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The health benefits of dietary fiber consumption of adults in the United States

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Abstract

Dietary fiber intake has been positively linked to the prevention of four of the ten leading causes of death among adults in the United States. The Centers for Disease Control and Prevention (CDC) listed the leading causes of death in 2010 as 1) heart disease, 2) cancer, 3) chronic lower respiratory disease, 4) stroke, 5) accidents, 6) Alzheimer's disease, 7) diabetes, 8) nephritis (kidney disease), 9) influenza/pneumonia, and 10) suicides (Murphy, Xu, & Kochanek, 2013). Heart disease was responsible for a proportional mortality ratio (PMR) of 27% of deaths. Stroke was fourth on the list with 6% of deaths (CDC, 2012). Diabetes is also a very serious condition that was responsible for approximately 69,000 deaths in 2010 (Murphy et al., 2013). The serious consequences of the aforementioned conditions have led researchers to study a variety of prevention strategies, including dietary fiber intake.

THE HEALTH BENEFITS OF DIETARY FIBER CONSUMPTION OF ADULTS IN
THE UNITED STATES

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THE HEALTH BENEFITS OF DIETARY FIBER CONSUMPTION
ON ADULTS IN THE UNITED STATES

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Definition of Terms – (Merriam-Webster, n.d.)

1. Dietary fiber- “ mostly indigestible material in food that stimulates the intestine to peristalsis—called also *bulk, dietary fiber, roughage*”
2. Coronary heart disease- “a condition and especially one caused by atherosclerosis that reduces the blood flow through the coronary arteries to the heart muscle and typically results in chest pain or heart damage—called also *coronary disease, coronary heart disease*”
3. Stroke- “sudden diminution or loss of consciousness, sensation, and voluntary motion caused by rupture or obstruction (as by a clot) of a blood vessel of the brain—called also *apoplexy, brain attack, cerebral accident, cerebrovascular accident*”
4. Low density lipoprotein (LDL) cholesterol- “a lipoprotein of blood plasma that is composed of a moderate proportion of protein with little triglyceride and a high proportion of cholesterol and that is associated with increased probability of developing atherosclerosis—called also *bad cholesterol, beta-lipoprotein, low-density lipoprotein*”
5. High density lipoprotein (HDL) cholesterol- “a lipoprotein of blood plasma that is composed of a high proportion of protein with little triglyceride and cholesterol and that is associated with decreased probability of developing atherosclerosis—called also *alpha-lipoprotein, good cholesterol, high-density lipoprotein*”
6. Total cholesterol- the combination of HDL and LDL levels

7. Blood pressure- “pressure that is exerted by the blood upon the walls of the blood vessels and especially arteries and that varies with the muscular efficiency of the heart, the blood volume and viscosity, the age and health of the individual, and the state of the vascular wall”
8. Systolic blood pressure- “the highest arterial blood pressure of a cardiac cycle occurring immediately after systole of the left ventricle of the heart—called also *systolic pressure*”
9. Diastolic blood pressure- “the lowest arterial blood pressure of a cardiac cycle occurring during diastole of the heart—called also *diastolic pressure*”
10. Added fiber- “ fiber added to foods during food processing” (Institute of Medicine, Food and Nutrition Board, 2005)
11. Total fiber- “ the sum of dietary fiber and added fiber (Institute of Medicine, Food and Nutrition Board, 2005)

INTRODUCTION

Dietary fiber intake has been positively linked to the prevention of four of the ten leading causes of death among adults in the United States. The Centers for Disease Control and Prevention (CDC) listed the leading causes of death in 2010 as 1) heart disease, 2) cancer, 3) chronic lower respiratory disease, 4) stroke, 5) accidents, 6) Alzheimer's disease, 7) diabetes, 8) nephritis (kidney disease), 9) influenza/pneumonia, and 10) suicides (Murphy, Xu, & Kochanek, 2013). Heart disease was responsible for a proportional mortality ratio (PMR) of 27% of deaths. Stroke was fourth on the list with 6% of deaths (CDC, 2012). Diabetes is also a very serious condition that was responsible for approximately 69,000 deaths in 2010 (Murphy et al., 2013). The serious consequences of the aforementioned conditions have led researchers to study a variety of prevention strategies, including dietary fiber intake.

A large body of evidence suggests that the consumption of fiber on a daily basis is beneficial to the health of humans. The American Diabetes Association (ADA) recommends adequate consumption of dietary fiber from a variety of plant foods (Marlett, McBurney, & Slavin, 2002; Mayo Clinic, 2012; see also Anderson, Baird, Davis Jr. et al., 2009). The ADA acknowledges the role dietary fiber plays in reducing the risk for heart disease, type II diabetes, diverticulitis, certain cancers, and other health benefits (Marlett et al., 2002). Hypertension, a risk factor for stroke, can be reduced by the consumption of dietary fiber as well (Anderson, Baird, Davis Jr. et al., 2009). In agreement with the ADA, the American Society for Nutrition stated that cereal fibers are modestly associated with a reduced risk of type II diabetes, obesity, and cardiovascular

disease (Cho, Qi, Fahey Jr., & Klurfield, 2013). When examining studies related to dietary fiber consumption and their health benefits, it is important to understand what fiber is and where it is found.

Dietary fiber is defined by the Mayo Clinic as “parts of plant foods that your body can't digest or absorb.” (Mayo Clinic, 2012, p.1). Fiber is also typically classified into two separate groups; soluble and insoluble. Soluble fiber forms a gel-like substance when exposed to water. Insoluble fiber is a solid form that does not break down when exposed to water (Mayo Clinic, 2012). Most plant-based foods contain some amount of dietary fiber; however, to ensure an adequate amount of both soluble and insoluble fiber, consuming a wide variety of plant-based foods is recommended (Mayo Clinic, 2012). Studies suggest that both water soluble and insoluble fibers have differing impacts on health.

Two research questions frame this investigation:

1. What are the health-related impacts of dietary fiber consumption among US adults age 18 and older?
2. To what extent and with what results have public health and/or health promotion interventions been tested to promote fiber consumption?

METHODS

All article searches were conducted via Google Scholar. Key search terms included, “dietary fiber intake in the U.S., dietary fiber and heart disease, dietary fiber and diabetes, dietary fiber and stroke, dietary fiber and cancer, health benefits of dietary fiber, and dietary fiber interventions.” Eligibility criteria for articles included publication

after the year 2000, unless the article was heavily cited by other sources in which case older articles were accepted. As background sources for information related to fiber, government agencies such as the CDC and professional organizations such as the American Diabetes Association were used.

REVIEW OF RELATED LITERATURE

“Dietary fiber — found mainly in fruits, vegetables, whole grains and legumes — is probably best known for its ability to prevent or relieve constipation. But foods containing fiber can provide other health benefits as well, such as helping to maintain a healthy weight and lowering your risk of diabetes and heart disease” (Mayo Clinic p. 1, 2012). The previous definition is only one of several in existence for dietary fiber. Experts in the fields of medicine, nutrition, fitness, etc. all seem to agree that dietary fiber is beneficial to health. However, various organizations and governing bodies have slightly different definitions. Most seem to agree that the definition should include that dietary fiber cannot be broken down during digestion (Duvall, 2009). Literature from previous studies regarding dietary fiber and its impact on diabetes, cholesterol levels, hypertension, obesity, cancer, and other health conditions will be reviewed. Current interventions concerning dietary fiber consumption and dietary fiber consumption trends will also be examined.

Dietary Fiber Consumption in the United States

It is estimated that more than 90% of all Americans do not meet the recommended intake for dietary fiber (Clemens et al., 2012). Depending on age and gender, the recommended intake of fiber should be 21-38 g/day or more. Younger individuals and

males should consume more than those who are older or female (Mayo Clinic, 2012). In 2010, the Dietary Guidelines Advisory Committee, a committee made up of experts from the United States Department of Agriculture and the Department of Health and Human Services, termed fiber as a “nutrient of public health concern” (Clemens et al. p. 1390, 2012).

In 1987, Lanza and colleagues examined a national study of fiber intake among US adults (N=11,658) with the purpose of showing that fiber intake was much lower than was originally thought. The work that Lanza and his colleagues performed was groundbreaking at the time because it more accurately assessed fiber intake in the US when compared to similar studies. The survey participants constituted varying populations, and all were consuming much less than the daily recommended amount (Lanza et al., 1987). A large sample size that included many different ages and ethnicities across the entire country was a major strength for this study. Being a larger sample coupled with the implementation of a new technique for assessing fiber consumption made this study a more accurate informative tool when assessing the nation’s fiber intake (Lanza et al., 1987).

The authors administered a survey to participants across the country. The participants were asked to keep track of their diets for a 24-hour period. Trained professionals then measured the fiber intake of participants based on the survey results. Data collected showed differences in intake between genders, races, education levels, and ages. When determining fiber intake values, the study researchers used relative fiber intake and absolute fiber intake. Relative fiber intake is the number of grams of fiber

consumed per 1,000 kilocalories (kcal). Absolute fiber intake was the number of grams of fiber consumed regardless of kcal (Lanza et al., 1987).

Interestingly, it was concluded that dietary fiber intake varied depending on certain demographic characteristics of the study participants. Lanza et al. discovered that the population was consuming much less dietary fiber than originally thought. Three previous methods of assessing fiber intake estimated that the average person consumed anywhere from 19.1-27g/day. However, Lanza et al. discovered the mean to be 11.1 g/day. All studies were performed on US adults but the difference in results can be attributed to how the data were collected. Lanza and his team collected 24-hour dietary recalls from the participants and had trained professionals determine fiber intake. The difference between methods implemented by Lanza et al. (1987) and other authors studying dietary fiber intake was that Lanza and colleagues used different dietary fiber assessment tools that more accurately estimated fiber content of foods. This was important because the dietary recall and how it was assessed showed previous methods to be less accurate and that US adults were not consuming enough fiber. In addition to suggesting that the American public consumed less fiber than previously thought, the authors also illustrated that there were differences between certain subgroups. Females consumed a diet that was more fiber-dense than that consumed by males; however, males ate more grams of fiber per day due to the fact that men consume more overall calories than women. This suggested that females consumed more relative fiber while men consumed more absolute fiber. In addition to the gender differences, fiber intake varied by race as well. The mean relative values for white women across all ages were 6.6

g/1000 kcal compared to 5.5 g/1000 kcal for black women. Mean relative values were 5.2 g/1000 kcal among white males and 5.5 g/1000 kcal for black males. Black males who lived in an urban setting consumed 5.3 g/1000 kcal of fiber, whereas, those living in a rural setting consumed only 4.6 g/1000 kcal. There was no significant difference among other racial or gender groups when it came to geographical location. Education and income impacted dietary fiber intake as well. Across both genders and races (black and white) more fiber was consumed by those who had an education above the high school level and those who had an income at or above the poverty level (Lanza et al., 1987).

Despite data collected by the authors, the biggest concern is the fact that this study was published in 1987. Despite the age of the article, the conclusions that were reached are still relevant today because Clemens et al. (2010) had similar conclusions regarding under consumption of fiber. There are still social inequalities that exist at the present moment that need to be addressed to improve the health of all individuals. To recap, the main conclusions of the study were 1) the researcher's new method for assessing fiber intake was much more accurate than previous methods; 2) the US population was consuming far less fiber than was originally presumed; 3) females eat more fiber-dense diets than males; 4) individuals eat more dietary fiber as they get older; and, 5) there is an increase in fiber consumption with higher levels of income and education (Lanza, et al., 1987). The findings of Clemens et al. (2012) raise the question of whether or not there is a connection between the under consumption of dietary fiber and the high prevalence of heart disease, stroke, and other leading causes of death.

Dietary fiber can come from a variety of sources including grain products, fruits, vegetables, legumes, nuts, and soy. Grain products accounted for approximately one third of the fiber in the United States food supply (Hiza et al., 2007). It is predicted that as interest in dietary fiber continues to increase, marketing of fiber products will increase due to the economic incentives (Hiza et al., 2007).

Water Soluble and Insoluble Dietary Fiber

Looking back, one of the many definitions of dietary fiber is “parts of plant foods that your body cannot digest or absorb.” (Mayo Clinic, 2012, p.1). When considering dietary fiber, it is important to understand that there are two main types of fiber that are often discussed in the literature, water soluble and insoluble fiber. Soluble fiber is found in apples, citrus fruits, carrots, oats, and psyllium; to name a few. Once in contact with water, soluble fiber creates a gel-like substance that is beneficial to health because of its ability to reduce LDL cholesterol levels, regulate blood glucose levels, and other benefits. (Mayo Clinic, 2012). Whole-grains, beans, nuts, and vegetables are good sources of insoluble fiber. This type of fiber promotes the movement of stools through the bowels and creates a bulkier stool. Insoluble fiber has been known to reduce the prevalence of diarrhea and constipation and can assist in weight loss and/or management. The following studies give a more in-depth picture of soluble and insoluble fiber.

A study was performed on a hospital-based sample of 28 men diagnosed with a variety of health conditions such as cardiovascular disease, high cholesterol, or high triglycerides. This sample was not ideal, as it was small and had the potential for gender bias. This was a crossover, controlled, single-blind study. It was conducted over an 8-

week period in which participants were given a low fat diet supplemented with fiber, which was either soluble or insoluble. One of the most important features of this research study was the detail used in tracking the diet and obtaining the laboratory measurements because it reduced potential errors (Sola et al., 2007). All meals were created under the supervision of a research dietitian. The investigators were able to track what each person ate and because all of the meals were supplied from the same source (the hospital), the diets were similar. Designing the study to control the environment, with the same food, and similar health issues allowed researchers to decrease the likelihood of confounding factors affecting the results. Measurements taken during the study included total cholesterol, triglycerides, HDL and LDL cholesterol specifically. Other factors indirectly related to atherosclerosis were also measured. Fasting blood tests were conducted on two separate days before and after the study period.

It was concluded that although both soluble and insoluble fiber had health benefits, the soluble fiber was more beneficial when evaluating atherosclerosis factors. Results from the study suggested the soluble fiber consumers had increased HDL concentrations, decreased ratio of total cholesterol to HDL, and of LDL to HDL ratio. These results show that the amount of “bad” cholesterol (LDL) that causes plaque buildup decreased, while the amount of HDL increased; protecting the heart from future heart disease. These lowered amounts of LDL cholesterol and fat allowed the decrease of plaque buildup and lower risk of heart disease. Although the food was created and tracked by the dietitian, that does not mean every participant ate that food every time, or ate all of it. Besides the possibility of the patient not participating as they reported, the

authors of the study suggested that genetics could play a factor in nutritional response (Sola et al., 2007).

Two hundred overweight or obese individuals were enrolled in a study conducted by Salas-Salvado et al., (2008) with the purpose of comparing mixtures of fiber types on weight loss, satiety, lipid profile, and glucose metabolism. The participants ranged in age from 18 to 70 years old and were recruited from primary care centers in Spain. This specific study was a double-blind, placebo controlled clinical trial which helped eliminate many threats to validity. The subjects had baseline data collected and then were put on a restricted diet. One group received a fiber supplement in the form of a powder and the other group received a placebo. The diets were followed for sixteen weeks and data were again collected at the conclusion of the study. It was found by the researcher that adherence to the diets were very high. It was suggested by the results of the study that fiber supplementation could be beneficial for overweight or obese individuals because fiber increases satiety and improves lipoprotein levels (Salas-Salvado et al., 2008). This study was interesting because it looked at the mixture of soluble and insoluble fiber and its effect on weight reduction, satiety, and lipoprotein levels.

Additional health benefits of fiber were studied by Samra & Anderson (2007); their research was designed to describe the effect of insoluble fiber on appetite, short-term food intake, and blood glucose 75 minutes before and after a meal. The subjects selected for this study were young men between the ages of 20 and 35 and had a body mass index between 20 and 27. The subjects were recruited through advertisements which were posted across the University of Toronto. There were three treatment groups

and a control group and all of the group assignments were randomized. The treatment groups were as follows: group one received a high fiber cereal, group two a low fiber cereal, group three was given white bread, and group four, which was the control, received water. Baseline measurements were taken and the subjects were told to come into the research area once a week to receive their treatment. The subjects were also instructed to fast the night before their appointment. Data were collected for appetite and blood glucose for 15 minute intervals starting 75 minutes before and after their meal. It was concluded by the authors that insoluble fiber consumption could reduce appetite, food consumption, and the glycemic response to a meal (Samra & Anderson, 2007). This study was similar to the study performed by Salas-Salvado et al. (2008) because it examined the effect of fiber on satiety, also known as appetite. However, Samra & Anderson (2007) did not mix soluble and insoluble fiber and, therefore, it can be definitively concluded that insoluble fiber is most likely associated with a decreased appetite. What this study lacks is a variance in the age of the subjects: only adults age 20 to 35 were included.

The association and potential impacts of exposures to dietary protein and soluble fiber on hypertension was examined in a study done by Burke et al. (2001). Thirty-six subjects were placed on a four-week low protein and low fiber diet. Next they were placed on a diet with increased levels of protein and psyllium fiber (soluble fiber). There was a significant decrease in blood pressure levels. When compared to the control subjects, there was a net reduction in 24-hour systolic blood pressure of 5.9 mmHg when consuming the diet which had higher fiber content (Burke et al., 2001). According to the

authors, the findings of the study had “important implications for the prevention and management of hypertension, particularly in populations in which high blood pressure is prevalent in association with diets low in protein, fiber, or both” (Burke et al. p. 821, 2001). Due to the fact that this study tested dietary protein and dietary fiber at the same time, it is hard to say which variable had an impact on hypertension. It is also possible that both dietary protein and fiber played a crucial role in the results of the study.

After examining the literature, both soluble and insoluble fibers are beneficial for human health, and both types have different impacts on various medical conditions and risk factors. Soluble fiber in general has been identified to reduce the risk of heart disease, stroke, and other cardiovascular conditions due to its ability to decrease risk factors for the aforementioned conditions (Sola et al., 2007). Those who consume more insoluble fiber tend to eat food that has a lower glycemic load and therefore does not cause spikes in blood glucose levels. Additionally, insoluble fiber cannot be broken down in the digestive system and makes individuals feel full for a longer period of time (Samra & Anderson, 2007). It can also be said that insoluble fiber indirectly lowers the risk of cardiovascular disease because those who consume food that is higher in insoluble fiber tend to eat less food and therefore consume less fat and sodium than is typically associated with a higher cardiovascular disease risk (Burke et al., 2001).

Impact of Dietary Fiber on Cardiovascular Disease

Dietary fiber intake may be a protective factor for cardiovascular disease, the leading cause of death among US adults (CDC, 2012). According to the American Heart Association (2011), cardiovascular disease includes several problems, many of which

include atherosclerosis. Atherosclerosis is a condition that involves the buildup of plaque along artery walls. This buildup can cause health problems including, but not limited to; heart attacks, strokes, arrhythmias, and heart failure (American Heart Association, 2011). Cardiovascular disease is a broad classification that includes several conditions that are especially dangerous to an individual's health. Heart disease is the leading cause of death in the US, causing 597,689 deaths in 2010 (Murphy et al., 2013). Stroke killed 129,476 in 2010 and in 2012; 6.4 million people had experienced a stroke at least once in their lifetime (Cerebrovascular Disease, 2012). An examination of literature was performed to ascertain the impact of dietary fiber, if any, on the risk of cardiovascular disease.

Ma et al. (2006) conducted a study to examine associations between dietary fiber and C-reactive protein (CRP). CRP has been associated with a greater risk of inflammation, which can be a predictor for cardiovascular disease (Ma, et al., 2006). Participants (N = 641) between the ages of 20 and 70 were enrolled in the study. Body composition, CRP levels, diet and physical activity were measured for baseline numbers at the beginning of the study. After the baseline data collection, quarterly check-ups were performed. Fiber intake was assessed and the results pointed to the fact that consuming dietary fiber was associated with a lower risk for elevated CRP levels. Therefore, it could be assumed that consuming dietary fiber has a positive association with lowering cardiovascular disease risk (Ma, et al. 2006). This study took a sample from 20 to 70 year olds and did not address the older population or very young populations directly.

Another important study was the Zutphen Study which was completed in the Netherlands for many years. A sample of 1,373 men participated in examinations from

1960 to 2000 (Streppel, Ocke, Boshuizen, Kok, & Kromhout, 2008). This study was used for many research questions, not just the effect of fiber on cardiovascular disease. The participant's diets were tracked for a period of time before the physical, which was typically given every 5 years. Besides participant's vitals and wellness checks, their causes of death were also tracked. The tracking of the diet allowed researchers to associate types of food with physical wellness. Results showed an inverse association between dietary fiber and cardiovascular disease mortality. This study was used in conjunction with 10 cohort studies and was able to conclude that for every additional 10g of fiber added, cardiovascular disease mortality risk was lowered by nearly 20% (Streppel et al., 2008). When the researchers observed the long term portion of this study it showed that the benefits of fiber slowly decreased with age. Although the conclusions were appropriate, the study did not give much detail about the reasoning for decreased fiber effectiveness with increased age. There was believed to be little bias possible in the study, although the relationship between fiber and CHD was weakened some as this study was based off subjects' reports, which could have been inaccurate (Streppel et al., 2008). The study did have limitations. Only men participated in this study, and they were all within 20 years of each other in age. With this sample composition they were not able to observe any differing effects between sexes.

To compare the health benefits of dietary fiber consumption among sexes, research by Pereira et al. (2004) was reviewed. Pereira and his colleagues conducted a pooled analysis of dietary fiber and its subtypes and the risk for coronary heart disease, with an emphasis on comparing sex-specific results. Participants (N = 336,244) were

recruited from ten different cohort studies. The cohorts were discovered through literature searches and by contacting experts in the field. The participants had their fiber intake as well as the type of fiber they were consuming, i.e. grains, fruits, vegetables, insoluble, and soluble fiber, measured by registered dietitians. Baseline data were collected from participants, who were then followed for six to ten years to observe any cardiac events or a death related to a cardiac complication. It was determined that corrected total dietary fiber consumption was associated with a 14% (relative risk [RR], 0.86) decrease in risk for all coronary events and a 27% (RR, 0.73) decrease in coronary death. The results reported were similar for both men and women. Furthermore, cereal and fruit fiber types had an inverse association with the risk for coronary heart disease, but vegetable fiber did not show a significant association (Pereira, O'Reilly, Augustsson, et al., 2004).

A prospective cohort study was conducted to determine whether fiber consumption from fruit, vegetable, and cereal sources was associated with incidence of cardiovascular disease among elderly individuals. The study was a prospective cohort from 1989 to 2000 and recruited 3,588 men and women who were 65 years or older and were free of known cardiovascular disease at the time of baseline. Dietary fiber intake was assessed and incidence of cardiovascular disease was observed throughout the follow up period. The authors concluded that the consumption of dietary fiber later in life, in the form of cereal fiber, was associated with lower risk of cardiovascular disease (Mozaffarian, Kumanyika, Lemaitre, et al., 2003). The findings of Mozaffarian et al. (2008) were similar and different from the findings of Pereira, O'Reilly, Augustsson, et

al. (2004). They were similar in that both studies concluded that cereal fiber had an inverse association between fiber consumption and cardiovascular disease. They differed in that Mozaffarian et al. (2008) did not conclude that fruit fiber had an inverse association with cardiovascular disease.

Anderson, Jones, & Riddell-Mason (1993) studied the comparative effects of 10 dietary fibers on serum and liver lipids in male rats. The rat's diets were manipulated to incorporate different sources of soluble and insoluble fiber. Serum and liver lipids were measured and it was concluded that rats who consumed psyllium, rich in soluble fiber, had the lowest serum and liver cholesterol levels. In agreement with the findings of other studies, Anderson et al. (1994) concluded that insoluble fiber was beneficial to weight loss or management and soluble fiber was best suited for reducing lipid levels.

The previously examined studies support the idea that dietary fiber decreases the risk of cardiovascular disease due to its ability to protect against risk factors such as high LDL levels, low HDL, and total cholesterol.

Dietary Fiber Consumption and Diabetes

People diagnosed with diabetes have medical expenditures that are approximately 2.3 times higher than if the disease was absent (ADA, 2013). Diabetes is a serious medical condition that impacts 25.8 million people or 8.3% of the population in the United States (ADA, 2013). Diabetes is the primary cause of death for 71,382 Americans each year and contributes to the death of 231,404. These numbers make diabetes the 7th leading cause of death in the US. In addition to mortality, diabetes also costs \$245 billion

due to direct medical costs and indirect costs (ADA, 2013). A high fiber diet is recommended by most diabetes and nutritional organizations. It is also accepted that soluble fiber can inhibit macronutrient absorption, reduce glucose response, and beneficially influence lipid levels. (Weickert & Pfeiffer, 2008).

In a study with the purpose of observing the effects of dietary fiber on glycemic load and lipid concentrations in patients with type II diabetes, 13 participants from a Dallas medical center were studied. The participants were given higher than recommended levels of fiber via fiber rich foods. The participants also received a diet with the recommended levels of dietary fiber and their results were compared. Physical examinations and blood work were used to assess the individual's health status. It was concluded by the authors of the study that the higher than recommended diet resulted in decreased glucose levels (-10% plasma glucose), total cholesterol (-6.7%), triglycerides (-10.2%), and very low-density lipoproteins (-12.5%), and therefore improved overall health status (Chandalia et al., 2000). This study suggests that even higher than recommended levels of fiber are beneficial to individuals with type II diabetes.

Meyer and colleagues (2000) examined the relationship between the intake of carbohydrates, dietary fiber, dietary magnesium, and carbohydrate rich foods and the incidence of diabetes among older women. This was a cohort study of 35,988 post-menopausal women, in Iowa, that were previously free of diabetes. After baseline data were collected, the incidence of diabetes was tracked for the duration of the six year follow-up. Dietary intake was assessed during the study and it was found that whole-

grains and cereal fiber may protect against the development of diabetes among older women.

In contrast to the Meyer study in 2000, Montonen and colleagues (2003) looked at both men and women ages 40-69 in a longitudinal study. This research examined the relationship between whole-grains and cereal fiber and the risk of type II diabetes (2003). All of the 4,316 participants were free of diabetes at the beginning of participation. Food consumption data and a diet history interview covering the previous year's dietary habits were collected. After a 10 year follow-up period, incidence rates of type II diabetes were identified. The adjusted relative risk between the highest and lowest quartiles of whole-grain consumption was 0.65 and the RR for cereal fiber between the highest and lowest quartiles was 0.39 (Montonen et al., 2003). This suggested that consumption of both whole-grain and cereal fiber was inversely associated with type II diabetes. It was hypothesized that "the whole-grain association is due to cereal fiber or another factor related to cereal fiber intake." (Montonen et al., 2003). These results strengthen the conclusions of Meyer et al. (2000) that suggested cereal fiber had an inverse relationship with type II diabetes in post-menopausal women. However, it can also be concluded that fiber is beneficial for those with type II diabetes in the general population as well.

Dietary Fiber and Weight Management

Several studies have pointed out the role that dietary fiber plays in weight loss and weight management (Du et al., 2010; Liu et al., 2003). According to the CDC, approximately one-third of all Americans are obese and another one-third are overweight. The CDC also states that heart disease, stroke, type 2 diabetes, and some types of cancer

are related to obesity and many of these conditions are leading causes of death in the US (CDC, 2013). Obesity was responsible for \$147 billion in annual medical costs in 2008. The average medical cost for obese individuals was \$1,429 higher than those of normal weight (CDC, 2013).

Howarth, Saltzman, and Roberts (2001) conducted a review of the literature to examine possible relationships between fiber intake and obesity. According to their findings, many healthy adult subjects demonstrated increased satiety, reduced energy intake, and body weight loss when consuming higher-fiber diets. This affirms the hypothesis by many researchers that dietary fiber consumption plays a role in reducing the number of overweight and obese individuals. The authors assert that more studies are needed to examine the effect of soluble and insoluble fiber types (Howarth, Saltzman, & Roberts, 2001).

In a study performed by Liu et al. (2003), female nurses in the United States were followed by the researcher for twelve years, starting in 1984. The nurses' food intake was assessed via questionnaire in 1984, 1986, 1990, and 1994. After adjusting for covariates; weight, body mass index, and long term weight changes, the odds ratio of becoming obese was calculated. The results of the study showed that the women with the greatest intake of dietary fiber gained an average of 1.52 kg (3.35lbs) less than did the women with the least amount of dietary fiber intake. Therefore, it was concluded by the researchers that "weight gain was inversely associated with the intake of high-fiber, whole-grain foods but positively related to the intake of refined-grain foods, which

indicated the importance of distinguishing whole-grain products from refined-grain products to aid in weight control” (Liu et al. p. 920, 2003).

Du et al., (2010) designed a prospective cohort study with the objective of investigating the association of total dietary fiber, cereal fiber, and fruit and vegetable fiber with changes in weight and waist circumference. European participants aged 20-79 (N = 89,432) were recruited for the study. Among these, 42% of participants were men and 58% were females. All participants were determined to be free of cancer, cardiovascular disease, and diabetes at baseline. The participants were followed for 6.5 years and dietary information was gathered via country-specific food-frequency surveys. The authors adjusted for follow-up duration, dietary variables, and demographic/lifestyle factors. The authors concluded that total fiber was inversely associated with subsequent weight and waist circumference change. An increase in 10 g/day of total fiber was associated with a decrease in weight of 39 grams per year and a decrease in waist circumference by -0.08 centimeters per year. A 10 g/day increase in cereal fibers specifically was associated with a decrease of 77 g/year for weight and a decrease of 0.10 cm/year in waist circumference. Similar results for fruit and vegetable fibers were found regarding the association with a decrease in waist circumference but not with a decrease in weight. Du et al. (2010) concluded that a higher intake of dietary fiber, especially cereal fiber, prevented body-weight and waist circumference gain.

When the findings of the previous studies are cumulated, an acceptable conclusion may be that an increase in dietary fiber can trigger reductions in weight and waist circumference, both of which are markers of obesity. What’s more, morbidity and

mortality rates for preventable conditions associated with obesity heart disease and diabetes can be decreased by consuming more dietary fiber.

Other Health Benefits

In addition to the more direct health benefits of dietary fiber that have been discussed in this literature review, there are also indirect benefits. It was alluded to earlier that dietary fiber improves the regularity of bowel movements, which prevents constipation and diarrhea. This benefit is especially important to those who suffer chronic diarrhea and/or constipation due to bowel disorders such as diverticulitis (Marlett et al., 2002). Another indirect benefit of fiber is that it increases satiety (feeling full), which can contribute to weight loss. (Howarth et al., 2001) Considering the fact that weight is a significant risk factor for hypertension, a reduction in weight would most likely result in a reduction in blood pressure (Galisteo, Duarte, & Zarzuelo, 2008).

A study was conducted by Cicero et al. (2007) over a six-month period with 96 subjects recruited from the Atherosclerosis and Metabolic Disease Clinic of University of Bologna, Italy and the Diabetes Centre of the University of Pavia, Italy. The criterion for participants was age between 50 and 70, high blood pressure, and a BMI between 25 and 30. Blood pressure was considered high in this experiment when systolic blood pressure (SBP) was over 140 and diastolic blood pressure (DBP) was over 90 mmHg. This sample included both men and women, and the sample size could have been larger. For the experiment the subjects were randomized into groups to receive one of three diets: 1) a non-supplemented diet, 2) a diet that included guar gum, and 3) a diet that included psyllium husk powder. Guar and psyllium are types of soluble fiber and both were

distributed in identical boxes (the experiment was a double-blind study). Patients were evaluated once a month on their blood pressure, weight, cholesterol, and other biochemical profile aspects. Psyllium husk was associated with a decrease in systolic blood pressure and diastolic blood pressure, while guar was only associated with a lower SBP but more significantly than psyllium (Cicero et al., 2007). This study also showed improvements in all cardiovascular factors such as improved LDL and HDL cholesterol, and a lowered BMI (Cicero et al., 2007). The possible bias in this study was the possibility of false reporting by the subjects and thus, altered the results. Not taking the supplements on a regular basis could decrease the cardiovascular improvements. (Cicero et al., 2007)

Previous research has shown somewhat inconclusive evidence regarding the impact of dietary fiber on cancer risk. In an effort to find a consensus, articles were reviewed and their results were as follows. The objective of a study by Schatzkin et al. (2007) was to investigate the relationship between dietary fiber and whole-grain food intakes and invasive colorectal cancer in the NIH-AARP Diet and Health Study. Participants included 291,988 men and 197,623 women aged 50-71; their diets were assessed by a self-administered food-frequency questionnaire. The results indicated no association with colorectal cancer risk; however whole-grain consumption was associated with a modest reduced risk. These findings suggest that the reduced risk associated with whole-grain consumption may be attributed to something other than dietary fibers [vitamins, minerals, phenols, etc.] (Schatzkin et al., 2007). Similar to the Schatzkin et al.

(2007) study, Park et al. (2005) concluded that after accounting for dietary risk factors, high fiber intake was not associated with a reduced risk of colorectal cancer.

A curious question that is not answered in the literature is whether there is an association between dietary fiber and sleep apnea. According to the National Heart, Lung, and Blood Institute (NHLB) at the National Institutes of Health (NIH), sleep apnea is a common disorder in which an individual has shallow breaths or doesn't breathe at all for a period of time while sleeping. Sleep apnea is a chronic condition that goes widely undiagnosed. This condition is more common in individuals that are overweight. If left untreated, sleep apnea can increase the risk for high blood pressure, heart attack, stroke, and obesity (What is Sleep Apnea?, 2012). This condition can also be responsible for heart arrhythmias and can increase the risk of, or worsen, heart failure. Considering that sleep apnea is more common in overweight individuals, and dietary fiber has been shown to reduce weight (Du et al., 2010) more research should be done to determine whether fiber can be used as a means of prevention or treatment for this disorder.

Negative Side Effects

As mentioned previously there are several health benefits associated with dietary fiber consumption. However, there are negative side effects that come along with increased consumption. "Adding too much fiber too quickly can promote intestinal gas, abdominal bloating and cramping" (Mayo Clinic p, 2, 2012). Drinking plenty of water is recommended when consuming higher levels of fiber because it allows for the absorption of water by the intestines and, therefore, produces a softer and bulkier bowel movement (Mayo Clinic, 2012). When thinking of increasing dietary fiber consumption it is also

recommended to gradually increase intake so the body can adjust. It is important to note that a large body of evidence indicates that the benefits of dietary fiber greatly outweigh the potential negative side effects associated with consumption.

Public Health Interventions

The fact that dietary fiber can reduce the risk for certain chronic diseases makes it very valuable to public health. An effort was made to determine what public health interventions and nutritional education programs were available related to dietary fiber. The purpose behind these interventions is to educate the general public about the health benefits of dietary fiber and which foods are fiber-dense. In 2002, a group of representatives from the food industry, scientists, and chefs met to form a new nonprofit consumer advocacy group that is now known as the Whole Grains Council (Whole Grains, n.d.). This organization had several goals including: 1) educate the public about whole-grains 2) Create a whole-grain symbol on food packaging to make it easier to find products that had more whole-grains 3) To lobby support from other food manufacturers and food professionals (Whole Grains, n.d.).

Some accomplishments of the Whole Grain Council include promoting the consumption of whole grains through media interviews and educational stories, rallied support from additional food manufacturers and others to promote whole-grain consumption, created a website with information regarding whole-grains, and developed and implemented a whole-grain stamp that is present on food products so consumers can easily identify foods that are made with whole-grains. Other manufacturers have engaged in efforts to change the recipes of some of their products to incorporate more

whole-grains that have a similar taste and texture as those made with refined grains (Hiza et al., 2007). Some companies that are marketing foods that contain more whole-grain are Kellogg Company, SaraLee, and ConAgra Foods (Whole Grains, n.d.).

Many food manufacturers understand that creating food products that contain more whole-grains is only the first step. Another aspect is educating the public about the benefits of whole-grains and the availability of food sources. The Kellogg Company started the 2-Week Fiber Challenge in 2005. The challenge asked consumers to eat one bowl of Kellogg's brand cereal for two weeks in the hopes of A) selling more Kellogg's products and B) increasing the amount of whole-grains that the individual consumes (Hiza et al., 2007).

The 2010 Dietary Guidelines Advisory Committee deemed dietary fiber as an "under-consumed nutrient of public health concern" (Clemens et al. p. 1390, 2012). Several government and non-government organizations have expressed how important fiber consumption is to the prevention of chronic conditions. After reviewing the past and current public health interventions, it seems more needs to be done by government agencies. Admittedly, the Healthy, Hunger-Free Kids Act, which was passed in 2010 and put into effect in 2012, is focused on providing healthier food options for kids when they are at school. However, the kids are not receiving adequate levels of education regarding which foods they should choose. Regulations can increase the availability of fruits and vegetables but if the students are not aware that they should eat them or why they should eat them, then the regulations could do more. Many of the educational campaigns are being conducted by non-government organizations and food manufacturers. Many food

manufacturers are creating and marketing foods that contain higher amounts of whole-grain. These foods are sometimes confusing to consumers because they assume that whole-grains translate to dietary fiber. This is sometimes a correct assumption but whole-grains and fiber are not always synonymous (Clemens et al., 2012). Some foods that contain whole-grains are not “good” sources of fiber but may rather contain low levels of fiber. The major problem is the fact that labeling for dietary fiber and whole-grains is unclear. Different standards have been put in place and changed in recent years. This change in qualifications for labeling is confusing to consumers (Clemens et al., 2012). In terms of behavioral intervention, Bhattarai et al. (2013) concluded, after reviewing four studies that measured the effect of interventions on dietary fiber intake, that a primary-care based intervention showed small beneficial changes in behavior. The studies reviewed by Bhattarai and colleagues used face-to-face and telephone coaching or interviewing as well as provided participants with informative brochures and other literature. Bhattarai and colleagues raised several concerns in their review which hopefully will be addressed by future research. 1) are interventions ineffective or are they difficult to deliver; 2) can a single diet counseling session bring about behavior change or is a more intensive educational session required; 3) will there be a similar effect in minority or deprived populations; 4) in the long-term are the limited effects worth the resources required? (Bhattarai et al., 2013)

DISCUSSION

Most of the articles outlined in *Chapter II. Review of Literature* came to the same conclusion: dietary fiber is beneficial to human health and to public health. The first

section of the review was focused on dietary fiber consumption in the U.S. The study published by Lanza et al. (1987) was a groundbreaking study because that it suggested that many Americans were not consuming as much fiber as was originally thought. The limitation for this study was the fact that it is from the 1980s. A lot could have changed over that period of time. However, after researching fiber consumption in the US, it was very hard to find updated information pertaining to fiber consumption. Additionally, Lanza and colleagues discovered that there were differences in fiber consumption between certain groups of individuals. The fact that those who had an education greater than the high school level tended to eat more fiber was not surprising. Those who lack education likely have lower health literacy, leading to a difficulty in understanding medical literature or educational material that is presented to them. Additionally, education and income are positively correlated: lower education level corresponds with lower household income. Low-income families and individuals may not expend their limited finances on fruits and vegetables but rather on cheaper processed foods that have little or no fiber content (Epstein, Dearing, Roba, & Finkelstein, 2010). Much research has been done on the social gradient and its effects on health. The social gradient refers to the relationship between a person's socioeconomic status and their health. A person that has less education and lower income will be lower on the social gradient than a person that has a high level of education and is in a higher income bracket (WHO, n.d.). Another finding of Lanza et al. (1987) was that as people age, they tend to eat more fiber. This may be attributed to the increase in knowledge and life experiences when it comes to diet. It would make sense that the longer a person has been alive the more chances

they have to come across an educational campaign or advertisement promoting the consumption of fruits, vegetables, grains, and other sources of fiber.

Fiber is broken into two main categories and both have benefits to health. There may be some confusion when studying dietary fiber because there are several working definitions depending on what source of information is used. Efforts have been made to create one universal definition for fiber; however, a consensus could not be reached among various organizations and nutrition professionals. Also leading to confusion is the lack of uniformity among nutrition labels on food products. Some labels specify the amount of both soluble and insoluble fiber while on the other hand, some labels may specify just one type of fiber, or not specify the type of fiber at all. This can lead to confusion for the public and make them wonder if one type of fiber is better. More confusion is created when the public hears the term “whole-grain.” As people shop for food products and see “whole-grain” or “multi-grain” they might associate that with high fiber content. Unfortunately, a food product that is whole-grain may not be considered a good source of fiber. The reasoning behind this is because there have been changing regulations, recently, that have dictated what exactly “whole-grain” means. Some regulations suggest that something that is whole-grain must have over half of its weight from whole grains rather than refined grains (Clemons et al., 2012). Regulations and guidelines need to be created and more strictly enforced for food labels in order to reduce confusion among consumers. This may increase the knowledge of shoppers and assist them in making healthier food choices.

Additionally, it would be wise to reach a consensus on the definition of dietary fiber. When considering interventions related to dietary fiber, it would be wise to utilize the social ecological model (SEM. First proposed by McLeroy, Bibeau, Steckler & Glanz (1988), the SEM takes 5 different levels into consideration in regards to public health interventions. 1) intrapersonal- characteristics of the individual including knowledge and attitudes, 2) interpersonal-social networks, 3) institutional factors- institutional regulations, 4) community factors-relationships among institutions, informal groups, and organizations, 5) public policy-laws and regulations. The most needed and effective changes come at the policy and intrapersonal levels of the social ecological model (SEM) for dietary fiber consumption. Once changes at the policy level are completed, it will make food labels easier to understand and potentially could increase the knowledge of shoppers. Additional efforts in all other aspects of the social ecological model need to be undertaken as well. More education campaigns are needed to stress the importance of consuming dietary fiber and what benefits it can bring to a person's health. Businesses and schools can implement healthier lunch and snack options so employees and students have the opportunity to replace food items high in fats, salt, and sugar with healthier options that contain higher fiber content.

With support from the literature, it is acceptable to conclude that fiber does indeed reduce the risk of developing cardiovascular disease. Thanks to Ma et al. (2006) we know that markers for inflammation related to heart disease were reduced when high-fiber diets were consumed. Additionally Streppel et al. (2008) noted that for every 10g of fiber added to a person's diet, the cardiovascular disease mortality risk is decreased by

20%. In addition to research outlining dietary fiber's cardiovascular benefits, several studies were examined in this review to determine the association between dietary fiber and the diabetes. From the results of the various articles, it is accepted that dietary fiber does help prevent diabetes by way of weight management and weight loss. Additionally, fiber can regulate blood glucose levels and the reduction of glycemic load in fiber-dense foods (Weickert & Pfeiffer, 2008).

The ability of fiber to assist in weight management and possibly even promote weight loss was alluded to in the previous paragraph. With the reduction in weight or the management of weight, not only does fiber help reduce the incidence of diabetes but it also contributes to other indirect benefits. If an individual were to reduce their body weight with help from eating a fiber-rich diet, they could theoretically have less severe symptoms that are associated with sleep apnea. This hypothesis comes from research indicating that sleep apnea impacts many individuals that are overweight or obese. It may be acceptable to think that if a person loses weight, they may see a reduction in their sleep apnea symptoms or may no longer have sleep apnea. This is an idea that I feel needs more research. It would appear more research is needed because sleep apnea is a very common and chronic condition that can have major health implications if left untreated.

Along with sleep apnea, another indirect benefit of weight loss due to a fiber-rich diet might be the improvement of self-esteem. If a person perceives themselves as thinner or others notice their weight loss, it would likely make that person feel good. This confidence boost could reinforce their positive health behaviors that had got them to

that point. The self-esteem boost could propel them from the action stage of the Transtheoretical Model (TTM) to the maintenance stage. The TTM is a biopsychosocial model to conceptualize the process of intentional behavioral change (The Transtheoretical model of behavior change, n.d.). In the TTM, there are different stages in which an individual passes through on their way to behavior change. The continuum of stages is assembled in the following order; pre-contemplation, contemplation, preparation, action, and maintenance (The Transtheoretical model of behavior change, n.d.). Individuals can skip steps or regress to previous steps. In the maintenance stage, which was previously mentioned, the individual has successfully attained and maintained a certain behavior for at least six months. More research with collaboration across multiple disciplines is needed to examine the potential association between fiber and improvement in self-esteem.

Currently, fiber is known to assist with regulating the digestive system. This is especially important for individuals with digestive disorders such as diverticulitis. Fiber creates a bulkier stool and is not digested so it moves through the digestive system and a relatively quick rate and therefore improves bowel movements.

Although fiber has been determined to provide many health benefits, negative side effects can develop. However, the health benefits far outweigh the side effects that can develop. The side effects that are most commonly reported are diarrhea, bloating, stomach cramps, and flatulence. These can be mitigated by increasing fiber intake gradually and by consuming large amounts of water when eating a diet that is high in fiber.

Much of the efforts to market whole-grains and dietary fiber are being done by private businesses. Government agencies and non-governmental agencies provide information and recommendations but few solid interventions are being created. National education campaigns need to be funded and created to help the public understand the seriousness of chronic disease in the U.S. and that many cases of chronic disease can be prevented. These education campaigns need to stress the importance of eating a well-balanced diet that includes whole-grains that are rich in fiber. Additionally, regular physical activity needs to be promoted as well because dietary fiber is only one aspect of improving the health of Americans.

Thanks to Lanza et al. (1987) and Clemens et al. (2012) we know that 90% of Americans are not getting enough dietary fiber in their diets and this needs to be changed. Dietary fiber has been shown to reduce the risk of developing heart disease, diabetes, and stroke; all of which are leading causes of death. Additionally, fiber plays a role in controlling and reducing weight which, besides direct benefits, may also provide indirect benefits including self-esteem boosts and improvement associated with sleep apnea. Additional funding, research, and educational campaigns needs to be established to make an impact. Not only will billions of dollars be saved by promoting the consumption of dietary fiber but many lives could potentially be saved as well.

CONCLUSION

When this review was being conducted, the goal was to answer two research questions:

- 1) What are the health-related impacts of dietary fiber consumption among US adults age 18 and older?
- 2) To what extent and with what results have public health and/or health promotion interventions been tested to promote fiber consumption?

After a comprehensive review of the literature, the previous research questions were answered. Dietary fiber has been shown to have a large impact on an individual's health. The risk of mortality and morbidity from cardiovascular disease, stroke, and diabetes is reduced when additional fiber is consumed (Center for Disease Control and Prevention, 2012; Cicero et al., 2007; Weickert & Pfeiffer, 2008).

Additionally, fiber has been shown to increase satiety which in turn limits weight gain and even promotes weight loss. Indirect benefits of fiber were also outlined in this review. Dietary fiber also relieves uncomfortable symptoms associated with gastrointestinal disorders such as diverticulitis (Marlett et al., 2002). Although not fully supported by the literature, interesting hypotheses were made about additional indirect benefits of fiber consumption and warrant additional thought and research. It was hypothesized in this review that a person's mental health might be improved by consuming more fiber due to the fact that they may lose weight which could increase their self-esteem. Additionally, a reduction in sleep apnea could be avoided by increasing dietary fiber consumption and losing weight (What is Sleep Apnea?, 2012).

Currently and in the recent past, interventions and educational campaigns have been implemented to promote the consumption of dietary fiber. However, the literature points out that more can and must be done. There is too much confusion about the definition of a whole-grain and if all whole-grains are good sources of fiber. A lack of large recognizable educational campaigns with the specific goal of increasing the knowledge of benefits associated with fiber consumption is alarming. Regulations have been put in place that mandate what food is provided at schools; however, more needs to be done at the lower levels of the social ecological model rather than at the policy level. It is the recommendation of this author that more research be done regarding the indirect benefits that were hypothesized in this review and that more emphasis be placed on educating the public on what dietary fiber is, what foods are fiber dense, and why fiber consumption is important.

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