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Approval Sheet

The Association Between Food Insecurity and Diabetes Status by Race and Ethnicity in the United States: An Analysis of National Survey Data

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The Association Between Food Insecurity and Diabetes Status by Race and Ethnicity in the United States: An Analysis of National Survey Data

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ABSTRACT

The Association Between Food Insecurity and Diabetes Status by Race and Ethnicity in the United States: An Analysis of National Survey Data

By Caitlyn S. Fong

Objective

To evaluate the association between food insecurity and diabetes status in US adults by race and ethnicity and to estimate the potential impact of food security interventions on prevalent diabetes.

Methods

Cross-sectional data from 4,348 adults in the 2015-2016 National Health and Nutrition Examination Survey (NHANES) were analyzed. Food insecurity was dichotomized as food insecure (very low, low, or marginal food security) or fully food secure (reference). Diabetes status was defined as overt diabetes, prediabetes, and no diabetes (reference). Multinomial logistic regression analysis was conducted to estimate the association of household food insecurity (exposure) with diabetes status (outcome) in all US adults and by race and ethnicity. Analyses controlled for diet quality, gender, age, citizenship status, education level, ratio of family income to poverty, and household size. An attributable fraction approach was used to estimate the fraction of diabetes cases associated with food insecurity.

Results

The study included 1,543 non-Hispanic White adults, 885 non-Hispanic Black adults, 1317 Hispanic adults, and 603 adults of other races. 28.2% were food insecure, 34.6% had prediabetes, and 14.9% had overt diabetes. Whereas there was no association between food insecurity and prediabetes in all US adults, there was a statistically significant association between experience of food insecurity and prediabetes in Hispanic adults (aOR: 1.6; 95%CI: 1.2, 2.3). Among all US adults, those reporting food insecurity had twice the relative odds of overt diabetes (aOR: 2.0; 95%CI: 1.4, 2.7). There was also a strong association between food insecurity and overt diabetes in non-Hispanic White adults (aOR: 2.5; 95%CI: 1.5, 3.9). Up to 6% of overt diabetes cases may be attributed to food insecurity across all races, with non-Hispanic White adults having the highest proportion of attributable cases at 15%.

Conclusions

US adults who report food insecurity in the past 12 months are more likely to have diabetes. The strongest observed association between food insecurity and diabetes, and largest cases of diabetes attributable to food insecurity, was among non-Hispanic white adults. Results suggest that food security initiatives may play a more impactful diabetes prevention role in non-Hispanic White communities compared to racial and ethnic minority communities.

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Table of Contents

List of Figures

List of Tables

CHAPTER 1: INTRODUCTION

In the United States, 34.2 million people have diabetes, or 10.5% of the population (1). The prevalence of diabetes is lower in the non-Hispanic White population (11.9%) than it is in non-Hispanic Black (16.4%), non-Hispanic Asian (14.9%), and Hispanic populations (14.7%) (1). Food insecurity is also different across racial and ethnic groups. In 2016, the prevalence of very low food security in non-Hispanic Black households (9.7%) and Hispanic households (5.8%) was significantly higher than the national average (4.9%) (2). Several studies have found a positive relationship between food insecurity and type 2 diabetes (3–5). However, the role of race and ethnicity in this relationship is unknown. Understanding whether food security differentially impacts diabetes status across race and ethnicities may inform and improve diabetes prevention efforts (6).

Nutrition is a key component in diabetes prevention, as improved diet quality is associated with a lower risk of type 2 diabetes and poor diet quality is associated with a greater risk (7). High quality diets associated with lower diabetes risk include large intake of plant-based foods such as whole grains and minimal consumption of red and processed meat, sodium, sugar-sweetened beverages, and trans-fat (8). It is important to note that food insecurity is also connected to poor diet quality, specifically dietary patterns with less fruits, vegetables, and legumes (2,9). Previous research suggests that this relationship is differential by race, as food insecurity has a lesser impact on diet quality in non-Hispanic Black adults compared with non-Hispanic White adults (10,11). Thus, it is expected that the correlation between food security and diabetes will be weakest for non-Hispanic Blacks and they will see the least improvement in prediabetes and diabetes if their food security were eliminated.

To fill this gap in knowledge, I examined the differential effects of race and ethnicity on food insecurity and diabetes status in the United States. Using data from the 2015-2016 National Health and Nutrition Examination Survey (NHANES), I determined the relationship between food insecurity and diabetes status for the full United States population, and also for each of the following race and ethnicity categories: Hispanic (Mexican American and Other Hispanic), Non-Hispanic White, Non-Hispanic Black, and Other (includes non-Hispanic Asians and multi-racial individuals). Then, I estimated the potential reduction in prediabetes and diabetes prevalence that each racial and ethnic group could experience if food insecurity were to be eliminated.

Specific Aims:

- Aim 1 determined the association between food insecurity and diabetes status for the full United States population.
- Aim 2 determined whether the association between food insecurity and diabetes estimated in Aim 1 varies by race and ethnicity.
- Aim 3 estimated the potential reduction in diabetes and prediabetes prevalence that could be experienced in each race and ethnic group if food insecurity were to be eliminated. This reduction was estimated as the population attributable fraction of diabetes associated with food insecurity.

The study evaluated the differential association by race and ethnicity between food insecurity and diabetes status in the United States and provided an estimate of the potential impact that food security interventions could have on prediabetes and diabetes prevalence. The results of this study can be used to direct and advise health professionals in implementing targeted diabetes prevention efforts.

CHAPTER 2: BACKGROUND & LITERATURE REVIEW

Type 2 Diabetes

Overview

In the United States, 34.2 million people have diabetes, or 10.5% of the population (1). Of all individuals with diabetes, 26.9 million (21.4%) are undiagnosed and 90-95% are Type 2 diabetics (1). In 2018, it was estimated that 88 million adults had prediabetes, which constitutes 34.5% of the adult population (1). Among adults aged 18-64 years old, diabetes is the leading cause of new cases of blindness and the seventh leading cause of death (1).

In 2017, the cost of diagnosed diabetes was estimated to be $237 billion in direct medical costs and $90 million in reduced productivity, totaling to $327 billion (12). Out of all U.S. healthcare dollars, care for those diagnosed with diabetes accounts for 25%, with over half of those dollars being directly attributable to diabetes (12). Aside from medical costs, indirect costs to the nation include "increased absenteeism ($3.3 billion) and reduced productivity while at work ($26.9 billion) for the employed population, reduced productivity for those not in the labor for ($2.3 billion), inability to work because of disease-related disability ($37.5 billion), and lost productivity due to 277,000 premature deaths attributed to diabetes ($19.9 billion)" (11).

For individuals with diabetes, the mean annual medical expenditure is $16,750, including $9,600 from diabetes-related expenses (12). On average, those who are diagnosed with diabetes spend 2.3 times more on medical expenses than they would if they did not have diabetes (12).

Pathophysiology & Diagnostic Criteria

Type 2 diabetes may develop through insulin resistance or insulin secretion defect (13). Insulin resistance occurs when the body's response to normal concentrations of insulin is decreased (13). Insulin secretion defect arises when there is insufficient insulin production by the pancreas (13). Both pathways result in a lack of insulin, which leads to increased blood sugar levels and the onset of prediabetes and type 2 diabetes (13).

There are three primary tests used to diagnose type 2 diabetes (14). The glycosylated hemoglobin, or HbA1c, test measures a person's average blood sugar for the past two to three months (14). A normal HbA1c level is less than 5.7%, prediabetes is 5.7-6.4%, and diabetes is diagnosed at 6.5% and above (14). The fasting blood glucose (FBG) test checks blood sugar levels after fasting, which is defined as not eating or drinking anything besides water for eight hours before the test (14). Normal FBG levels are under 100 mg/dl, prediabetes ranges from 100-125 mg/dl, and diabetes is at least 126 mg/dl (14). The oral glucose tolerance test (OGTT) indicates how one's body processes sugar by measuring the blood sugar before and two hours after he/she drinks a glucose solution (14). The OGTT normal range is below 140 mg/dl, prediabetes is categorized as 140-199 mg/dl, and diabetes is 200 mg/dl and over (14).

Leading Risk Factors for Type 2 Diabetes

Several studies have established type 2 diabetes risk factors, including overweight and obesity (15), hypertension (16), gestational diabetes (17), polycystic ovary syndrome (PCOS) (18), and physical inactivity (19). In a meta-analysis of 18 prospective cohort studies, Abdullah et al. (15) observed that compared to those of normal weight, the relative risk of developing type 2 diabetes was 2.99 (95% CI: 2.42, 3.72) for overweight individuals and 7.19 (95% CI: 5.74, 9.00) for obese individuals. The cohort study by Emdin et al. (16) observed that the relative risk of new-onset diabetes for a 20 mmHg increase in usual systolic blood pressure was 1.77 (95% CI: 1.53, 2.05). A meta-analysis of 20 cohort studies over 50 years found that the risk of developing type 2 diabetes among women with a history of gestational diabetes is 7.43 times the risk among women with normoglycemic pregnancies (95% CI: 4.79, 11.51) (17). In a 35 study meta-analysis, Moran et al. (18) observed that compared to women without PCOS, there was an increased prevalence of type 2 diabetes among women with PCOS (OR: 4.43; 95% CI: 4.06, 4.82). Biswas et al. (19) conducted a meta-analysis on 47 studies assessing adult sedentary behavior and found that there was a significant hazard ratio association between sedentary time and type 2 diabetes incidence (HR: 1.91; 95% CI: 1.64, 2.22).

Racial Disparities in Diabetes Prevalence

The American Diabetes Association (ADA) indicates that African Americans, Hispanic/Latino Americans, Native Americans, Asian Americans, and Pacific Islanders are at a higher risk for type 2 diabetes compared with White Americans (14). An analysis of nationally representative data from 2011-2016 found that the age- and sex-adjusted prevalence of total diabetes varies across races/ethnicities, with a prevalence of 12.1% for non-Hispanic white adults, 20.4% for non-Hispanic black adults, 22.1% Hispanic adults, and 19.1% for non-Hispanic Asian adults (20). The CDC reports that the current prevalence of total diabetes continues to be lower for non-Hispanic Whites (11.9%) than it is for non-Hispanic Blacks (16.4%), non-Hispanic Asians (14.9%), and Hispanics (14.7%) (1). However, the prevalence of prediabetes appears to be similar among all racial/ethnic groups and education levels (1,20).

Prevention of Type 2 Diabetes

Existing Programs

For prevention of type 2 diabetes, the ADA recommends lifestyle interventions, such as weight loss, physical activity, and reduced calorie meal plan (14). Initiated in 1996, the Diabetes Prevention Program (DPP) focused on a 7% weight loss/weight maintenance goal, at least 150 minutes of physical activity per week, and restriction of fat and calorie intake (21). Results from this randomized clinical trial showed that over the course of three years, the lifestyle change program decreased the risk of developing type 2 diabetes by 58%, as opposed to a 31% reduction in the pharmacological therapy group (21). The follow-up study also found that compared to individuals who took a placebo, lifestyle intervention participants were 33% less likely to develop diabetes 10 years later and those who did develop diabetes delayed onset by approximately four years (22).

Since 2010, the Centers for Disease Control and Prevention (CDC) has been coordinating the National DPP, a partnership between public and private organizations to provide prevention programs nationwide (22). "A key part of the National DPP is the lifestyle change program to prevent or delay type 2 diabetes. Hundreds of lifestyle change programs nationwide teach participants to make lasting lifestyle changes, like eating healthier, adding physical activity into their daily routine, and improving coping skills" (22).

Nutrition & Diet Quality

An important component of the recommended lifestyle intervention for diabetes prevention is nutrition and diet (14). Research by Ley et al. (7) concluded that improved diet quality is associated with a lower risk of type 2 diabetes and poor diet quality is associated with a higher risk. Another study demonstrated that in adult men, "several diet-quality scores were associated with a lower risk of type 2 diabetes and reflect a common dietary pattern characterized by high intakes of plant-based foods such as whole grains; moderate alcohol; and low intakes of red and processed meat, sodium, sugar-sweetened beverages, and *trans* fat" (8). They also suggest that diets of higher quality could lead to the "greatest reduction" of diabetes in individuals who have a high BMI (8). In adult women, it was similarly found that a higher diet-quality score was associated with a lower risk of type 2 diabetes (23). Additionally, women who increased their diet-quality score had a lessened risk of diabetes compared to those whose low score did not change, indicating that efforts to improve diet may be effective in reducing one's diabetes risk (23).

Influence of Food Insecurity on Diet Quality

Diet quality often varies based upon a household's food security level (2,9). Food-insecure households face difficulties in food acquisition and those categorized as low food security tend to avoid substantially reducing or disrupting their food intake by only consuming a few basic foods and decreasing the variety in their diets (2). In a study by Berkowitz et al. (9), participants who experienced food insecurity reported lower overall dietary quality, "specifically diets lower in total fruit, whole fruit, total vegetables, and dark green and orange vegetables and legumes". This deterioration in diet quality has been associated with an increased diabetes risk among adults (7).

Food Insecurity

Overview

In 2016, 15.6 million U.S. households (12.3%) were food insecure and 6.1 million (4.9%) had very low food security (2). These food-insecure households are composed of 41.2 million people, or 12.9% of the U.S. population (2). In the United States, food-insecure households have significantly greater estimated mean annualized health care expenditures that food-secure households ($6,072 vs. $4,208), which amounts to $77.5 billion in additional national healthcare expenditures annually (24). After adjusting for age, gender, race/ethnicity, education, income, insurance, and residence area, food insecurity is found to be associated with an increase of

$1,800 in annual healthcare expenses, especially for people with "common and costly conditions such as diabetes" (24). Similarly, food-insecure individuals have a higher likelihood of needing to spend money on inpatient hospitalizations and prescription medications (24).

Definition

Food insecurity is defined as the lack of "access by all people at all times to enough food for an active, healthy life" (2). Food-insecure households have "difficulty at some time during the year providing enough food for all their members due to a lack of resources" (2). The definition of food-insecure households includes two subcategories: low food security and very low food security. A household with very low food security is "food insecure to the extent that eating patterns of one or more household members were disrupted and their food intake reduced, at least some time during the year, because they could not afford enough food" (2). The difference between low and very low food security is in how the household changes its eating patterns and food intake (2). Households with low food security have issues acquiring food and poorer diet quality, but not much reduction in food intake (2). On the other hand, households with very low food security often experience decreased food intake and "disrupted eating patterns" (2).

Racial Disparities in Food Insecurity

In 2016, "the prevalence of very low food security was significantly higher than the national average (4.9%)" for non-Hispanic Black households (9.7%) and Hispanic households (5.8%) (2). Among non-Hispanic white-headed households, very low food security declined significantly from 4.3% in 2015 to 3.8% in 2016 (2). However, during this same year, the prevalence of very low food security for non-Hispanic Black-headed households had a "statistically significant increase" from 7.9% in 2015 to 9.7% in 2016 (2).

The association between food insecurity and poor diet quality may also vary across racial groups (10,11). The results from one study indicates that this association is "most pronounced" among non-Hispanic whites, Asians, American Indian or Alaska Natives, Native Hawaiian or other Pacific Islanders, and multiracial adults (10). However, another study by Allen et al. (11) found that as food insecurity increased, diet quality scores were "substantially lower" for whites compared to blacks, suggesting that "the influence of food insecurity on diet quality may be potentiated for whites, but not blacks".

Food Insecurity and Diabetes

Several studies provide evidence for the relationship between food insecurity and type 2 diabetes (4,5,25). Findings from Nagata et al. (4) indicate that food-insecure young adults were 1.67 times more likely to have self-reported diabetes than those who were food secure (95% CI: 1.19, 2.40). Walker et al. (5) examined the literature from 2005 to 2014 and found that food insecurity was 39% more likely among individuals with prediabetes, 58% more likely among individuals with diagnosed diabetes, and 81% more likely among individuals with undiagnosed diabetes, compared to those without diabetes. An explanation for this association is that those who experience food insecurity may feel pressured to purchase cheaper yet less healthy foods, resulting in poorer diet quality. Since food insecurity can impact diet quality and diet quality is one of the modifiable risk factors targeted by diabetes prevention programs, eliminating food insecurity may be an avenue to reducing diabetes prevalence. For example, research by Nagarajan et al. (25) suggests that in adolescents, the availability of healthy food and an increase in supermarket spending is associated with decreased prevalence of prediabetes and diabetes.

Gaps in Research

Understanding how food insecurity and diet quality uniquely influence the burden of diabetes for each race is necessary to direct the development of effective diabetes prevention efforts, such as emphasizing (or de-emphasizing) the implementation of food security initiatives in certain populations with the goal of improving feasibility of dietary modifications. Yet, there has been minimal research conducted on this differential relationship by race between food insecurity, diet quality, and diabetes (6,10). A study by Leung & Tester (10) saw the association between food insecurity and poor diet quality primarily among non-whites, but the authors indicate that more research is needed for a better understanding of this relationship in understudied racial groups. In reviewing literature centered around social determinants and diabetes health outcomes, Walker et al. (6) found “strong evidence” that race and other social determinants “significantly” impact health outcomes for individuals with diabetes. However, most articles “were only tangentially related to social determinants and did not explicitly examine their influence on outcomes” (6). They emphasize that further research is needed to determine the individual and combined effects of social determinants, such as food insecurity, on diabetes outcomes (6). A greater understanding of how food insecurity and diabetes health outcomes interact with one another “would improve development of cost-effective, culturally tailored programs for patients with diabetes that are sensitive to the needs of the populations being served” (6). Specifically, the impact of food insecurity on the burden of diabetes needs to be assessed and addressed for each race.

Objectives/Aims

The purpose of this study was to examine the association between food insecurity and diabetes status for different racial and ethnic groups in the United States. First, the study determined the association between food insecurity and diabetes status for the full United States population using data from the 2015-2016 National Health and Nutrition Examination Survey (NHANES). Then, the study determined whether this association differed by race. Lastly, the study estimated the reduction in diabetes and prediabetes prevalence that each race would experience if food insecurity were to be eliminated.

Chapter 3: Methodology

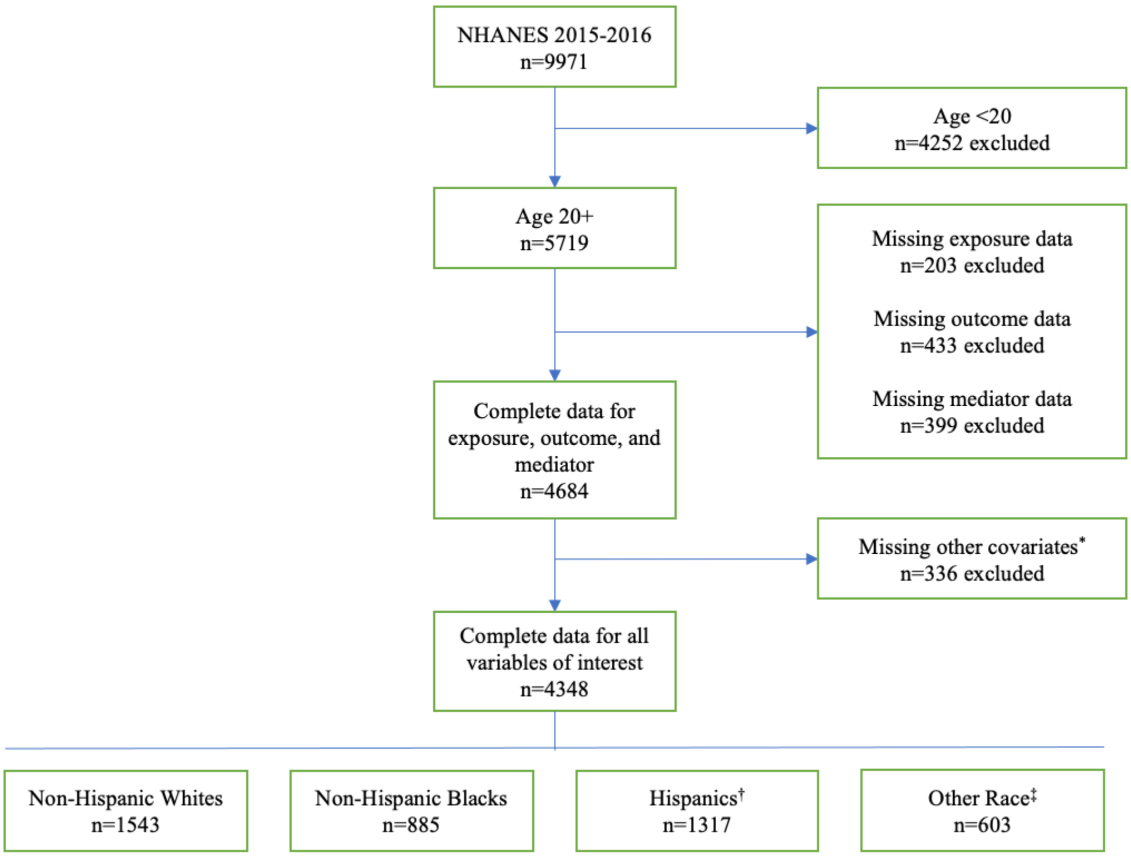
Data Source

The National Health and Nutrition Examination Survey (NHANES) is a multi-stage survey conducted in the United States by the CDC's National Center for Health Statistics (NCHS). In-person interviews occurred in the respondent's home and included demographic, socioeconomic, dietary, and health-related questions. Health examinations took place in a mobile examination center (MEC) in which trained fieldworkers collected medical, dental, and physiological measurements, along with biomarker data and laboratory results. The participant selection process was designed to produce a nationally representative sample. Detailed methods, survey instruments, data collection procedures, and analysis protocols for NHANES are available online (26).

Study Design & Population

Cross-sectional data from the 2015-2016 NHANES were used in this study. Participants were civilian, noninstitutionalized individuals residing in the United States. 15,327 individuals were initially selected, with 9,971 completing interviews and 9,544 completing health examinations. Eligibility for this study was restricted to adults aged 20 years and older (n=5719). The analytic sample included 4,348 age-eligible adults who had complete data for all measures of interest. The participant exclusion criteria are shown in Figure 1. First, 4,252 individuals under 20 years old were not eligible for this analysis. Then, 1,035 participants missing exposure, outcome, or mediator data were also excluded. Finally, 336 individuals were omitted from the analytic sample because they did not have information on at least one of the following covariates: gender, age, citizenship status, education level, ratio of family income to poverty, and household size.

Figure 1. Participant inclusion & exclusion criteria



* Other covariates consists of the following: gender, age, race, citizenship status, education, ratio of income to poverty, and household size
† Hispanic includes Mexican American and Other Hispanic
‡ Other Race includes Non-Hispanic Asian and Multi-Racial

Measures

Household Food Security

Household food security was the exposure of interest and was measured using the US Food Security Survey Module, which has 18 questions for households with children and 10 questions for households without children. The four household food security categories were full, marginal, low, and very low. This designation was based on the number of questions answered "yes" and whether or not the household included children. Households who had zero food insecurity items were designated as full, 1-2 were marginal, 3-5 (no children) or 3-7 (with children) were deemed low, and 6-10 (no children) or 8-18 (with children) were assigned to the very low category. A binary categorization of fully food secure (no food insecurity items) and food insecure (at least one food insecurity item) was also created.

Diabetes Status

The outcome of interest was diabetes status, classified as a three-level variable of overt diabetes, prediabetes, and no diabetes. Biomarker data and diabetes questionnaire information were reviewed to determine each participant's diabetes status according to standard definitions used by the CDC (1). Individuals with a hemoglobin A1C of 6.5% or greater, an FBG greater than or equal to 126 mg/dl, or who reported previous diagnosis by a healthcare provider were classified as having overt diabetes. Among those without overt diabetes, participants who had an A1C between 5.7-6.4% or an FBG of 100-125 mg/dl were designated as having prediabetes. Individuals with an A1C below 5.7%, an FBG under 100 mg/dl, and no self-reported diagnosis were defined as having no diabetes. A1C and FBG levels were recorded through direct measurement in the MEC. Self-reported diagnoses were gathered from interview responses about whether participants had been told by a doctor or health professional that they had diabetes, excluding during pregnancy.

Diet Quality

As a potential mediator of the association between food insecurity and diabetes, I examined diet quality measured by the Healthy Eating Index (HEI) 2015 guidelines. The 2015-2016 NHANES collected dietary intake information from participants through two 24-hour dietary recall interviews, the first is conducted in the MEC and the second is completed over the phone 3-10 days after. This dietary data is used in estimating the participant's consumption of foods and beverages as well as intake of energy, nutrients, and other food components.

The HEI 2015 measures diet quality by assessing food items based on key recommendations of the 2015-2020 Dietary Guidelines for Americans (27). Overall HEI scores are the summation of 13 individual components, each of which reflect a different food group and its corresponding dietary recommendation (27). Scores can range from 0 to 100, with higher scores indicating diets that better follow the recommended dietary patterns (27).

Using publicly available SAS macros provided by the National Cancer Institute (28), overall HEI scores were calculated according to the simple HEI scoring algorithm per person. Data included in this calculation were the 2015-2016 NHANES Total Nutrient Intakes files for both days and the Food Patterns Equivalent Database (FPED).

Race & Ethnicity

Race and ethnicity (i.e., Hispanic origin) was analyzed as an effect modifier of the relationship between food insecurity and diabetes status. Based on reported race and ethnicity information, NHANES assigns participants to one of the following six categories: Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Non-Hispanic Asian, or Other Race including Multi-Racial. For this study, individuals were recategorized into four mutually exclusive groups: Hispanic, Non-Hispanic White, Non-Hispanic Black, or Other Race. Hispanic combines Mexican American and Other Hispanic while Other Race consists of Non-Hispanic Asian and Other Race including Multi-Racial.

Confounders

Potential confounders included in the analysis were gender (men; women), age (20-80 years old), citizenship status (not a citizen of the United States; citizen by birth or naturalization), education level (no college-level education; at least some college-level education), ratio of family income to poverty (0-5), and household size (1-7).

Statistical Analysis

Statistical analysis was conducted utilizing SAS software (version 9.4) and accounted for the complex survey design and survey weights. 95% confidence intervals (CI) were calculated and the significance level for statistical tests was set at 5% for all analyses.

Descriptive analysis of the distribution of all study measures was performed.

Multinomial Logistic Regression

Multinomial logistic regression was used to determine the association between food insecurity and diabetes status for the total study population. Crude and adjusted odd ratios (OR) were calculated for prediabetes and diabetes, relative to adults with no diabetes, at each household food security level. The four-level and binary categorizations for food security were both explored. Because they yielded similar results, the decision was made to primarily analyze the binary categorization (reference=food secure), while using the four-level as a sensitivity analysis (included in Appendix A).

Rao-Scott chi-square analyses and t-tests were completed to assess for statistical evidence of potential confounders. Variables that were statistically associated with both the exposure and outcome – yet not on the causal pathway -- were included as independent variables in the adjusted regression model.

The interaction of race and ethnicity with food insecurity and diabetes status was also tested. There was no evidence of statistically significant interaction. All the same, findings were reported by race/ethnicity due to an express interest in the magnitude of the association of food insecurity and diabetes in each race/ethnic group separately.

Population Attributable Fraction (PAF)

According to the World Health Organization, population-attributable fraction (PAF) is the "proportional reduction in population disease or mortality that would occur if exposure to a risk factor were reduced to an alternative ideal exposure" (29). In this study, an attributable fraction approach was followed to estimate the reduction in overt diabetes prevalence that each race would experience if food insecurity were to be eliminated. Using indirect standardization, PAF and 95% CI were calculated for the entire United States population in addition to each race individually.

CHAPTER 4: RESULTS

Participant Characteristics

Table 1 describes characteristics of n=4348 US adults by race and ethnicity analyzed in this study. Participants were 66.9% non-Hispanic White adults, 10.5% non-Hispanic Black adults, 14.3% Hispanic adults, and 8.3% adults of other races. The mean age of participants was 48.1 years. Hispanic Americans were on average the youngest (42.6 years) and Non-Hispanic White Americans were the oldest (50.2 years). Most participants were US citizens (91.2%) and had at least a high school level education (65.8%). Hispanic adults had the smallest proportion of US citizens (62.2%) and high school graduates (40.9%) while non-Hispanic White adults had the largest proportion of citizens (98.9%) and high school graduates (71.3%). The mean ratio of family income to poverty was 3.0, which was lowest in Hispanic Americans (2.0±0.1) and highest in non-Hispanic White Americans (3.4±0.1). The average household size was 3 people. Hispanic adults had the largest mean household size (3.9±0.1) and non-Hispanic White adults had the smallest (2.7±0.1). The average HEI score was 53.3, which was the lowest among non-Hispanic Black participants (50.9±0.7) and the highest among participants of other races (55.8±0.7). The majority of individuals experienced full household food security (71.8%). Non-Hispanic White Americans reported the highest prevalence of full food security (79.4%), Hispanic Americans reported the highest proportion of marginal and low food security households (18.5%, 21.6%), and non-Hispanic Black Americans reported the highest very low food security (12.2%).

Table 1. Participant characteristics, stratified by race and ethnicity; NHANES 2015-2016 (n=4348)

Variable Name	Total (n=4348)		Non-Hispanic White (n=1543)		Non-Hispanic Black (n=885)		Hispanic* (n=1317)		Other Race† (n=603)	
	Mean‡/N§	SE‡/%‡	Mean‡/N§	SE‡/%‡	Mean‡/N§	SE‡/%‡	Mean‡/N§	SE‡/%‡	Mean‡/N§	SE‡/%‡
Gender: female	2245	52.2%	762	52.2%	469	55.5%	722	50.6%	292	50.9%
Age (in years)	48.1	0.6	50.2	0.7	44.8	0.6	42.6	1.0	44.3	1.3
Citizenship status: citizen by birth or naturalization	3652	91.2%	1526	98.9%	841	94.6%	861	62.2%	424	75.6%
Education level: at least high school graduate/GED or equivalent	2431	65.8%	1005	71.3%	500	58.9%	492	40.9%	434	73.3%
Ratio of family income to poverty	3.0	0.1	3.4	0.1	2.3	0.1	2.0	0.1	2.9	0.1
Household size	3.0	0.1	2.7	0.1	3.2	0.1	3.9	0.1	3.2	0.1
HEI score	53.3	0.5	53.6	0.7	50.9	0.7	52.1	0.6	55.8	0.7
Household food security										
Full	2654	71.8%	1106	79.4%	481	54.4%	644	48.6%	423	72.3%
Marginal	601	10.3%	151	7.5%	134	15.4%	232	18.5%	84	12.8%
Low	680	10.7%	158	7.2%	164	18.1%	282	21.6%	76	10.6%
Very low	413	7.2%	128	5.9%	106	12.2%	159	11.4%	20	4.3%

*Hispanic includes Mexican American and Other Hispanic

†Other Race includes Non-Hispanic Asian and Multi-Racial

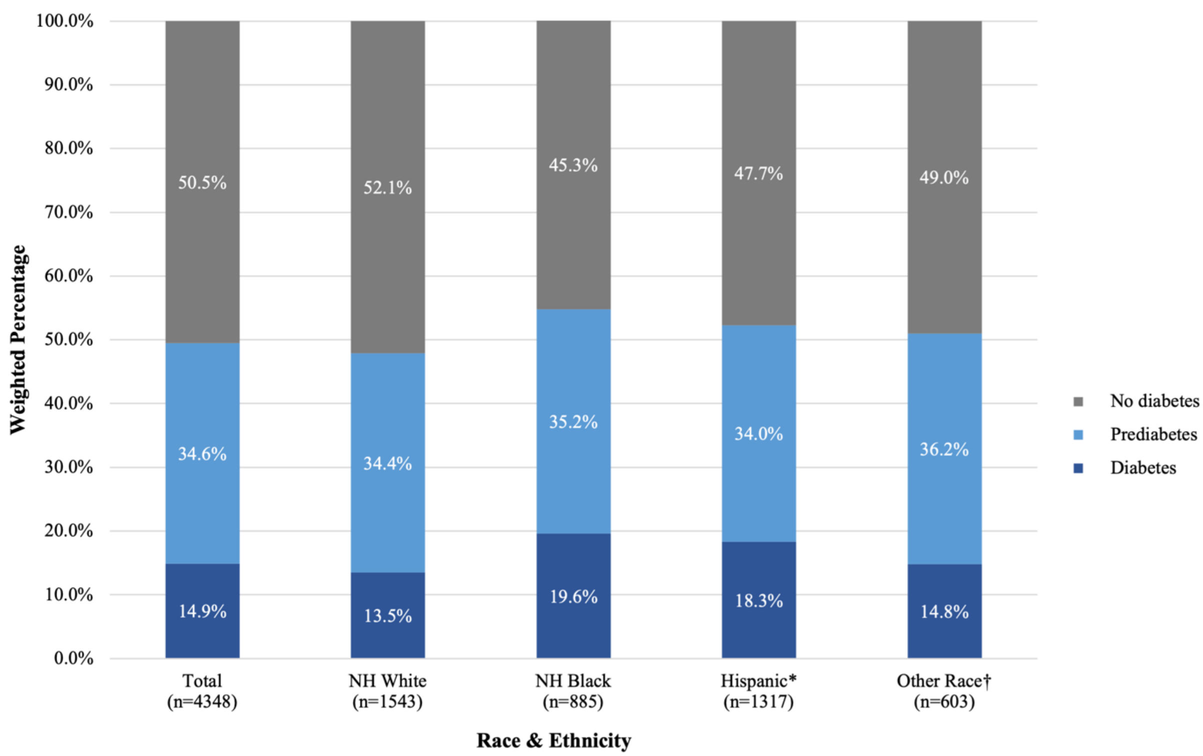
‡Accounts for survey weight, cluster, and stratum

§Unweighted frequency

Prediabetes & Diabetes Prevalence

Figure 2 shows the prediabetes and diabetes prevalence among US adults by race and ethnicity. Of the total population, 34.6% had prediabetes and 14.9% had overt diabetes. When stratified by race and ethnicity, prediabetes was highest among Non-Hispanic White Americans (34.9%), followed by Americans of other race (36.2%), Non-Hispanic Black Americans (35.2%), and Hispanic Americans (34.0%). Overt diabetes was highest in Non-Hispanic Black adults (19.6%), followed by Hispanic adults (18.3%), adults of other races (14.8%), and lowest in Non-Hispanic White adults (13.5%).

Figure 2. Diabetes status of participants, stratified by race and ethnicity; NHANES 2015-2016



* Hispanic includes Mexican American and Other Hispanic
† Other Race includes Non-Hispanic Asian and Multi-Racial

Association Between Food Insecurity and Diabetes Status

Figure 3 displays the adjusted odds ratios and associated 95% confidence intervals for the association between food insecurity and diabetes status, both for the total population as well as stratified by race. All adjusted odds ratios accounted for diet quality as a mediator, in addition to controlling for the following confounders: gender, age, citizenship status, education level, and ratio of family income to poverty. The crude odds ratios are included in Appendix B.

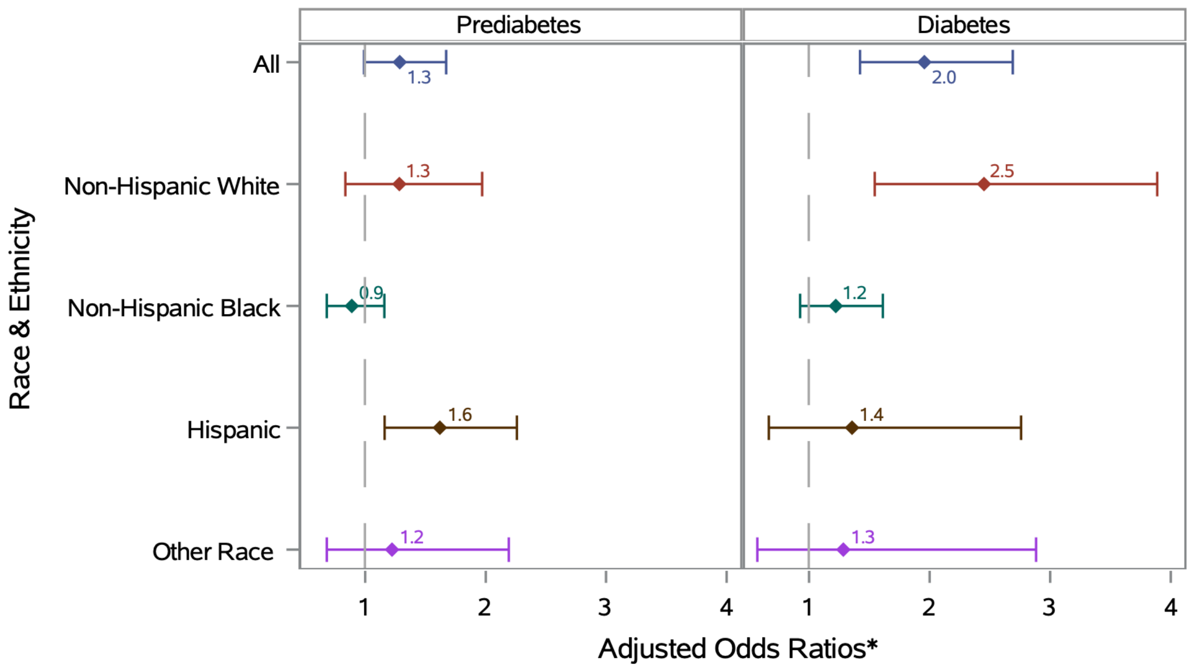
Prediabetes

After controlling for diet quality and confounders, there was a statistically significant association between food insecurity (reference: fully food secure) and prediabetes (adjusted OR [aOR]=1.6; 95% CI: 1.2, 2.3) in the Hispanic population. The association in the full population was also marginally significant (aOR=1.3; 95% CI: 1.0, 1.7). No other group had a statistically significant association for prediabetes.

Diabetes

In the total population, there was a statistically significant association between experience of food insecurity and overt diabetes after adjusting for diet quality and confounders: adults reporting food insecurity had twice the relative odds of diabetes compared to adults who were fully food secure (aOR= 2.0; 95% CI: 1.4, 2.7). A statistically significant association was also found among non-Hispanic White adults (aOR=2.5; 95% CI: 1.5, 3.9).

Figure 3. Adjusted odds ratios for the association between food insecurity and diabetes status, stratified by race and ethnicity



- - - Null reference line (1.0)
*Adjusted for gender, age, citizenship status, education level, ratio of family income to poverty, household size, and HEI score. Full food security is the reference category for all odds ratios.

Estimated Impact of Food Insecurity Elimination on Diabetes Prevalence

Table 2 presents the population-attributable fraction, observed diabetes prevalence, and estimated diabetes prevalence associated with the elimination of food insecurity for the total population and each race and ethnicity separately. The proportion of overt diabetes cases attributable to food insecurity across all races was 0.06 (95% CI: 0.02, 0.10), which means that eliminating food insecurity could reduce up to 6% of diabetes prevalence. Stratified by race, the attributable fractions ranged from 0.01 in non-Hispanic Black adults to 0.15 in non-Hispanic White adults. Thus, it appears that the greatest potential for reduction in diabetes prevalence associated with food insecurity is in the non-Hispanic White population. The population-attributable fractions for the total population and non-Hispanic White adults were statistically significant, while the results for non-Hispanic Black adults, Hispanic adults, and individuals of other races were not.

Table 2. Population-attributable fractions for overt diabetes cases, stratified by race and ethnicity; NHANES 2015-2016 (n=4348)

		Prevalence of Diabetes Under Differing Scenarios	
Race & Ethnicity	**Population-Attributable Fraction (95% CI)[*]**	**Observed in 2015-16**	**With Elimination of Food Insecurity**
All Races	0.06 (0.02, 0.10)[†]	14.9%	14.0%
Non-Hispanic White	0.15 (0.07, 0.22)[†]	13.5%	11.5%
Non-Hispanic Black	0.01 (-0.08, 0.09)	19.6%	19.4%
Hispanic[‡]	0.02 (-0.05, 0.09)	18.3%	17.9%
Other Race[§]	0.09 (-0.04, 0.20)	14.8%	13.5%

[*]adjusted for gender, age, citizenship status, education level, ratio of family income to poverty, household size, and HEI score
[†]denotes statistically significant results
[‡]Hispanic includes Mexican American and Other Hispanic
[§]Other Race includes Non-Hispanic Asian and Multi-Racial

CHAPTER 5: DISCUSSION

Using nationally representative data, I estimated the association of food insecurity with prediabetes and overt diabetes and the heterogeneity of these associations by race and ethnicity. When adjusting for diet quality and confounders, Hispanic adults were the only population in which there was a statistically significant association between experience of food insecurity and prediabetes. Hispanic adults reporting food insecurity had 1.6 times the relative odds of prediabetes compared to Hispanic adults who were fully food secure. The association among the full population was also marginally significant, with food-insecure adults having 1.3 times the relative odds of prediabetes compared to fully food secure adults.

As for the relationship between food insecurity and overt diabetes, there were statistically significant associations among the overall United States population and among non-Hispanic White adults, after controlling for diet quality and confounders. For adults of all races, the relative odds of having diabetes were twice as high in adults experiencing food insecurity compared to adults with full food security. Among non-Hispanic White adults, the relative odds of having diabetes for food-insecure adults were 2.5 times the odds for fully food secure adults. No statistically significant associations between food insecurity and diabetes status were found among non-Hispanic Black adults and individuals of other races.

Across all races, up to 6% of overt diabetes cases may be attributed to food insecurity. Non-Hispanic White adults had the highest proportion of attributable cases at 15%, suggesting that the greatest potential for reduction in diabetes prevalence associated with food insecurity is in the non-Hispanic White population.

These findings are consistent with and build upon previous studies. Among the adult population in the United States, food insecurity increases the likelihood of developing type 2 diabetes and experiences of food insecurity are more strongly associated with overt diabetes than prediabetes (4,5). A nationally representative study from 2005-2014 found that adults with prediabetes were 39% more likely to be food insecure and adults with diagnosed diabetes were 58% more likely to be food insecure, compared to those without diabetes (5). In this study, non-Hispanic White adults had a higher odds ratio than the overall population for the association between food insecurity and diabetes. This may be explained by prior literature on race differences in diet quality of food-insecure adults (11). Results from a comparison of diet quality in food-insecure, non-Hispanic Black and White populations suggested that the non-Hispanic White adults experience a greater decrease in diet quality as food insecurity increases (11). One potential explanation is that minority communities have poorer diet quality overall independent of food security, and thus experiencing food insecurity has a lessened impact on the reduction in diet quality. This could be the case in my study, where non-Hispanic Black adults and Hispanic adults had lower average HEI scores compared to non-Hispanic White adults. A different explanation is that non-Hispanic White adults were less likely to participate in the Supplemental Nutrition Assistance Program (SNAP), which could help food-insecure households obtain healthier food options and decrease the risk of developing diabetes (11). Similarly, another possibility is that historical experience of high levels of food insecurity have led to resiliency and coping skills in non-White populations (11). My findings support the presence of racial disparities in food insecurity, as non-Hispanic White adults reported the lowest proportion of food insecurity at 20.6% while non-Hispanic Black adults, Hispanic adults, and adults of other races had food insecurity prevalences of 45.6%, 51.4%, and 27.7% respectively. Due to food insecurity experiences in a greater proportion of their population, non-White households may have learned how to acquire and cook meals of high diet quality on a small budget (11). The cultural transmission of food knowledge and coping skills may have helped non-White households eat good quality foods despite higher levels of food insecurity (11). This mitigated reduction in diet quality could be buffering the effects of food security on developing diabetes in non-White adults, resulting in the non-Hispanic White population having the highest proportion of attributable cases in my study.

Strengths & Limitations

This study had both strengths and limitations. Regarding strengths, NHANES was designed to collect nationally representative data, so the results are generalizable to the overall United States population. In addition, the analytic sample size was relatively large with 4,348 participants. On the other hand, this was a cross-sectional study, which limits the conclusions that can be made, as the study can estimate upper bounds of the potential impact of food insecurity on diabetes status, but it cannot determine causation or the isolate true impact. Another limitation was the categorization of race. Other race combines multiple race and ethnic groups, such as non-Hispanic Asian and multi-racial, while Hispanic merges Mexican American and other Hispanic subgroups due to a relatively small amount of those participants. Also, there are many ethnicities included in Non-Hispanic White and Non-Hispanic Black because of the way NHANES collects and reports race data. Thus, differences between ethnic-specific groups may have been hidden in the study results. Additionally, the food security and diet quality measures were collected through self-report methods, which may be subjected to social desirability and recall biases. The lack of data for residence location (urban; suburban; rural) and other geographical factors also a limitation, as these potential confounders were not measured by NHANES and therefore not included in the analysis.

Public Health Recommendations

The results of this study indicate that the implementation of food security initiatives may be more effective at reducing diabetes prevalence in non-Hispanic White communities as compared with minority communities. This is largely due to the stronger association of food insecurity with diabetes in non-Hispanic White adults compared with other groups. In fact, non-Hispanic White adults have the lowest observed prevalences of food insecurity and diabetes, compared to non-Hispanic Black adults, Hispanic adults, and individuals of other races.

My findings also suggest that different approaches to diabetes prevention are needed in minority communities. The weak associations between food insecurity and diabetes in these communities indicate that food security initiatives—though worthwhile for overall wellbeing and other health outcomes—may not be impactful for preventing diabetes in minority communities. Alternative nutrition interventions should be identified and evaluated for racial and ethnic minority groups.

This study did not explore all facets of food security and diabetes, nor did it examine the influence of medical risk factors, such as obesity. Prior studies have found that food-insecure adults have increased odds of being overweight and obese, and overweight and obese populations are more likely to develop diabetes (4,15). Therefore, obesity may be an important mediator of food insecurity and diabetes. Further research must be done on the effectiveness of food security initiatives combined with other interventions in preventing diabetes and the role of additional risk factors in the relationship between food insecurity and diabetes status.

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APPENDICES

*Appendix A. Sensitivity analysis of association between food insecurity and diabetes status, stratified by race and ethnicity; NHANES 2015-2016 (n=4348)**

All Races (n=4348)				
Household Food Security	**Relative Odds of Prediabetes**		**Relative Odds of Diabetes**	
	OR (95% CI)	**Adjusted OR (95% CI)†**	**OR (95% CI)**	**Adjusted OR (95% CI)†**
Full	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Marginal	1.1 (0.9, 1.5)	1.4 (1.0, 1.9)	1.8 (1.1, 2.7)‡	2.3 (1.6, 3.4)‡
Low	1.1 (0.8, 1.4)	1.2 (0.9, 1.6)	1.6 (1.1, 2.3)‡	1.9 (1.3, 2.9)‡
Very low	1.1 (0.8, 1.5)	1.2 (0.8, 1.8)	1.4 (0.8, 2.4)	1.5 (0.9, 2.6)
Non-Hispanic White (n=1543)				
Household Food Security	**Relative Odds of Prediabetes**		**Relative Odds of Diabetes**	
	OR (95% CI)	**Adjusted OR (95% CI)†**	**OR (95% CI)**	**Adjusted OR (95% CI)†**
Full	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Marginal	1.3 (0.9, 1.9)	1.6 (0.9, 2.6)	2.9 (1.6, 5.3)‡	3.9 (2.5, 6.1)‡
Low	1.1 (0.7, 1.6)	1.2 (0.7, 2.1)	1.7 (0.9, 3.3)	2.1 (1.0, 4.6)
Very low	1.0 (0.6, 1.5)	1.1 (0.65, 2.0)	1.1 (0.4, 2.7)	1.4 (0.6, 3.1)
Non-Hispanic Black (n=885)				
Household Food Security	**Relative Odds of Prediabetes**		**Relative Odds of Diabetes**	
	OR (95% CI)	**Adjusted OR (95% CI)†**	**OR (95% CI)**	**Adjusted OR (95% CI)†**
Full	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Marginal	0.7 (0.6, 1.0)	1.0 (0.6, 1.4)	0.8 (0.5, 1.4)	1.2 (0.8, 2.0)
Low	0.7 (0.5, 1.0)	0.8 (0.5, 1.2)	1.0 (0.5, 2.0)	1.3 (0.7, 2.8)
Very low	0.8 (0.6, 1.2)	0.9 (0.6, 1.4)	0.7 (0.5, 1.1)	1.0 (0.7, 1.4)
Hispanic§ (n=1317)				
Household Food Security	**Relative Odds of Prediabetes**		**Relative Odds of Diabetes**	
	OR (95% CI)	**Adjusted OR (95% CI)†**	**OR (95% CI)**	**Adjusted OR (95% CI)†**
Full	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Marginal	1.3 (0.8, 2.1)	1.5 (0.8, 2.5)	0.8 (0.3, 1.9)	1.1 (0.4, 3.0)
Low	1.5 (1.1, 2.0)‡	1.7 (1.4, 2.2)‡	1.0 (0.7, 1.6)	1.5 (0.8, 2.6)
Very low	2.0 (1.1, 3.5)‡	1.8 (1.0, 3.4)	1.9 (1.0, 3.3)	1.8 (0.9, 3.7)
Other Race‖ (n=603)				
Household Food Security	**Relative Odds of Prediabetes**		**Relative Odds of Diabetes**	
	OR (95% CI)	**Adjusted OR (95% CI)†**	**OR (95% CI)**	**Adjusted OR (95% CI)†**
Full	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Marginal	0.9 (0.6, 1.3)	1.1 (0.7, 2.0)	0.7 (0.2, 2.3)	0.8 (0.3, 2.1)
Low	0.8 (0.4, 1.6)	1.1 (0.5, 2.4)	1.8 (0.7, 4.4)	1.7 (0.6, 4.8)
Very low	1.5 (0.4, 4.9)	2.3 (0.5, 9.8)	2.6 (0.5, 11.8)	2.2 (0.3, 13.2)

*Tests for trends between food security level and diabetes status were also conducted. For the full population and all subgroups except for non-Hispanic Black, there was a positive trend, which suggests that as household food insecurity increases, diabetes status also becomes higher. There was a negative trend for non-Hispanic Blacks, indicating that as Black households' food insecurity increases, diabetes status lowers.

†Adjusted for gender, age, citizenship status, education level, ratio of family income to poverty, household size, and HEI score

‡denotes statistically significant results

§Hispanic includes Mexican American and Other Hispanic

‖Other Race includes Non-Hispanic Asian and Multi-Racial

Appendix B. Association between food insecurity and diabetes status, stratified by race and ethnicity; NHANES 2015-2016 (n=4348)

All Races (n=4348)				
	Relative Odds of Prediabetes		**Relative Odds of Diabetes**	
Household Food Security	**OR (95% CI)**	**Adjusted OR (95% CI)***	**OR (95% CI)**	**Adjusted OR (95% CI)***
Full	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Not Full†	1.1 (0.9, 1.4)	1.3 (1.0, 1.7)	1.6 (1.2, 2.1)‡	2.0 (1.4, 2.7)‡
Non-Hispanic White (n=1543)				
	Relative Odds of Prediabetes		**Relative Odds of Diabetes**	
Household Food Security	**OR (95% CI)**	**Adjusted OR (95% CI)***	**OR (95% CI)**	**Adjusted OR (95% CI)***
Full	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Not Full†	1.1 (0.8, 1.5)	1.3 (0.8, 2.0)	1.9 (1.2, 3.0)‡	2.5 (1.5, 3.9)‡
Non-Hispanic Black (n=885)				
	Relative Odds of Prediabetes		**Relative Odds of Diabetes**	
Household Food Security	**OR (95% CI)**	**Adjusted OR (95% CI)***	**OR (95% CI)**	**Adjusted OR (95% CI)***
Full	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Not Full†	0.7 (0.6, 0.9)‡	0.9 (0.7, 1.2)	0.9 (0.7, 1.2)	1.2 (0.9, 1.6)
Hispanic§ (n=1317)				
	Relative Odds of Prediabetes		**Relative Odds of Diabetes**	
Household Food Security	**OR (95% CI)**	**Adjusted OR (95% CI)***	**OR (95% CI)**	**Adjusted OR (95% CI)***
Full	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Not Full†	1.5 (1.2, 1.9)‡	1.6 (1.2, 2.3)‡	1.1 (0.7, 1.8)	1.4 (0.7, 2.8)
Other Race‖ (n=603)				
	Relative Odds of Prediabetes		**Relative Odds of Diabetes**	
Household Food Security	**OR (95% CI)**	**Adjusted OR (95% CI)***	**OR (95% CI)**	**Adjusted OR (95% CI)***
Full	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Not Full†	0.9 (0.6, 1.5)	1.2 (0.7, 2.2)	1.3 (0.6, 2.7)	1.3 (0.6, 2.9)

*Adjusted for gender, age, citizenship status, education level, ratio of family income to poverty, household size, and HEI score

†Not Full includes marginal, low, and very low food security

‡denotes statistically significant results

§Hispanic includes Mexican American and Other Hispanic

‖Other Race includes Non-Hispanic Asian and Multi-Racial