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David Thoms 4/11/2022

Examining Independent Associations Between Low Food Security, Race and Glycemic Control Among Older Americans with Diabetes in the NHANES 2009-2016 Waves

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Abstract

Background: Glycemic control is an important indicator of health in people with diabetes, and failure to maintain it can lead to worse health outcomes. Previous research found independent associations between race/ethnicity and food security on glycemic control in adults with type 2 diabetes. These associations have not been adequately explored in older adults.

Methods: We conducted a secondary analysis of 1,326 adults with diabetes aged 65 and older who participated in the 2009-2016 National Health and Nutrition Examination Survey waves. Using logistic regression analysis, we examined relationships between glycemic control, food security, and race, controlling for demographic, social determinants of health, behavioral, and biomedical factors. We examined participants who identified as being non-Hispanic White, non-Hispanic Black, and Hispanic/Latino.

Results: We found a significant positive association between food security and glycemic control when adjusted for covariates. When compared to non-Hispanic Whites, there were group differences in glycemic control with Hispanic/Latinos but not with non-Hispanic Blacks. However, these differences were not significant when controlling for biomedical factors. Among the covariates, moderate to vigorous physical activity and oral medication use were found to be significantly associated with glycemic control.

Discussion: The consistent significant association between food security and glycemic control suggests the importance for glycemic control of macro factors, such as food security, even in the presence of behavioral (e.g., exercise) and biomedical (e.g., medication use) factors. The attenuation of relationship between race and glycemic control in the presence of biomedical factors needs to be examined by future research.

Conclusion: There is a positive association between food security and glycemic control in older adults with diabetes. Screening for food security in diabetes patients is recommended, as is expanding policies that improve food security, such as the Supplemental Nutrition Assistance Program. Ensuring medication adherence may be particularly important for improved glycemic control in Hispanic/Latino older adults.

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Chapter 1: Introduction and Rationale

Food security is defined by the USDA as access to food by all people at all times for a healthy and active life.(A Coleman-Jensen, Rabbitt, & Gregory, 2020) Food security can be further subdivided into full and marginal, in which no changes in food intake are observed, and low and very low food security, where reductions in quality and amount of food intake are observed. Although low and very low food security reached a post-recession peak of 14.9% in 2011 and has been declining since then, its prevalence remains significant at estimated 10.5% in 2019.(Alisha Coleman-Jensen, Rabbitt, Gregory, & Singh) It is estimated that 7.3% of older Americans over the age of 60, approximately 5.3 million people, experienced low food security in 2018 while an additional 2.7%, or 2 million people, experienced very low food security for a total prevalence of 10%.(Ziliak & Gundersen, 2020) For brevity, we will refer to the categories as food security and low food security unless otherwise specified.

Low food security is correlated with low socioeconomic status. (Dean, Sharkey, & Johnson, 2011; Montgomery, Lu, Ratliff, & Mezuk, 2017; Rhee, Marottoli, Cooney, & Fortinsky, 2020) Households with income 185% of the federal poverty line and below had a greater share of low food security, with a prevalence of 29.1% compared to those over 185% with a prevalence of 5.4%.(Alisha Coleman-Jensen, Rabbitt, Gregory, & Singh, 2019) Households in which the head of household was single were also more food insecure, at 27.8% and 15.9% for female and male heads of household respectively, compared to 8.3% for two-parent households.(Alisha Coleman-Jensen et al., 2019) Race is also correlated with food security. Households with non-Hispanic Black (NHB) and

Hispanic/Latino heads of households experienced higher rates of low food security compared to non-Hispanic White (NHW) households, with a prevalence of 21.2% and 16.2% respectively, compared to 8.1% for white households.(Alisha Coleman-Jensen et al., 2019)

Low food security among older adults, which was estimated at a prevalence of 10% in 2018, is associated with a number of deleterious health effects such as risk of functional limitations, greater risk for malnutrition, as well as increased risk of cognitive decline, depression and other mental illnesses. Furthermore, individuals with low food security are also at increased risk for type 2 diabetes, which is a condition in which the body's ability to regulate glucose is impaired.(American Diabetes, 2015; *National Diabetes Statistics Report 2020*, 2020) Diabetes can lead to a number of macro- and microvascular complications, which can result in blindness, renal failure, lower extremity amputations, and cardiovascular disease. (Haw, Shah, Turbow, Egeolu, & Umpierrez, 2021; Kanter & Bornfeldt, 2016) Diabetes is also associated with higher mortality among adults over the age of 65.(Tang et al., 2020) The prevalence of diabetes increases with age and is also higher in race/ethnic minority populations compared to whites. While the national prevalence of diabetes is estimated at 13.0%, among adults aged 65 and older it is estimated at 26.8%.(*National Diabetes Statistics Report 2020*, 2020) Additionally, while NHW populations have a prevalence of 11.9%, NHB and Hispanic/Latino populations have a prevalence of 16.4% and 14.7%, respectively.(*National Diabetes Statistics Report 2020*, 2020) NHB and Hispanic/Latino populations also suffer from higher rates of diabetes complications, but are less likely to receive preventative care compared to NHW populations. (Haw et al., 2021; Heidemann, Joseph, Kuchipudi, Perkins, & Drake, 2016; Osborn, de Groot, & Wagner, 2013) These disparities persist among older adults.(Blazer, Moody-Ayers, Craft-Morgan, & Burchett, 2002; Kim, Ford, Chiriboga, & Sorkin, 2012; McBean, Li, Gilbertson, & Collins, 2004)

Diabetes is commonly measured via glycohemoglobin (HbA1c). The American Diabetes Association considers a HbA1c level of 6.5% or higher to indicate diabetes, while a level greater than 7.0% indicates uncontrolled diabetes.(American Diabetes, 2015) This study intends to use this indicator, which we will refer to as glycemic control, to investigate the independent relationships between food security, race and glycemic control. Glycemic control is important because uncontrolled diabetes increases the risk for negative health outcomes, such as the macro- and micro-vascular complications mentioned above.

Problem Statement

The purpose of this study is to investigate independent effects of food security and race/ethnicity on glycemic control in older adults. It aims to investigate this relationship in the presence of other social determinants of health, biomedical, and behavioral factors.

Problem Justification

Low food security is correlated with poor glycemic control, which increases the likelihood of adverse outcomes in persons with diabetes.{Monami, 2021 #218}{Maiorino, 2021 #220}{Tian, 2020 #217} In addition, race has been associated with both food security and glycemic control. (Berkowitz, Gao, & Tucker, 2014; Berkowitz et al., 2018; Chatterji, Joo, & Lahiri, 2012; Essien, Shahid, & Berkowitz, 2016; Fitzgerald, Hromi-Fiedler, Segura-Pérez, & Pérez-Escamilla, 2011; Heerman et al., 2016; Murillo, Reesor, Scott, & Hernandez, 2017; R. J. Walker et al., 2020) While there is significant literature on low food security and glycemic control, there is little recent work that focuses on older adults. Given that glycemic control is influenced by nutritional intake, that individuals with low food security have reduced nutritional intake, that older adults have greater nutritional needs compared to younger adults, and that racial disparities in food security exist, this represents a gap that needs to be researched.{Berkowitz, 2014 #61}{Boirie, 2014 #52}{Coleman-Jensen, 2019 #72} This study aims to contribute to closing this gap by investigating the independent relationships between food security, race, and glycemic control.

Theoretical Framework

This study was informed by a Social Determinants of Health (SDOH) approach to public health. SDOH is defined by the World Health Organization as the social, physical and economic conditions which impact upon health.(WHO) SDOH are categorized by the Office of Disease Prevention and Health Promotion into 5 spheres: Economic Stability, Education, Social and Community Context, Health and Healthcare, and Neighborhood and Built Environment.(*Healthy People 2020: Social Determinants of Health*, 2020) Economic Stability includes factors such as employment, food security, housing, and poverty.(*Healthy People 2020: Social Determinants of Health*, 2020) Education includes language and literacy, enrollment in higer education, high school graduation and early childhood education.(*Healthy People 2020: Social Determinants of Health*, 2020) Social and Community Context includes civic participation, discrimination, incarceration, and social cohesion.(*Healthy People 2020: Social Determinants of Health*, 2020) Health and Healthcare includes access to healthcare, access to primary care, and health literacy.(*Healthy People 2020: Social Determinants of Health*, 2020) Neighborhood and Built Environment includes access to foods that support healthy eating patterns, crime and violence, environmental concerns, and quality of housing.(*Healthy People 2020: Social Determinants of Health*, 2020) Race informs SDOH in the US context by influencing factors such as discrimination, employment, incarceration, access to primary care, access to healthy foods, and others.(*Healthy People 2020: Social Determinants of Health*, 2020) As food security is a component of SDOH, this is an appropriate framework to examine the issue.

Purpose Statement

Using data from the 2009-2016 National Health and Nutrition Examination Surveys (NHANES) administered by the Centers for Disease Control and Prevention (CDC), this study intends to understand how food security and race affect glycemic control in older adults with diabetes mellitus.

Research Question & Sub-Questions

What are the independent effects of food security and race on glycemic control among adults aged 65 and older with diabetes who participated in the 2009-2016 NHANES waves? Do the independent effects of food security and race on glycemic control hold in the presence of other SDOH, sociodemographic, behavioral, and biomedical factors?

Significance Statement

This study aims to understand the independent relationships between glycemic control, food security and race in older adults. Low food security impacts the quality of a person's nutritional intake. The changing nutritional needs of older adults may mean that low food security impacts them in different ways from younger adults. As diabetes is a nutrition-sensitive chronic illness, investigating the relationship between the two is important. Race is important to this discussion as NHBs and Hispanic/Latinos have disproportionately higher rates of diabetes than NHWs. Good glycemic control, as an indicator of well-managed diabetes and a necessary means to reduce the likelihood of its complications, is a useful outcome variable to investigate these relationships .

Chapter 2: Literature Review

Diabetes

Diabetes mellitus is a condition in which the body's ability to regulate glucose uptake is impaired.(American Diabetes, 2015) This can lead to a number of macro- and microvascular problems which can result in blindness, renal failure, lower extremity amputations, and cardiovascular disease. (Haw et al., 2021; Kanter & Bornfeldt, 2016) The most common type, comprising approximately 90-95% of all cases, is Type 2 diabetes (T2D).(CDC, 2020) T2D is commonly diagnosed by measuring the level of glycohemoglobin (HbA1c) in the blood. According to the American Diabetes Association, a measurement of above 6.5% is considered to be a diagnosis of diabetes , while a measurement between 6.5 and 7.0% is considered to be controlled diabetes.(American Diabetes, 2015)

While the national prevalence of diabetes is estimated at 13.0%, among adults aged 65 and older, it is estimated at 26.8%.(*National Diabetes Statistics Report 2020*, 2020) Diabetes is associated with higher mortality among adults over the age of 65.(Tang et al., 2020) Additionally, while NHW populations have a diabetes prevalence of 11.9%, NHB and Hispanic/Latino populations have a prevalence of 16.4% and 14.7%, respectively.(*National Diabetes Statistics Report 2020*, 2020) NHB and Hispanic/Latino adults also suffer from higher rates of diabetes complications, but are less likely to receive preventative care compared to NHW populations.(Haw et al., 2021; Heidemann et al., 2016; Osborn et al., 2013) These disparities persist among older adults.(Blazer et al., 2002; Kim et al., 2012; McBean et al., 2004)

Glycemic Control

Glycemic control is important to improve health outcomes in individuals with diabetes.(Maiorino et al., 2021; Monami, Candido, Pintaudi, Targher, & Mannucci, 2021; Tian et al., 2020) HbA1c levels are used to assess glycemic control in individuals with diabetes, with a measurement between 6.5 and <7.0% being considered controlled, while levels equal and above 7% are considered uncontrolled.(American Diabetes, 2015) Uncontrolled diabetes increases the likelihood of adverse health outcomes, while controlling diabetes decreases the likelihood.{Maiorino, 2021 #220}{Monami, 2021 #218}{Tian, 2020 #217} In a meta-analysis of 18 randomized control trials (n=161,156) investigating associations between glycemic control and major cardiovascular events (MACE), they found an association between treatment and MACE (hazard ratio: 0.90 CI: 0.86, 0.94) with significant heterogeneity between studies (I(2)=45.2%, p=0.040).(Maiorino et al., 2021) Monami et al conducted a meta-analysis of 13 studies to investigate associations between glycemic control and MACE.(Monami et al., 2021) They found that improvement in glycemic control was associated with reduced MACE (OR:0.89 CI:0.85-0.94). Tian et al conducted a secondary analysis of clinical trial data (n=11,071) to investigate the effect of intensive glycemic control on major vascular events.(Tian et al., 2020) They found that after a 5-year follow-up, it was associated with a reduction in major vascular events (hazard ratio:0.90 CI:0.83-0.98).

SDOH and Sociodemographic Factors

Evidence suggests an association between SDOH, diabetes, and glycemic control.(Chatterji et al., 2012; Walker, Smalls, Campbell, Strom Williams, & Egede, 2014) Previous research has shown an association between low socio-economic status and risk for diabetes.(Robbins, Vaccarino, Zhang, & Kasl, 2001) In the United States, individuals with lower education levels were less likely to have their diabetes controlled.(Chatterji et al., 2012). Income has also been shown to be positively associated with glycemic control in older adults.(Branfield Day, Austin, & Shah, 2020; Kollannoor-Samuel et al., 2011)

Food Security

Food security is a significant public health concern in the United States. Low food security is defined by the USDA as "a household-level economic and social condition of limited or uncertain access to adequate food."(A Coleman-Jensen et al., 2020) Food security is measured in four levels. The first is high food security, meaning there are no indications of food access problems.(A Coleman-Jensen et al., 2020) The second is marginal, where there are one or two indicators but not enough to affect changes in diet.(A Coleman-Jensen et al., 2020) The third is low, where the quality but not amount of food eaten is decreased.(A Coleman-Jensen et al., 2020) The fourth is very low with multiple indications of disrupted eating and reduced food intake.(A Coleman-Jensen et al., 2020) Food security is measured using the 18 question Food Security Survey module used by the USDA, though adult-only households use a modified 10 question survey instead.(Bickel, Nord, Price, Hamilton, & Cook, 2000; Nord, 2002) The USDA considers households with a high and marginal score to be food secure, and those with a low and very low score to be food insecure.(A Coleman-Jensen et al., 2020) Low and very low food security among older adults is associated with a number of deleterious health effects, including increased risk of functional limitations, frailty, malnutrition, diabetes, and depression.(Rachel S. Bergmans et al., 2018; R. S. Bergmans & Wegryn-Jones, 2020; R. S. Bergmans, Zivin, & Mezuk, 2019; Jung, Kim, Bishop, & Hermann, 2019; Petersen, Brooks, Titus, Vasquez, & Batsis, 2019; Rhee et al., 2020; Schroeder et al., 2019; Wong et al., 2016) Older adults may be particularly at risk for these functional limitations due to increased nutritional needs as they age.(Boirie, Morio, Caumon, & Cano, 2014; Lee & Frongillo, 2001)

Low food security is associated with poor glycemic control.(Berkowitz et al., 2014; Berkowitz et al., 2018; Schroeder et al., 2019; Seligman, Bindman, Vittinghoff, Kanaya, & Kushel, 2007; Walker, Garacci, Ozieh, & Egede, 2021) In a study of 584 Puerto Ricans living in Boston, MA, Berkowitz et al (2014) found that lower quality diets were associated with higher HbA1c levels, while high quality diets were associated with an average decrease I HbA1c of 0.5% per year.(Berkowitz et al., 2014) In a longitudinal study of 391 participants, 31% of whom lived in an area with low food access, Berkowitz et all (2018) found that low food security was associated with a HbA1c level that was on average 0.6% higher compared to participants who had high food security.(Berkowitz et al., 2018) Schroeder et all followed a group of 2,968 participants, 742 of whom were identified as having low food security.(Schroeder et al., 2019) They found that participants with low food security had an average HbA1c level of 7.5% compared to 7.2% for participants who were food secure.(Schroeder et al., 2019) A study of 1,622 adults found that low food security and lack of a regular source of healthcare were associated with poor glycemic control.(Shaheen et al., 2021)We could only find a single study that examined the association with food security and glycemic control in older adults in a randomized cross-over trial.(Berkowitz et al., 2019) In it, 44 adults with diabetes randomly received a 12-week dietary intervention, with intervention recipients reporting healthier eating habits and lower hypoglycemia.(Berkowitz et al., 2019)

One possible mechanism by which low food security impacts glycemic control is a reduction in diet quality, which was found to be associated with increased levels of HbA1c in a secondary analysis of adults with T2D in the 2011-2016 NHANES waves.(Shaheen et al., 2021) A review of literature on food security and diabetes found that households with low food security struggled to tailor food selection to a diabetes regimen, especially when having to balance medication and other living expenses.(Gucciardi, Vahabi, Norris, Del Monte, & Farnum, 2014) . Another possible mechanism is stress-induced decreases in self-care behavior. It has been shown that associations exist between low food security and poor diabetes control.(Patel, 2020; Silverman et al., 2015) Low food security has also been associated with poor adherence to diabetes self-care behaviors and medication adherence.(Heerman et al., 2016; Schroeder et al., 2019) While there is not a direct link between low food security and diabetes control, research has suggested a link between the two via stress, which reduces capacity to perform diabetes self-care behaviors.(Walker, Campbell, & Egede, 2019; Walker, Williams, & Egede, 2018)

Race

There is also an association between race and glycemic control.(Campbell et al., 2012; Heidemann et al., 2016; Kirk et al., 2008; Shaheen et al., 2021) A review of 22 papers on the impact of racial difference on glucose control and diabetes found that NHBs and Hispanics/Latinos tended to have consistently worse control compared to NHWs.(Campbell et al., 2012) The difference in HbA1c compared to NHWs ranged from

0.2 to 0.9 for NHBs and 0.28 to 0.76 for Hispanics/Latinos. Heidemann et al conducted a retrospective cohort study of 25,123 patients with diabetes at a large urban academic medical center to investigate if race was an independent factor of glycemic control.(Heidemann et al., 2016) They found that white patients were significantly more likely to have lower HbA1c compared to Black patients.(Heidemann et al., 2016) Kirk et al conducted a literature review on racial differences in glycemic control between Hispanics/Latinos and NHWs.(Kirk et al., 2008) A meta-analysis of the literature revealed that Hispanics/Latinos had a mean HbA1c level that was ~0.5% higher than NHW populations. Shaheen et al found in a retrospective cohort study of 1,682 adults that individuals who were identified as NHB or Hispanic/Latino were more likely to have poor glycemic control.(Shaheen et al., 2021)

Other SDOH Factors

Our review of the literature suggests a connection between socioeconomic status and glycemic control, namely income, education, and health insurance status.(Branfield Day et al., 2020; Kollannoor-Samuel et al., 2011; Rebekah J. Walker et al., 2020; Walker et al., 2014) Branfield Day et al found in a cross-sectional study of 716,267 Canadians between 40 and 89 years of age that there was a significant positive association between income and glycemic control, after controlling for baseline factors.(Branfield Day et al., 2020) They found that the effects were greatest among adults under the age of 65 (mean difference HbA1c +2.5 mmol/mol, CI +2.3 to +2.7) and that the effect significantly lessened once they reached the age of 65 (+1.2 mmol/mol, CI 1.0 to 1.3, <0.001 for interaction), when universal public drug insurance is acquired. A survey of 211 Latinos with T2D investigated sociodemographic determinants of HbA1c.(Kollannoor-Samuel et al., 2011) They found that having a lower income was a risk factor for higher HbA1c levels (OR:10.4 CI:1.54-69.30). A longitudinal study of SDOH in 2,662 older adults with diabetes found that financial hardship, such as difficulty paying bills, was associated with increasing HbA1c.(Rebekah J. Walker et al., 2020) In a systematic review of 621 articles, Walker et al found a significant association between SDOH and glycemic control. (Walker et al., 2014)

Sociodemographic Factors

Previous research found that there is evidence to indicate that age had a significant relationship with glycemic control, but gender and marital status did not. (Chiu & Wray, 2010; Khaled, 2020; Trief, Himes, Orendorff, & Weinstock, 2001) Chiu and Wray found in a prospective cohort study that differences in age made a difference in treatment, with the impact of oral medication increasing as participants aged.(Chiu & Wray, 2010) A cross-sectional study of 945 patients with T2D, who had a mean age of 58 and were evenly distributed between men and women, investigated the relationship between gender and glycemic control.(Khaled, 2020) They found that HbA1c levels were comparable between genders and that medical treatment outcomes were based on comorbidities and complications rather than gender. To investigate the relationship between marital status and glycemic control, an assessment of 78 insulin-treated adults with both T1D and T2D was conducted.(Trief et al., 2001) Participants were given 2 marital quality assessments and 4 quality of life measures related to diabetes, as well as having HbA1c measured. While the marital quality measures were positively related to diabetes and quality of life measures, they did not find a significant relationship to

HbA1c. Despite this literature, the investigators believe that controlling for gender and marital status will still be valuable. .

Behavioral Factors

Behavioral factors are personal determinants of health. These are activities which an individual performs that impact their own health. These include the use of substances such as alcohol and tobacco, as well as physical activity, such as exercise performed on its own or as part of work or hobbies. We found in our review of the literature that high rates of smoking were associated with high prevalence of and risk for diabetes, and that physical activity was associated with improved glycemic control.(Ooi et al., 2021; Peng et al., 2018; Su et al., 2017; Yao et al., 2021)

Physical Activity

Physical activity has been associated with improved glycemic control in participants with T2D.(Ooi et al., 2021; Yao et al., 2021) Yao et al conducted a secondary analysis of a randomized control trial which separated 799 participants into a control and three interventions groups, which received interventions for health literacy, exercise, or both and followed them for 2 years.(Yao et al., 2021) They found that glycemic control improved with greater levels of physical activity, with the greatest improvements coming from participants with a low baseline level of physical activity.(Yao et al., 2021) Ooi et al conducted a 16 week quasi-experimental trial examining the impact of aerobic exercise on older adults with T2D.(Ooi et al., 2021) Half of the 70 participants received the intervention and showed an improvement in HbA1c, fasting glucose, and systolic blood pressure compared to the control group.(Ooi et al., 2021)

Smoking

Cigarette smoking has been associated with reduced glycemic control.(Peng et al., 2018; Su et al., 2017) In a cross-sectional survey of 7,763 men with T2D, a significant negative association between cigarette smoking and glycemic control was found.(Su et al., 2017) Participants were surveyed for smoking history and had HbA1c measured. When compared to participants who had never smoked, the HbA1c levels of current smokers were higher ($p<0.001$). In addition, the HbA1c levels of former smokers decreased with the length of time since they had last smoked ($p<0.05$). Similarly, a cross sectional study of 10,551 men and 15,297 women also found a negative relationship between smoking and glycemic control.(Peng et al., 2018) They also found a dose-dependent negative relationship between active smoking and glycemic control. These studies suggest that smoking activity is worth investigating in this study.

Biomedical Factors

Personal and biomedical factors can include mental health conditions such as depression, weight/obesity, self-rated health (SRH), and oral medication use. Our review of the literature found a mixed relationship between glycemic control and depression, a positive relationship between oral medication use and glycemic control, and a significant negative relationships between obesity, SRH, and glycemic control.(Assari, Lankarani, Piette, & Aikens, 2018; Bae, Lage, Mo, Nelson, & Hoogwerf, 2016; Boye et al., 2021; Chiu & Wray, 2010; Hirst, Farmer, Ali, Roberts, & Stevens, 2012; Kane, Hoogendoorn, Commissariat, Schulder, & Gonzalez, 2020; Nouwen et al., 2010) Other comorbidities, such as hypertension or chronic kidney disease, affect glycemic control butare not reviewed here.(Ozieh, Garacci, Walker, Palatnik, & Egede, 2021)

Depression

The literature indicates a mixed association between depression and glycemic control. In a longitudinal study of 11,525 veterans with T2D, Richardson et al found a mean difference in HbA1c of 0.13 (CI: 0.03, 0.22) for participants with depression compared to those without depression.(Richardson, Egede, Mueller, Echols, & Gebregziabher, 2008) Aikens et al conducted a longitudinal study on 253 adults with T2D where they did not find a significant association between depression and glycemic control once baseline HbA1c levels were taken into account. They did find that poor glycemic control predicted worse depressive symptoms among participants being treated with insulin ($\beta=0.31$, $P=0.002$), but not for those being treated with oral medication alone ($\beta=-.10$, $P=.210$).(Aikens, Perkins, Lipton, & Piette, 2009) Fisher et al failed to find an association between depression and HbA1c levels in T2D patients.(Fisher et al., 2010) In a longitudinal study of 506 participants with T2D, they examined for symptoms of major depressive disorder (MDD), depressive symptoms, and diabetes distress.(Fisher et al., 2010) In a multi-level modeling analysis, they found that only diabetes distress was associated with HbA1c levels ($b=0.024$, $p=0.001$).(Fisher et al., 2010) Given the mixed evidence on this relationship, it is clear that more research is required.

Obesity

There is evidence to indicate a negative association between obesity and glycemic control. In an analysis of physician electronic health records from 2009-2011 in the U.S. (n=262,595), Bae et al found a statistically significant positive association between weight and poor glycemic control.(Bae et al., 2016) They compared weight by categories with HbA1c levels.(Bae et al., 2016) Boye et al obtained similar results in a retrospective cohort study of insurance claims data for 44,723 patients.(Boye et al., 2021) They found that when compared to baseline weight, patients classified as obese class I and II were 24% more likely to have a HbA1c level greater than or equal to 7%, while patients classified as class III were 16% more likely.(Boye et al., 2021) These studies suggest that obesity may be linked to worsened glycemic control.

Self Rated Health

SRH serves as an overall indicator of health.(Assari et al., 2018). There is little literature describing the relationship between SRH and glycemic control. Assari et al examined the relationship between SRH and glycemic control in a cross sectional study of adults with T2D.(Assari et al., 2018) After adjusting for demographic and medical factors, they analyzed HbA1c and SRH with and without interactions by race and gender.(Assari et al., 2018) They did not find a relationship between HbA1c and SRH alone, but did find a significant negative relationship when race and gender were included.(Assari et al., 2018) Specifically, they found a negative association between SRH and glycemic control in Black men, but not Black women, white men, or white women.(Assari et al., 2018) This study suggests it would be useful to examine SRH as part of our study.

Oral Medication Use

A review of literature on oral medication use and glycemic control suggests a strong relationship exists.(Chiu & Wray, 2010; Hirst et al., 2012) In a prospective cohort study of 430 older adults aged 65 and older who self-identified as having diabetes in the 1998 and 2000 Health and Retirement Study (HRS), and the HRS 2003 Diabetes Study, Chiu and Wray examined associations between demographics, treatment modality, clinical conditions, behaviors and glycemic control.(Chiu & Wray, 2010) They found that among older adults, only treatment modality (insulin only, insulin and another treatment, oral medication, diet only) was significantly associated with glycemic control.(Chiu & Wray, 2010) When compared to insulin alone or in combination with another treatment, they found that participants treated with diet only or oral medication had lower HbA1c levels.(Chiu & Wray, 2010) Hirst et al conducted a meta-analysis of literature examining the effect of metformin, a first-line oral medication recommended for glycemic control in patients with T2D.(Hirst et al., 2012) They examined 35 trials, and a subset of 7 for dose-comparison analysis.(Hirst et al., 2012) They found that metformin lowered HbA1c in all cases, and that the effect was stronger with higher doses when compared to lower doses, with no significant increase in side effects.(Hirst et al., 2012) These two studies suggest that oral medication has a significant effect of lowering HbA1c and maintaining glycemic control.

Chapter 3: Methods

Description of the NHANES dataset

This investigation uses the National Health and Nutrition Examination Survey (NHANES) data collected by the National Center for Health Statistics (NCHS), which is part of the Centers of Disease Control and Prevention (CDC). NHANES is a series of examinations designed to assess the health and nutritional status of adults and children in the United States. It combines interviews and physical examinations and has been continuously running since 1999.

NHANES collects data from a representative sample of 5000 persons across 15 counties in the United States every two years. The interview portion collects data on demographics, socioeconomic status, diet, and health questions. The physical examination collects medical, dental and physiological data, as well as collecting samples for laboratory measurements. The data are used to assess the health and nutritional status of the United States as well as the prevalence and risk factors for disease. To ensure adequate representation, older adults are oversampled. To have a suitably large sample for analysis, it was necessary to combine the 2009-2010, 2011-2012, 2013-2014 and 2015-2016 waves (n=40,439). Due to methodology changes, waves prior to 2009 were excluded. The 2017-2018 and 2019-2020 waves lacked food security data at the time of analysis and were therefore excluded.

Study Sample

The sample for this analysis was limited to adults over the age of 65 with a focus on NHW, NHB, and Hispanic/Latinos. Eligibility criteria included those who: (a) participated in the 2009-2010, 2011-2012, 2013-2014, or 2015-2016 NHANES waves,

(b) were over the age of 65 (c) specified their race/ethnicity as NHW, NHB, Mexican, or Hispanic/Latino, (d) met the criteria as having diabetes, which was defined as two of the following being valid: (1) HbA1c levels were greater than or equal to 6.5%, (2) Doctor diagnosis after the age of 30, (3) taking glucose lowering medication, and (e) responded to sections of NHANES pertaining to food security, diabetes, depression, and HbA1c. The decision to limit age of diagnosis to 30 and above was to lower the chance that a participant had T1D.

To identify our study sample, we started with 40,439 participants in NHANES waves 2009-2016. Next, participants aged 65 and over were identified (n=5,457). Of the 5,457 over the age of 65, 1,647 were identified as meeting criteria for diabetes. Of these, 1,426 individuals were identified as belonging to the specified racial/ethnic groups. Finally, 1,326 individuals submitted data for the specified datasets. Figure 1 below summarizes this process.

Figure 1
Inclusion Process within NHANES waves 2009-2016

Sample Size	Steps in Inclusion Process
40439	Participants in NHANES waves 2009-2016
5457	Participants aged 65 and older
1647	Participants 65+ identified with diabetes
1426	Participants 65+ with diabetes identifying as NHW, NHB, or Hispanic/Latino
1326	**Eligible participants who completed Food Security and Depression Screenings and HbA1c lab work**

Data Collection

Participants were identified through linking NHANES demographic datasets with relevant datasets by their sequence ID in SAS 9.4. Appropriate sample weights were used in the analysis. Demographic data was de-identified prior to publication by NCHS. Demographic variables included age, gender, race, marital status, household income, and education. Food security data consisted of a rating based on the USDA Food Security Questionnaire. The data was stored on the researcher's personal password-protected computer.

This study was determined not to meet the definition of human subjects research by the Emory University Institutional Review Board.

Measures

We examined questions related to food security, other SDOH, behavioral factors, and biomedical factors. Below are the specific variables examined for analysis.

Glycemic Control. Glycemic control was assessed by dichotomizing lab tested fasting HbA1c levels into "controlled" and "uncontrolled" groups. HbA1c was considered uncontrolled when it was higher than or equal to 7%.(American Diabetes, 2015)

Food Security. We assessed Food Security using the US Food Security Survey Module. It is an 18-item survey, with 10 items for households without children.(Bickel et al., 2000; Nord, 2002) For our analysis, we used the 10-item score. The number of affirmative answers is tallied and the total correlates with a categorical variable. Scores were calculated the following way: Full Security is no affirmative responses. Marginal Security is 1-2 affirmative responses. Low Security is 3-5 affirmative responses. Very Low Security was defined as 6-10 affirmative responses. We used the score summary from the dataset and dichotomized the rankings into Secure and Insecure. Secure was defined as a rating of Full or Marginal food security, while low food security was defined as a rating of Low or Very Low food security.

Race. Race/ethnicity was characterized as NHW, NHB, or Hispanic/Latino. Hispanic/Latino combined responses for Mexican American and Other Hispanic Origin. While race is a complex, socially determined identity that can encompass many sub identities and change over time, for purposes of ease of analysis it was necessary to shrink the categories.

Other SDOH and Sociodemographic Characteristics. The characteristics we assessed were age, gender, education, income, marital status, and health insurance coverage. Age was used as a continuous variable. Gender was a categorical variable using "male" and "female" categories. While this study acknowledges that gender encompasses more than the cisgender male/female binary, these nuances are not contained within the NHANES questionnaire. Education was dichotomized into High School or Less and Some College and above. Income was dichotomized as greater than or equal to, and less than $45,000 in annual household income. Marital status was dichotomized into Married/With Partner and Divorced/Separated/Widowed/Single. Insurance coverage was dichotomized into 0 for "insured" and 1 for "not insured".

Behavioral Factors. Behavioral factors were smoking status and physical activity. Alcohol use was considered but was not included due to a low response rate. Smoker status was measured by the NHANES question "Have you smoked 100 cigarettes in your life?" This was intended to capture people who have smoked previously but may not smoke now. Physical activity was measured by whether the participant had indicated they performed moderate or strenuous physical activity as part of their daily work. This was dichotomized based on an affirmative or negative response.

Biomedical Factors. We assessed Body Mass Index (BMI), self-rated health, oral medication use, and depression. BMI was a continuous variable measuring body fat as a percentage of weight. For analysis, it was dichotomized into a categorical variable based on whether they met or exceeded the cut off point for obesity (30 kg/m^2).(Weir & Jan, 2022) Self-rated health is a self-reported measure of overall health. It was dichotomized into Excellent/Very Good/Good, and Fair/Poor. Oral medication use was dichotomized based on whether the participant indicated they took oral medication to help manage their diabetes. Depression was assessed using the Patient Health Questionnaire (PHQ-9), which is a validated measure of depression.(Levis, Benedetti, & Thombs, 2019) This consists of nine questions asking about symptoms of depression, with responses given on a Likert Scale of 0-3 for a total possible response of 27. Scores of 10 or higher are categorized as "elevated" symptoms of depression.(Levis et al., 2019; Montgomery et al., 2017; Silverman et al., 2015) We dichotomized depression into "None/Mild" and "Elevated" states based on the score or 10 or higher. Overnight hospital stay was dichotomized based on whether the participants had any overnight hospital stays in the last 12 months or not.

Data Analysis

Participant characteristics were summarized using descriptive statistics. Differences between racial/ethnic groups and food security status were examined for significance, using χ^2 tests for dichotomous and t-tests for continuous variables. Those variables significant at $p<=0.1$ level were included in the subsequent bivariate and multivariate regression models. Bivariate logistic regressions examined the relationship between glycemic control, food security, race, and potential covariates. A series of multivariate logistic regression models were fit to assess the relationships between glycemic control, food security, race, and important covariates, ranging from the macro- (i.e., SDOH) to the micro-level (i.e., biomedical characteristics) variables. Each subsequent model includes the variables significant in the previous models. Model 1 was unadjusted and examined the relationship of race and food security on glycemic control. Model 2 included other SDOH and demographic factors along with race and food security. These additional factors were marital status, education, income, insurance status, and gender. Model 3 added behavioral factors, i.e. smoking status and physical activity level. Model 4 included biomedical factors, i.e. BMI, depression severity, self-rated health, and oral medication use.

Chapter 4: Results

Sample Description

The full sample description is provided in Table 1 of Appendix A. In total, 1326 participants had the required dataset responses to be analyzed. The mean age of the sample was about 73 years. Slightly less than half of participants were female. Most participants were NHW, with the remainder being Hispanic/Latino (18.4%) or NHB (13.2%). Slightly over half were married or living with a partner. About half of participants had some or more college education, slightly less than two-thirds had an income under $45,000. Almost all participants were covered by health insurance. Just over half of participants identified as current or former smokers. About a third of participants reported regular moderate to vigorous physical activity. A large majority (85.1%) of participants reported taking oral medication to manage diabetes. Half of participants met the criteria for obesity. Most participants did not report elevated symptoms of depression. A third of participants rated their health as fair or poor.

Group Differences by Food Security Status

Table 1 in Appendix A examines group differences by food security status. We found several statistically significant differences between participants who were food secure and those with low food security. Compared to food secure participants, a significantly higher proportion of those with low food security had poor glycemic control. Fewer participants with low food security were NHW, and more were NHB or Hispanic/Latino. A higher proportion of low food security participants were single and had less than a $45,000/year income, while a lower proportion had some college education or more. Participants with low food security were more likely to report elevated depressive symptoms and rate their health as fair or poor.

Group Differences by Race

Table 2 in Appendix A examines sample group differences by race/ethnicity. We found several statistical differences when comparing NHWs to NHBs and Hispanic/Latinos. Both NHB and Hispanic/Latino groups were more likely to report low food security than NHWs. Hispanic/Latinos had a higher proportion with poor glycemic control compared to NHWs. Both HNBs and Hispanic/Latinos were more likely to be, women, single people, and have incomes less than $45,000/year than NHWs. NHWs had a higher proportion of participants with some college education or greater, when compared to NHBs and Hispanic/Latinos. Hispanic/Latinos had a lower proportion of participants with health insurance than NHWs. Hispanic/Latinos also had a lower proportion of participants who were current or former smokers compared to NHWs. Both NHBs and Hispanic/Latinos had a lower proportion of participants who reported moderate to vigorous daily activity and rated their health as fair or poor, compared to NHWs. Hispanic/Latinos had a lower proportion of participants classified as obese compared to NHWs, while NHBs had a higher proportion compared to NHWs. Hispanic/Latinos had a higher proportion of participants display elevated symptoms of depression compared to NHWs.

Bivariate Logistic Regressions

Each variable in the dataset was tested for association with glycemic control. The full results can be seen in Table 1 of Appendix B. We found a number of significant associations. Being Hispanic/Latino and rating your health as fair or poor, were independently significantly associated with poor glycemic control. Moderate to vigorous physical activity, food security, and oral medication use were independently associated with better glycemic control.

Multivariate Logistic Regressions

Multivariate logistic regression analysis examined independent effects of food security and race on glycemic control in the presence of other important covariates. The results of each model can be seen fully in Table 2 of Appendix B.

Model 1: Race and Food Security

When examining Model 1, both Hispanic/Latino race (p=0.0102, OR: 0.701, CI: 0.537, 0.917) and food security (p=0.0354, OR: 0.684, CI: 0.481, 0.974) were found to be significantly associated with glycemic control. The odds of controlled HbA1c were 30% lower for Hispanic/Latinos compared to other races. Individuals with low food security had 32% lower odds of glycemic control compared to food secure individuals.

Model 2: SDOH and Demographic Factors

When including education, income, marital status and gender, only Hispanic/Latino race/ethnicity (p=0.0513, OR:0.768, CI:0.589, 1.002) and food security (p=0.0765, OR:0.765, CI: 0.494, 1.037) were significantly associated with glycemic control. Education (p=0.2053), income (p=0.6795), marital status (p=0.1730), gender (p=0.1824), and insurance coverage (p=0.5959) were not significantly associated.

Model 3: Behavioral Factors

When including physical activity and smoking status, it was found that food security (p=0.0303, OR:0.675, CI: 0.473, 0.962), race (p=0.0223, OR: 0.744, CI: 0.578, 0.957), and regular moderate to vigorous physical activity (p=0.0130, OR:1.509, CI:1.094, 2.081) were significantly associated with glycemic control. Moderate to vigorous physical activity was associated with improved glycemic control.

Model 4: Personal & Biomedical Factors

When adding overnight hospital stays, self-rated health, medication use, and depression status to previous models, only medication use ($p<0.0001$, OR: 3.339, CI: 2.242, 4.975), physical activity ($p=0.0074$, OR:1.624, CI:1.145, 2.303) and food security ($p=0.0235$, OR: 0.643, CI: 0.440, 0.940) were significantly associated with glycemic control. Both medication use and physical activity were positively associated with glycemic control, while low food security was negatively associated.

Chapter 5: Discussion

In this study, we examined independent associations between food security, race, and glycemic control. We found that low food security was negatively associated with glycemic control in older adults. Participants with low food security were more likely to have poor glycemic control, while those who were food secure were more likely to have good glycemic control. In initial models, race was significantly associated with glycemic control, and Hispanic/Latino participants were more likely to have poor glycemic control compared to the rest of the study group. However, this relationship was no longer significant once biomedical covariates were introduced. Among the control variables, only physical activity and oral medication use were significantly associated with glycemic control.

Unsurprisingly, without controlling for biomedical variables, food security and race had a significant relationship with glycemic control. This is consistent with the literature on the relationship between food security and glycemic control.(Berkowitz et al., 2014; Berkowitz et al., 2018; Schroeder et al., 2019; Rebekah J. Walker et al., 2020) Examining glycemic control and food security by race appears to broadly conform to the literature.(Fitzgerald et al., 2011; Strings et al., 2016)

While most SDOH and demographic factors such as education, income, gender, insurance status, and marital status were not significantly associated with glycemic control, food security was consistently significantly associated with glycemic control, even when adjusted for other covariates. The relationship was positive -- as food security decreased, glycemic control decreased as well. This suggests that food security is an important measure when considering glycemic control, beyond other SDOH factors. This makes sense at face value, as diabetes is a nutrition sensitive condition, and low food security necessarily means poor nutrition, which would reduce glycemic control. This conforms to expectations based on the pathway analysis of diet quality and glycemic control.(Shaheen et al., 2021)

One potential reason the other SDOH covariates as well as sociodemographic variables were not significant may be because food security was acting as an aggregate measure, since it is influenced by income, education, and other factors. This may make it similar to the findings of Ozieh et al, Khaled, and Trief et al but is contrary to the findings of Leroux et al, Seligman et al, Branfield Day et al, and Kollannoor-Samuel et al..(Branfield Day et al., 2020; Khaled, 2020; Kollannoor-Samuel et al., 2011; Leroux, Morrison, & Rosenberg, 2018; Ozieh et al., 2021; Seligman et al., 2007; Trief et al., 2001) Ozieh et al found that aggregate SDOH was significantly associated with diabetes and chronic kidney disease, but individual covariates were not.(Ozieh et al., 2021) With regards to sociodemographic characteristics, Khaled had found that comorbidities and complications in treatment had a greater impact on HbA1c than gender.(Khaled, 2020) Trief et al found that marital status and satisfaction did not have a significant impact on HbA1c levels.(Trief et al., 2001) Leroux et al found that disaggregating data in among older adults by age group helped to illuminate differences within age cohorts, and that sex and marital status were confounding factors for their analysis of food security.(Leroux et al., 2018) Seligman et al broke down income by percentage of the federal poverty line, with several strata.(Seligman et al., 2007) Branfield Day et al found that there were significant differences in HbA1c by income levels when controlling for other factors.(Branfield Day et al., 2020) Kollannoor-Samuel et al found that socioeconomic status was positively associated with HbA1c levels.(Kollannoor-Samuel et al., 2011) Additionally, while we examined such SDOH factors as education, income, and health insurance, other important factors (e.g., healthcare utilization and neighborhood characteristics) were not considered. Lastly, it is possible that the way this study measured age, marital status, and education accounts for the different outcomes. Aggregating marital status and education into dichotomous variables may have obscured some granular relationships within the data. It may be that incorporating data on neighborhood conditions may also shed light on some of these differences.

The fact that race and food security remained significant when behavioral factors were included suggests that macro factors remain impactful on glycemic control even when participants exercised. While exercise has an impact, this alone does not appear able to overcome barriers like low food security. When examining behavioral factors, physical activity conformed to the findings of the literature, but smoking status did not.(Ooi et al., 2021; Peng et al., 2018; Su et al., 2017; Yao et al., 2021). Based on our literature review, moderate to vigorous physical activity was associated with higher likelihood of glycemic control.(Ooi et al., 2021; Yao et al., 2021) Our study did not find a significant relationship between smoking and glycemic control. This is surprising, as our literature review indicated that a significant relationship should exist.(Peng et al., 2018; Su et al., 2017) It is possible that this association is best explored in studies which examine a single population, and avoid multi-ethnic study populations. It may also be related to our definition of smoking status. This study chose to use a question which asked participants whether they had ever smoked 100 cigarettes in their lifetime as a criterion for inclusion in this category. This relies on a self-estimate of the number of cigarettes the participant has smoked and may be unreliable as a result. It may also have required an explicit measure of current smoking. Both Su et al and Peng et al examined smoking based on number of cigarettes smoked daily, as well as stratified results based on dosage.(Peng et al., 2018; Su et al., 2017) They both also measured the time since former smokers had ceased smoking. These differences in population and measurement may account for some of the discrepancy.

Interestingly, food security remained significantly associated with glycemic control when biomedical factors were included, but race did not. As oral medication also had a significant relationship, this may suggest that differences by race fall away if the participants are taking oral medication. This may be partly explained by the strong relationship oral medication had with glycemic control. This may be due to factors related to race and medication use that go beyond the parameters of this study, such as consistent access to healthcare. (Chatterji et al., 2012) With this in mind, it may be that Hispanic/Latinos who were taking oral medication may have also had better and more consistent access to care than those who did not, but without additional analysis it cannot be said for certain, especially as some of those who were not taking oral medication may have been taking insulin instead. The fact that food security remained significant suggests that it has a powerful impact on glycemic control, even when medication is taken. This may suggest that ensuring a steady supply of healthy food for patients with diabetes is as important as medication use. The nutritional benefits of a healthy diet would seem to be just as important for managing HbA1c. As stated above, this conforms to expectations based on the review of diet quality and glycemic control.(Shaheen et al., 2021)

Among the biomedical covariates that we examined, oral medication use had a strong association with glycemic control in this study. This is consistent with the literature. (Chiu & Wray, 2010; Hirst et al., 2012) A more detailed analysis including insulin use or other interventions may have been useful, as Chiu and Wray did.(Chiu & Wray, 2010) Depression was not significantly associated with glycemic control in this study. That is not surprising considering the mixed evidence observed in the literature review.(Aikens et al., 2009; Fisher et al., 2010) Aikens et al found that insulin use predicted depressive symptoms and oral medication alone did not, whereas this study did not examine insulin use. (Aikens et al., 2009) In addition, this study did not investigate depression beyond the PHQ-9 used in the NHANES questionnaire, and may have missed some subtleties of diabetes-related distress that Fisher et al found in their study.(Fisher et al., 2010) Obesity was not significantly associated with glycemic control in our regression analysis. This is in contrast to the literature, which did find an association with glycemic control.(Bae et al., 2016; Boye et al., 2021) One potential reason for this conflict may be the way we measured weight, by only examining a dichotomized variable at the cutoff point for obesity, whereas both Bae et al and Boye et al examined multiple weight categories and both found a significant negative relationship between weight and glycemic control.(Bae et al., 2016; Boye et al., 2021) However, this explanation does not seem sufficient, as there was a significant negative association between weight and glycemic control in those studies at the weight level (obesity) we examined.(Bae et al., 2016; Boye et al., 2021) It is possible that the other variables we examined confounded the association. Lastly, a significant association between SRH and glycemic control was not observed in this study. This contradicts the literature reviewed, but it may be explained by differences in measurement and demographics examined.(Assari et al., 2018) Assari et al examined each level of SRH individually, whereas this study aggregated into a dichotomized variable.(Assari et al., 2018) Assari et al examined participants by both race and gender together, and their study population did not include Hispanic/Latinos.(Assari et al., 2018) These differences may explain the discrepancy.

The results of our study suggest that, among older adults, food security is associated with glycemic control as is physical activity and medication use. Clinical practitioners treating diabetes should screen older patients for food security. Such screening would be especially important for those patients who are low income, as they may be at risk for low food security and consequently have difficulty controlling their HbA1c, leading to complications with their diabetes. This may be particularly applicable for Hispanic/Latino patients who are low income, as they may have additional neighborhood-level barriers to accessing foods important for controlling diabetes. Additionally, increasing physical activity, particularly interventions for individuals who may struggle with such activities in a normal setting, should be prioritized. Helping patients who are struggling with medication adherence find ways to sustainably improve it should also be a priority for practitioners, as this has a large effect on HbA1c.

The results of our study suggest that monitoring food security and nutritional intake would be beneficial for many older adults. This aligns with studies that have examined fresh fruit and vegetable deliveries and found that participants improved their nutritional intake when they received deliveries of fresh fruits and vegetables.(Berkowitz et al., 2019) This may be achieved by expanding programs such as the Supplemental Nutrition Assistance Program (SNAP). Alternatively, expansion of Medicaid may be a viable way to cover more services that older adults need, saving money for purchasing healthier foods. Partnering with non-governmental organizations and placing literature on their services in offices may help improve food security.

We recommend further investigation into the pathways by which low food security influences glycemic control in adults over the age of 65. Understanding more about how older adults living in institutional, group living, or multi-generational home settings may also enhance our understanding of relationships between food security and diabetes care. More granular understanding of how race and ethnicity play a factor in food security and diabetes as a SDOH is also a potential avenue for research. Particularly, a better understanding of how Hispanic/Latino older adults are impacted by food security would be useful. Further examination of the pathways between depression, food security, and glycemic control would also be beneficial. A better understanding of neighborhood conditions and how this informs a SDOH approach to health may be useful as well.

This study had several limitations. The first was that this study does not account for potential differences in diet by region. This may be important because food intake varies by region and impacts health outcomes.(Freimer, Echenberg, & Kretchmer, 1983) This assessment was not possible in this study because the process NHANES uses the anonymize data includes removing references to states or other geographic locations. This limits the applicability of the results. The second was that this study excludes Asians, native Americans, and other ethnicities not included in the racial/ethnic categories due to low representation in the data. Similarly, the category of "Hispanic/Latino" collapses several ethnicities into a single category for ease of analysis. This limits the applicability of these findings to these sub-populations. Third, gender identity beyond the male/female binary was not included in this data, nor was information on sexual orientation. This limits the applicability of this data to gender/sexual minorities. Limiting the dataset to individuals who were diagnosed with diabetes at the age of 30 or above does limit the likelihood of type 1 diabetes in the analysis. However, it is possible that some participants may have had type 1 diabetes. In addition, the focus on oral medication use to the exclusion of insulin use may impact the results, especially with regard to covariates that were shown in the literature to be related to insulin treatment, such as depression.(Aikens et al., 2009) The measurement of physical activity via a self-report measure of daily physical activity may limit the accuracy of the results. Our definition of diabetes based on the participant having two of the three diagnostic criteria may have unintentionally excluded some participants from the sample. The decision to dichotomize categorical variables for ease of analysis limits our ability to draw conclusions on more nuanced results. These decisions may limit the generalizability of our findings.

Conclusion

There appears to be an association between low food security and poor glycemic control in older adults with diabetes. Steps should be taken to ensure this population retains high food security. Hispanic/Latino populations may be at significant risk for poor glycemic control, especially if they exhibit difficulty with medication adherence. More thorough examination of how living arrangements, race, and other demographic factors affect this relationship should occur. Practitioners and public health professionals should take steps to ensure that older adults remain active and have sustainable plans to adhere to their medication regimen. More research should be conducted to examine the relative benefits of oral medication versus insulin and other interventions in this population. Depression in older adults with diabetes should be further examined to establish a clear relationship with glycemic control, particularly as it relates to race.

References

Aikens, J. E., Perkins, D. W., Lipton, B., & Piette, J. D. (2009). Longitudinal analysis of depressive symptoms and glycemic control in type 2 diabetes. *Diabetes Care, 32*(7), 1177-1181. doi:10.2337/dc09-0071

American Diabetes, A. (2015). Standards of medical care in diabetes-2015 abridged for primary care providers. *Clinical diabetes : a publication of the American Diabetes Association, 33*(2), 97-111. doi:10.2337/diaclin.33.2.97

Assari, S., Lankarani, M. M., Piette, J. D., & Aikens, J. E. (2018). Self-Rated Health and Glycemic Control in Type 2 Diabetes: Race by Gender Differences. *J Racial Ethn Health Disparities, 5*(4), 721-727. doi:10.1007/s40615-017-0416-3

Bae, J. P., Lage, M. J., Mo, D., Nelson, D. R., & Hoogwerf, B. J. (2016). Obesity and glycemic control in patients with diabetes mellitus: Analysis of physician electronic health records in the US from 2009-2011. *J Diabetes Complications, 30*(2), 212-220. doi:10.1016/j.jdiacomp.2015.11.016

Bergmans, R. S., Berger, L. M., Palta, M., Robert, S. A., Ehrenthal, D. B., & Malecki, K. (2018). Participation in the Supplemental Nutrition Assistance Program and maternal depressive symptoms: Moderation by program perception. *Social Science & Medicine, 197*, 1-8. doi:https://doi.org/10.1016/j.socscimed.2017.11.039

Bergmans, R. S., & Wegryn-Jones, R. (2020). Examining associations of food insecurity with major depression among older adults in the wake of the Great Recession. *Soc Sci Med, 258*, 113033. doi:10.1016/j.socscimed.2020.113033

Bergmans, R. S., Zivin, K., & Mezuk, B. (2019). Depression, food insecurity and diabetic morbidity: Evidence from the Health and Retirement Study. *J Psychosom Res, 117*, 22-29. doi:10.1016/j.jpsychores.2018.12.007

Berkowitz, S. A., Delahanty, L. M., Terranova, J., Steiner, B., Ruazol, M. P., Singh, R., . . . Wexler, D. J. (2019). Medically Tailored Meal Delivery for Diabetes Patients with Food Insecurity: a Randomized Cross-over Trial. *J Gen Intern Med, 34*(3), 396-404. doi:10.1007/s11606-018-4716-z

Berkowitz, S. A., Gao, X., & Tucker, K. L. (2014). Food-insecure dietary patterns are associated with poor longitudinal glycemic control in diabetes: results from the Boston Puerto Rican Health study. *Diabetes Care, 37*(9), 2587-2592. doi:10.2337/dc14-0753

Berkowitz, S. A., Karter, A. J., Corbie-Smith, G., Seligman, H. K., Ackroyd, S. A., Barnard, L. S., . . . Wexler, D. J. (2018). Food Insecurity, Food "Deserts," and Glycemic Control in Patients With Diabetes: A Longitudinal Analysis. *Diabetes Care, 41*(6), 1188-1195. doi:10.2337/dc17-1981

Bickel, G., Nord, M., Price, C., Hamilton, W., & Cook, J. (2000). Measuring food security in the United States. *Guide to measuring household food security. Revised*.

Blazer, D. G., Moody-Ayers, S., Craft-Morgan, J., & Burchett, B. (2002). Depression in diabetes and obesity: Racial/ethnic/gender issues in older adults. *Journal of Psychosomatic Research, 53*(4), 913-916. doi:https://doi.org/10.1016/S0022-3999(02)00314-8

Boirie, Y., Morio, B., Caumon, E., & Cano, N. J. (2014). Nutrition and protein energy homeostasis in elderly. *Mechanisms of Ageing and Development, 136-137*, 76-84. doi:https://doi.org/10.1016/j.mad.2014.01.008

Boye, K. S., Lage, M. J., Thieu, V., Shinde, S., Dhamija, S., & Bae, J. P. (2021). Obesity and glycemic control among people with type 2 diabetes in the United States: A retrospective cohort study using insurance claims data. *J Diabetes Complications, 35*(9), 107975. doi:10.1016/j.jdiacomp.2021.107975

Branfield Day, L., Austin, P. C., & Shah, B. R. (2020). Universal drug coverage and income-related disparities in glycaemic control. *Diabet Med, 37*(5), 822-827. doi:10.1111/dme.14051

Campbell, J. A., Walker, R. J., Smalls, B. L., & Egede, L. E. (2012). Glucose control in diabetes: the impact of racial differences on monitoring and outcomes. *Endocrine, 42*(3), 471-482. doi:10.1007/s12020-012-9744-6

CDC. (2020). What is diabetes? Retrieved from https://www.cdc.gov/diabetes/basics/diabetes.html

Chatterji, P., Joo, H., & Lahiri, K. (2012). Racial/ethnic- and education-related disparities in the control of risk factors for cardiovascular disease among individuals with diabetes. *Diabetes Care, 35*(2), 305-312. doi:10.2337/dc11-1405

Chiu, C. J., & Wray, L. A. (2010). Factors predicting glycemic control in middle-aged and older adults with type 2 diabetes. *Prev Chronic Dis, 7*(1), A08. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2811503/pdf/PCD71A08.pdf

Cohen, S. (2020). Defund Social Security And Medicare? Trump's Dangerous Attack On America's Safety Net. Retrieved from https://www.forbes.com/sites/sethcohen/2020/08/10/defund-social-security-and-medicare-trumps-dangerous-attack-on-americas-safety-net/?sh=4132a7cf3410

Coleman-Jensen, A., Rabbitt, M., & Gregory, C. (2020, September 9, 2020). USDA ERS - Definitions of Food Security. Retrieved from https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx

Coleman-Jensen, A., Rabbitt, M. P., Gregory, C. A., & Singh, A. Household Food Security in the United States in 2019.

Coleman-Jensen, A., Rabbitt, M. P., Gregory, C. A., & Singh, A. (2019). Household Food Security in the United States in 2018.

Dean, W. R., Sharkey, J. R., & Johnson, C. M. (2011). Food insecurity is associated with social capital, perceived personal disparity, and partnership status among older and senior adults in a largely rural area of central Texas. *J Nutr Gerontol Geriatr, 30*(2), 169-186. doi:10.1080/21551197.2011.567955

Essien, U. R., Shahid, N. N., & Berkowitz, S. A. (2016). Food Insecurity and Diabetes in Developed Societies. *Curr Diab Rep, 16*(9), 79. doi:10.1007/s11892-016-0774-y

Fisher, L., Mullan, J. T., Arean, P., Glasgow, R. E., Hessler, D., & Masharani, U. (2010). Diabetes distress but not clinical depression or depressive symptoms is associated with glycemic control in both cross-sectional and longitudinal analyses. *Diabetes Care, 33*(1), 23-28. doi:10.2337/dc09-1238

Fitzgerald, N., Hromi-Fiedler, A., Segura-Pérez, S., & Pérez-Escamilla, R. (2011). Food insecurity is related to increased risk of type 2 diabetes among Latinas. *Ethnicity & disease, 21*(3), 328-334. Retrieved from https://pubmed.ncbi.nlm.nih.gov/21942166
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4048712/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4048712/pdf/nihms-580687.pdf

Freimer, N., Echenberg, D., & Kretchmer, N. (1983). Cultural variation--nutritional and clinical implications. *West J Med, 139*(6), 928-933.

Gucciardi, E., Vahabi, M., Norris, N., Del Monte, J. P., & Farnum, C. (2014). The Intersection between Food Insecurity and Diabetes: A Review. *Curr Nutr Rep, 3*(4), 324-332. doi:10.1007/s13668-014-0104-4

Haw, J. S., Shah, M., Turbow, S., Egeolu, M., & Umpierrez, G. (2021). Diabetes Complications in Racial and Ethnic Minority Populations in the USA. *Curr Diab Rep, 21*(1), 2. doi:10.1007/s11892-020-01369-x

Healthy People 2020: Social Determinants of Health. (2020). Washington, D.C. Retrieved from https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-of-health

Heerman, W. J., Wallston, K. A., Osborn, C. Y., Bian, A., Schlundt, D. G., Barto, S. D., & Rothman, R. L. (2016). Food insecurity is associated with diabetes self-care behaviours and glycaemic control. *Diabet Med, 33*(6), 844-850. doi:10.1111/dme.12896

Heidemann, D. L., Joseph, N. A., Kuchipudi, A., Perkins, D. W., & Drake, S. (2016). Racial and Economic Disparities in Diabetes in a Large Primary Care Patient Population. *Ethn Dis*, *26*(1), 85-90. doi:10.18865/ed.26.1.85

Hirst, J. A., Farmer, A. J., Ali, R., Roberts, N. W., & Stevens, R. J. (2012). Quantifying the effect of metformin treatment and dose on glycemic control. *Diabetes Care*, *35*(2), 446-454. doi:10.2337/dc11-1465

Jung, S. E., Kim, S., Bishop, A., & Hermann, J. (2019). Poor Nutritional Status among Low-Income Older Adults: Examining the Interconnection between Self-Care Capacity, Food Insecurity, and Depression. *J Acad Nutr Diet, 119*(10), 1687-1694. doi:10.1016/j.jand.2018.04.009

Kane, N. S., Hoogendoorn, C. J., Commissariat, P. V., Schulder, T. E., & Gonzalez, J. S. (2020). Glycemic control and self-rated health among ethnically diverse adolescents with type 1 diabetes. *Pediatr Diabetes, 21*(1), 69-76. doi:10.1111/pedi.12928

Kanter, J. E., & Bornfeldt, K. E. (2016). Impact of Diabetes Mellitus. *Arteriosclerosis, thrombosis, and vascular biology, 36*(6), 1049-1053. doi:10.1161/ATVBAHA.116.307302

Khaled, A. A. (2020). Impact of Gender on Type II Diabetes Glycemic and Cardiovascular Markers Control and Treatment. *Pak J Biol Sci, 23*(12), 1643-1649. doi:10.3923/pjbs.2020.1643.1649

Kim, G., Ford, K. L., Chiriboga, D. A., & Sorkin, D. H. (2012). Racial and Ethnic Disparities in Healthcare Use, Delayed Care, and Management of Diabetes Mellitus in Older Adults in California. *Journal of the American Geriatrics Society, 60*(12), 2319-2325. doi:https://doi.org/10.1111/jgs.12003

Kirk, J. K., Passmore, L. V., Bell, R. A., Narayan, K. V., D'Agostino Jr, R. B., Arcury, T. A., & Quandt, S. A. (2008). Disparities in A1C levels between Hispanic and non-Hispanic white adults with diabetes: a meta-analysis. *Diabetes Care, 31*(2), 240-246. Retrieved from https://watermark.silverchair.com/zdc00208000240.pdf?token=AQECAHi208BE49Ooan9kkhW_Ercy7Dm3ZL_9Cf3qfKAc485ysgAAAsMwggK_BgkqhkiG9w0BBwagggKwMIICrAIBADCCAqUGCSqGSIb3DQEHATAeBglghkgBZQMEAS4wEQQMDhuGZquDWElumo8sAgEQgIICdpAV5m4b69WXmp_IRwq44I3B4HujWKUEUcHBX0R-ExRs2An8aCe3kOMV6yYAaHFcjKkiNU9JPzLXWJkXFKdojGy9vHF8_dBFvZLhj6dmt2CodN61pwNALXo-TzSvNIoecK_Xr0y1H0oL4rsbxR9xQyCprZ7MBxnLjfbJsP07R2OT71c30_MdD12CUO5pBoKSl850wjHolitnjql6ZOftMyGZpDg0yZIOX0ffEfGHr7M5gWK0wG2wv60aCgS9IZZBPmFv_Lp88_xPBOhr_cA_HspHbytKs-lJwaPLnljATzlW6BljlQEdIBxWV-1-kK5eclU8LNP4AYEgHkj-AmzpWI4q_2sqcJVyaczCeU_35ZVFU2dBWzTxAw0M7qp-pcPQNutKUrgmihtNOh16ys61iHps6dvJQ6X2F9XeIBSNpwKf3lAkcoKiddWOdg7e4jUZVW6K0qWNKD9bX712W--cKoW9ElGWXHDsavS7OnSe23lPix8QnUZei_h7fFeRpN-rei0FnSdMsPDypNbalU9fO7uGH3P-kunjEq_p2Rm19dv65viddG7n7KbhB25QQTPs7ipzdLmZ6--mjhhu2Wu7isd9mmBvDggN8XwczzL2PRkz4631DjI9rIaO9gsCrCQQ7OJ6-9KpuXbDYE1hKbh4Nmz_-FVUOkr4vYVkXiT2wFML8OBldPzFH_zxC-w53KwBTFk3ex_PBE-rpWzm6s_UASSrTQQ1cMpaOPRTIlExIYZeBrkrBxvEKc4j3SSt-beXaSEku6fbDTcU1P70aaEVTeohp6H6x2pUz7K31XRGHq_21PM_gt9VsIGe_IAkABKcH7IGtS1pdg

Kollannoor-Samuel, G., Chhabra, J., Fernandez, M. L., Vega-López, S., Pérez, S. S., Damio, G., . . . Pérez-Escamilla, R. (2011). Determinants of fasting plasma glucose and glycosylated hemoglobin among low income Latinos with poorly controlled type 2 diabetes. *J Immigr Minor Health, 13*(5), 809-817. doi:10.1007/s10903-010-9428-3

Lee, J. S., & Frongillo, E. A., Jr. (2001). Nutritional and Health Consequences Are Associated with Food Insecurity among U.S. Elderly Persons. *The Journal of Nutrition, 131*(5), 1503-1509. doi:10.1093/jn/131.5.1503

Leroux, J., Morrison, K., & Rosenberg, M. (2018). Prevalence and Predictors of Food Insecurity among Older People in Canada. *Int J Environ Res Public Health, 15*(11). doi:10.3390/ijerph15112511

Levis, B., Benedetti, A., & Thombs, B. D. (2019). Accuracy of Patient Health Questionnaire-9 (PHQ-9) for screening to detect major depression: individual participant data meta-analysis. *Bmj, 365*, l1476. doi:10.1136/bmj.l1476

Maiorino, M. I., Longo, M., Scappaticcio, L., Bellastella, G., Chiodini, P., Esposito, K., & Giugliano, D. (2021). Improvement of glycemic control and reduction of major cardiovascular events in 18 cardiovascular outcome trials: an updated meta-regression. *Cardiovasc Diabetol, 20*(1), 210. doi:10.1186/s12933-021-01401-8

McBean, A. M., Li, S., Gilbertson, D. T., & Collins, A. J. (2004). Differences in Diabetes Prevalence, Incidence, and Mortality Among the Elderly of Four Racial/Ethnic Groups: Whites, Blacks, Hispanics, and Asians. *Diabetes Care, 27*(10), 2317. doi:10.2337/diacare.27.10.2317

Monami, M., Candido, R., Pintaudi, B., Targher, G., & Mannucci, E. (2021). Improvement of glycemic control in type 2 diabetes: A systematic review and meta-analysis of randomized controlled trials. *Nutr Metab Cardiovasc Dis, 31*(9), 2539-2546. doi:10.1016/j.numecd.2021.05.010

Montgomery, J., Lu, J., Ratliff, S., & Mezuk, B. (2017). Food Insecurity and Depression Among Adults With Diabetes: Results From the National Health and Nutrition Examination Survey (NHANES). *The Diabetes educator*, *43*(3), 260-271. doi:10.1177/0145721717699890

Murillo, R., Reesor, L. M., Scott, C. W., & Hernandez, D. C. (2017). Food Insecurity and Pre-diabetes in Adults: Race/Ethnic and Sex Differences. *Am J Health Behav, 41*(4), 428-436. doi:10.5993/AJHB.41.4.7

National Diabetes Statistics Report 2020. (2020). Atlanta, GA

Nord, M. (2002). *Measuring children's food security in US households, 1995-99*: US Department of Agriculture, Economic Research Service.

Nouwen, A., Winkley, K., Twisk, J., Lloyd, C. E., Peyrot, M., Ismail, K., . . . European Depression in Diabetes Research, C. (2010). Type 2 diabetes mellitus as a risk factor for the onset of depression: a systematic review and meta-analysis. *Diabetologia, 53*(12), 2480-2486. doi:10.1007/s00125-010-1874-x

Ooi, T. C., Mat Ludin, A. F., Loke, S. C., Fiatarone Singh, M. A., Wong, T. W., Vytialingam, N., . . . Lew, L. C. (2021). A 16-Week Home-Based Progressive Resistance Tube Training Among Older Adults With Type-2 Diabetes Mellitus: Effect on Glycemic Control. *Gerontol Geriatr Med, 7*, 23337214211038789. doi:10.1177/23337214211038789

Osborn, C. Y., de Groot, M., & Wagner, J. A. (2013). Racial and ethnic disparities in diabetes complications in the northeastern United States: the role of socioeconomic status. *J Natl Med Assoc, 105*(1), 51-58. doi:10.1016/s0027-9684(15)30085-7

Ozieh, M. N., Garacci, E., Walker, R. J., Palatnik, A., & Egede, L. E. (2021). The cumulative impact of social determinants of health factors on mortality in adults with diabetes and chronic kidney disease. *BMC Nephrol, 22*(1), 76. doi:10.1186/s12882-021-02277-2

Patel, M. R. (2020). Social Determinants of Poor Management of Type 2 Diabetes Among the Insured. *Curr Diab Rep*, *20*(11), 67. doi:10.1007/s11892-020-01354-4

Peng, K., Chen, G., Liu, C., Mu, Y., Ye, Z., Shi, L., . . . Ning, G. (2018). Association between smoking and glycemic control in diabetic patients: Results from the Risk Evaluation of cAncers in Chinese diabeTic Individuals: A lONgitudinal (REACTION) study. *J Diabetes, 10*(5), 408-418. doi:10.1111/1753-0407.12625

Petersen, C. L., Brooks, J. M., Titus, A. J., Vasquez, E., & Batsis, J. A. (2019). Relationship Between Food Insecurity and Functional Limitations in Older Adults from 2005-2014 NHANES. *J Nutr Gerontol Geriatr*, *38*(3), 231-246. doi:10.1080/21551197.2019.1617219

Rhee, T. G., Marottoli, R. A., Cooney, L. M., Jr., & Fortinsky, R. H. (2020). Associations of Social and Behavioral Determinants of Health Index with Self-Rated Health, Functional

Limitations, and Health Services Use in Older Adults. *J Am Geriatr Soc, 68*(8), 1731-1738. doi:10.1111/jgs.16429
Richardson, L. K., Egede, L. E., Mueller, M., Echols, C. L., & Gebregziabher, M. (2008). Longitudinal effects of depression on glycemic control in veterans with Type 2 diabetes. *Gen Hosp Psychiatry, 30*(6), 509-514. doi:10.1016/j.genhosppsych.2008.07.001
Robbins, J. M., Vaccarino, V., Zhang, H., & Kasl, S. V. (2001). Socioeconomic status and type 2 diabetes in African American and non-Hispanic white women and men: evidence from the Third National Health and Nutrition Examination Survey. *American journal of public health, 91*(1), 76-83. doi:10.2105/ajph.91.1.76
ROSENBAUM, D., & NEUBERGER, Z. (2020). President's 2021 Budget Would Cut Food Assistance for Millions and Radically Restructure SNAP. Retrieved from https://www.cbpp.org/research/food-assistance/presidents-2021-budget-would-cut-food-assistance-for-millions-and
Schroeder, E. B., Zeng, C., Sterrett, A. T., Kimpo, T. K., Paolino, A. R., & Steiner, J. F. (2019). The longitudinal relationship between food insecurity in older adults with diabetes and emergency department visits, hospitalizations, hemoglobin A1c, and medication adherence. *J Diabetes Complications, 33*(4), 289-295. doi:10.1016/j.jdiacomp.2018.11.011
Seligman, H. K., Bindman, A. B., Vittinghoff, E., Kanaya, A. M., & Kushel, M. B. (2007). Food insecurity is associated with diabetes mellitus: results from the National Health Examination and Nutrition Examination Survey (NHANES) 1999-2002. *J Gen Intern Med, 22*(7), 1018-1023. doi:10.1007/s11606-007-0192-6
Shaheen, M., Kibe, L. W., & Schrode, K. M. (2021). Dietary quality, food security and glycemic control among adults with diabetes. *Clin Nutr ESPEN, 46*, 336-342. doi:10.1016/j.clnesp.2021.09.735
Silverman, J., Krieger, J., Kiefer, M., Hebert, P., Robinson, J., & Nelson, K. (2015). The Relationship Between Food Insecurity and Depression, Diabetes Distress and Medication Adherence Among Low-Income Patients with Poorly-Controlled Diabetes. *J Gen Intern Med, 30*(10), 1476-1480. doi:10.1007/s11606-015-3351-1
Strings, S., Ranchod, Y. K., Laraia, B., & Nuru-Jeter, A. (2016). Race and Sex Differences in the Association between Food Insecurity and Type 2 Diabetes. *Ethn Dis, 26*(3), 427-434. doi:10.18865/ed.26.3.427
Su, J., Qin, Y., Shen, C., Gao, Y., Pan, E. C., Pan, X. Q., . . . Wu, M. (2017). [Association between smoking/smoking cessation and glycemic control in male patients with type 2 diabetes]. *Zhonghua Liu Xing Bing Xue Za Zhi, 38*(11), 1454-1459. doi:10.3760/cma.j.issn.0254-6450.2017.11.003
Tang, O., Matsushita, K., Coresh, J., Sharrett, A. R., McEvoy, J. W., Windham, B. G., . . . Selvin, E. (2020). Mortality Implications of Prediabetes and Diabetes in Older Adults. *Diabetes Care, 43*(2), 382-388. doi:10.2337/dc19-1221
Tian, J., Ohkuma, T., Cooper, M., Harrap, S., Mancia, G., Poulter, N., . . . Chalmers, J. (2020). Effects of Intensive Glycemic Control on Clinical Outcomes Among Patients With Type 2 Diabetes With Different Levels of Cardiovascular Risk and Hemoglobin A(1c) in the ADVANCE Trial. *Diabetes Care, 43*(6), 1293-1299. doi:10.2337/dc19-1817
Trief, P. M., Himes, C. L., Orendorff, R., & Weinstock, R. S. (2001). The marital relationship and psychosocial adaptation and glycemic control of individuals with diabetes. *Diabetes Care, 24*(8), 1384-1389. doi:10.2337/diacare.24.8.1384
Walker, R. J., Campbell, J. A., & Egede, L. E. (2019). Differential Impact of Food Insecurity, Distress, and Stress on Self-care Behaviors and Glycemic Control Using Path Analysis. *Journal of General Internal Medicine, 34*(12), 2779-2785. doi:10.1007/s11606-019-05427-3
Walker, R. J., Garacci, E., Ozieh, M., & Egede, L. E. (2021). Food insecurity and glycemic control in individuals with diagnosed and undiagnosed diabetes in the United States. *Prim Care Diabetes*. doi:10.1016/j.pcd.2021.05.003

Walker, R. J., Garacci, E., Palatnik, A., Ozieh, M. N., & Egede, L. E. (2020). The Longitudinal Influence of Social Determinants of Health on Glycemic Control in Elderly Adults With Diabetes. *Diabetes Care, 43*(4), 759. doi:10.2337/dc19-1586

Walker, R. J., Knapp, R. G., Dismuke-Greer, C. E., Walker, R. E., Ozieh, M. N., & Egede, L. E. (2020). Lowering the impact of food insecurity in African American adults with type 2 diabetes mellitus (LIFT-DM) - Study protocol for a randomized controlled trial. *Contemp Clin Trials*, *99*, 106206. doi:10.1016/j.cct.2020.106206

Walker, R. J., Smalls, B. L., Campbell, J. A., Strom Williams, J. L., & Egede, L. E. (2014). Impact of social determinants of health on outcomes for type 2 diabetes: a systematic review. *Endocrine*, *47*(1), 29-48. doi:10.1007/s12020-014-0195-0

Walker, R. J., Williams, J. S., & Egede, L. E. (2018). Pathways between food insecurity and glycaemic control in individuals with type 2 diabetes. *Public Health Nutr*, *21*(17), 3237-3244. doi:10.1017/s1368980018001908

Weir, C. B., & Jan, A. (2022). BMI Classification Percentile And Cut Off Points. In *StatPearls*. Treasure Island (FL): StatPearls Publishing
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WHO. Social Determinants of Health. Retrieved from https://www.who.int/teams/social-determinants-of-health

Wong, J. C., Scott, T., Wilde, P., Li, Y. G., Tucker, K. L., & Gao, X. (2016). Food Insecurity Is Associated with Subsequent Cognitive Decline in the Boston Puerto Rican Health Study. *J Nutr*, *146*(9), 1740-1745. doi:10.3945/jn.115.228700

Yao, W.-Y., Han, M.-G., De Vito, G., Fang, H., Xia, Q., Chen, Y., . . . Xu, W.-H. (2021). Physical Activity and Glycemic Control Status in Chinese Patients with Type 2 Diabetes: A Secondary Analysis of a Randomized Controlled Trial. *International Journal of Environmental Research and Public Health*, *18*(8), 4292. doi:10.3390/ijerph18084292

Ziliak, J., & Gundersen, C. (2020). The State of Senior Hunger in America 2018: An Annual Report. *Feeding America*, 25.

Appendix A: Descriptive Tables

Table 1. Baseline Characteristics of Individuals with Diabetes 65 Years and Older in NHANES Waves 2009-2016 by Food Security Status

Variables	Total	Food Secure	Low Food Security	p-value
N (weighted %)	1326 (100)	1097(88.0)	229 (12.0)	
Non-Hispanic White N (%)	617 (68.3)	553 (78.4)	64 (50.7)	<0.0001
Non-Hispanic Black N (%)	330 (13.2)	273 (11.8)	57 (20.4)	0.0003
Hispanic/Latino N (%)	379 (18.4)	271 (9.8)	108 (28.9)	<0.0001
Poor Glycemic Control N (%)	568 (39.6)	452 (38.3)	116 (49.3)	0.0152
Demographics				
Female N (%)	630 (49.3)	496 (50.3)	134 (47.7)	.4983
Age years, Mean (SE)	72.8 (0.2)	72.8 (0.16)	72.3(0.33)	0.27
Education, Some College+ N (%) m=5	484 (48.4)	434 (51.0)	50 (28.7)	<0.0001
Marital Status, Single N (%)	603 (39.7)	482 (38.0)	121 (52.4)	0.0012
Income <45k N (%) m=101	866 (61.5)	268 (57.5)	39 (91.4)	<0.0001
Covered by Health Insurance N (%) m=6	1274(97.8)	1058(98.0)	216 (96.8)	0.2655
Behavioral Factors				
Smoker N (%) m=2	729 (55.9)	610 (56.2)	119 (54.2)	0.6626
Moderate to Vigorous Physical Activity N (%)	324 (29.9)	267 (29.9)	57 (30.0)	0.9729
Biomedical Factors				
Taking Oral Medication N (%) m = 114	1017(85.1)	836 (85.1)	181 (85.5)	0.9091
Obesity N (%) m=37	702 (56.6)	570 (53.6)	132 (61.4)	0.2604
Elevated Depression Score N (%)	136 (8.9)	94 (7.5)	42 (19.1)	<0.0001
Self-Rated Health Fair/Poor N% m=64	538 (32.6)	411 (29.4)	127 (55.6)	<0.0001
Overnight Hospital Stay Last 12 Mo N (%) m=1	326 (22.9)	262 (22.6)	64 (25.5)	0.4231

Table 2. Baseline Characteristics of Individuals with Diabetes 65 Years and Older in NHANES Waves 2009-2016 by Race/Ethnicity

Variables	Total	NHW	NHB	p-value NHW v NHB	Hispanic	p-value NHW v Hispanic
N (weighted %)	1326 (100)	617 (68.3)	330 (13.2)		379 (18.4)	
Low Food Security N (%)	229 (12.0)	64 (8.1)	57 (19.1)	<0.0001	108 (28.6)	<0.0001
Poor Glycemic Control N (%)	520 (35.8)	223 (33.9)	122 (37.4)	0.327	175 (45.9)	0.0006
Social Determinants/Demographics						
Female N (%)	630 (49.3)	271 (47.0)	171 (58.0)	0.0027	200 (54.9)	0.0282
Age years, Mean (SE)	72.8 (0.2)	72.9 (0.3)	72.8 (0.3)	0.8981	72.0 (0.3)	0.0625
Education Some College+ N (%) m=5	484 (48.4)	297 (55.6)	112 (34.1)	<0.0001	75 (18.6)	<0.0001
Marital Status Single N (%)	603 (39.7)	251 (35.9)	183 (58.3)	<0.0001	169 (43.9)	0.0216
Income >45k N (%) m=101	359 (38.6)	199 (43.1)	84 (27.0)	<0.0001	76 (20.8)	<0.0001
Covered by Health Insurance N (%) m=3	1277(96.3)	608 (98.8)	324 (97.8)	0.4073	345 (91.0)	<0.0001
Behavioral Factors						
Smoker N (%) m=2	729 (55.9)	360 (57.3)	192 (56.9)	0.9551	177 (46.6)	0.0003
Moderate to Vigorous Physical Activity N (%)	324 (29.9)	187 (33.3)	72 (22.0)	0.0052	65 (16.9)	<0.0001
Biomedical Factors						
Taking Oral Medication N (%) m=114	1017(85.1)	468 (85.0)	261 (86.2)	0.6422	288 (84.9)	0.979
Obesity N (%) m=37	702 (56.6)	331 (55.3)	188 (58.2)	<0.0001	183 (49.9)	<0.0001
Elevated Depression Score N (%)	136 (8.9)	54 (8.9)	28 (9.2)	0.6193	54 (13.7)	0.0126
Self-Rated Health Fair/Poor N (%) m=63	538 (32.6)	187 (26.5)	132 (42.8)	<0.0001	219 (59.8)	<0.0001
Overnight Hospital Stay Last 12 Mo N (%) m=1	326 (22.9)	155 (22.3)	76 (24.3)	0.5693	95 (24.6)	0.4174

Note: m=missing values

Appendix B: Bivariate and Multivariate Logistic Regression Analysis

Table 1. Bivariate Logistic Regressions as Related to Glycemic Control

Variable	p-value	Odds Ratio	95% CI	N
Race- Hispanic/Latino	0.0012	0.653	0.508, 0.840	1326
Food Security-Low	0.0093	0.640	0.459, 0.892	1326
SDOH/Demographics				
Gender-Female	0.1146	1.191	0.957, 1.480	1326
Insurance-No	0.7112	0.737	0.313, 1.735	1323
Age	0.3836	1.013	0.983, 1.044	1326
Education-Some College+	0.1434	1.254	0.924, 1.702	1321
Marital Status-Single	0.2858	1.188	0.863, 1.637	1326
Income->45,000	0.8413	0.969	0.706, 1.329	1225
Behavioral Factors				
Smoker-Yes	0.9833	0.997	.750, 1.325	1324
Physical Activity-Moderate/Vigorous	0.0096	1.535	1.114, 2.116	1326
Biomedical Factors				
Oral Medication-Yes	<0.0001	3.282	2.225,4.840	1212
Obesity-Yes	0.1936	0.823	0.613, 1.107	1326
Depression-Elevated	0.8399	0.957	0.619, 1.478	1326
Self-Rated Health-Poor/Fair	0.1032	0.734	0.519, 1.064	1263
Overnight Hospital Stay- Yes	0.365	0.848	0.591,1.217	1326

Table 2. Effects of Food Security and Race on Glycemic Control: Multivariate Logistic Regression Analysis

	OR (95% CI)			
Variable	Model 1	Model 2	Model 3	Model 4
Food Security - low	0.684 (0.481,0.974)*	0.716 (0.491,1.043)*	0.675 (0.473,0.962)*	0.643 (0.440,0.940)*
Race-Hispanic/Latino	0.701 (0.537,0.917)*	0.759 (0.587,0.981)*	0.744 (0.578,0.957)*	0.856 (0.628,1.166)
Age		1.011 (0.979,1.043)		
Education-Some College+		1.242 (0.898,1.718)		
Income-		1.067 (0.749,1.520)		
Marital Status-Single		0.807 (0.579,1.124)		
Gender-Female		1.189 (0.926,1.528)		
Physical Activity-Moderate to Vigorous			1.509 (1.094,2.081)*	1.626 (1.139,2.322)**
Smoking Status-Yes			0.978 (0.736,1.300)	
Self-Rated Health-Fair/Poor				1.236 (0.829,1.842)
Depression-Elevated				1.195 (0.752,1.900)
Medication				3.345 (2.263,4.946)***

*p<0.05 **p<0.01 ***p<0.001