage consisted of liquid?, BHQ040 - Bowel leakage consisted of solid stool?, BHD050 - How often have bowel movements?, BHQ060 - Common Stool Type, BHQ070 - Had an urgent need to empty bowels?, BHQ070 - Had an urgent need to empty bowels?, and BHQ090 - In past 12 months had diarrhea?

The final question "Are there changes in bowel health based on the amount of whole grains consumed for people consuming whole grain at the recommended daily amount, as compared to people who consume less than half of the recommended daily amount as determined by increased gluten sensitivity?" was analyzed using the analysis from the previous question, so two groups could be stratified. Correlation coefficients were used to compare the two groups responses to the dietary and bowel health questions. Additionally the bowel health questions were compared to the questions: DTQ.010 During the past month, how often did {you/SP} eat hot or cold cereals?, DTQ.020 During the past month, what kinds of cereal did {you/SP} usually eat?, and used chi squared to determine any possible issues of confounding and alternate conclusions for the results.

Ethical Considerations

As with all study protocols consistent with National Institutes of Health (NIH) and The Collaborative Institute Training Initiative (CITI) good clinical practice and human subject protection standards, the NHANES questionnaire was and is put through a

continuous review process with institutional review boards which examine ethicacy of the study content, consent form, protocol, and data usage. Since IRB approval was first established a continuing review process is performed annually by the NCHS Research Ethics Review Board (formerly NHANES Research Ethics Review Board). This process collects data including the number of participants, the number who have consented but failed the screening process, any changes that occur during the calendar year that can impact the study and its participants, as well as information on all of the active sites approved for administering the survey. There have been three protocol changes from the outset of the IRB approval with the current approved protocol being the Continuation of Protocol #2011-17. The protocols that were used and approved for this study are Protocol #2005-06 and the continuation of that protocol and Protocol #2011-17. Both protocols are IRB approved through the NCHS Research Ethics Review Board (ERB).

All information researchers are privy to has been de-identified to remove connection to the actual person who completed the questionnaire. This de-identification process is generally a standard operating procedure in studies. This allows for subject anonymity, so disclosure of personal information with regard to this specific study is not possible, as there is no access to that information.

Internal/External Validity

The sample used was drawn from the vast population of the United States. One of the primary concerns with the data extracted from NHANES is that the survey tool was not designed for the explicit purpose of studying whole grain consumption and gluten intolerance. While the tool has been revised and continues to evolve to gather the most

comprehensive and best nutritional data for the United States population, the results of the data gathered and analyzed might only be applicable to the population from which they are taken (NHANES, 2012). This is mainly, the United States population, because diets and nutritional recommendations vary from country to country.

Several considerations were made when determining if the external and internal validity of the study were relevant. The primary determination made was whether or not the questions asked in the database were relevant and specific enough to the population and topic being studied. The number of nutritional questions based on fiber rich foods and whole grain foods or servings eaten every day, as well as the bowel symptom questions as a comparison makes the database very appropriate. With the timeliness of the data collection and the changes made to NHANES accordingly from year to year the data collected by the survey as far as timeliness and appropriateness is very relevant and current. Confounding variables present another obstacle when determining the validity of data collected by someone other than the individual performing the research. The data collected by NHANES are designed to determine a number of public health conclusions on population health, nutritional habits, and various health allergies and behaviors.

In addition, the survey questions and data were not specifically collected to determine gluten intolerance based on dietary habits and bowel health, so when specifically considering that topic there were a number of potential confounding issues that could impact the validity of the study. Inaccurate responses and under-reporting are important considerations when determining the validity of self-reported data. This study relied solely on self-reported data so this is an important consideration to the validity of

the study. One of the most important considerations is how generalizable the results of the study are to the overall validity. The overall study results are very generalizable to the general United States population. This does not necessarily translate to the rest of the world, due to the variations in dietary habits, availability of food and certain food sources, and diets endorsed by the individual countries. Self-reported nutritional data suffers from under-reporting and the information available in NHANES is no different. Archer, Hand, and Blair (2013) found that dietary intake was under-reported through 2010. Despite this, the survey is used as one of the best possible tools available to inform FDA recommendations (FDA, 2014) and My Plate nutrition.

Varying questions and components of the NHANES survey are added, evolved, and discontinued every year in order to ensure that the most accurate, most population relevant data are captured by the survey. The survey is highly regarded and considered a very rigorous examination of public health data and issues, as well as scientific validity. There are emerging threats to this validity which include a survey redesign and resource allocation to continue the study into the foreseeable future. With the ultimate goal of creating specific data for the local and state levels the current survey and budget do not meet the needs of specifically targeting these types of populations (NHANES, 2012).

The NHANES survey maintains good internal and external validity despite the very large sample population and small primary sampling unit size. The sampling results in large cluster sizes, because the primary sampling units are very expensive. This means that statistical estimates are slightly less efficient than some other surveys. The nature of the survey and cost constraints of the continual conduction of the survey has come at this

slight cost. However, the survey and sampling still provide a very broad range of significant data and a very large sample population.

Conclusion

Prior research indicates that whole grains should be avoided in individuals who have diagnosed celiac disease and gluten intolerance. There is also information indicating that celiac disease has increased four-fold since 1950. However, recently there has been increased pressure to consume whole grains. Gluten-free diets are also a trending topic due to the increase in celiac disease. However, it is not known if resulting increased gluten sensitivity in young people and adults is due to higher consumption of whole grains. Chapter 4 analyzes NHANES questions related to reported dietary consumption of foods and corresponding bowel health questions that are symptomatic of gluten sensitive diseases. SAS was used to compare bowel health questions and diet questions from the database with chi-squared analysis determining relationships between study variables and drawing conclusions about gluten sensitivity and dietary consumption of whole grains.

Chapter 4: Results

Introduction

The purpose of this study was to determine if diets high in whole grains or those that meet the recommended daily intake of whole grains help minimize or increase gluten sensitivity. I used NHANES data to answer three research questions:

1. Is there an increase, defined as a 5 to 10% increase or higher, in whole grain consumption by adults 20 and older after the release of the 2010 dietary guidelines compared to prior to the release of the 2010 guidelines? (independent variable: 2010 dietary guidelines; dependent variable: whole grain consumption),

   $H1_0$: There is no or limited increase (less than 5%) in whole grain consumption by adults in the United States after the release of 2010 dietary guidelines.

   $H1_a$: There is an increase of at least 5% in whole grain consumption by adults in the United States after the release of 2010 dietary guidelines.

2. Does an increase in whole grain consumption by adults 20 and older result in increased gluten sensitivity or bowel problems? (independent variable: daily amount of whole grain consumption; dependent variable: gluten sensitivity illustrated by bowel problems)

   $H2_0$: The increase consumption of whole grains has not resulted in an increase in gluten sensitivity and related bowel symptoms.

$H2_a$: The increase in consumption of whole grains has resulted in an increase in gluten sensitivity and related bowel symptoms in adults ages 20 and older.

3. Is consumption of whole grains by adults 20 and older equivalent to and at half of the 2010 dietary guidelines recommendation linked to increased gluten sensitivity and changes in bowel health and intolerance (as indicated by increased bowel problems)? And if so, for what percentage range or amount in grams of whole grain wheat is there a noted difference?

$H3_0$: Individuals who meet or exceed the recommended daily consumption of whole grains show no significant bowel symptoms, noted by no increase in bloating, gas, and loose stools.

$H3_a$: There are bowel health changes and responses, noted by increase in bloating, gas, and loose stools as a result of any consumption of whole grains, but the frequency of reported incidences of bloating, gas, and loose stool are greater in those who meet or exceed the recommended daily amount.

In this chapter, I present the analysis and results of the data outlined in Chapter 3. Each research question and resulting data analysis are presented with tables and figures. Additional data are presented on the sample demographics. In this chapter, I provide the results of the analyses of the three research questions presented above.

Sample Demographics

The total sample size for the years 2007 to 2010 was $n = 5,746$ individuals. All individuals included were ≥ 20 years old. Only $n = 425$ individuals were over the age of 80, and the rest of the sample was between 20 and 79 years. Individuals who reported health status were adjusted to $n = 5,746$ applying appropriate weights. Over half of those included in the survey felt they were in fair to very good health, with 40% feeling they were in good health, 27% feeling they were in very good health, and 19% feeling they were in fair health. Only 10% of the population felt they were in excellent health, and 4% felt they were in poor health. The sample was not stratified by age with only two age groupings nor were demographic statistics run for ethnicity and gender. The focus of study was not on differences between races or sexes but rather on the adult respondents in general, not age divided data.

Data Analysis

These hypotheses were tested using secondary data from the NHANES 2007 to 2012, which is a stratified, multistage probability sample of the civilian, noninstitutionalized U.S. population (NHANES, 2012b). All analyses were performed using SAS statistical software (SAS ver. 9.3), and all tests were run on datasets obtained from the NHANES conducted by the CDC. Analyses here include survey data from 2007-2008 and 2009-2010 on dietary health (including the frequency with which whole grains were consumed). Significant changes were made to the 2011-2012 NHANES questions on diet and bowel health. The bowel health questions were excluded altogether in the 2011-2012 dataset, and only perceptions on whole grain consumption were included in the dietary

component of the survey. Due to these changes in the NHANES 2011-2012 data set, only questions related to whole grain perceptions were analyzed. As recommended by the CDC, all samples were weighted using the appropriate sample weight to adjust for the complex sample design

For the 2009-2010 survey data, reports of dietary health (including the frequency with which whole grains were consumed) were correlated with reports of bowel health to test whether reported whole grain consumption was associated with indices of bowel health. Whole grain consumption was analyzed as the number of times per week respondents reported consuming whole grains. Correlations between whole grain consumption and indices of bowel health (the number of bowel movements reported per week, and the frequency of bowel leakage that consisted of gas, liquid, or solid stool) were tested using generalized linear models (PROC GLIMMIX). Because of the skew in the frequency of reported occurrences (including many zeroes), generalized linear models assuming a Poisson distribution were used in analyzing continuous response variables. For the bowel-health questionnaire, respondents also reported whether they had experienced an urgent need to empty their bowels, had experienced constipation, had taken a laxative, and/or had experienced diarrhea. These data were reported on a "yes" or "no" basis, and were thus analyzed according to the frequency of whole grain consumption using a generalized linear model with a binary response distribution, similar to a logistic regression.

Results

Research Question 1

Perceived dietary needs were analyzed in order to answer Research Question 1: Is there an increase, defined as a 5 to 10% increase or higher, in whole grain consumption by adults 20 and older after the release of the 2010 dietary guidelines compared to prior to the release of the 2010 guidelines? (independent variable: 2010 dietary guidelines; dependent variable: whole grain consumption),

> $H1_0$: There is no or limited increase (less than 5%) in whole grain consumption by adults in the United States after the release of 2010 dietary guidelines.
>
> $H1_a$: There is an increase of at least 5% in whole grain consumption by adults in the United States after the release of 2010 dietary guidelines.

First, variation in perceived dietary needs for whole grains were assessed as well as changes in consumption from one survey year to the next, as a response to the question of how many ounces of whole grains should a person of their age, sex, and health status consume on a daily basis. A marked increased was noted from 2007 to 2010 (Figure 1).

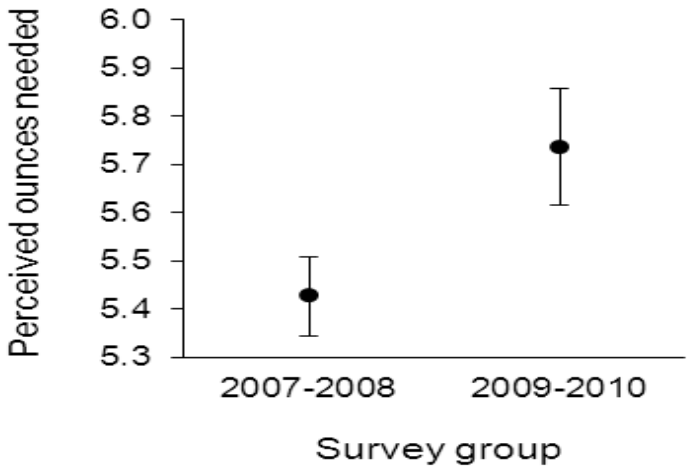

Figure 1. Perceived need for whole grain consumption from 2007 to 2010. Average daily amount of whole grains (ounces) that respondents thought a person of their age, sex, and health status should consume (means ± SE).

From 2007 to 2010 (i.e., 2007-2008 and 2009-2010 survey years), the average adult thought that a person of their age, sex, and health should consume 5.6 ± 5.7 ounces (mean ± SD; $N = 5746$) of whole grains per day, and respondents varied widely in this perception (see Table 1). The mean perceived amount of whole grains needed per day increased, on average 7.4%, from the 2007-2008 to the 2009-2010 survey years (Figure 1), a statistically significant increase ($t_{5298.3} = 2.13$, $P = 0.033$), allowing for a rejection of the null hypothesis.

Table 1.
Daily Whole Grain Consumption

	Min	Mean	Median	Mode	Max
Daily whole grain consumption	0oz	5.6oz	4.0oz	4.0oz	203oz

Note. The minimum whole grain consumption need was 0 oz, while the maximum was perceived to be 203 oz. There was high variance in perceived needs with the average need being 5.6oz with the lower quartile = 3 oz and the upper quartile = 8 oz daily.

Research Question 2

Generalized linear models using one way ANOVA assuming a Poisson distribution were used in order to answer Research Question 2: Does an increase in whole grain consumption by adults 20 and older result in increased gluten sensitivity or bowel problems? (independent variable: daily amount of whole grain consumption; dependent variable: gluten sensitivity illustrated by bowel problems)

$H2_0$: The increase consumption of whole grains has not resulted in an increase in gluten sensitivity and related bowel symptoms.

$H2_a$: The increase in consumption of whole grains has resulted in an increase in gluten sensitivity and related bowel symptoms in adults ages 20 and older.

The results of the generalized linear models are reported in Tables 2 and 3. Data were analyzed as continuous response variables assuming a Poisson distribution. Generalized linear models were used to analyze bowel health in relation to weekly consumption of whole grains. There was a significant, positive association between the

frequency of whole grain consumption and the number of bowel movements reported per week (Table 2, Fig. 2). There was also a significantly negative correlation between the consumption of whole grains and instances of bowel leakage in the form of gas (Table 2, Fig. 3). Consistent with the correlation between whole grain consumption and the frequency of bowel movements, there was also a positive correlation between daily whole grain consumption (in ounces) and instances of solid, as opposed to liquid, stool leakage (Table 2). People, on average, reported that they consumed 6 ounces of whole grains every day, making the weekly average consumption of whole grains 42 ounces. Over 50% of respondents had bowel leakage that consisted of gas 1 or more times per month. Twice as many people experienced liquid bowel movements as opposed to solid bowel movements. High nonresponse rates were noted in the bowel health questionnaires.

Table 2.
Weekly Consumption of Whole Grains and Impact on Bowel Health

Bowel movements per week	Estimate ± SE	F	df	P
Whole grain consumption	0.008 ± 0.003	6.29	1, 1727	0.012
Intercept	2.260 ± 0.009			
Instances of gas leakage per week	Estimate ± SE	F	df	P
Whole grain consumption	–0.024 ± 0.008	9.28	1, 1732	0.002
Intercept	0.813 ± 0.020			
Instances of liquid stool leakage per week	Estimate ± SE	F	df	P
Whole grain consumption	–0.050 ± 0.057	0.78	1, 1731	0.376
Intercept	–2.824 ± 0.128			
Instances of solid stool leakage per week	Estimate ± SE	F	df	P
Whole grain consumption	0.138 ± 0.018	58.25	1, 1731	< 0.001
Intercept	–3.376 ± 0.130			

Note. Results of generalized linear models analyzing indices of bowel health in relation to weekly consumption of whole grains. Four response variables are listed along with their correlation with the consumption of whole grains.

There was no association between the consumption of whole grains and whether respondents had experienced an urgent need to empty their bowels, had experienced constipation, had taken a laxative, had and/or experienced diarrhea (Table 3). However, there was a significant association between the frequency of laxative usage and whether or not respondents had experienced constipation within a given month (parameter estimate ± SE = 1.755 ± 0.091, $F_{1, 5265} = 369.5$, $P < 0.001$). Thus, respondents who had taken laxatives may have been less likely to experience constipation than those not taking laxatives.

Table 3.

Whole grain consumption and Bowel Health Events

Experienced an urgent need to empty bowels	Estimate ± SE	*F*	df	*P*
Whole grain consumption	0.012 ± 0.024	0.23	1, 1731	0.630
Intercept	0.968 ± 0.066			
Experienced constipation	**Estimate ± SE**	***F***	**df**	***P***
Whole grain consumption	0.018 ± 0.027	0.5	1, 1731	0.494
Intercept	1.235 ± 0.071			
Taken a laxative	**Estimate ± SE**	***F***	**df**	***P***
Whole grain consumption	0.025 ± 0.040	0.4	1, 1731	0.544
Intercept	2.269 ± 0.103			
Experienced diarrhea	**Estimate ± SE**	***F***	**df**	***P***
Whole grain consumption	0.044 ± 0.029	2.2	1, 1731	0.139
Intercept	1.228 ± 0.072			

Note. Results of generalized linear models analyzing indices of bowel health in relation to weekly consumption of whole grains. Data were analyzed using a binary response distribution with 'yes' or 'no' responses, estimates indicate the probability of a 'yes' being reported in the past month.

Research Question 3

Linear regression was used to identify correlations and answer the Research Question: 3.Is consumption of whole grains by adults 20 and older equivalent to and at half of the 2010 dietary guidelines recommendation linked to increased gluten sensitivity and changes in bowel health and intolerance (as indicated by increased bowel problems)? And if so, for what percentage range or amount in grams of whole grain wheat is there a noted difference?

$H3_0$: Individuals who meet or exceed the recommended daily consumption of whole grains show no significant bowel symptoms, noted by no increase in bloating, gas, and loose stools.

$H3_a$: There are bowel health changes and responses, noted by increase in bloating, gas, and loose stools as a result of any consumption of whole grains, but the frequency of reported incidences of bloating, gas, and loose stool are greater in those who meet or exceed the recommended daily amount. (Figures 2 and 3)

Results demonstrated high variability in the data and response rates. Regression lines using 95% confidence intervals were drawn, but no distinct pattern emerged.

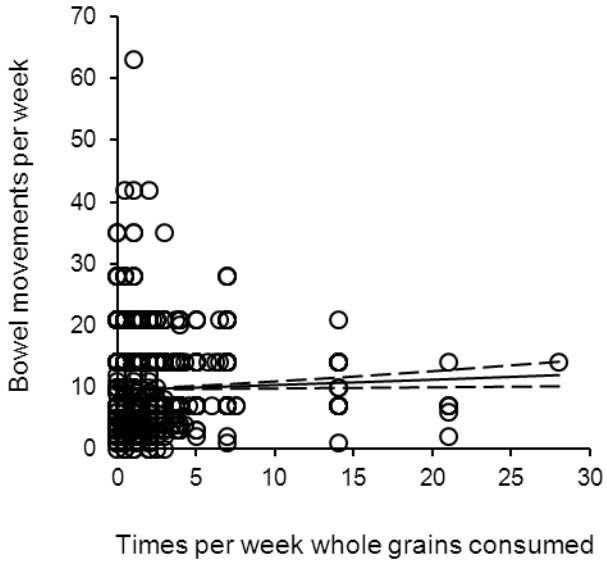

Figure 2. Relationship between whole grain consumption (times per week that respondents reported consuming whole grains) and the number of bowel movements reported per week. Points represent individual respondents, and the curves represent the regression line ± 95% confidence limits.

Figure 2 illustrates whole grain consumption per week and bowel movements per week, while figure 3 illustrates whole grain consumption and bowel leakage. The data had significant degrees of freedom (Table 2 and 3) creating a significant problem identifying a percentage increase or decrease in whole grain consumption. However, if examined as the average value from 2007 to 2010 whole grain consumption per day increased, on average, from the 2007-2008 to the 2009-2010 survey years (Figure 1), a statistically significant increase ($t_{5298.3} = 2.13$, $P = 0.033$). Taken with the linear regression, while there was a statistically significant increase in whole grain consumption and perception of need for whole grain, the only definitive statistical correlation is to an increase in bowel movements.

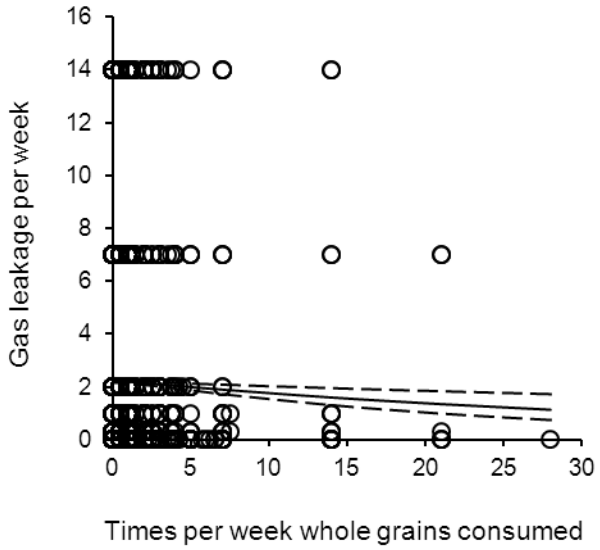

Figure 3. Relationship between whole grain consumption (times per week that respondents reported consuming whole grains) and the number of bowel leakages consisting of gas per week. Points represent individual respondents, and the curves represent the regression line ± 95% confidence limits.

Conclusion

The data analysis revealed a significant increase in reported whole grain consumption, as well as higher consumption of whole grains correlating to increases in solid stool leakage and instances of gas leakage. However, more research needs to be done to determine if these results are reproducible and what amounts of whole grains show correlations to these reported findings. Chapter 5 will discuss the implications of these findings, what further research needs to be conducted, and how these findings might impact health.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this study was to determine if diets high in whole grains or those that meet the recommended daily intake of whole grains help minimize or increase gluten sensitivity. I examined how whole grain consumption impacts bowel health and specifically focused on if whole grain consumption increased symptoms of gluten sensitivity. This study targeted adults, ages 20 and older, and used specific dietary survey questions related to whole grain consumption and compared that to bowel problems/issues as a primary indicator of gluten sensitivity. One way ANOVA was used to analyze the data was using Poisson distribution and linear models.

Three research questions were explored to determine if gluten sensitivity had increased with the upsurge in recommendations for the consumption of whole grains. The questions were used to examine if there had been an increase in whole grains based on recommendations, if an increase in the consumption of whole grains resulted in an increase in gluten sensitivity, and what range of whole grain consumption in grams had an impact on bowel health. In the current study, there was a significant increase in reported whole grain consumption. In addition, people who reported higher consumption of whole grains experienced increases in solid stool leakage and instances of gas leakage. However, more research needs to be done to determine if these results are reproducible and what amounts of whole grains show correlations to these reported findings. In this chapter, I examine the implications of the findings of this study. I also discuss future directions for research in this area.

Interpretation of Findings

There was a significant increase, 7.4%, in the amount of whole grains people believed they should consume on a daily basis from 2007 to 2010. The Whole Grains Council (2012) reported a 1,960% increase in the number of whole grain products available to the public from 2000 at 164 grain based products on consumer shelves to 2011 at 3,378. Based on dietary recommendations and the public health campaigns pushing for consumption of grains daily as part of a healthy diet, people have increased the consumption of whole grain foods. Tommasini et al. (2011) determined that wheat products now contain higher concentrations of gluten and are more readily available than they were previously. Additionally, the availability of these foods and the incorporation of whole grains into foods people eat every day have made this transition to eating more whole grains easier for people.

Furthermore, there were significant positive correlations in the number of bowel movements and higher whole grain consumption reported by individuals in the survey. People, on average, reported that they needed to consume 6 ounces of whole grains every day, making the weekly average consumption need of whole grains 42 ounces. However, the perceived consumption needs differed from actual grain consumption. Using NHANES data from 1999 to 2004, Zanovec et al. (2010) reported adults aged 19 to 50 years old consumed an average of 0.63 servings of whole grains on a daily basis. Using NHANES data from 2009-2010, Reicks, Jonnalagadda, Albertson, and Joshi (2014) determined that most adults (over 50% of those surveyed) aged 19 and older consumed 1 to 3 servings of whole grains daily. Zanovec et al.'s findings, when compared to Reicks

et al. illustrate the increase examined by this study. People are trying to consume more whole grains but have yet to be successful at meeting dietary recommendations. Zanovec et al.(2010) and Reicks et al. (2014) looked specifically at the dietary screener questions for actual reported dietary intake for 2 days. The findings of the NHANES study, used for this research, are supposed to be nationally representative. However, these only looked at a small portion of the population, and the reported data are representative of those who reported eating whole grains.

Six to eight ounces is the daily recommendation for grain consumption, half of which should be whole grains according to the USDA MyPlate recommendations (2014). The Dietary Guidelines for Americans (2010, p. 36) stated that people are getting the total number of grain servings recommended per day, but not enough of those are whole grains. This study illustrated that people are aware of the need to consume more whole grains and that whole grain consumption has increased. Over 50% of adults surveyed reported they eat between 1 and 3 servings of whole grains daily (Reicks et al., 2014). However, people still fall short of the recommendations. One possible explanation is that people think they are consuming whole grains, but the mislabeling of products and the genetic modification of crops discussed earlier are altering actual whole grain values of products. This increase in the availability of whole grain products makes it easier for consumers to obtain whole grains and consume them at a higher rate than previously.

The symptoms that define celiac disease and IBS are also symptoms that define gluten sensitivity and include gas, bloating, and diarrhea (Verdu et al., 2009). Responses

by individuals to questions that reported frequency of bowel movements and bowel leakage were examined. In addition to the number of whole grains reported, over half of respondents had bowel leakage that consisted of gas more than once per month with double the number of those surveyed experiencing diarrhea-type bowel movements as opposed to solid bowel movements. These two pieces of information together illustrate a connection between whole grain consumption and gluten sensitivity based on symptoms and suggest such a link between whole grain consumption and symptoms of gluten sensitivity. Some researchers have concluded that nonceliac related gluten intolerance does exist with whole grain wheat consumption (Biesiekiersk et al., 2011; Carroccio et al. 2012). Biesiekiersk et al. (2011) found that individuals fed diets with gluten experienced identifiable symptoms of gluten intolerance as compared to those fed placebos, but the exact source or type of gluten food was not explicitly noted. Carroccio et al. (2012) examined gluten sensitivity using individuals who had known dietary sensitivity to wheat and found eosinophil infiltration in those groups when they consumed wheat and corresponding gluten sensitive symptoms.

Higher amounts of whole grain consumption also resulted in increased numbers of bowel leakage that was more solid than liquid. Bowel leakage is defined by NHANES (2012b) as accidental and cannot be controlled. This finding requires further research because of the nature of the questionnaire. The exact type of stool represented on the Bristol Stool Scale would need to be connected to whole grain consumption to be able to determine if the stool that people reported was 4 or 5 on the scale, indicating normal, or if it just was not completely liquid. This finding could be the result of links that already

exist in the literature between whole grain consumption and more bowel movements as a measure of good health. As illustrated by Vuksan et al. (2008), increases in soluble and insoluble dietary fiber result in minimal to no discomfort and increased stool frequency and bulk. Additionally, Slavin et al. (2009) suggested that soluble fiber helps regulate the digestive system, including the prevention of constipation and diarrhea as well as the regulation of irritable bowel disease. However, the increase in bowel leakage could be indicative of what I examined in the current study, a link between increased whole grain consumption and a higher incidence of bowel leakage as indicative of gluten sensitivity, since the bowel movements were not only more frequent but also classified as involuntary with no specific stool type noted.

I made an effort to determine the number of whole grains individuals consumed that resulted in the symptoms of bowel movements previously described. However, there was not a way to create a best fit line in the data to determine averages. Individuals' responses were extremely varied, making this question very difficult to answer. There was also not a way to determine the number of whole grains an individual had to consume to provoke symptoms. Response rates were very limiting for this data point.

Limitations

The primary limitation of this study is that the survey does not directly measure gluten sensitivity as a disease outcome. In order to examine gluten sensitivity as an outcome, bowel symptoms had to be examined. This is not an explicit measure of gluten sensitivity, but the symptoms of the disorder are measurable.

Additionally, the sole source of data was participant reported. This can result in limitations of selective memory, event recall that may not match what is being asked or the time that is being asked about, exaggeration of the truth, lying to protect the perception of the person reporting the data, and incorrect associations or correlations of events or actions and outcomes (Fricker & Schonlau, 2002). The Hawthorne effect is an additional concern when dealing with surveys that are administered to individuals. This is the tendency of people to act atypically when they know they are being observed. Borigini (2010) illustrated this by placing research teams in a work environment and giving individuals more attention that were in the trial. He found that the productivity of those in the trial was higher due to the extra attention. Since the data are secondary, the control for these factors was with the primary collectors of the data, The National Center for Health Statistics, an agency within the CDC.

Due to limited funding from the CDC, the data collected are not geographically representative or reflective of the different demographics of individuals sampled and, therefore, are only good for national conclusions. In addition, another limitation of NHANES data related to the geographic distribution is that the same samples are not surveyed every year. Geographic irregularities from year to year make for less than ideal conditions for tracking changes over time. This limitation is of minimal consequence with this study as it examines whole grain consumption over a period of time, tracking for an increase. In this study, I compared food consumption to the corresponding years of bowel health questions. The actual examination for increases from year to year based on individual question responses was a smaller component of supportive evidence to the

study when compared to the conclusions being reached by the actual comparison of the bowel and nutrition questions.

Additional limitations included what the survey measures from year to year. For example, due to the admitted limitations of NHANES from a financial standpoint, certain sets of questions were not gathered from year to year. Once some of these questions were eliminated, and they were not added back in. Dietary questions were also limited as a result of this process. Whole grain consumption had to be illustrated differently than originally anticipated, since that data were not collected after 2010. This information was not known at the outset of the dissertation process because all of the data from the 2011-2012 set had not been released.

Future Research/Recommendations

This study illustrates a need for further research. Being able to isolate important dietary factors and measure exact whole grain consumption are important factors for future studies. Additionally, isolating different types of whole grains foods and products (such as barley, buckwheat, and rye) and measuring their effects on bowel health would be very beneficial in determining if it is all whole grains that can cause increased gluten sensitivity or if it is just specific ones.

More targeted studies involving individuals with celiac disease and known gluten populations are needed. In particular, ethnic minority populations should be studied for both dietary patterns and incidence of gluten sensitivity and celiac disease, as this information is mostly absent from the literature. Quite a few studies focus on children

and adolescents, so future studies should focus on adult populations. These studies would be important in measuring the response to numbers of whole grains that trigger symptoms. These also would give baseline data and comparison/control groups when measuring symptoms in actual placebo controlled studies. Being able to control for a number of individual variables in a more targeted study would be of great benefit in determining if the results of this study are repeatedly accurate.

This study provides a start to a conversation between individuals and medical practitioners about food sources, how they feel when they consume specific foods, and future steps to take in order to minimize discomfort as a result of foods, specifically whole grains. It is also imperative that practitioners understand the difference between whole grain food sources that contain gluten and those that do not. This will better allow practitioners to make educated recommendations, keeping in mind both the benefits and drawbacks of consuming whole grains products for people.

More studies pertaining to gluten sensitivity, the development of gluten sensitivity or symptoms of gluten sensitivity, and the progression of the symptoms of gluten sensitivity are also important for future research areas. These studies would help illuminate the problem, triggers, and potential treatments and solutions. This study is a good start to exploring this issue at a basic level, but more research must be conducted.

Implications

Currently the PAPM, the foundational model used for this study, is illustrated by the answer shown to Research Question 1. Over the past 5 years, there has been a

statistically significant increase in whole grain consumption. According to the American Dietetic Association (2011) and Kapsak, Rahavi, Childs, and White (2011), 48% of adults aged 18 and older reported increasing their consumption of whole grains. The International Food Information Council Foundation (2012) corroborates this increase, reporting a steady increase in individual's desire to consume more whole grains from 68% in 2006 to 81% in 2009. People might have changed their diets to incorporate whole grain foods over the past 5 years due to the increase in whole grain food products available mentioned previously and the information promoting the health benefits of whole grains. According to Mobley, Slavin, and Hornick (2013), Americans are attempting to consume more whole grains but are not as successful as what they think due to the misleading packaging of products. This attempt is likely due to a specific health concern that has prompted them to act on this information, such as diabetes or heart disease.

As more research is conducted and published on the topic of whole grain consumption and gluten sensitivity, people's awareness of the potential issue will grow. It is the promotion of that research and the incorporation of that research into dietary recommendations that will ultimately help the public make decisions, as it has with the noted increased consumption of whole grains.

This research helped identify components in the American diet that are healthy as well as contribute to the increase in symptoms of gluten sensitivity. This research, with future studies in the area, has the potential to inform dietary policy about whole grains and the recommendations for consumption, increase the popularity of the gluten-free diet,

and change the way many Americans view their health through dietary changes. Dietary changes made based on people understanding the way they feel after eating specific types of food can lower morbidity and mortality rates that are linked in some literature to the consumption of whole grain products like wheat and barley. Whole grain consumption of grains like oats and barley can reduce the risk of heart disease (Harris & Etherton, 2010). In fact, 83% of consumers are aware that there is a link between whole grain consumption and reduced risks of heart disease (IFIC, 2009). At the very least, this information will allow people to take a closer look at what they are eating and how that makes them feel.

Conclusions

More research is necessary to really understand the mechanisms and confounding factors of whole grain consumption and gluten sensitivity. Since there are no actual medical tests for gluten sensitivity and it remains a diagnosis of exclusion, more information is needed on what portion of the population is at risk for the problem. Additionally, excluding confounding factors of other potential digestive diseases are important for further investigation of the issue of whole grain consumption and increased gluten sensitivity. This study showed a potential link between increased consumption of whole grains and increases in bowel leakage. It additionally showed an increase in whole grain consumption and an increase in knowledge of the number of whole grain servings that should be consumed daily.

Three research questions were explored to determine if gluten sensitivity had increased with the increase in recommendations for consumption of whole grains. The

first question examined if there had been an increase in whole grains based on recommendations, the second question examined if an increase in consumption of whole grains resulted in an increase in gluten sensitivity, and the third question looked at what range of whole grain consumption in grams had an impact on bowel health. In the current study, there was a significant increase in reported whole grain consumption, confirming hypothesis for research question one. In addition, people who reported higher consumption of whole grains experienced increases in solid stool leakage and instances of gas leakage, but did not report increases in diarrhea confirming part of research question two's hypothesis, but rejection the second part. Research question three could not be effectively answered, due to the variance in the in respondent answers to. More research, using more objective and controlled measures for symptoms and dietary consumption is needed to verify the findings of this study and make a more substantial impact on specifics of dietary factors.

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