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Food Insecurity and Chronic Disease Among Working-Age US Adults

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by

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Author's Statement Page

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ABSTRACT

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By

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Studies of the health impact of low food security among adults are limited and generally focus on the association between low food security and one chronic illness. These studies do not examine the full range of food security status which include high, marginal, low, and very low. Past studies have focused only on two groups: food secure and food insecure. We, therefore, examined the association between the four levels of food security and six chronic conditions: hypertension, diabetes, coronary heart disease (CHD), cancer, asthma, and kidney disease. Our study compared two nationally representative population-based samples from the National Health and Nutrition Examination Survey (NHANES). A total of 3,709 and 3,161 adults aged 20-64 were included from NHANES 2007-2008 and 2017-2018, respectively. We estimated the association between food security status and each chronic disease using logistic regression. We adjusted the models to account for differences in age, gender, race/ethnicity, educational attainment, and income. In 2007-2008, in our adjusted analysis, having marginal food security was associated with significantly higher odds of having CHD. Having low food security was associated with significantly higher odds of having CHD and kidney disease. Having very low food security was associated with higher odds of having hypertension, asthma, CHD, and kidney. In 2017-2018, those with marginal food security were not found to be statistically significantly associated with the presence of any of the chronic conditions examined. However, having low food security was associated with significantly higher odds of having hypertension and diabetes. Having very low food security was again associated with significantly higher odds of having hypertension, asthma, CHD, and kidney disease. Those with lower income were more likely to report asthma, diabetes, CHD, and kidney disease. Also, non-Hispanic Blacks were more likely to report most conditions compared to non-Hispanic Whites. This study shows the strong association between low food security and chronic diseases in working-age US adults. Food security should be increased through a more concerted effort to link individuals to available resources.

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Chapter I: Introduction

Opening

The U.S. Department of Agriculture (USDA) defines low food security as a lack of consistent access to enough food for an active, healthy life (1). Having a low food security status indicates a lack of available financial resources for food at the household level (1). The USDA found 89.8 percent of U.S. households were food secure throughout the year in 2021 through data self-reported census data (2). The remaining 10.2 percent of households experienced low food security at some point in the year, including 3.8 percent that had very low food security. Food security status is an important social determinant of health for all Americans (2). Adults with low food security may be at an increased risk for various negative health outcomes and health disparities. Numerous studies have shown associations between low food security and adverse health outcomes among children (3). However, studies of the health effects of low food security among adults are more limited and generally focus on the association between one health outcome (4). These studies also rarely examine these associations along the four ranges of food security status defined by the USDA. This study aims to identify associations between levels of these food security and the prevalence of six chronic diseases among working-age adults. These diseases include hypertension, coronary heart disease (CHD), cancer, diabetes, asthma, and kidney disease. This chapter will introduce the study by first discussing the background and context, followed by the research problem, the research aims, objectives and questions, and the significance.

Background

The USDA separates food security status into four ranges of severity. The ranges include high and marginal food security, which are seen as food secure, and low and very low food security, which are seen as food insecure (1, 5). High food security is described as having no reported indications of

food-access problems or limitations. Those categorized as having marginal food security have one or two reported indications, such as not being able to afford balanced meals, fear of running out of food, or not being to eat due to lack of food (1, 5). They also have little or no indication of changes in diets or food intake. Comparatively, those categorized as having low food security report reduced quality, variety, or desirability of diet (1,5). They also have little or no indication of reduced food intake. Finally, those who have very low food security report multiple indications of disrupted eating patterns and reduced food intake (1, 5).

Ranges of Food Security

Level of Security		Definition
Food Secure	High Food Security	Households had no problems, or anxiety about, consistently accessing adequate food
	Marginal Food Security	Households had problems or anxiety at times about accessing adequate food, but the quality, variety, and quantity of food were not substantially reduced
Food Insecure	Low Food Security	Households reduced the quality, variety, and desirability of their diets, but the quantity of food intake and normal eating patterns were not substantially disrupted
	Very Low Food Security	At times during the year, eating patterns of one or more household members were disrupted and food intake reduced because the household lacked money or other resources for food

Source: USDA ERS - Definitions of Food Security. (n.d.). https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-u-s/definitions-of-food-security/

Many adults living in low food security households report such indicators as being unable to afford balanced meals, worrying about the adequacy of their food supply, running out of food, and cutting the size of meals or skipping meals (6). These episodes of low food security are generally short. However, the dietary changes associated with low food security may persist over extended periods. This is due to low food security households experiencing repeated food budget shortages (6). On average, households that report having low food security at some time during the year experience this for at least 7 months during the year. Common household responses to inadequate food supplies

include food budget adjustments, reduced food intake, and alterations in the types of food served (1, 5, 6). It is found that when dietary variety decreases, consumption of energy-dense foods increases. These energy-dense foods, including refined grains, added sugars, and saturated/trans fats, tend to be of poor nutritional quality and less expensive calorie-for-calorie than healthier alternatives (7). U.S. adults living in households with low food security consume fewer weekly servings of fruits, vegetables, and dairy and lower levels of micronutrients, including the B complex vitamins, magnesium, iron, zinc, and calcium (7). These dietary patterns are linked to the development of chronic diseases, including hypertension, hyperlipidemia, and diabetes (8).

In the general population, household low food security is associated with markers of chronic disease risk and chronic conditions (6). Adults with low food security may be at a higher risk for several adverse health consequences and health inequities. As an example, one study found that people with a low food security status may be at higher risk for obesity (6). Another study indicated people with low food security and a lower income between the ages of 18 and 65 had greater incidences of chronic illness (6). Children with low food security may be at an elevated risk for several adverse health consequences as well, including obesity (6). In addition, they suffer a greater risk of developmental issues compared to children with high food security (6). In addition, decreased frequency, quality, diversity, and quantity of eaten meals may negatively impact the mental health of children (6). Low food security among low-income families has also been associated with a significantly higher percentage of diabetes in community samples and studies with representative samples in the United States and Canada (9). This is especially true among women (8, 9). Although there are consistent findings for an association between household low food security and chronic

disease prevalence, the measure used for household low food security, sample restrictions, and clinical markers varies among these studies (10). Some studies restrict the sample to low-income households only to better compare the association of low food security among only those who were at risk of exposure, whereas others compared individuals from low food security households with the general population (10, 11). However, only comparing individuals from low food security households with those from wealthier families, even when controlling for income, may overestimate the association. This study will assess the association between individuals food security status and having hypertension, coronary heart disease (CHD), cancer, diabetes, asthma, or kidney disease while adjusting for age, sex, race/ethnicity, income, and education.

Research Problem

Many studies have suggested that children's low food security has adverse health effects. This includes increased rates of iron deficiency anemia, acute infection, chronic illness, and developmental and mental health problems (3, 12). Several studies have also demonstrated associations between low food security and overweight/obesity among children and adult women using both self-reported and objective measures of body mass index (BMI) (3, 12, 13). However, results among children have been inconsistent (12).

Conversely, not many studies have evaluated the association between low food security and chronic disease among working-age adults. Notably, many studies about food security and health among adults only focus on one health outcome. Many studies, for example, have found a consistent association between household food insecurity and diabetes prevalence as well as poor diabetes control and management (2). Another study found a positive association between having low food

security and an increased atherosclerotic cardiovascular disease (ASCVD) risk among adults aged 40-79 (40). The limited number of studies assessing working-age adults have found that low food security is associated with decreased nutrient intakes, increased rates of mental health problems and depression, diabetes, hypertension, and hyperlipidemia (39). They also found food insecure working-age adults to have worse outcomes on health exams, to self-report poor or fair health, and have poor sleep outcomes (39). Also, in most prior research, adults are classified as belonging to either food-secure or food-insecure households (14). Conversely, these classifications ignore specific distinctions between adults in households that report no low food security conditions and those that report only one or two low food security conditions (9, 14). Instead, these groups are often combined into one food-secure group. Similarly, differences between those with low food security and very low food security are often disregarded and labeled together as low food security (14). As a result, the existing research obscures differences and possible similarities between the four USDA food security ranges. This may also lead to potentially inaccurate associations between food security level and chronic disease risk. This may in turn affect policies and programs targeted at those who are food insecure.

Aim, Objectives, & Questions

Given the lack of research examining the association between the four levels of food security and multiple chronic diseases in adults, this study will aim to identify the association between these levels and six chronic diseases among US adults aged 20-64, comparing data from the National Health and Nutritional Examination Survey (NHANES) 2007-2008 and 2017-2018. These include hypertension, coronary heart disease (CHD), cancer, diabetes, asthma, and kidney disease. These are

six of the twenty conditions the Centers for Disease Control and Prevention (CDC) have identified as being particularly important to population health and worthy of research (15).

Objectives:

- To examine the associations between food security status and hypertension, coronary heart disease (CHD), cancer, diabetes, chronic asthma, and kidney disease among working-age US adults.
- To examine the associations between food security status and hypertension, coronary heart disease (CHD), cancer, diabetes, chronic asthma, and kidney disease among working-age US adults, controlling for age, gender, race/ethnicity, educational attainment, and income level.

Research Questions:

- What are the associations between food security status and hypertension, coronary heart disease (CHD), cancer, diabetes, asthma, and kidney disease in working-age US adults?
- What are the associations between food security status and income level in working-age US adults?
- What are the associations between food security status and race/ethnicity in working-age US adults?

Significance

Many studies have overlooked the possible direct associations between low food security and chronic disease independent of obesity (11). Several recent literature reviews have attempted to clarify the relationships between various chronic diseases and low food security. They show a strong

focus specifically on diet-related chronic diseases such as heart disease and stroke, diabetes, cancer, and hyperlipidemia and emphasize obesity as the primary mediator that links low food security with these chronic diseases (3). Very few studies have directly assessed this assumed relationship.

This study will add important population-based data to the understanding of the association between low food security and chronic disease. This study will also contribute to the body of knowledge by producing a better understanding of how food security relates to chronic disease, specifically in working-age adults in the US, and by documenting this association empirically. This will help address the current shortage of research in this area and provide real-world value to the field of study. This study will provide an analysis examining food insecurity within the individual, whereas many studies have relied on household or community-based measures. Low food security is an important social determinant of health. Programs and policies aimed at improving food security are continually needed to ensure they are reaching those in need.

Chapter II: Literature Review

Low Food Security in the US

Most American households have constant, reliable access to sufficient food for an active, healthy lifestyle, making them food secure (6). Yet, an increasing percentage of American households face inadequate food security at periods during the year, indicating that their access to appropriate food is limited due to a lack of money and other resources (1, 2, 6). In 1995, when the USDA issued its first report on household food security in the United States, roughly 11.9% of families were experiencing low food security. In 2013, about fifty million Americans (14.3%) had a low food security status (4). Almost one-third of these individuals had "extremely low food security" (4). In 2017, 11.8 percent of American families were predicted to have low food security, with 4.5 percent of households having extremely low food security (5). In addition, rates of food insecurity were greater than the national average in low-income families, households led by African Americans and Hispanics, and homes with children (6). The fact that so many people are food insecure is alarming; nevertheless, the potential negative health effects of food insecurity are more alarming. A consistently unfavorable link between low food security and health has been shown in the scientific literature. Low food security in children and adolescents has been linked to asthma, anemia, and behavioral, cognitive, and emotional difficulties (3, 4, 8). Studies have revealed that low food security among adults is connected to poor nutritional quality, depression, cardiometabolic illnesses, diabetes and inadequate diabetes management, and obesity, particularly among adult women (3, 4, 16).

The USDA defines household food security as “access by all members at all times to enough food for an active, healthy life” (1). At a bare minimum, nutritionally appropriate and safe meals are easily available and may be obtained without resorting to theft, emergency food supplies, or other

coping mechanisms (1, 5). Low food security also refers to "limited or unclear availability of nutritionally adequate and safe meals or restricted or uncertain capacity to get appropriate foods in socially acceptable ways" (1, 5). As of 2006, the continuum of food security is classified into four categories: high, marginal, low, and extremely low, according to responses to the 18-item USDA Core Food Security Module (CFSM) (1). Owing to the increased use of the CFSM in national surveys, the USDA and other prominent researchers in the field have identified the groups most likely to be affected by inadequate food security (1, 16). Many studies have identified low-income, single-female-headed families, minority races, lower levels of education, and a greater number of children or other household members as indicators of this type of hardship (5, 16). Additional research indicates inadequate availability and accessibility of healthy eating establishments as a contributing factor (5). These factors frequently influence dietary intake and food-related behavior. These practices cause dietary disorders, such as obesity and diabetes, as well as chronic and mental health problems (3).

Chronic Disease in the US

A disease is deemed chronic if it lasts for at least a year, needs continuing medical care, or severely restricts everyday activities (16). In 2014, around 47 percent of the US population, or approximately 150 million people, suffered from at least one chronic condition (16). Approximately 30 million Americans suffer from five or more chronic conditions (16). Age increases the risk and prevalence of chronic illness. Around 6 percent of children in the United States have more than one chronic ailment. Roughly 27 percent of children in the United States suffer from a chronic condition (16, 17). In comparison, around 60% of individuals have at least one chronic ailment, and 42% have many chronic disorders (16). At least 80% of persons aged 60 or older have at least one chronic

condition, and 50% have two (16). These conditions account for 70% of all fatalities in the United States, causing more than 1.7 million deaths annually (17). Chronic illness, already widespread in the United States, is projected to worsen over the next several decades among all age groups (16, 17). The accompanying physical and financial expenditures will also increase. 90% of the country's $4,1 trillion healthcare expenditures are for those with chronic and mental health disorders (17).

While the risk of chronic illness is not increasing in older adults, its incidence is, and this increase is not exclusive to this group (16). A recent study comparing the incidence of seventeen chronic illnesses across various age groups between 2005 and 2014 indicated rises in virtually every condition, including in the study's youngest age categories: 35-50 and 51-65. (18). Increasing incidence of chronic illness have also been observed in children. In 1960, less than 2% of youngsters had a health problem serious enough to impede everyday activities (19). Fifty years later, this illness affected almost 8% of children (19). Most of the rise is attributable to an increase in the prevalence of asthma, obesity, mental health issues, and neurodevelopmental abnormalities (19). Throughout the past three decades, the prevalence of childhood and teenage obesity has more than quadrupled in children and tripled in adolescents, reaching almost 19 percent in 2016 overall (20). The incidence of juvenile diabetes increased by 23% between 2001 and 2009. (16). The University of Michigan estimates that 15 to 18 percent of youngsters suffered from at least one chronic disease in 2012. (16).

A balanced diet promotes optimal growth and development in children and minimizes their chance of developing chronic disorders. Adults who consume a nutritious diet have a decreased risk

of obesity, heart disease, type 2 diabetes, and some malignancies, and live longer (7). A healthy diet can aid individuals with chronic illnesses in managing their symptoms and preventing complications. But, when healthy alternatives are unavailable, individuals may settle for foods that are higher in calories and have fewer nutrients (7). Individuals in low-income neighborhoods and certain racial and ethnic groups frequently lack access to convenient, inexpensive, and nutritious food sources (9, 12, 21). Most Americans do not follow a healthy diet and consume excessive amounts of salt, saturated fat, and sugar, increasing their risk of chronic illnesses (7, 9).

Low Food Security and Obesity

The link between food insecurity and obesity is very well established (3, 7, 12). It appears to be a bimodal urban phenomenon involving "underconsumption and overconsumption, hunger and obesity, quality and quantity" (3, 11, 12). Several studies presume that inadequate food security is associated with an increased risk of chronic diet-related disorders, although they frequently do so without evaluating this risk directly (11). The American Dietetic Association (ADA) considers low food security a risk factor for the development of chronic diseases due to the increased risk of obesity among those with low food security. However, this perspective ignores the potential health-degrading effects of low food security for health independent of obesity (22). Therefore, obesity is not a prerequisite for the development of diet-related or non-diet-related chronic illnesses (11). In the absence of clinical obesity or noticeable overweight, the "thin fat" phenotype, which develops when fat is added to an existing slender body frame with relatively little muscle mass, raises the risk of metabolic illness (23). This is especially prevalent in persons born with a low birth weight who underwent fast development during childhood (23). More generally, the evidence on early-life

adversity reveals that exposure to hunger in prenatal or early infancy is associated with an increased risk for cardiometabolic disorders in adulthood, even when obesity is controlled for (24).

Some mostly cross-sectional studies on adults also reveal a heterogeneous pattern of findings. Leung et al. discovered in a study of 35,740 low-income people that extremely low food security was related to an increased risk of obesity and a higher BMI (8). This connection remained after stratification by race and ethnicity for male and female Hispanics and Asian women (8). Low food security was related to a higher BMI and a greater risk of obesity among multiracial men (8). In a similar vein, Nguyen et al. discovered that food insecurity is related to an increased risk of obesity and a higher BMI (25). In a survey of 13,720 persons, Gooding et al. discovered a correlation between inadequate food security and a higher BMI among young women, but not among young males (26). Similarly, several further studies have revealed that a lack of food security relates to obesity in women but not in males. In a study of 7,931 people, Martin and Lippert discovered that poor food security moms are more likely to be overweight or obese than low food security dads and childless women (independent of their low food security status) (27). Mohammadi et al. discovered that moderately low food security is related to a decreased chance of being overweight, but severely low food security was associated with an increased risk of obesity among women (28).

In contrast, Shariff et al. reported that poor food security was related to a decreased chance of obesity among Malaysian women, while many studies revealed no relationship between low food security and obesity (29). Many of the studies that did not find an association between low food security and obesity were relatively small, which may have reduced their power to detect an

association, and conducted in countries other than the United States, which may indicate that the overall food environment modifies the association between low food security and weight (7).

In a longitudinal study of low food security and BMI in adults, low food security was related to a higher rise in BMI among community health center people during nearly three years of follow-up (30).

Effects of Low Food Security on Children

Most of the research examining low food security in general and its effects on health outcomes has concentrated on children. This research has found that low food security is associated with increased risks of some birth defects, anemia, lower nutrient intake, cognitive problems, and aggression and anxiety (3). Childhood low food security is also associated with higher risks of being hospitalized, poorer general health, having asthma, behavioral problems, depression, suicide ideation, and worse oral health (3, 7, 11). Compared to children in food-secure households, children in low food security households had 2–3 times higher odds of having anemia, 2 times higher odds of being in fair or poor health, and 1.4–2.6 times higher odds of having asthma, depending on the age of the child (13). Most studies used binary comparisons of children in low food security households with children in food-secure households. However, households in the category of marginal food security may be more like low food security households than food secure households and may also be at risk of suffering from negative health outcomes (7).

Low food security may be associated with both poor diet and unhealthy weight, but the relationship between low food security, dietary patterns, and weight gain is not fully understood (3). Previous research on the relationship between low food security and dietary patterns has linked low food security with lower consumption of healthy food groups and poor diet quality, particularly regarding fruit and vegetable intake (3, 11). Past work on low food security and obesity has yielded mixed evidence of associations, especially for children and adult men, while stronger evidence for an adverse association has been noted in women (3, 7). The relationship between low food security and body weight is complicated. While low food security may be obesogenic due to its relationship with unhealthy dietary patterns, low food security could also lead to weight loss, especially in its most extreme form of hunger (7).

24 percent of children in the United States between the ages of 2 and 17 are obese (38). 8.6 million additional children are at risk for obesity (38). There are not many differences in health between obese and non-obese children. Yet, obese children frequently continue to be obese as adults (38). Obesity is a risk factor for four of the 10 top causes of mortality in the United States, including coronary heart disease, type 2 diabetes, stroke, and cancer (38). Each year, obesity and inactivity are responsible for about 300,000 early deaths in the United States (38).

The Body Mass Index (BMI) measures the connection between weight and height and is used to screen for and track the risk of obesity (38). The Centers for Disease Control and Prevention have prepared BMI charts for children aged 2 to 20 that are adjusted for age and gender (38). Children whose BMI is at or above the 95th percentile are considered obese or overweight (38). Between the

85th and 95th percentiles, children are deemed to be "at risk for obesity or overweight (38)." This Profile covers children ages 2 to 17 with BMI values at or above the 95th percentile, as well as those with BMI values between the 85th and 95th percentiles and refers to them as "obese" and "at risk for obesity (38)."

Obesity in childhood or adolescence generally persists because physical activity and nutritional patterns established early in life are frequently maintained into maturity (38). The likelihood that an obese child will grow up to be obese rises with age (38). Adult obesity is a risk factor for a variety of chronic illnesses, including diabetes and hypertension (38). Obese children under the age of three are often at low risk for adult obesity (38). Yet, more than fifty percent of obese children older than six become fat adults (38). Overweight children aged 12 to 17 have an even greater likelihood of being obese as adults (38). Seventy to eighty percent of obese teenagers continue to be obese as adults (38). This may indicate that parents have a greater influence on the food and physical activity patterns of younger children (38). On the other hand, as they approach maturity, older children are prone to acquire autonomous habits (38).

In a study of 28,353 children followed prospectively from their first infancy visit to their last child visit as part of the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), Metallinos-Katsaras et al. discovered that sustained low food security without hunger was related with an increased risk of obesity at the final child visit (31). Only in children whose moms were either overweight/obese or underweight before pregnancy did connections persist (31). The findings of this study indicate that maternal weight before pregnancy affects the association between

food insecurity and juvenile obesity. Suglia et al. followed 1,589 mother-child couples prospectively for two years and discovered that the cumulative social risk score related to obesity at age 5 was for females, but not for boys (32). Poor food security was one of the six risk categories that contributed to the social risk score. Additional risks were housing instability, maternal drug abuse, maternal depressive symptoms, paternal imprisonment, and allegations of domestic violence (32). A third study likewise identified an association between greater BMI and a history of food insecurity (33). Even though these studies shed significant insight into the topic, few studies have explored the temporal link between food insecurity, obesity, and eating habits.

In contrast, several studies have not identified an association between food insecurity and childhood obesity. In an examination of 2–11-year-old individuals in the National Health and Nutrition Examination Surveys (NHANES) from 2001 to 2010, Kaur et al. found that food insecurity was not connected with childhood obesity (34). Personal food insecurity, a measure of food insecurity at the person level, is related to obesity in children aged 6–11, but not in children aged 2–5. (32). This study suggests that the level at which food insecurity is quantified might affect the outcomes.

Effects of Low Food Security on Adults

Few studies have evaluated the relationship between food insecurity and chronic illness in adults. Most previous research has relied on self-reported measures without confirming the connection with objective indicators of chronic illness (9). Low food security has been linked to diabetes, hypertension, and hyperlipidemia in adults (9). Low food security relates to increasing body mass index in young adult women, according to one of the few studies devoted to young adults (13).

Nevertheless, the relationship between inadequate food security and other cardiometabolic outcomes in young adults, such as diabetes, hypertension, and hyperlipidemia, is uncertain (13).

In the past two decades, food insecurity among older persons has grown by 45 percent, but its association with health consequences has not been fully researched (8). In a study conducted by Leung et al. to examine the relationships between low food security, multiple chronic conditions, and self-reported health status among US adults aged 50 to 80, approximately 54% of individuals with low food security had multiple chronic conditions, compared to 41% of individuals with food security (8). Low food security persons were more likely to report having asthma, chronic bronchitis, chronic obstructive pulmonary disease (COPD), chronic pain, diabetes, renal illness, or a sleep disturbance compared to food-secure individuals (8). There were no significant differences between food security level and cancer, heart disease, high blood pressure, high cholesterol, or non-alcoholic fatty liver disease (8). Those with inadequate food security were also more likely to report poorer overall health than those with adequate food security (8). Around 45 percent of persons with low food security reported fair or poor physical health, compared to 14 percent of food-secure individuals (8).

Lower food security was related to an increased risk of hypertension, coronary heart disease (CHD), hepatitis, stroke, cancer, asthma, diabetes, arthritis, COPD, and renal disease, according to a USDA study of working Americans aged 19 to 64 (14). The relationship between food security and the risk of chronic disease in general, the number of chronic diseases reported, and self-assessed health were similarly substantial (14). Notably, statistically significant disparities were between adults in families with marginal, low, and very low food security (14). In several situations, the study indicated

that food security was a stronger predictor of chronic disease than wealth. There was only a significant association between income and three of the 10 chronic illnesses studied (14). Included among them are hepatitis, arthritis, and COPD. In contrast, inadequate food security was substantially connected with each of the 10 most prevalent chronic illnesses (14). All investigated chronic diseases were more likely to be diagnosed among adults residing in families with a lower level of food security. People in very low food security households were 15.3 percentage points more likely to have any chronic illness than individuals in high food security households (14). People in families with marginal food security were 9 percentage points less likely to report good health and 1.3 percentage points more likely to report bad health than those in households with high food security (14). The number of people with chronic conditions was 18 percent greater in homes with low food security than in households with high food security (14).

Conclusion

Low food security is one of the socioeconomic determinants of health that has the greatest effect on the overall health of individuals. Also, those with low food security are disproportionately impacted by chronic illnesses, such as diabetes, hypertension, and obesity, which increase negative consequences on health and well-being (5). Low food security affects around 11% of households in the United States, with 1 in 8 adults and 1 in 6 children living in low food security homes (5, 6). These households report being unable to afford balanced meals and being concerned that they may run out of food before they can afford to purchase more. Poor food security in the United States is associated with an increased frequency of chronic diseases (6). In a 2018 study, researchers discovered that diabetes, hypertension, and arthritis were the most prevalent chronic illnesses among individuals

with inadequate food security (16). Unsurprisingly, these chronic illnesses result in greater healthcare expenditures and consumption (16). In the same study, researchers discovered that the adjusted yearly incremental healthcare expenses of older persons with low food security were greater than those who did not have low food security (16). One research demonstrates, for instance, that diabetics with restricted access to food are at a greater risk for hypoglycemia episodes, which can increase visits to emergency departments. Patients with inadequate food security are about twice as likely to report such occurrences (160). Overall, the average healthcare expenses for adults with low food security were $1,834 more than for individuals with food security, totaling $52.6 billion across all families with low food security. These additional expenses encompass all direct healthcare-related expenditures, such as clinic visits, hospitalizations, and prescription drugs (17).

Therefore, the purpose of this study is to investigate the relationship between food security status and chronic disease in the United States to contribute to the existing literature and raise awareness of the issue in the hopes of guiding future efforts to address the pressing need for food security for all. Particularly describe the relationship between food security and chronic illness in terms of income, race/ethnicity, gender, and degree of education.

Chapter III: Methodology

Sample

The National Health and Nutritional Examination Survey (NHANES) is a program of studies designed to assess the health and nutritional status of adults and children in the US (35). The NHANES is a cross-sectional nationally representative health and nutrition survey of the noninstitutionalized U.S. civilian population aged 2 months and older (35). The NHANES is conducted by the National Center for Health Statistics (NCHS) and the Centers for Disease Control and Prevention (CDC) using a stratified, multistage probability cluster design with oversampling of minorities, children, and the elderly (35). Sampling and survey design information are described in detail elsewhere (35). Data are released in two-year cycles to protect participants' confidentiality and increase statistical reliability. The survey consists of interviewer-administered questionnaires conducted in participants' homes, standardized physical examinations conducted in specially equipped Mobile Examination Centers (MECs), and laboratory tests utilizing blood and urine specimens provided by participants during the physical examination (35). The NHANES interview includes demographic, socioeconomic, dietary, and health-related questions. The examination component consists of medical, dental, and physiological measurements and laboratory tests (35). The earliest continuous NHANES data are from 1999, with the most up-to-date data being from 2019–2020 at the time of this study. This study compared data from the 2007-2008 and 2017-2018 waves of NHANES to observe any patterns or changes over time in the population. The analysis was restricted to adults aged 20–64 years. Children were excluded because of the low prevalence of the chronic diseases we were interested in (9). Likewise, the elderly were excluded because of the high prevalence of the chronic diseases in which we were interested and because of differences in access to health care between poor elderly and poor non-elderly adults

(9). Pregnant women were excluded because pregnancy affects the clinical variables in which we were interested.

Data Collection

All NHANES participants completed an English or Spanish version of an interviewer-administered questionnaire in their own homes. Participants then attended a specially equipped mobile examination center where they underwent a standardized physical (including height, weight, and blood pressure measurements) and laboratory examination. A random subset of participants underwent a fasting laboratory examination (35).

Primary Predictor Variable: Food Security

More than 99 percent of the eligible sample participated in the Food Security Survey Module (FSSM), which is a well-validated questionnaire developed by the USDA to measure household food security over the prior 12 months (1, 35). One adult in a household was interviewed and the questions referred to all household members. Because we were interested in adult health outcomes, we used responses to only the 10 household and adult items in the 18-item scale. The remaining 8 items refer to household children (35). Food security status was determined by the answers to the 10 questions. Each question asks about conditions or behaviors that characterize households when they are having difficulty meeting their basic food needs and stipulates that the reason for the difficulty was a lack of money or other resources. Affirmative responses (“often,” “sometimes,” and “yes”) to the food security questions were summed for all households. Answers to questions about the frequency of behaviors (cutting or skipping meals, not eating for a whole day in the previous 12 months) that were greater than or equal to 1 month were counted as affirmative. Households that

affirmed none of the low food security conditions were categorized as having high food security, while those with one or two affirmatives were counted as having marginal food security. Households that affirm three to five conditions are counted as having low food security, while those affirming six or more conditions are counted as having very low food security (35).

Questions Used to Assess Food Security of Households in the National Health and Nutrition Examination Survey (NHANES)

1. "We worried whether our food would run out before we got money to buy more." Was that often, sometimes, or never true for you in the last 12 months?
2. "The food that we bought just didn't last and we didn't have money to get more." Was that often, sometimes, or never true for you in the last 12 months?
3. "We couldn't afford to eat balanced meals." Was that often, sometimes, or never true for you in the last 12 months?
4. In the last 12 months, did you or other adults in the household ever cut the size of your meals or skip meals because there wasn't enough money for food? (Yes/No)
5. (If yes to question 4) In the last 12 months, how many months did this happen?
6. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food? (Yes/No)
7. In the last 12 months, were you ever hungry, but didn't eat, because there wasn't enough money for food? (Yes/No)
8. In the last 12 months, did you lose weight because there wasn't enough money for food? (Yes/No)
9. In the last 12 months did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food? (Yes/No)
10. (If yes to question 9) In the last 12 months, how many months did this happen?

Source: *NHANES 2019-2020 Questionnaire Instruments*. https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/questionnaires.aspx?Cycle=2019-2020

Outcome Variables

We evaluated as dependent variables self-reported diagnosis of hypertension, coronary heart disease (CHD), cancer, diabetes, asthma, and kidney disease. The self-reported diseases were identified by affirmative answers to the question "Has a doctor or other health professional ever told you (that you had hypertension, also called high blood pressure) (that you had cancer or a malignancy

of any kind) (that you had coronary heart disease) (that you have diabetes or sugar diabetes) (that you had asthma) (that you had weak or failing kidneys)" (35).

Covariates

Age, sex, race/ethnicity, and health insurance coverage were recorded based on self-report. The highest level of education was based on self-report and categorized into less than high school (9th grade or less or some high school), high school graduate, and college graduate (completed college, some graduate school, or masters or doctoral degree). The household income-to-poverty ratio was based on participant self-report. Participants were asked, "Thinking about your income and the income of everyone who lives in your household and contributes to the household budget, what was the total monthly household income before taxes and deductions? Include all sources of income, including non-legal sources" (35). The income-to-poverty ratio was calculated by dividing family (or individual) income by the poverty guidelines specific to the survey year (35). The value was not computed if the respondent only reported income as < $20,000 or ≥ $20,000 (35). If family income was reported as a more detailed category, the midpoint of the range was used to compute the ratio (35). Values at or above 5.00 were coded as 5.00 or more because of disclosure concerns. The values were not computed if the income data was missing (35).

Statistical Analysis

Data analysis for this study was conducted using SAS 9.4. A logistic regression model was run for a nationally weighted sample. Our predictors were the four food security levels. We had a total of 6 chronic disease outcomes (as binary measures). Our models were adjusted for age, gender, race/ethnicity, education, and household income-to-poverty ratio. All estimates were weighted to

account for the unequal probability of selection that resulted from the survey cluster design, nonresponse, and oversampling of certain target populations (36). The NHANES uses a complex sampling design, with stratification and multiple stages of selection, and unequal probabilities of selecting respondents. Descriptive statistics were used to depict participants' background characteristics categorized by food security status. Odds ratios (OR) were estimated by logistic regression models for the relationship between food security level and hypertension, coronary heart disease (CHD), cancer, diabetes, asthma, and kidney disease, with high food security as the referent group at $P< 0.05$ significant level.

Confounding variables included in the logistic regression models were age, gender, race/ethnicity, and household income-to-poverty ratio. In this study, age is a continuous variable. According to the guidelines of the NHANES analyses, sample sizes were small for some race/ethnic groups, race/ethnicity was categorized as Hispanic, White, Black, Asian, and Other (35). Health insurance status was obtained from the household questionnaires and reflected whether the participants were covered by health insurance or some other type of health care plan including health insurance obtained through employment or purchased directly as well as government programs such as Medicare and Medicaid (35).

Chapter IV. Results

The NHANES 2007-2008 included 10,149 individuals. We restricted from the analysis participants with missing data (n = 575), pregnant women and those who could not ascertain their pregnancy status (n = 95), youth (<20 y of age) (n = 4,214), and the elderly (>64 y of age) (n = 1,556). These exclusions resulted in 3,709 participants. The NHANES 2017-2018 included 9,254 individuals. We restricted from the analysis participants with missing data (n = 810), pregnant women and those who could not ascertain their pregnancy status (n = 98), youth (<20 y of age) (n = 3,685), and the elderly (>64 y of age) (n = 1,500). These exclusions resulted in 3,161 participants.

Table 1 shows descriptive statistics for sampled adults categorized by food security status from NHANES 2007-2008 compared to NHANES 2017-2018. Approximately 19 percent of the 2007-2008 sample had either low or very low food security. Women made up a little less than half of the sample and approximately 50 percent of each food security category. Non-Hispanic Whites were more likely to have high food security compared to other races/ethnicities. Non-Hispanic Blacks made up approximately 20 percent of each food security category. Mexicans and other Hispanics were more likely to have marginal food security. Also, over 75 percent of those who had health insurance had high food security.

Approximately 25 percent of the NHANES 2017-2018 sample had either low or very low food security, a 6 percent increase from 2007-2008. Again, the average age of sampled adults was similar in all food security status categories. Women still comprised half of the sample and made-up half of each food security category. In the 2017-2018 sample, those of other races/ethnicities made up much more of the high food security category compared to 2007-2008. The group saw an increase of 21

percent in the category. Non-Hispanics Whites also saw a noticeable decrease of 13 percent of those with high food security. Non-Hispanic Blacks still made up roughly 20 percent of each food security category, with the highest percentage having marginal food security. In 2017-2018, Mexicans and other Hispanics were more likely to have low food security. This is a change from their majority marginal status in 2007-2008.

Table 1. Characteristics of study adults by food security status, 2007-2008 vs 2017-2018

			Food security status							
	Total		High		Marginal		Low		Very Low	
	07-08	17-18	07-08	17-18	07-08	17-18	07-08	17-18	07-08	17-18
n	3709	3161	2605	1922	423	460	462	428	229	351
Age (mean)	42.64	43.68	43.52	44.19	40.57	41.57	40.00	44.27	41.59	42.92
Female (%)	49.29	50.62	48.68	49.79	50.85	51.52	50.00	51.64	51.97	52.71
Race (%)										
NH-White	42.98	32.27	47.91	34.08	24.21	24.57	34.20	23.36	38.43	43.30
NH-Black	22.03	22.90	21.61	21.33	24.21	27.83	23.38	23.60	20.09	24.22
Mexican	19.47	14.01	16.20	11.29	30.99	18.70	24.03	21.73	26.64	13.39
Other Hispanic	11.08	9.14	9.64	7.08	17.19	11.74	13.20	14.95	12.23	9.97
Other	4.45	21.67	4.64	26.22	3.39	17.17	5.19	16.36	2.62	9.12
Insured = Yes (%)	69.78	81.56	76.28	87.41	50.61	72.17	57.14	72.66	55.90	72.65

Table 2 shows descriptive statistics for sampled households categorized by food security status from NHANES 2007-2008 compared to NHANES 2017-2018. In the 2007-2008 sample, those in households where the highest level of education was college or more were more likely to have high food security with 27 percent in this category. On the other hand, those in households where the highest level of education was less than high school were more likely to have low or very low food security. There was not much difference in food security status across households where the highest level of education was high school/GED. The average age of sampled adults and family size were similar in all food security status categories. Households with high food security had a much higher average income-to-poverty ratio than the other three food status categories. Those in high food security households had an average income-to-poverty ratio of 3.06 while those in marginal, low, and very low food security households averaged 1.64, 1.35, and 1.21, respectively. In general, a ratio of less than 1 means that the income is less than the poverty level (5). When the ratio equals 1, the income and poverty level are the same, and when the ratio is greater than 1, the income is higher than the poverty level (5). Also, over 75 percent of those who had health insurance had high food security.

In the 2017-2018 sample, households with high food security continued to have a much higher average income-to-poverty ratio compared to the other three food status categories. The sample average family size did not change. However, there was a slight decrease in average family size for households with very low food security. Those in marginal, low, and very low food security households did experience a slight increase in their average income-to-poverty ratios compared to 2007-2008. There was an increase in those insured for the sample in all food security categories in

2017-2018. Households where the highest level of education was college or more still had mostly high food security and the least amount of low or very low food security compared to households with the highest level of education being less than high school.

Table 2. Characteristics of study households by levels of food security status, 2007-2008 vs 2017-2018

			Food security status							
	Total		High		Marginal		Low		Very Low	
	07-08	17-18	07-08	17-18	07-08	17-18	07-08	17-18	07-08	17-18
n	3709	3161	2605	1922	423	460	462	428	229	351
Education (%)										
Less than HS	27.77	16.80	21.04	10.25	41.65	25.65	42.42	28.27	49.78	27.07
HS/GED/AA	24.86	57.48	23.84	54.79	24.46	58.48	30.95	61.68	24.89	65.81
College or more	20.81	25.72	27.37	34.96	8.96	15.87	3.25	10.05	3.06	7.12
Family size (mean)	3.18	3.17	3.02	3.07	3.58	3.54	3.79	3.51	3.03	2.77
Income-to-poverty ratio (mean)	2.57	2.56	3.06	3.18	1.64	1.84	1.35	1.59	1.21	1.26

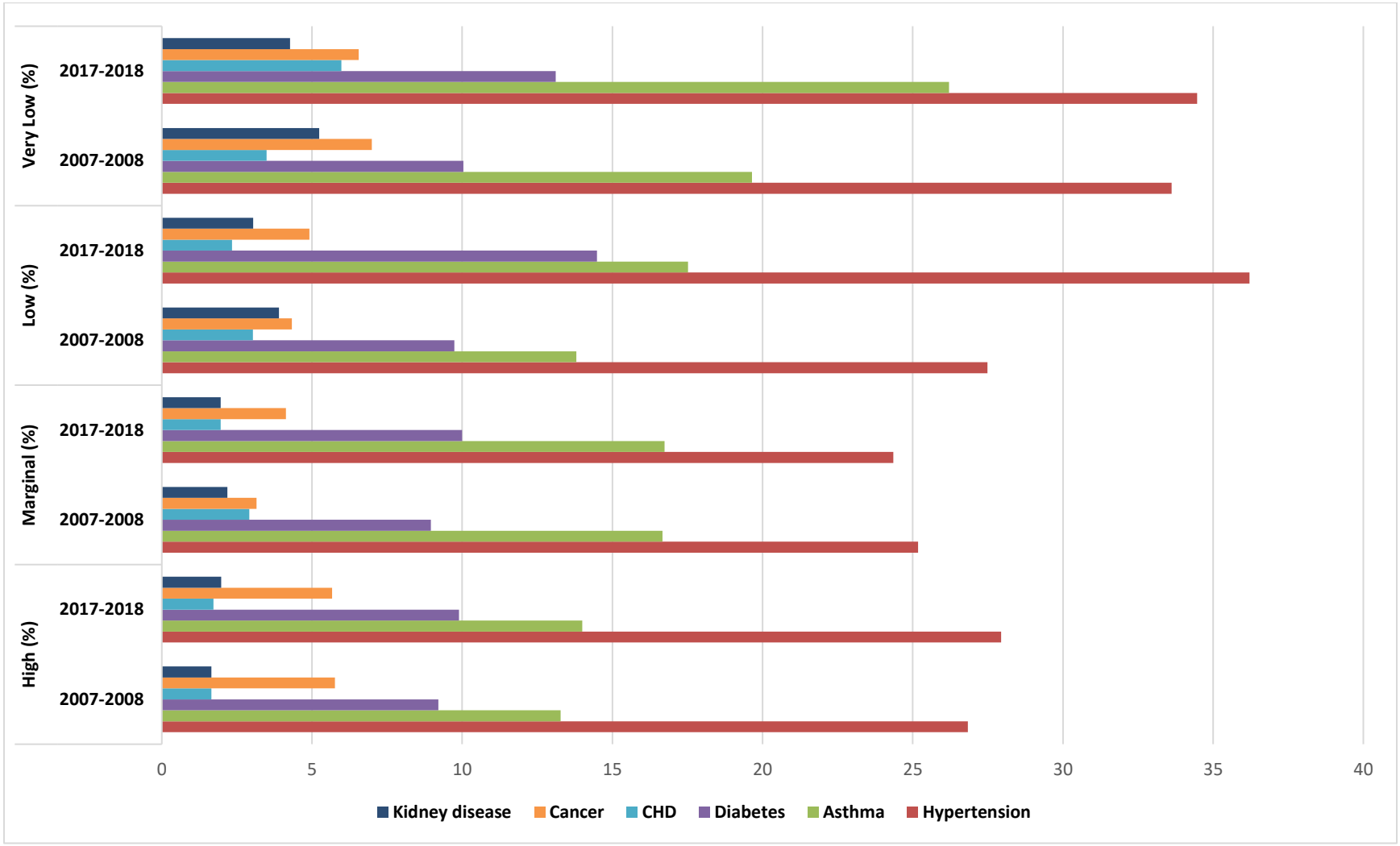
Notes: Data was collected differently for education in NHANES 2007-2008 and 2017-2018. To account for this, for NHANES 2007-2008, "Less than 9th "and "Less than 11th" were combined to create "Less than HS". NHANES 2007-2008 "Some College" was also omitted from this table. Due to this, the 07-08 columns do not equal 100 percent.

We report the relationship between food security status and the six specified chronic conditions for each sample in **Table 3**. This is also displayed in **Figure 1**. There was not much difference between the samples in terms of sample percent for each condition. In both samples, hypertension is the most common condition followed by asthma and diabetes, respectively. Adults with low and very low food security experienced an increased prevalence of all chronic conditions compared to those with high and marginal food security in both samples. For example, the prevalence of hypertension for adults in households with high, marginal, low, and very low food security is 26.83, 25.18, 27.49, and 33.62 percent, respectively, in 2007-2008. Similarly, the prevalence of asthma is 14.00, 16.74, 17.52, and 26.21 percent across worsening food security status in 2017-2018.

Table 3. Prevalence of chronic illnesses by food security status, 2007-2008 vs 2017-2018

			Food security status							
	Total n (%)		High (%)		Marginal (%)		Low (%)		Very Low (%)	
	07-08	17-18	07-08	17-18	07-08	17-18	07-08	17-18	07-08	17-18
Condition										
Hypertension = Yes	1007 (27.15)	925 (29.26)	26.83	27.94	25.18	24.35	27.49	36.21	33.62	34.47
Hypertension= No	2702 (72.85)	2236 (70.74)	73.17	72.06	74.82	75.65	72.51	63.79	66.38	65.53
Asthma = Yes	525 (14.15)	513 (16.23)	13.28	14.00	16.67	16.74	13.80	17.52	19.65	26.21
Asthma = No	3184 (85.85)	2648 (83.77)	86.72	86.00	86.20	83.26	83.33	82.48	80.35	73.79
Diabetes = Yes	345 (9.30)	344 (10.88)	9.21	9.89	8.96	10.00	9.74	14.49	10.04	13.11
Diabetes = No	3364 (90.70)	2817 (89.12)	90.79	90.11	91.04	90.00	90.26	85.51	89.96	86.89
CHD = Yes	77 (2.08)	73 (2.31)	1.65	1.72	2.91	1.96	3.03	2.34	3.49	5.98
CHD = No	3632 (97.92)	3088 (97.69)	98.35	98.28	97.09	98.04	96.97	97.66	96.51	94.02
Cancer = Yes	199 (5.37)	172 (5.44)	5.76	5.67	3.15	4.13	4.33	4.91	6.99	6.55
Cancer = No	3510 (94.63)	2989 (94.56)	94.24	94.33	96.85	95.87	95.67	95.09	93.01	93.45
Kidney disease = Yes	82 (2.21)	75 (2.37)	1.65	1.98	2.18	1.96	3.90	3.04	5.24	4.27
Kidney disease = No	3627 (97.79)	3086 (97.63)	98.35	98.02	97.82	98.04	96.10	96.96	94.76	95.73

Figure 1. Prevalence of chronic illnesses by food security status, 2007-2008 vs 2017-2018



We estimated unadjusted and adjusted logistic regressions to determine the conditional association of food security status with each of the chronic conditions examined for each sample. **Table 4** shows the unadjusted and adjusted odds ratios for each of the six chronic health conditions. In both samples, very low food security status is strongly associated with most chronic diseases, relative to high food security (the reference group). For each condition, as food insecurity worsens, the likelihood of having the condition increases.

For sampled adults in these regressions, age was positively associated with the probability of each chronic illness except asthma. In 2007-2008, women were less likely than men to report diabetes and CHD. In 2017-2018 hypertension was added to that list. Mexicans and other races/ethnicities were less likely to have most of the chronic conditions, while non-Hispanic Black and other Hispanic adults are more likely to report some conditions and less likely to report others, relative to non-Hispanic Whites (the reference group). For example, in 2007-2008, non-Hispanic Blacks were less likely to report asthma, CHD, and cancer than non-Hispanic Whites, but more likely to report hypertension, diabetes, and kidney disease. Other Hispanics were less likely to report hypertension, CHD, cancer, and asthma, and more likely to report diabetes and kidney disease than non-Hispanic Whites. Mexicans were less likely to report all chronic conditions, except diabetes, less than non-Hispanic Whites. Other races/ethnicities adults were less likely than non-Hispanic Whites to report all conditions except CHD.

Persons who were not insured were less likely to report all conditions. Generally, having health insurance is associated with having a higher income (14). These results reflect the higher

probability that low-income individuals with health insurance will seek care and receive a diagnosis. It also suggests that the negative correlation of employment with chronic illness is related to unobserved characteristics associated with attachment to the labor market (14). Adults in households that included a college graduate were less likely to report most chronic health conditions than adults in households where the highest level of education was either less than high school, high school, or some college. Particularly significant in this regard are the associations with diabetes and kidney disease. Also, adults in households with an income-to-poverty ratio less than or equal to 2.0 were more likely to report asthma, diabetes, CHD, and kidney disease, and less likely to report hypertension and cancer.

In 2017-2018, other Hispanics, Mexicans, and other races/ethnicities were less likely to have most of the chronic conditions, while non-Hispanic Blacks were more likely to report most conditions, relative to non-Hispanic Whites. Non-Hispanic Blacks were more likely to report hypertension, asthma, diabetes, and kidney disease than non-Hispanic Whites, but significantly less likely to report CHD and cancer. Other Hispanics, Mexicans, and other races/ethnicities were less likely to report all conditions except diabetes compared to non-Hispanic Whites.

Persons who were not insured were still less likely to report all conditions. There was also no change in the educational groups. Adults in households that included a college graduate were still less likely to report most chronic health conditions than adults in households with the highest level of education being either less than high school, high school, or some college. Particularly significant in this regard are the associations with hypertension, asthma, diabetes, and kidney disease. Also, adults

in households with an income-to-poverty ratio less than or equal to 2.0 were still more likely to report asthma, diabetes, CHD, and kidney disease, and less likely to report hypertension and cancer.

Associations between food security status and each chronic condition for each sample are shown in **Table 4**. High food security was used as the reference group for each association separately. In 2007-2008, after adjusting for age, gender, race/ethnicity, educational attainment, and income, having marginal food security was significantly associated with 2 times higher odds of having CHD (AOR 2.03, 95% CI 1.01, 4.05). Having low food security was significantly associated with 2 times higher odds of having CHD (AOR 2.03, 95% CI 1.03, 3.98) and nearly 2 times higher odds of having kidney disease (AOR 1.79, 95% CI 0.98, 3.27) compared to those with high food security. Having very low food security was significantly associated with higher odds of having four of the chronic conditions compared to those with high food security. These included nearly 2 times higher odds of having hypertension (AOR 1.62, 95% CI 1.17, 2.22) and asthma (AOR 1.65, 95% CI 1.14, 2.37), and 2 times higher odds of having CHD (AOR 2.12, 95% CI 0.92, 4.86) and kidney disease (AOR 2.33, 95% CI 1.16, 4.68).

By contrast, in 2017-2018, those with marginal food security had no significant associations with any of the chronic conditions. Having low food security was no longer significantly associated with CHD and kidney disease. Instead, when adjusted, having low food security was significantly associated with having nearly 2 times higher odds of having hypertension (AOR 1.59, 95% CI 1.24, 2.04) and diabetes (AOR 1.34, 95% CI 0.95 - 1.90). Having very low food security was again

significantly associated with having nearly 2 times higher odds of having hypertension (AOR 1.61, 95% CI 1.22 - 2.12) and kidney disease (AOR 1.98, 95% CI 1.01, 3.88), 2 times higher odds of having asthma (AOR 2.03, 95% CI 1.51, 2.73), and 5 times higher odds of having CHD (AOR 5.02, 95% CI 2.56, 9.84), which was a drastic change from 2007-2008.

Table 4. Crude and adjusted odds ratios for the association between food security status and chronic illnesses among NHANES participants, 2007-2008 vs 2017-2018

	Marginal COR (95% CI) AOR (95% CI)		Low COR (95% CI) AOR (95% CI)		Very Low COR (95% CI) AOR (95% CI)	
Condition						
	07-08	17-18	07-08	17-18	07-08	17-18
Hypertension	0.92 (0.72 - 1.17)	0.83 (0.66 - 1.05)	1.03 (0.83 - 1.29)	**1.46 (1.17 - 1.83) ***	**1.38 (1.04 - 1.84) ***	**1.36 (1.066 - 1.728) ***
	1.12 (0.86 - 1.45)	1.00 (0.77 - 1.29)	1.26 (0.98 - 1.63)	**1.59 (1.24 - 2.04) ***	**1.62 (1.17 - 2.22) ***	**1.61 (1.22 - 2.12) ***
Asthma	1.05 (0.77 - 1.41)	1.24 (0.94 - 1.63)	1.31 (1.00 - 1.71)	1.31 (0.99 - 1.72)	**1.60 (1.13 - 2.26) ***	**2.18 (1.67 - 2.86) ***
	1.10 (0.80 - 1.50)	1.17 (0.87 - 1.56)	1.30 (0.97 - 1.74)	1.25 (0.93 - 1.69)	**1.65 (1.14 - 2.37) ***	**2.03 (1.51 - 2.73) ***
Diabetes	0.97 (0.68 - 1.39)	1.01 (0.72 - 1.42)	1.06 (0.76 - 1.49)	**1.54 (1.14 - 2.10) ***	1.10 (0.70 - 1.73)	1.38 (0.97 - 1.94)
	0.93 (0.63 - 1.37)	1.09 (0.75 - 1.56)	0.99 (0.69 - 1.43)	1.34 (0.95 - 1.90)	0.92 (0.57 - 1.49)	1.31 (0.89 - 1.93)
CHD	1.78 (0.93 - 3.41)	1.14 (0.54 - 2.40)	**1.86 (1.01 - 3.43) ***	1.37 (0.67 - 2.80)	**2.16 (1.00 - 4.65) ***	**3.64 (2.08 - 6.37) ***
	2.03 (1.01 - 4.05) *	1.52 (0.69 - 3.33)	**2.03 (1.03 - 3.98) ***	1.53 (0.71 - 3.33)	2.12 (0.92 - 4.86)	**5.02 (2.56 - 9.84) ***
Cancer	**0.53 (0.30 - 0.95) ***	0.72 (0.44 - 1.18)	0.74 (0.46 - 1.19)	0.86 (0.53 - 1.39)	1.23 (0.72 - 2.10)	1.17 (0.73 - 1.86)
	0.57 (0.31 - 1.03)	0.78 (0.47 - 1.32)	0.81 (0.48 - 1.35)	0.82 (0.49 - 1.37)	1.26 (0.71 - 2.22)	1.21 (0.73 - 2.02)
Kidney disease	1.33 (0.64 - 2.74)	0.99 (0.48 - 2.06)	**2.42 (1.38 - 4.23) ***	1.55 (0.82 - 2.94)	**3.30 (1.71 - 6.34) ***	**2.21 (1.20 - 4.07) ***
	1.11 (0.52 - 2.34)	0.98 (0.46 - 2.09)	1.79 (0.98 - 3.27)	1.36 (0.69 - 2.71)	**2.33 (1.16 - 4.68) ***	**1.98 (1.01 - 3.88) ***

Notes: COR, Crude Relative Risk. AOR, Adjusted Relative Risk. Odds ratios were estimated by logistic regression models for the relationship between food security status and each chronic condition, with high food security as the referent group. AOR is adjusted for age, gender, race/ethnicity, educational attainment, and income. *p<.05.

Chapter V - Discussion

This study details the association between food security status and chronic health conditions among working-age US adults. Overall, lower food security is associated with higher odds of each chronic disease examined—hypertension, coronary heart disease (CHD), cancer, asthma, diabetes, and kidney disease. It is also important to note that the differences between working-age adults in households with marginal, low, and very low food security are often statistically significant. This displays the importance of looking at the entire range of food security to better understand the association between chronic illness and food security status. Low food security was a statistically significant predictor of having self-reported hypertension and CHD in both cycles and kidney disease in 2017-2018 while the income-to-poverty ratio was not, supporting previous findings of food security as a stronger predictor of chronic disease than wealth (**See Tables 5 & 6 in the Appendix**). The income-to-poverty ratio was significantly associated with only two of the six chronic diseases—asthma and kidney disease—while food insecurity is significantly associated with all except cancer.

In this sample of working-age US adults, those experiencing lower food security were more likely to have multiple chronic conditions compared to their food-secure counterparts, even after adjustment for age, gender, race/ethnicity, educational attainment, and household income. Low food security is associated with hypertension, diabetes, CHD, and kidney. Very low food security is associated with hypertension, asthma, diabetes, CHD, and kidney disease. Marginal food security is associated with CHD and cancer. Several studies have reported cross-sectional associations between low food security and self-reported chronic disease, including heart disease, diabetes, hypertension, and general health status (9). A study of more than 2500 adults in rural Ohio found no association between food security status and hypertension, hyperlipidemia, and hyperglycemia (9). However, this

population-based sample study suggests low food security may be a risk factor for hypertension and diabetes among working-age adults. The results from this study further contribute to the growing literature, demonstrating that low food security is associated with lower self-reported health, which may be due to a higher burden of chronic conditions experienced by those with lower food security. Food insecurity has been independently linked to the emergence of several chronic illnesses that continue to overburden our healthcare system (41). Type 2 diabetes mellitus, cardiovascular disease, HIV/AIDS, and mental problems are among these ailments (41). Considering diabetes and heart disease, diet has a complicated function in both disorders. Obesity, a risk factor for diabetes and heart disease, is more frequent among those with low food security (41). Those with very low food security are more likely to develop type 2 diabetes, even after correcting for sociodemographic characteristics and physical activity level (41). Blood sugar management over time, as measured by hemoglobin A1c, is poorer in those with low food security. This may be linked to low income and their inability to afford and adhere to a diabetic diet that restricts processed foods such as simple carbs (41). Interventions fall short when patients do not have access to adequate meals. Many of these patients are instead provided medicines and insulin, which increases their healthcare expenses and reduces their total income (41). This contributes to the perpetuation of food insecurity and chronic illness.

There are potential processes that could explain the link between food insecurity and cardiometabolic illness. First, food insecurity has been associated with the consumption of inexpensive, calorie-dense, but nutrient-poor foods such as increased fats and carbohydrates, and decreased consumption of fruits and vegetables (13). Second, the cyclical nature of food insecurity,

which is reflected in monthly wages and food aid, may induce insulin resistance due to times of food access and food lack (13). Moreover, alternating periods of food abundance and deprivation encourage binge eating and subsequent obesity (13). Lastly, persistent stress and anxiety brought on by food insecurity may contribute to insulin resistance, obesity, and hypertension (13). Food insecurity-induced stress can activate the hypothalamic-pituitary-adrenal axis and stimulate the production of glucocorticoids, which can change metabolism, lead to increased visceral fat deposition and storage, and exacerbate binge eating behaviors (13). Stress-induced increases in cortisol lead to a rise in blood glucose and insulin resistance, both of which play crucial roles in the development of type 2 diabetes (13).

Moreover, chronic conditions might contribute to food insecurity (13). Chronic disorders such as diabetes and hypertension may necessitate medication and more frequent doctor's appointments, resulting in higher healthcare expenses. When individuals develop increasingly severe chronic diseases, their ability to work and earn money may diminish (13). In addition, nutritional counseling and health education during healthcare visits may enhance knowledge of diet guidelines and the difficulty of buying nutritious foods, resulting in a greater impression of food insecurity (13).

Comorbidities

Chronic medical disorders frequently coexist, as comorbidities, as opposed to being discrete illnesses. For many of them, the burden of chronic disease is exacerbated by the fact that chronic disorders frequently occur as comorbidities as opposed to as separate conditions. Age is a factor in the frequency of comorbidity, with 69 percent of those over 65 having two or more chronic conditions (42). It is estimated that more than 40 percent of individuals with a chronic ailment have

at least one comorbidity and that individuals aged 60 and older have, on average, 2.2 chronic conditions (42). A growing number of chronic illnesses has been linked to an increase in disability and a decline in physical health. Furthermore, comorbidity has been linked to higher mortality, worse quality of life, and greater utilization of health services. Not only do comorbid illnesses have additively detrimental impacts on physical functioning, but several chronic disease pairings can also have synergistic consequences (42). Individuals, such as those in this sample, afflicted with a combination of diabetes, cardiovascular disease, and/or chronic respiratory illness are at a greater risk of a physical handicap than would be predicted from the impact of these diseases individually (42). Consequently, preserving functional ability should be a key goal of therapy for these individuals with multiple chronic conditions.

Food Deserts

Food deserts are another issue leading to poor food security that should be investigated. Since 2013, the USDA has used the term "low-income and low-access" to designate these areas with limited access to healthy food (44). This term more accurately reflects what is statistically measured in the Food Access Research Atlas (FARA), a tool used to provide insight into a neighborhood or community's access to food stores that offer a variety of healthy and affordable food (44). Living in a food desert directly influences the availability and consistency of healthful meals. The Office of Disease Prevention and Health Promotion estimates that in the United States, more than 23 million people (about the population of New York), including 6.5 million children (about twice the population of Oklahoma), live in food deserts (43). There are fewer full-service supermarkets in these food deserts, and inhabitants may be required to drive considerable distances to reach grocery shops, with few automobile or public transit choices (43). Convenience stores and small independent stores that

may lack adequate variety, quantity, and consistency of affordable, nutritious foods are more prevalent in food deserts than full-service supermarkets, and national reports indicate that, overall, Black and Hispanic neighborhoods have fewer supermarkets than white and non-Hispanic neighborhoods (43). Food desert residents had lower levels of serum carotenoids, a biomarker of fruit and vegetable consumption, and higher systolic blood pressures, according to a 2015 observational research based on a nationwide health survey with over 22,000 participants (40). Moreover, those with lower incomes were also more likely to acquire chronic renal disease (40).

Healthcare Costs

Food insecurity has also been linked to higher subsequent healthcare expenses. A 2018 longitudinal study indicated that those with low food security had higher yearly healthcare expenses, amounting to an additional $1,863 per person, or $77.5 billion (about $240 per person in the US) (about $240 per person in the US) in increased annual healthcare expenditures in the United States (43). Analysis of national survey data from 2011-2015 revealed that the yearly healthcare expenditures associated with low food security among older persons were greater in the presence of certain chronic diseases, such as hypertension, stroke, arthritis, and diabetes (43).

Food Secure vs Food Insecure

Individuals with a high level of food security have constant access to the types and quantities of foods required for all family members to live an active and healthy existence (14). Those with low or very low food security, on the other hand, struggle to consistently procure sufficient sustenance due to limited economic resources (14). Food-insecure households face additional challenges,

particularly in terms of health. Extensive research has investigated the relationships between food security and health, with nearly all of it demonstrating the strong correlation between food insecurity and adverse health outcomes (14). There is a documented correlation between income, wealth, and health status (14). There is also a significant correlation between food security and health indicators (14). While this correlation has been recognized on a macroeconomic or aggregate level for some time, the relationship between the health of adults of working age and household food insecurity has received less attention (14). In most previous research on the correlates of food insecurity, adults are categorized as either belonging to food-secure or food-insecure households (14). This classification scheme, however, obscures distinctions between adults in households reporting no food-insecure conditions (highly food secure) and those reporting only one or two food-insecure conditions (marginally food secure), as these groups are frequently grouped together within the food-secure group (14). Similarly, this classification may overlook distinctions between those with low food security and those with very low food security, who are frequently grouped together and labeled "food insecure (14)." This study was able to investigate the prevalence of chronic diseases among adults of working age living in various food-secure households to demonstrate the relationship between food security status and both individual conditions and chronic illness in general. In general, food security status and health outcomes correlate with the food security classifications of high, marginal, low, and very low. This study shows that most differences in health are statistically significant, implying substantial prospective differences in the expected costs of illness across food security categories. Significant differences in health outcomes between households with high and marginal (as well as low and very low) food security—typically categorized together as food secure (food insecure)—suggest that the more precise food-insecurity classification captures crucial

information about economic hardship and how it translates to poorer health outcomes (14). In addition, the similarity in health outcomes between households with marginal and low food security suggests that the prevalent binary classification (food secure and insecure) may obfuscate how households considered to be food secure are more like those that are food insecure (14). This is consistent with research indicating that marginally food-secure households share more demographic characteristics with food-insecure households than with food-secure households (14).

The extent of the increased likelihood of chronic illness resulting from food insecurity is startling. Even for individuals residing in marginally food-secure households, which are typically categorized as food-secure and endure relatively moderate food hardships. Understanding the relationship between food insecurity and chronic illness is not only vital from a financial standpoint (14). Chronic diseases have short- and long-term effects on both quality of life and morbidity; food insecurity may be one of many factors contributing to the impact of these chronic conditions on adults with limited income (14). Understanding these correlations is also an endeavor to comprehend the additional obstacles encountered by low-income adults with any level of food insecurity (14).

Limitations

Our study was limited by small sample sizes for some variables. The Food Security Survey Module evaluates food security at the household level, which may misclassify certain people as food insecure if other members of the home are food insecure. However, most adults in a food-insecure family are also food-insecure, and any misclassification biases our findings toward the null hypothesis (9). Varying rates of nonparticipation from diverse groups may have influenced the findings. Lastly, we used a self-reported food security metric. Yet, a self-reported measure is suitable since many of

the impacts of food insecurity might be mediated by an individual's judgment of the extent to which food expenditures are insufficient. Notwithstanding these limitations, this research contributes significant population-based information to our knowledge of the relationship between food security status and chronic disease.

Conclusion

Food insecurity is an important social determinant of health. To potentially increase access to resources, patients should be screened for food insecurity by their healthcare providers. This could lead to referrals to appropriate social services and provide additional information on choosing healthy foods from these programs. Given the link between food insecurity and several chronic illnesses after controlling for other factors, it is likely that efforts to minimize food insecurity may also contribute to the reduction of chronic diseases (13). This is a topic that should be explored in future longitudinal or interventional studies. To minimize food insecurity in the United States, the Supplemental Nutrition Assistance Program (SNAP) has a well-established infrastructure (13). It may be beneficial to incorporate interventions into programs such as SNAP to increase food security. SNAP is a well-established and effective infrastructure used to minimize food insecurity in the United States (9). If SNAP can induce dietary adjustments toward healthier food options, it may also be able to reduce the development of diet-sensitive chronic illnesses and enhance health outcomes (9). Continual and planned improvements to the Supplemental Nutrition Assistance Program are intended to promote these dietary changes. Utilizing physiologic metrics to objectively examine the health implications of these alterations will assist in determining the extent to which these initiatives

may enhance the health of the population by decreasing the prevalence of chronic conditions such as hypertension and diabetes.

Food insecurity is associated with several self-reported chronic diseases including diabetes, hypertension, and asthma in a nationally representative sample of working-age US adults. Given the high prevalence of chronic disease in older adults, it is important to screen for and address food security in this age group given the development of many of these chronic conditions during this period. Future research should also examine the association between food security status and chronic disease longitudinally and integrate interventions to combat low food security and chronic disease development in working-age adults.

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Appendix

Table 5. Regression parameters, logistic regression for the probability of chronic illness, 2007-2008

Variable	Hypertension	Asthma	Diabetes	CHD	Cancer	Kidney Disease
	Food security status					
Marginal	-0.086	0.044	-0.031	0.578	-0.631***	0.283
	(0.122)	(0.154)	(0.185)	(0.331)	(0.294)	(0.370)
Low	0.033	0.267	0.062	0.622***	-0.300	0.882**
	(0.113)	(0.138)	(0.171)	(0.312)	(0.244)	(0.285)
Very Low	0.323***	0.468**	0.096	0.769***	0.207	1.192**
	(0.147)	(0.176)	(0.230)	(0.391)	(0.273)	(0.334)
	Characteristics of sampled adult					
Age ≥ 40	1.560*	-0.078	1.772*	2.962***	1.326*	0.618***
	(0.090)	(0.095)	(0.165)	(0.570)	(0.189)	(0.245)
Female	0.031	0.387*	-0.013	-0.718**	0.606*	0.280
	(0.074)	(0.095)	(0.113)	(0.246)	(0.151)	(0.225)
NH-Black	0.513*	-0.089	0.727*	-0.201	-0.642**	0.652***
	(0.092)	(0.118)	(0.139)	(0.301)	(0.202)	(0.264)
Mexican	-0.358**	-1.147*	0.320***	-0.287	-0.762**	-0.127
	(0.109)	(0.171)	(0.158)	(0.325)	(0.222)	(0.345)
Other Hispanic	-0.187	-0.041	0.097	-0.910	-0.680***	0.155
	(0.130)	(0.150)	(0.205)	(0.529)	(0.272)	(0.384)
Other	-0.334	-0.110	-0.317	0.435	-0.751	-0.447
	(0.201)	(0.227)	(0.356)	(0.447)	(0.427)	(0.735)
Insured = No	-0.650*	-0.642*	-0.395**	-1.204**	-0.778*	-0.441
	(0.088)	(0.116)	(0.133)	(0.357)	(0.192)	(0.269)
	Characteristics of household					
Less than 9^{th}	-0.053	-0.443***	1.106*	0.300	-0.194	0.882
	(0.148)	(0.206)	(0.214)	(0.432)	(0.273)	(0.522)
9^{th} – 11^{th}	0.221	0.045	0.791*	0.359	-0.447	1.417**
	(0.120)	(0.152)	(0.199)	(0.365)	(0.242)	(0.433)
HS/GED	0.203	0.018	0.594**	0.075	-0.168	0.935***
	(0.111)	(0.140)	(0.193)	(0.360)	(0.205)	(0.439)

Some college/AA	0.198	0.138	0.418***	0.063	-0.259	0.915***
	(0.110)	(0.136)	(0.195)	(0.356)	(0.206)	(0.437)
Income-to-poverty ratio ≤2.0	-0.089	0.193***	0.147	0.412	-0.037	0.961*
	(0.074)	(0.094)	(0.113)	(0.233)	(0.146)	(0.242)

Notes: Parameters from logistic regressions for individual conditions. Standard errors in parentheses. All models account for complex survey design. ***p<.05, **p<.01, *p<.001.

Table 6. Regression parameters, logistic regression for the probability of chronic illness, 2017-2018

Variable	Hypertension	Asthma	Diabetes	CHD	Cancer	Kidney Disease
Food Security Status						
Marginal	-0.186	0.211	0.013	0.133	-0.333	-0.011
	(0.120)	(0.141)	(0.173)	(0.380)	(0.254)	(0.374)
Low	0.382**	0.267	0.435**	0.314	-0.153	0.440
	(0.113)	(0.143)	(0.157)	(0.365)	(0.245)	(0.326)
Very Low	0.305***	0.781*	0.318	1.293*	0.154	0.795***
	(0.123)	(0.138)	(0.176)	(0.286)	(0.237)	(0.311)
	Characteristics of sample adult					
Age ≥ 40	1.520*	-0.198***	2.135*	2.812*	1.279*	0.872
	(0.095)	(0.097)	(0.195)	(0.591)	(0.207)	(0.278)
Female	-0.117	0.237***	-0.145	-1.092*	0.715*	0.112
	(0.078)	(0.097)	(0.114)	(0.269)	(0.166)	(0.234)
NH-Black	0.397**	0.116	0.176	-0.863***	-0.588**	0.151
	(0.102)	(0.124)	(0.161)	(0.348)	(0.219)	(0.286)
Mexican	-0.571*	-0.581**	0.461**	-0.688	-0.532***	-0.428
	(0.138)	(0.173)	(0.174)	(0.395)	(0.258)	(0.405)
Other Hispanic	-0.108	-0.087	0.193	-0.958	-0.386	-0.989
	(0.148)	(0.178)	(0.216)	(0.531)	(0.291)	(0.611)
Other	-0.233***	-0.324***	0.195	-0.562	-0.564***	-0.378
	(0.111)	(0.138)	(0.163)	(0.319)	(0.222)	(0.339)
Insured = No	-0.417*	-0.345***	-0.316***	-0.620	-0.898**	-0.176
	(0.108)	(0.135)	(0.160)	(0.378)	(0.274)	(0.318)
	Characteristics of household					
Less than high school	0.083	-0.012	0.682**	0.777	0.236	0.530
	(0.128)	(0.160)	(0.177)	(0.418)	(0.266)	(0.441)
HS/GED/AA	0.378*	0.258***	0.331***	0.800	0.440	0.900**

	(0.096)	(0.118)	(0.149)	(0.350)	(0.203)	(0.347)
Income-to-poverty ratio ≤2.0	-0.024	0.371**	0.177	0.029	-0.130	0.416
	(0.078)	(0.097)	(0.114)	(0.237)	(0.158)	(0.236)

Notes: Parameters from logistic regressions for individual conditions. Standard errors in parentheses. All models account for complex survey design. ***p<.05, **p<.01, *p<.001.