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Dietary quality, food security and glycemic control among adults with diabetes

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Abstract

Background and Aims: Nutritionally adequate diets can slow the progression of diabetes, but adherence to recommended dietary choices can be hindered by food insecurity. We examined the relationship between dietary quality, food insecurity, and glycemic control among adults with Type 2 Diabetes.

Methods: We analyzed data from the National Health and Nutrition Examination Survey (2011–2016) for 1,682 adults =>20 years old with Type 2 diabetes. Glycemic control was measured by HbA1c. Dietary quality was computed using the Healthy Eating Index 2015 score. Food security was assessed by a questionnaire. We analyzed the data using multinomial regression models.

Results: About 16% of the population had an HbA1c ≥9; 31.8% had food insecurity; 68.3% consumed a poor quality diet. About 24% consumed a poor quality diet and had food insecurity. In the multinomial model, an HbA1c of 8-<9% was associated with poor diet quality (adjusted odds ratio (AOR)=5.2, 95% confidence interval (CI)=1.4–19.2, p=0.01) and food insecurity (AOR=8.5, 95% CI=1.4–52.0, p=0.02). Those with both factors had higher odds of both an HbA1c 8-<9% (AOR=6.1, 95% CI=1.5–24.8, p=0.01) and HbA1c ≥9% (AOR=6.7, 95% CI=2.0–22.2, p<0.01). Other risk factors for poor glycemic control were being Black or Hispanic, having no regular source of care, and ever having visited a diabetes specialist (p<0.05).

Conclusions: Poor glycemic control among adults with diabetes was associated with poor quality of diet and/or food insecurity, being Black, Hispanic, and lacking a regular source of care.

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Data Statement The data used in this study are publically available at https://www.cdc.gov/nchs/nhanes.

There is a need for policies that improve access to healthy food in patients with type 2 diabetes, particularly among minority populations.

Keywords

food insecurity; diet quality; NHANES; type 2 diabetes

Introduction

Over 34 million (13%) American adults are living with diabetes mellitus [1]. In 2017, the direct and indirect healthcare cost burden of diabetes increased to $327 billion from $188 billion in 2012 [1]. When patients are unable to manage the disease, diabetes can lead to complications and death. Patients with poorly-controlled blood glucose levels are more likely to have cardiovascular risk factors such as obesity, hypertension, stroke and heart disease [1, 2]. There is compelling evidence that higher dietary quality can improve these cardiovascular disease factors thus reducing the morbidity, mortality and healthcare costs related to diabetes [3–6].

Among other lifestyle factors, dietary management is one of cornerstones of diabetes treatment. Nutritionally adequate diets can slow the progression of diabetes [7–9]. The American Diabetes Association recommends healthful eating patterns composed of a variety of nutrient-dense foods to help maintain appropriate glycemic control and prevent or delay diabetes-related outcomes [2].

Despite the well-known phenomenon that a good quality diet is important for diabetes management, the dietary quality of patients with diabetes has remained sub-optimal over the past few decades [10–12]. While the explanation for this incongruity are multifactorial, optimal access to quality foods has surfaced as an important *and solvable reason*. Food insecurity - the limited or uncertain availability, or ability to reliably afford safe and nutritionally adequate food- can hinder recommended dietary choices [10]. Several studies have demonstrated that patients with diabetes who have food insecurity are more likely to have poor glycemic control, compared to patients with food security [13, 14]. During the COVID-19 pandemic, the prevalence of food insecurity doubled via multiple pathways including financial constraints, quarantine requirements, and reduced social support, and availability [15–17]. This is important because both diabetes and poor dietary quality are risk factors for COVID-19 infections and death.

Our objective was to examine the relationship between dietary quality and glycemic control and whether this association is modified by food insecurity among adults living with Type 2 Diabetes in the US population.

Materials and Methods:

We analyzed data from the National Health and Nutrition Examination Survey (NHANES) years 2011–2016 for 1,526 adults =>20 years old with Type 2 diabetes. NHANES is a cross-sectional survey conducted by the National Center of Health Statistics (NCHS) of the Center of Disease Control and Prevention (CDC). Using the multistage cluster sample, they collected questionnaire, examination, food intake, and laboratory data from a representative sample of the US non-institutionalized population. Our analysis included only those with type 2 Diabetes. Type 2 diabetes was determined through a series of questions. Individuals that answered yes to the question “other than during pregnancy, have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes?”, or had an HbA1c that was ≥6.5% were determined to have diabetes. Persons who indicated that they were diagnosed by the age of 20 were excluded from the Type 2 diabetes population and presumed to have type 1 diabetes.

The outcome variable, control of diabetes, was categorized using HbA1c values into the following groups <7%, 7%-<8%, 8% -<9%, and =>9%, using cutoffs that have been used previously [18].

The main independent variable was diet quality, based on the Healthy Eating Index score 2015 (HEI-2015). This index takes the NHANES food intake module that includes data on two days of 24-hour dietary recall and scores the quality of diet based on the recommendations of the Dietary Guidelines for Americans. Although there have been several iterations of the HEI, the HEI-2015 is the most recent and is based on the 2015–2020 Dietary Guidelines for Americans. The HEI-2015 considers intake of total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids, refined grains, sodium, added sugars, and saturated fats. The score was classified as (poor=0-<60, needs improvement=60-<80, good=80–100), and is henceforth referred to as the HEI [19].

We considered the role of food security as a potential effect modifier. We estimated the level of food security for the participant by the adult household food security score. While this household measure does not necessarily exactly represent the experience of the individual, food insecurity is expected to affect all adults in the household [20]. This score was determined by asking the participant a series of 10 questions relating to food security (response yes=1, no=0) [20] and summing the scores of the 10 questions (range from 0 to 10). Based on the total score, NHANES categorized participants into four main groups: full security (score=0), marginal security (score=1–2), low security (score=3–5), and very low security (score=6–10). In the analysis, we categorized full security as food secure (score=0), and all other groups as food insecure (score=1–10) [21].

To determine the participant’s level of diabetes treatment, the following questions were asked: 1) “When was the last time you saw a diabetes nurse educator or dietitian or nutritionist?” We categorized the responses into binary categories of Ever and Never; 2) “Are you now taking diabetic pills to lower your blood sugar? These are sometimes called oral agents or oral hypoglycemic agents” 3) “Are you now taking insulin?” Based on these last two questions, we classified participants as taking any kind of medical treatment for diabetes or not.

We categorized age in years into 20–39, 40–59, and 60–85 years old. Gender was measured using questionnaire as male and female. Race/ethnicity was measured by self-report and categorized as non-Hispanic White, Hispanic, non-Hispanic Black, and others. Education level was measured by questionnaire and reported as less than high school, high school, and more than high school. The relationship status was measured by self-report question and reported as single or in a partnered relationship. Federal poverty level ratio was classified as <1, 1–2, and >2.

Smoking status was classified into never smoker, former smoker (quit at least 2 months ago), and current smokers. Alcohol intake (average number of drinks per day) was classified into never, less than one per day, about one per day, and more than one per day. Obesity was assessed using body mass index (BMI) and we classify participants as normal (BMI <25), overweight (BMI=25-<30) and obese (BMI 30 and above).

Level of physical activity was determined using the guidelines declared by NHANES. NHANES asks about engagement in moderate work-related activity, walking or bicycling for transportation, vigorous leisure-time physical activity, and moderate leisure-time physical activity. People who responded that they engaged in any of these activities were considered active, while those who did not engage in any activities were classified as inactive [22].

Access to healthcare was determined by asking the participants “are you covered by health insurance or some other kind of health care plan?” To determine where the participants seek health care, they were asked “What kind of place do you go to most often - a clinic, doctor’s office, emergency room, or some other place?”

Comorbidities were determined by asking individuals if a doctor has ever diagnosed them with hypertension, kidney disease, liver disease, and heart disease. The participant was considered to have the comorbid condition if they responded “Yes.” A depression score was calculated from responses to the Patient Health Questionnaire (PHQ9) [23]. Those with a score of 5 or greater were considered to have depressive symptoms. We calculated the number of comorbid conditions by summing the number of self-reported comorbid conditions, including depression.

Data Analysis:

We analyzed the data using descriptive statistics to depict the population characteristics and we presented the data as unweighted number and weighted percent. We used Chi square tests to examine the difference in the diabetes control status by the independent variables. We used multinomial logistic regression models to examine the association between HEI and food security and glycemic control, controlling for demographic variables, alcohol consumption, smoking status, diabetes treatment, physical activity, utilizing diabetes care, insurance status, having regular source of care, and number of chronic conditions. In addition, we examined whether the relationship between HEI and glycemic control was modified by food security by including the interaction of HEI and food security in the model. We presented the data as adjusted odds ratio (AOR) and 95% confidence interval (CI). We estimated the adjusted probability and 95% CI of the diabetes control status among the HEI and food security groups with good food quality and food secure as the reference group. A p-value of <0.05 was considered statistically significant. We used SAS version 9.4 in the analysis, taking into consideration the design and the sample weights provided by the

NCHS to correct for differential selection probabilities and to adjust for non-coverage and non-response.

Results

Population characteristics

Table 1 shows the population characteristics for the sample of 1,682 adult participants with type 2 diabetes. Of the participants, 52.0% had an HbA1c <7% and 15.5% had an HbA1c ≥9%; 31.8% had food insecurity; 68.3% consumed a poor-quality diet. About 24% consumed a poor-quality diet and had food insecurity. The sample was older, with 49.7% being 60–85 years old and 41.8% being 40–59 years old. Most participants (55.2%) had some education beyond high school and the majority (58.3%) had incomes at least twice the national poverty level. About 2% regularly use the ER for healthcare and 6% reported not having a regular source of care. Most (58.8%) had seen a diabetes specialist at some point, and 72.5% reported taking diabetic pills or insulin.

Approximately 35.9% reported never engaging in any physical activity, and most of the sample were obese (64.5%). Almost half did not consume alcohol (47.0%) and only 7.2% reported consuming an average of more than a drink per day. About thirty-five percent were current smokers, and another 17.3% were former smokers.

While our sample was predominantly non-Hispanic White, the group with an HbA1c ≥9% had the largest proportions of individuals who were non-Hispanic Black (17.9%) and Hispanic (26.8%) (p<0.001). The majority of those with an HbA1c <7% or 7-<8% were 60–85 years old (52.9% and 59.9%, respectively) while those with an HbA1c ≥9% had the largest proportion (11.8%) of the youngest age group (p<0.001). Of those with an HbA1c <7%, 59.7% were in the highest poverty ratio (>2) group, while 26.2% of those with an HbA1c ≥9% were in the lowest poverty ratio group (<1) (p=0.021). Twenty two and a half percent of those with an HbA1c ≥9% were uninsured compared to 12.9% of those with an HbA1c <7% (p<0.001). Of those with an HbA1c ≥9%, around 15% reported having no regular source of health care, compared to 6% or less of the other glycemic control groups (p<0.001). People with an HbA1c 7-<9% were more likely to be taking diabetes medication than those with HbA1c <7% or ≥9% (p=0.003). Among those with an HbA1c < 7%, 20.8% had food insecurity and a poor diet, compared to 37.7% of those with an HbA1c ≥9% (p<0.001).

Multivariable analysis:

The multinomial logistic model indicates the likelihood of having an HbA1c ≥7% compared to the likelihood of having an HbA1c <7%. We first ran the model without including the interaction between diet quality and food security (data not shown). Poor diet quality was associated with a greater odds of having HbA1c >=9 relative to having HbA1c <7 (adjusted odds ratio (AOR)=4.50, 95% confidence interval (CI)=1.76–11.50, p=0.002). It was not significantly associated with any other level of glycemic control, and having a diet quality that needs improvement was not significantly associated with any level of glycemic control. Food insecurity was not significantly associated with any level of glycemic control.

When we included the interaction between food security and diet quality in the model, HbA1c 8 -<9 was associated with poor diet quality and food insecurity (p<0.05), and the interaction was statistically significant (p<0.05) (Table 2). Consuming a poor quality diet relative to a good quality diet increased the likelihood of being in the group with an HbA1c 8-<9% (AOR=5.18, 95% CI=1.40–19.2, p=0.01) rather than the group with HbA1c <7%. Relative to those with food security, those with food insecurity were over eight times more likely to have HbA1c 8-<9% than to have an HbA1c <7% (AOR=8.51, 95% CI=1.39–52.0, p=0.02).

The results of the multinomial logistic regression also indicate that those with poor diet quality and those with food insecurity had higher odds to be in the group with HbA1c >=9% than to be in the group with HbA1c <7% (Table 2; AOR=4.32, 95% CI=1.39–13.4, p=0.01). The interaction between food security and diet quality was statistically significant for the group with HbA1c 8-<9% (needs improvement: AOR=0.12, 95% CI=0.02–0.81, p=0.03; poor diet: AOR=0.14, 95% CI=0.02–0.84, p=0.03), indicating that the association of diet quality and glycemic control differed between those with food security and those without food security.

Table 3 shows the adjusted predicted probability for each interaction group relative to the good food quality/food secure group. Relative to those with a good diet quality and food security, those with a good diet and food insecurity were more likely to have HbA1c 8-<9% than to have an HbA1c <7% (AOR=8.51, 95% CI= 1.39 – 52.0, p=0.02). Those with a poor diet were more likely to have an HbA1c of 8-<9% than <7%, regardless of whether they had food security (AOR=5.18, 95% CI= 1.40 – 19.2, p=0.01) or insecurity (AOR=6.12, 95% CI =1.51–24.8, p=0.01). Similarly, those with a poor diet were more likely to have an HbA1c of ≥9% than <7%, regardless of food security level (secure: AOR=4.32, 95% CI= 1.39 – 13.4, p=0.01; insecure: AOR=6.73, 95% CI= 2.04 −22.2, p=0.002).

Other risk factors for having an HbA1c ≥9% (Table 2) were being Black (AOR=1.7, 95% CI=1.1–3.7, p=0.017) or Hispanic (AOR=3.0, 95% CI=2.0–4.5, p<0.01, having no regular source of care (AOR=3.2, 95% CI=1.7–6.1, p<0.01), and ever having seen a diabetes specialist (AOR=2.2, 95% CI=1.5–3.3,p<0.01).

Discussion

Diet quality is an important factor in diabetes control and outcomes. We found that poor diet quality was associated with poor glycemic control among adults living with type 2 diabetes in the US. In addition, food insecurity modified the relationship between poor glycemic control and poor dietary quality. Those who ate a poor diet and had food insecurity had significantly higher odds of having poor glycemic control ([AOR=6.12 for HbA1c=8-<9% and AOR=6.7 for HbA1c =>9%), while those who ate a poor diet but had food security did not. We also found that lack of access to health care (AOR=2.04) was associated with HbA1c 8-<9%. In addition, minority status (Black [AOR=1.71] and Hispanic [AOR=2.95]) were associated with poor glycemic control (HbA1c=>9%).

Overall, 15.5% of participants had an HbA1c of >9%. This is similar to estimates of 12.9% from a previous study using NHANES 2007–2010 data [24] and the CDC's estimate of 14.6% for the years 2013–2016 [1]. These previous estimates are among those diagnosed with type 2 diabetes, while our data included those that did not have a formal diagnosis but had a high HbA1c, which may explain why our prevalence estimate is slightly higher.

Most participants (68.3%) had a poor quality diet. While average diet quality in participants with diabetes improved slightly between 1999 and 2014, the average HEI score in 2014 was still only 52.4, which we classified as a poor diet [10]. The average HEI score for all adults in 2013–2014 was 59 [19], suggesting that participants with diabetes tend to have a slightly poorer diet than the general public. In the multinomial model, poor diet quality was associated with poorer glycemic control, consistent with previous literature [8, 25].

We also reported a high level (32%) of food insecurity among participants compared to the national prevalence of food insecurity (10.5% in 2019)[26]. In NHANES 1999–2008 data, 12% of participants with diabetes reported food insecurity [27], with the proportion increasing to around 30% in the 2011–2012 cycle [28], consistent with our estimate. The prevalence of poor quality diets was higher in those who with food insecurity compared to those with food security. Others have also reported that diet quality suffers in patients with diabetes who have food insecurity [29]. In the multinomial model, food insecurity was associated with an HbA1c 8-<9% relative to <7%. The significant food security x HEI (needs improvement) interaction term for the HbA1c 8-<9% outcome indicated that the negative association between poorer diet quality and glycemic control was smaller in those with food insecurity compared to those with food security. This could indicate that having food insecurity impacts glycemic control so strongly that variation in diet quality does not have much additional impact. However, the simple effect of diet quality in those with food insecurity was larger than that in those without food security. Few previous studies have investigated the impact of the interaction between food security and diet quality on glycemic control. In a longitudinal study of Puerto Rican patients with diabetes in Boston, improvements in dietary quality were associated with improvements in HbA1c in those with food security, but not those without [25]. This result is consistent with our results, although we saw associations between diet quality and glycemic control independent of food security status.

It is well established that there are persistent racial disparities in the prevalence of diabetes, with non-Hispanic Black, Hispanic, and native individuals having the highest rates [30]. Racial minority populations also have much lower rates of glycemic control and higher rates of mortality [30, 31]. Our results support this previous literature. Factors that contribute to these disparities include behavioral factors, as well as life stressors including socioeconomic status, early life trauma, mental health, access to care, and racism [30].

While those not having a regular source of care were a small proportion of our sample, (6%), they were much more likely to have HbA1c >9%. A previous study based on older NHANES III data similarly showed that participants with diabetes with a regular source of care were more likely to have HbA1c <=7 than those without [32]. Patients with diabetes who receive regular care are less likely to be hospitalized compared to those who do not see a healthcare provider or see one infrequently [33], likely due to complications associated with poor diabetes management. Factors that may present barriers to regular care include discrimination and poor quality of care, language barriers, and location [30].

The finding regarding low education level is unusual, as most studies find that low socioeconomic status is associated with decreased glycemic control [30]. Being partnered increased the odds of having an HbA1c 7-<8% relative to <7%. Marriage is typically associated with better mental and physical health [34]; however, even though marriage quality has been associated with better diabetes outcomes, it was not significantly associated with glycemic control [35].

Participants who had seen a diabetes specialist had a higher odds of having an HbA1c ≥9% than an HbA1c <7%. This is likely because patients tend to be referred to a diabetes specialist when their glycemic control is not good, which may explain why glycemic control was poorer in NHANES participants who had seen a diabetes specialist [36]. Others have found the opposite relationship in patients with type 1 diabetes, but only among patients with an annual income >$20,000 [37], suggesting that the impact of diabetes specialist differs by socioeconomic status.

Strengths

We analyzed the data from multiple years of the large national representative sample of the non-institutionalized population of US. Rather than focusing on either diet quality or food security, our investigation included both of these factors, as well as their interaction. This is important because these two factors can be intertwined.

Limitations

The limitations of our study are that NHANES is a cross-sectional design, so we cannot make causal inference and are only able to determine associations. Additionally, some variables were collected by self-report, so these estimates are possibly prone to some recall bias. Limited small sample size in some of the combined variable and in the sub-analysis is another limitation. Although we adjusted for major confounding variables, it is possible that other unknown confounders could account for the associations found.

Policy implications and impact on practice

People who experience food insecurity often rely on service programs like the Supplemental Nutrition Assistance Program (SNAP) and food banks, which can limit food options. However, a small number of participants who had food insecurity did report having a good quality diet. Culturally sensitive and linguistically appropriate interventions that involve healthcare providers and community partnerships are needed to increase awareness about nutritionally healthy diets among the people with diabetes in the US. Diet quality can be improved through increased food security by interventions such as client-choice pantries and incentive programs in conjunction with opening grocery stores in underserved communities [38–40], although evidence has shown that increased spatial access to grocery stores alone may not improve quality of diet [38, 41–43]. In addition to dietary education, health care providers should be part of advocacy solutions to increase access to healthy food options in their communities, particularly among minority populations. Policy changes at the individual, community, and system levels are needed to increase access to healthy food in ways that go beyond merely increasing spatial access to healthy food.

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Abbreviations:

NHANES	National Health and Nutrition Examination Survey
HEI	Healthy Eating Index

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Table 1.

Characteristics of the overall population and by glycemic control

	Overall	HbA1c <7	HbA1c 7 - <8	HbA1c 8- <9	HbA1c >=9	
	n=1682 # (%)	**n=836 (52.0%) # (%)**	**n=364 (20.0%) # (%)**	**n=197 (12.5%) # (%)**	**n=285 (15.5%) # (%)**	**p-value**
Race/ethnicity						**<.0001**
Non-Hispanic White	567 (61.8)	297 (65.8)	128 (62.0)	73 (63.3)	69 (47.0)	
Hispanic	462 (15.4)	205 (12.4)	90 (14.1)	59 (15.7)	108 (26.8)	
Non-Hispanic Black	466 (14.7)	240 (14.2)	95 (14.3)	51 (13.5)	80 (17.9)	
Other	187 (8.1)	94 (7.5)	51 (9.6)	14 (7.5)	28 (8.4)	
Age						**<.0001**
18–39	129 (8.5)	59 (8.2)	22 (6.8)	14 (7.9)	34 (11.8)	
40–59	615 (41.8)	281 (38.9)	109 (33.3)	75 (45.3)	150 (59.7)	
60–85	938 (49.7)	496 (52.9)	233 (59.9)	108 (46.8)	101 (28.4)	
Sex						0.2790
Male	866 (51.5)	416 (48.6)	198 (55.7)	103 (54.9)	149 (53.0)	
Female	816 (48.5)	420 (51.4)	166 (44.3)	94 (45.1)	136 (47.0)	
Education level						0.7926
Less Than High School	483 (20.3)	236 (20.7)	100 (19.8)	54 (17.2)	93 (22.3)	
High school diploma (including GED)	394 (24.5)	193 (23.4)	78 (24.2)	50 (25.6)	73 (27.7)	
More Than High School	805 (55.2)	407 (55.9)	186 (56.0)	93 (57.2)	119 (50.0)	
Relationship status						0.2381
Single	661 (35.6)	342 (38.6)	134 (30.9)	72 (33.0)	113 (33.8)	
Partnered	1021 (64.4)	494 (61.4)	230 (69.1)	125 (67.0)	172 (66.2)	
Federal poverty level						**0.0215**
< 1	420 (18.1)	198 (17.8)	88 (16.9)	38 (11.1)	96 (26.2)	
1–2	494 (23.6)	246 (22.5)	102 (22.8)	63 (29.4)	83 (23.5)	
>2	768 (58.3)	392 (59.7)	174 (60.3)	96 (59.5)	106 (50.3)	
Has health insurance						**0.0002**
Yes	1426 (87.1)	727 (89.2)	323 (91.5)	170 (83.4)	206 (77.5)	
No	256 (12.9)	109 (10.8)	41 (8.5)	27 (16.6)	79 (22.5)	
Where go for health care						**<.0001**
doctor office	1532 (92.0)	776 (93.5)	338 (95.0)	181 (93.5)	237 (82.3)	

	Overall	HbA1c <7	HbA1c 7 - <8	HbA1c 8- <9	HbA1c >=9	
	n=1682 # (%)	n=836 (52.0%) # (%)	n=364 (20.0%) # (%)	n=197 (12.5%) # (%)	n=285 (15.5%) # (%)	p-value
ER	41 (1.8)	13 (1.1)	12 (2.3)	5 (1.9)	11 (3.3)	
no regular place	109 (6.2)	47 (5.5)	14 (2.7)	11 (4.7)	37 (14.5)	
Takes diabetes medication						**<.0001**
No	494 (27.5)	326 (35.9)	67 (15.6)	24 (12.7)	77 (26.4)	
Yes	1188 (72.5)	510 (64.1)	297 (84.4)	173 (87.3)	208 (73.6)	
Last time saw a diabetes specialist						**0.0024**
Never	729 (41.2)	418 (46.6)	157 (42.4)	59 (30.5)	95 (29.9)	
Ever	953 (58.8)	418 (53.4)	207 (57.6)	138 (69.5)	190 (70.1)	
Food security level						**0.0025**
full security	1043 (68.2)	541 (71.0)	234 (70.6)	121 (68.0)	147 (56.0)	
not food secure	639 (31.8)	295 (29.0)	130 (29.4)	76 (32.0)	138 (44.0)	
Healthy eating index						**0.0066**
Good diet	54 (3.0)	29 (3.8)	11 (3.0)	6 (1.6)	8 (1.3)	
Needs improvement	500 (28.7)	271 (32.0)	108 (28.8)	51 (23.9)	70 (21.5)	
Poor diet	1128 (68.3)	536 (64.2)	245 (68.1)	140 (74.5)	207 (77.2)	
Interaction of food security and healthy eating index						**0.0004**
full security and good diet	40 (2.5)	23 (3.3)	8 (2.4)	3 (0.8)	6 (1.0)	
not food secure and good diet	14 (0.5)	6 (0.5)	3 (0.6)	3 (0.8)	2 (0.3)	
Full security and diet need improvement	345 (21.8)	190 (24.3)	77 (22.3)	35 (18.0)	43 (15.5)	
Not food secure and diet need improvement	155 (7.0)	81 (7.7)	31 (6.6)	16 (5.8)	27 (6.0)	
full security and poor diet	658 (44.0)	328 (43.4)	149 (45.9)	83 (49.2)	98 (39.6)	
not food secure and poor diet	470 (24.3)	208 (20.8)	96 (22.3)	57 (25.4)	109 (37.7)	
Physical activity						0.1647
Active	1075 (64.1)	543 (67.5)	225 (61.4)	124 (58.4)	183 (60.7)	
Inactive	607 (35.9)	293 (32.5)	139 (38.6)	73 (41.6)	102 (39.3)	
Alcohol consumption (mean # of drinks/day)						0.5711
Never	896 (47.0)	449 (46.2)	196 (48.9)	106 (46.3)	145 (47.5)	
one or less than day	675 (45.9)	330 (45.9)	146 (44.8)	83 (50.4)	116 (43.3)	
more than one per day	111 (7.2)	57 (7.8)	22 (6.3)	8 (3.3)	24 (9.2)	
Smoking status						0.2753

	Overall	HbA1c <7	HbA1c 7 - <8	HbA1c 8- <9	HbA1c >=9	
	n=1682 # (%)	**n=836 (52.0%) # (%)**	**n=364 (20.0%) # (%)**	**n=197 (12.5%) # (%)**	**n=285 (15.5%) # (%)**	**p-value**
Never smoker	853 (48.1)	423 (47.9)	177 (43.6)	99 (49.8)	154 (53.5)	
former smoker (quit at least 2 months ago)	286 (17.3)	135 (16.0)	61 (17.5)	36 (19.3)	54 (19.8)	
current smoker	543 (34.6)	278 (36.1)	126 (38.9)	62 (30.9)	77 (26.8)	
BMI						0.1627
normal weight	209 (10.8)	110 (11.9)	44 (10.5)	21 (7.5)	34 (10.0)	
Overweight	453 (24.7)	242 (26.3)	98 (27.2)	49 (21.6)	64 (18.7)	
Obese	1020 (64.5)	484 (61.8)	222 (62.4)	127 (70.8)	187 (71.3)	
	mean ± std err	**mean ± std err**	**mean ± std err**	**mean ± std err**	**mean ± std err**	**p-value**
# chronic conditions	1.4 ± 0.03	1.4 ± 0.05	1.4 ± 0.07	1.3 ± 0.10	1.3 ± 0.07	**<.0001**

Table 2.

Adjusted multinomial regression for glycemic control (reference glycemic control: HbA1c <7%)

	HbA1c 7 - <8 N=364 (20.0%)		HbA1c 8- <9 N=197 (12.5%)		HbA1c >=9 N=285 (15.5%)	
	AOR	**p-value**	**AOR**	**p-value**	**AOR**	**p-value**
Food security level						
Full security	Reference		Reference		Reference	
Not food secure	2.03 [0.27 – 15.5]	0.493	**8.51 [1.39 – 52.0]**	**0.020**	1.73 [0.18 – 16.5]	0.632
Healthy eating index						
Good diet	Reference		Reference		Reference	
Needs improvement	1.51 [0.41 – 5.58]	0.534	3.80 [0.92 – 15.8]	0.066	3.09 [0.98 – 9.73]	0.054
Poor diet	1.64 [0.44 – 6.15]	0.462	**5.18 [1.40 – 19.2]**	**0.014**	**4.32 [1.39 – 13.4]**	**0.012**
Food security x healthy eating index interaction						
Full security x Good diet	Reference		Reference		Reference	
Not food secure x Needs improvement	0.48 [0.06 – 3.81]	0.487	**0.12 [0.02 – 0.81]**	**0.030**	0.47 [0.05 – 4.68]	0.518
Not food secure X Poor diet	0.55 [0.07 – 4.38]	0.572	**0.14 [0.02 – 0.84]**	**0.032**	0.90 [0.10 – 8.47]	0.926
Race/ethnicity						
Non-Hispanic White	Reference		Reference		Reference	
Hispanic	1.58 [1.00 – 2.50]	0.050	1.67 [0.97 – 2.86]	0.063	**2.95 [1.95 – 4.47]**	**<.001**
Non-Hispanic Black	1.33 [0.88 – 2.00]	0.177	1.11 [0.71 – 1.71]	0.654	**1.71 [1.10 – 2.65]**	**0.017**
Other	1.53 [0.86 – 2.72]	0.149	1.16 [0.50 – 2.72]	0.728	1.49 [0.86 – 2.59]	0.155
Age						
18–39	Reference		Reference		Reference	
40–59	0.88 [0.46 – 1.70]	0.713	1.23 [0.51 – 2.96]	0.647	1.28 [0.74 – 2.20]	0.374
60–85	1.08 [0.53 – 2.19]	0.842	]0.93 [0.34 – 2.55]	0.880	0.54 [0.28 – 1.02]	0.058
Sex						
Male	Reference		Reference		Reference	
Female	0.79 [0.54 – 1.13]	0.197	0.73 [0.50 – 1.06]	0.096	0.77 [0.47 – 1.28]	0.315
Education level						
Less Than High School	0.79 [0.47 – 1.31]	0.354	**0.60 [0.37 – 0.95]**	**0.030**	0.58 [0.27 – 1.26]	0.169
High School Diploma or equivalent	Reference		Reference		Reference	
More Than High School	0.93 [0.60 – 1.43]	0.732	0.79 [0.48 – 1.30]	0.359	0.80 [0.49 – 1.31]	0.375

	HbA1c 7 - <8 N=364 (20.0%)		HbA1c 8- <9 N=197 (12.5%)		HbA1c >=9 N=285 (15.5%)	
	AOR	**p-value**	**AOR**	**p-value**	**AOR**	**p-value**
Relationship status						
Single	Reference		Reference		Reference	
Partnered	**1.44 [1.03 – 2.00]**	**0.032**	1.18 [0.74 – 1.88]	0.493	1.26 [0.85 – 1.85]	0.251
Federal poverty level						
< 1	0.96 [0.55 – 1.68]	0.892	0.55 [0.25 – 1.20]	0.133	1.18 [0.61 – 2.30]	0.625
1–2	1.03 [0.65 – 1.64]	0.902	1.27 [0.71 – 2.29]	0.422	1.06 [0.59 – 1.90]	0.850
>2	Reference		Reference		Reference	
Has health insurance						
Yes	Reference		Reference		Reference	
No	0.95 [0.56 – 1.60]	0.851	**2.04 [1.04 – 4.01]**	**0.038**	1.41 [0.78 – 2.53]	0.254
Where goes for health care						
Doctor’s office	Reference		Reference		Reference	
No regular place	0.74 [0.33 – 1.63]	0.449	1.36 [0.43 – 4.34]	0.603	**3.21 [1.70 – 6.08]**	**<.001**
ER	**3.22 [1.12 – 9.25]**	**0.030**	2.25 [0.62 – 8.08]	0.215	2.58 [0.74 – 8.94]	0.136
Takes diabetes medication						
No	Reference		Reference		Reference	
Yes	**3.30 [2.29 – 4.74]**	**<.001**	**4.48 [2.44 – 8.21]**	**<.001**	**2.15 [1.33 – 3.46]**	**0.002**
Has seen a diabetes specialist						
Never	Reference		Reference		Reference	
Ever	0.83 [0.58 – 1.19]	0.311	1.53 [0.79 – 2.97]	0.205	**2.23 [1.48 – 3.34]**	**<.001**
Physical activity						
Active	Reference		Reference		Reference	
Inactive	1.25 [0.89 – 1.74]	0.201	1.58 [0.93 – 2.70]	0.093	1.48 [0.94 – 2.35]	0.094
Alcohol consumption (mean # drinks/day)						
Never	Reference		Reference		Reference	
One or less per day	0.96 [0.62 – 1.48]	0.837	0.98 [0.62 – 1.57]	0.949	0.86 [0.61 – 1.21]	0.386
More than one per day	0.75 [0.40 – 1.38]	0.352	0.33 [0.09 – 1.22]	0.096	0.74 [0.36 – 1.53]	0.413
Smoking status						
Never smoker	Reference		Reference		Reference	
Former smoker (quit at least 2 months ago)	1.32 [0.77 – 2.29]	0.314	1.32 [0.71 – 2.46]	0.379	0.95 [0.53 – 1.71]	0.860

	HbA1c 7 - <8 N=364 (20.0%)		HbA1c 8- <9 N=197 (12.5%)		HbA1c >=9 N=285 (15.5%)	
	AOR	**p-value**	**AOR**	**p-value**	**AOR**	**p-value**
Current smoker	1.13 [0.81 – 1.57]	0.480	0.87 [0.49 – 1.55]	0.639	0.84 [0.59 – 1.19]	0.334
BMI						
Normal weight	Reference		Reference		Reference	
Overweight	1.01 [0.50 – 2.05]	0.981	1.10 [0.44 – 2.76]	0.837	0.77 [0.44 – 1.37]	0.380
Obese	1.07 [0.62 – 1.86]	0.804	1.57 [0.60 – 4.15]	0.360	1.26 [0.70 – 2.29]	0.445
Number of chronic conditions	1.01 [0.84 – 1.20]	0.952	0.82 [0.63 – 1.07]	0.150	0.90 [0.75 – 1.08]	0.249

* Bold indicates significant at the level of $p<0.05$

Table 3.

Adjusted predicted probability for patterns of food security and diet quality

	HbA1c: 7 - <8		HbA1c: 8- <9		HbA1c: >=9	
	AOR	**p-value**	**AOR**	**p-value**	**AOR**	**p-value**
Food security x healthy eating index interaction						
Food secure X Good diet	Reference		Reference		Reference	
Food insecure X Good diet	2.03 [0.27 – 15.5]	0.493	**8.51 [1.39 – 52.0]**	**0.020**	1.73 [0.18 – 16.5]	0.632
Food secure X Diet needs improvement	1.51 [0.41 – 5.58]	0.534	3.80 [0.92 – 15.8]	0.066	3.09 [0.98 – 9.73]	0.054
Food insecure X Diet needs improvement	1.48 [0.38 – 5.67]	0.570	3.74 [0.87 – 16.2]	0.077	2.50 [0.66 – 9.49]	0.177
Food secure X Poor diet	1.64 [0.44 – 6.15]	0.462	**5.18 [1.40 – 19.2]**	**0.014**	**4.32 [1.39 – 13.4]**	**0.012**
Food insecure X Poor diet	1.84 [0.52 – 6.46]	0.344	**6.12 [1.51 – 24.8]**	**0.011**	**6.73 [2.04 – 22.2]**	**0.002**

* Bold indicates significant at the level of $p<0.05$