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The Association Between Dietary Patterns and Diabetes Status Among U.S. Adults

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This is to certify that the doctoral dissertation by

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Walden University
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Abstract

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MS, Georgia State University, 2006

BS, Wesleyan College, 2004

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Type 2 diabetes mellitus, or T2DM, is a leading cause of preventable death in the United States. Multiple studies have found that certain dietary patterns can significantly influence the risk of T2DM. The purpose of this study was to understand the dietary patterns associated with diabetes by comparing the relative adherence to these dietary patterns by individuals in 5 stages of diabetes: no diabetes, undiagnosed prediabetes, diagnosed prediabetes, undiagnosed diabetes, and diagnosed diabetes. Using the health belief model as the theoretical foundation, the primary research question examined whether adherence to specific dietary patterns significantly differed between individuals in different stages of diabetes. This question was important for understanding the dietary behaviors of individuals in early or unknown stages of diabetes that may lead to more harmful health consequences. Using data from the National Health and Nutrition Examination Survey (n = 15,237), multiple logistic regression analyses compared the odds of adherence to specific dietary patterns, adjusting for covariates. There was no statistically significant association between dietary pattern adherence and diabetes status. However, certain covariate factors—such as age and gender—were found to significantly influence the odds of high adherence to certain dietary patterns. Specifically, males were significantly more like than were females to adhere to diets associated with increased T2DM risk, and adults aged 50 years and older were significantly more likely than were younger adults to adhere to diets associated with decreased T2DM risk. The impact of these findings could lead to more targeted interventions promoting better eating habits and reduced T2DM incidence among U.S. adults aged 20 years older.

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Dedication

I dedicate this work to my wonderful, loving husband, Erick, for supporting me every day along this journey. I also dedicate this work to our two children, our beautiful, precious Erielle and our new bundle of joy Ericka, for giving me a purpose to complete this journey. Finally, I dedicate this dissertation to my wonderful mother and sisters for providing the support and encouragement I needed and for being proud of me throughout this endeavor.

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Chapter 1: Introduction to the Study

Introduction

Type 2 diabetes mellitus (T2DM) is a major public health concern characterized by an abnormally high blood glucose level. It is one of the top causes of preventable death in the United States (Hoyert & Xu, 2012), and more than 29 million people are currently living with the condition (U.S. Department of Health and Human Services, Centers for Disease Control and Prevention [CDC], 2014). African-Americans comprise a larger proportion of new cases in comparison to other racial and ethnic groups (CDC, 2014). T2DM is especially challenging given that many people are unaware that they have the condition and, thus, fail to appropriately manage the condition (CDC, 2014). Furthermore, more than 33% of U.S. adults over the age of 20 are considered to be “borderline” diabetic or prediabetic (also known as impaired glucose tolerance), defined as a blood glucose level that is above normal yet not within the range defined for diabetes (CDC, 2014). Similar to those with undiagnosed diabetes, individuals with prediabetes may be unaware of their status, missing key opportunities to make appropriate lifestyle modifications in order to reduce their risk of developing T2DM.

Healthy eating is essential for preventing the development of T2DM. In fact, lifestyle modifications are nearly twice as effective in preventing diabetes in comparison to the use of glucose-lowering drugs, as pharmaceuticals tend to be effective only in specific subgroups of patients (Diabetes Prevention Program Research Group, 2002; Sherwin et al., 2003). Moreover, lifestyle modifications offer a cost-efficient approach for preventing diabetes. Existing studies of the association of diet and diabetes outcomes have primarily focused on the diets of those with diagnosed T2DM (Jarvandi, Davidson, Jeffe, & Schootman, 2012; Montonen et al., 2005), yet few studies have compared the diets of individuals who are unaware of their diabetes status. This study will seek to compare the diets of individuals with undiagnosed prediabetes and undiagnosed T2DM to those with no history of diabetes and to determine if certain dietary patterns are more likely than others to increase the risk of undiagnosed prediabetes or undiagnosed T2DM.

A major assumption of the study is that eating habits are a function of perceived health status. That is, compared to individuals who are unaware of their chronic disease status (i.e., those who are borderline for a disease or those who are unaware that they have a disease), individuals with known (i.e., diagnosed) chronic disease are more likely to follow recommended nutrition guidelines in order to mitigate the effects of the disease. Using available dietary recall, physical examination, laboratory, and questionnaire data collected in the National Health and Nutrition Examination Survey (NHANES), this study will aim to determine the relative risk of undiagnosed prediabetes and undiagnosed T2DM associated with distinct dietary patterns. This study will also test the validity of the assumption that knowledge of disease status is associated with less risky dietary patterns by comparing the frequency of adherence to risky diets between individuals with diagnosed versus undiagnosed prediabetes and T2DM.

Individuals at high risk of diabetes can be identified early in the disease process, thus delaying or preventing the disease altogether (Sherwin et al., 2003). Thus, opportunities exist for increased public health interventions and education efforts designed to lower the risk of T2DM among individuals with prediabetes. Furthermore, individuals with undiagnosed T2DM could benefit from public health interventions designed to detect diabetes early in its progression and prevent diabetes-related complications (Ochoa et al., 2014). This study will seek to contribute to this area of chronic disease prevention and control by comparing dietary patterns that are known to influence the risk of T2DM.

The social change implications of this study include new insights about dietary patterns that are more prone to increasing blood glucose levels among individuals with prediabetes. This study may also lead to new insights about the association between diet and perceived health status. This new information could lead to more targeted nutritional guidelines for individuals with prediabetes; it could also lead to more targeted diabetes prevention interventions for reducing exposure to dietary patterns associated with higher adherence among individuals with undiagnosed prediabetes and undiagnosed T2DM. In addition, financial costs associated with diagnosed diabetes are estimated to be $245 billion, which is 40% higher than the previous estimate of $174 billion in 2007 (American Diabetes Association, 2013). Thus, the current study may help to address the growing financial and personal burdens of diabetes by providing a more cost-effective prevention strategy that focuses on making lifestyle modifications rather than paying for costly medical interventions.

Chapter 1 provides background information on the current state of knowledge of prediabetes and undiagnosed T2DM. It summarizes the literature on the association between diet and diabetes outcomes and it delineates knowledge gaps that this study sought to address. The chapter then describes the relevant theoretical framework for the study, the research questions and hypotheses, and the definitions relevant to the study. Finally, this chapter describes the nature of the study and its assumptions, scope and delimitations, and limitations.

Background

Few studies have compared the epidemiologies of prediabetes, undiagnosed diabetes, and diagnosed diabetes. One study used data from the National Health and Nutrition Examination Survey (NHANES) and estimated prediabetes, undiagnosed diabetes, and diagnosed diabetes prevalence in U.S. adults, aged 20 years and older, to be 29.5%, 4.7%, and 7.9%, respectively (Cowie et al., 2009). In another study, the future risk of developing prediabetes or undiagnosed diabetes was predicted from a combination of self-reported health information and laboratory data collected in NHANES. Specifically, the future risk of prediabetes and undiagnosed diabetes was estimated based on survey responses pertaining to age, height, central obesity, gestational diabetes, race/ethnicity, hypertension, family history of diabetes, and exercise (Heikes, Eddy, Arondekar, & Schlessinger, 2008). This tool, known as the Diabetes Risk Calculator, can be used in the absence of more reliable information on patient diabetes risk. The risk of prediabetes and undiagnosed diabetes as calculated by the tool was 4.2 and 26.1 %, respectively, which is similar to the findings from the Cowie et al. (2009) study and provides evidence of the utility of combining self-reported health information with laboratory data to accurately predict chronic disease outcomes.

Both diabetes and prediabetes have significant negative health impact. For example, diabetes can lead to more serious complications, including heart disease, stroke, blindness, and kidney failure (CDC, 2014). Furthermore, prediabetes is significantly associated with four major risk factors for cardiovascular disease, which include obesity in the central region of the body, high levels of triglycerides, low levels of HDL cholesterol, and high blood pressure (Li, Ford, Zhao, & Mokdad, 2009). This association seems to depict a clustering effect in which the greater the number of cardiovascular disease risk factors present, the greater the risk of prediabetes (Li, Ford, Zhao, & Mokdad, 2009). However, the precise nature of the association is still unclear, as prediabetes also appears to be an independent risk factor for cardiovascular disease and is associated with a higher mortality rate among persons with cardiovascular disease (Standl, Erbach, & Schnell, 2013).

Individuals with prediabetes would benefit the most from diabetes prevention strategies due to greater opportunities for delaying the progression to diabetes. That is, interventions targeting prediabetic populations would have a greater impact on preventing future diabetes complications and future diabetes-related mortalities (Narayan, Imperatore, Benjamin, & Engelgau, 2002). Specific strategies for preventing the progression of prediabetes into diabetes include increased physical activity, improved diet, and glucose-lowering drug treatments (Ryden et al., 2007). However, weight loss alone (whether by means of healthy eating, increased physical activity, or other means) appears to be the single most important factor in predicting the normalization from prediabetes to normal glucose levels (Perreault, Kahn, Christophi, Knowler, & Hamman, 2009).

Prediabetes is diagnosed using various screening tools. A commonly used method for screening prediabetes is the use of both the fasting plasma glucose (FPG) and oral glucose tolerance test (OGTT) screening tools. The former test primarily measures insulin resistance in the liver and detects impaired fasting glucose (IFG) while the latter test measures insulin resistance in other major organs of the body and detects impaired glucose tolerance (Cowie et al., 2009). The FPG test measures blood glucose levels after a period of fasting. One of the limitations of the FPG test is the potential for inconsistent results, as the test may indicate diabetes diagnosis for a given individual on a given day, yet may indicate normal blood glucose levels for the same individual 2 weeks later (Sacks, 2011). The sources of variation in FPG results can be attributed to various factors that influence changes in blood glucose concentrations, including stress, acute illness, or noncompliance with the requirement to fast prior to the test. The OGTT similarly requires participants to fast prior to the test but also requires participants to consume glucose in order to determine how well the body metabolizes the glucose after a short period of fasting (Sacks, 2011). However, like the FPG test, the OGTT is subject to lack of reproducibility and is more time-consuming, costly, and inconvenient than the FPG (Sacks, 2011).

While some argue that both the FPG and OGTT should be used as a comprehensive assessment of prediabetes, others support the use of hemoglobin A1c (HbA1c) for screening and diagnosing early diabetes onset (Saudek et al., 2008). Proponents of the HbA1c screening test argue that unlike the FPG and OGTT screening tests, the HbA1c test does not require patients to go without eating for a period of time before the test and also better reflects long-term glycemic levels as opposed to detecting short-term lifetime changes initiated close to the screening time (i.e., increased exercise or increased vegetable intake prior to the screening test; see Saudek et al., 2008). Early diabetes studies revealed that HbA1c concentration is independent of fasting blood glucose yet is highly correlated with glucose tolerance (Koenig, Peterson, Kilo, Cerami, & Williamson, 1976). Recent studies comparing HbA1c concentration and fasting blood glucose found that HbA1c is less sensitive in identifying individuals with an increased risk for diabetes (Lorenzo et al., 2010; Olson et al., 2010), yet it could be useful in clinical settings for early detection of high-risk patients if strictly used as a screening tool rather than a diagnostic tool (Silverman et al., 2011). Recommendations for accurately diagnosing diabetes include the use of multiple diagnostic tools that include, at a minimum, both the HbA1c screening test and at least one of the FPG or OGTT screening tests. The present study will follow this recommendation and define laboratory-confirmed diabetes using all available diagnostic test results in NHANES. Ultimately, behavior modifications such as weight loss and increased physical activity may predict future diabetes risk more strongly than biochemical measures (Simmons, Harding, Wareham, & Griffin, 2007).

Like prediabetes, undiagnosed diabetes is a public health priority area given the implications for early detection. A major concern for early detection is the idea that undiagnosed cases, unbeknownst to them, are in a latent phase of diabetes onset characterized by rising diabetic complications that require immediate attention in order to mitigate damaging effects (Harris & Eastman, 2000). This latent phase between diabetes onset and diagnosis typically lasts an average of 7 years (Saudek et al., 2008). Individuals at high-risk of being in this latent phase include those with no health insurance or no routine access to a medical provider (Zhang et al., 2010) as well as elderly men with high blood pressure, high BMI levels, and a large waist circumference (Franse et al., 2001).

Dietary behaviors can influence subsequent diabetes risk. In general, a higher consumption of plant-based foods combined with a lower consumption of animal-based food products is associated with reduced diabetes risk, although fish consumption may be an exception given its potential positive health benefits (Parillo, & Riccardi, 2004). Generally, reducing total fat intake and increasing the amount of fiber and antioxidants in the diet is associated with reducing the burden of T2DM (Bhoraskar, 2005), and increased intake of whole grains is associated with reduced diabetes incidence (Perry, 2002). In addition, increased fish and vegetable intake is moderately associated with reduced incidence of glucose intolerance (Perry, 2002).

Some specific diets, such as the “Western” diet (Perry, 2002) and the “Conservative” diet (Montenen et al., 2005), are associated with increased diabetes risk; whereas, others, such as the Mediterranean diet (Salas-Salvadó et al., 2011) and the prudent diet (Perry, 2002; Montenen et al., 2005), are associated with decreased risk. The “Western” dietary pattern features a high level of red meat and processed meat, high-fat dairy products, refined grains, fried starchy foods, and sugary foods. The “Conservative” diet similarly features high consumption of red meats, whole milk, butter, and potatoes (Montenen et al., 2005). The “Western” diet is associated with a 1.6 times increased diabetes risk compared to those not exposed to the diet (Perry, 2002), and a “Conservative” diet is associated with a 1.5 times increased risk of diabetes (Montenen et al, 2005). In contrast, the Mediterranean diet, or MedDiet, includes high consumption of fruits, grains, legumes, nuts, olive oil, and vegetables as well as moderate amounts of fish and wine (Salas-Salvadó et al., 2011). Similarly, the prudent diet includes high amounts of fruit and vegetables, low-fat dairy products, fish, pasta and rice combined with low amounts of processed meats and fried starchy foods (Perry, 2002). A Mediterranean diet is associated with a 52% reduction in diabetes incidence (Salas-Salvadó et al., 2011) and a greater reduction in diabetes risk than other low-fat diets recommended for high-risk cardiovascular disease patients (Jensen & Sherman, 2014). Consumers of the prudent diet are approximately 0.72 times less likely to develop diabetes (Montenen, 2005).

Food intake patterns differ between individuals with diabetes versus those without diabetes. A recent study found that diabetics were more likely to consume artificially-sweetened foods in comparison to those with prediabetes, and the latter group was more likely to consume sugary foods and regular (non-diet) sodas (Fitzgerald, Damio, Segura-Pérez, & Pérez-Escamilla, 2008). Findings from the study also revealed that knowledge of food labels was significantly associated with healthy eating, but this finding was not significantly associated with diabetes status. The present study will further explore differences in food intake patterns of individuals in different stages of diabetes.

This study will advance current knowledge of dietary patterns associated with diabetes in several ways. First, this is the first known investigation of the relationship between dietary patterns and knowledge of diabetes status. Much of what is currently known about dietary risk factors for diabetes is derived from samples of individuals who are aware of their diabetes status. A major advantage of this study is the use of combined biochemical (blood glucose tests) and self-reported (dietary recall) data collected in the NHANES survey. This combined information will provide a unique snapshot of the influence of disease unawareness on the prevalence of risky eating behaviors.

Secondly, the present study is one of few studies to investigate the behaviors of persons with undiagnosed prediabetes. Identifying effective strategies for preventing prediabetes is of public health importance given the dual association of prediabetes with both diabetes and cardiovascular disease. It is also essential to identify ways to reduce the burden of undiagnosed diabetes in order to mitigate the effects of the condition among persons unaware of their diabetes status.

This study is needed in order to compare risky dietary patterns and determine which patterns are more significantly associated with undiagnosed prediabetes and undiagnosed diabetes that can be eliminated in either the prediabetes stage to prevent progression to diabetes or in the diabetes stage to prevent further diabetes complications. Furthermore, this study is needed in order to assess whether knowledge of diabetes status leads to lower frequency of consumption of foods associated with increased diabetes risk, providing implications for undiagnosed populations with respect to increased awareness of their condition and increased education about risky dietary patterns.

Problem Statement

Certain dietary patterns significantly increase the risk of diabetes while other patterns significantly decrease the risk. However, little is known about the relative contribution of these dietary patterns to the development or mitigation of diabetes, especially among patient populations in the early stages of the disease process (i.e., those with prediabetes or undiagnosed T2DM). Thus, there is a need to improve knowledge of the dietary patterns most significantly associated with undiagnosed prediabetes and undiagnosed diabetes. Presumably, lack of awareness is a major hindrance to adopting healthier eating patterns to reduce one's diabetes risk. However, prior studies have failed to examine whether individuals undergoing screening for diabetes were aware of their diabetes risk prior to the screening test (Silverman et al., 2011) or to measure whether awareness of diabetes status is a predictor of adherence (Jensen & Sherman, 2014; Mann & Morenga, 2013). Thus, there is a second critical need to increase knowledge about the association between awareness of risk status and adherence to risky dietary patterns among different diabetes groups. Addressing these two critical gaps in knowledge will aid prevention efforts aimed at those unaware of their diabetes risk status.

This study will build upon this recent body of work by examining the relation of diabetes awareness with dietary patterns of individuals with diabetes. This study will also address a meaningful gap in the current literature regarding the exposure to risky dietary patterns among persons with clinical defined prediabetes or diabetics that are reportedly unaware of their condition based on self-reports that they had not been told by a doctor that they have diabetes or borderline diabetes. To our knowledge, this is the first study to compare the exposure to risky dietary patterns among individuals in different stages of diabetes.

Purpose

The present study will seek to advance current understanding of known dietary patterns associated with diabetes by comparing the relative adherence to these diets among different diabetes groups. The rationale for the research is that dietary patterns are likely to differ based on an individual's perceived risk of illness. In other words, compared to individuals who are unaware of their disease status (i.e., undiagnosed), individuals with known (i.e., diagnosed) chronic disease status are more likely to follow recommended nutrition guidelines as standard practice for mitigating the effects or controlling the condition. This study will seek to determine if certain dietary patterns are more frequently consumed by those with undiagnosed prediabetes and undiagnosed T2DM. Improved knowledge of these risky dietary patterns could lead to lower consumption of these foods by individuals at greatest risk, thus, effectively preventing or reducing the occurrence of new cases. This quantitative study will compare exposures to diabetes-associated dietary patterns among undiagnosed diabetes groups using publically available data from NHANES.

The NHANES survey includes a dietary recall component in which respondents are asked to report all foods and beverages consumed within 24 hours of the survey interview (CDC, 2013). Respondents are also asked within a household questionnaire component of NHANES to report whether or not they have ever been diagnosed with T2DM. Blood glucose values of NHANES respondents are also collected within the laboratory component of the survey. These sources of data will be combined in order to identify diagnosed T2DM, undiagnosed T2DM, diagnosed prediabetes, and undiagnosed prediabetes cases and their corresponding dietary habits. Adherence to distinct dietary patterns associated with T2DM risk will serve as the primary dependent variable while diabetes status will serve as the primary independent variable. A dichotomous variable regarding diet adherence scores that are above or below the median score of the study population will be created for purposes of running logistic regression analyses with dietary adherence as the dependent variable. A dichotomous variable regarding known versus unknown diabetes status will also be created in order to flag diabetes cases who are aware versus unaware of their condition, and this variable will be used for analyses regarding the role of diabetes awareness on eating habits. Other covariates associated with diabetes will also be included, such as age, gender, race, family history of diabetes, body mass index (BMI), and physical activity level, (Diabetes Prevention Program Research Group, 2002).

Research Questions/Hypotheses

This study will examine one primary and two secondary research questions.

Research question 1 (primary): Among individuals with no diabetes, undiagnosed prediabetes, undiagnosed T2DM, diagnosed prediabetes, and diagnosed T2DM, is there a statistically significant difference in the mean adherence scores of dietary patterns known to increase the risk of diabetes? The null hypothesis is that there is no statistically significant difference in the mean adherence scores of dietary patterns known to increase the risk of diabetes. The alternative hypothesis is that there is a statistically significant difference in the mean adherence scores of dietary patterns known to increase the risk of diabetes among different diabetes subgroups.

Research question 2: Among individuals with no diabetes, undiagnosed prediabetes, undiagnosed T2DM, diagnosed prediabetes, and diagnosed T2DM, is there a statistically significant difference in the mean adherence scores of dietary patterns known to decrease the risk of diabetes? The null hypothesis is that there is no statistically significant difference in the mean adherence scores of dietary patterns known to decrease the risk of diabetes. The alternative hypothesis is that there is a statistically significant difference in the mean adherence scores of dietary patterns known to decrease the risk of diabetes among different diabetes subgroups.

Research question 3: Among all diabetes groups, what are the odds of adherence to dietary patterns known to increase the risk of diabetes, adjusting for covariates? The null hypothesis is that the odds of adherence to “risky” dietary patterns are not statistically different among the different diabetes groups. The alternative hypothesis is that the odds of adherence to ”risky” dietary patterns are statistically different among the different diabetes groups.

Research question 4: Among all diabetes groups, what are the odds of adherence to dietary patterns known to decrease the risk of diabetes, adjusting for covariates? The null hypothesis is that the odds of adherence to “protective” dietary patterns is not statistically different among the different diabetes groups. The alternative hypothesis is that the odds of adherence to “protective” dietary patterns is statistically different among the different diabetes groups.

Research question 5: Among all diabetes groups, are self-perception of diabetes risk and knowledge of diabetes status significant predictors of adherence to dietary patterns associated with diabetes risk, adjusting for covariates? The null hypothesis is that self-awareness of diabetes status and self-perception of diabetes risk are not statistically significant predictors of adherence to dietary patterns. The alternative hypothesis is that at least one of the variables self-awareness of diabetes status and self-perception of diabetes risk is a statistically significant predictor of adherence to dietary patterns.

For each research question, any findings of statistical significance will be further assessed for clinical significance, as the latter would more directly correlate with future positive social change implications of the research.

Nature of the Study

The nature of the study will consist of a retrospective, cross-sectional study design using secondary data from NHANES. The rationale for using a quantitative approach is that the collected NHANES variables are quantitative in nature, which rules out a qualitative design. That is, the NHANES data set consists of nationally -representative survey data pertaining to food intakes and diabetes status of U.S. adults. This study will capitalize on this existing dataset rather than select a different study design and data collection approach. Furthermore, previous studies with a similar research question regarding dietary patterns and chronic disease risk have used a quantitative approach and, thus, this research would contribute to this body of work by applying similar methods in a different context.

The sampling approach for NHANES consists of multistage probability sampling; the first stage includes stratified sampling and a subsequent stage includes cluster sampling (CDC, 2013). By default, this study will adopt the same sampling procedure and will select study participants from a secondary dataset. Specific inclusion criteria for the sample selection include completion of the dietary recall component and providing a response to the survey question regarding T2DM diagnosis by a doctor. The analytic approach for the study will consist of ANOVA analyses comparing the mean number of risky meals and healthy meals consumed across different diabetes groups. In addition, multiple logistic regression analyses will be conducted to determine the odds of adherence to specific dietary patterns among different diabetes groups. Separate regression models will be generated consisting of each dietary pattern adherence score as the dependent variable, diabetes status as the main independent variable, and demographic and other T2DM-associated covariates as secondary independent variables.

Theoretical Framework

The health belief model (HBM) is a well-known health behavior theory which suggests that an individual's decision to adopt positive health behavior change is influenced by the individual's perception of the risks, negative health consequences, barriers, and benefits associated with continuing to engage in the behavior (Glanz & Bishop, 2010). The HBM is applicable to the dissertation topic given the notion that an individual's perception of their personal risk of developing prediabetes or T2DM may influence their health behavior with respect to adopting a healthier diet. In this regard, observed differences in the consumption of foods associated with increased risk of prediabetes or T2DM among individuals with known diabetes versus unknown diabetes may reflect differences in dietary behavior modification that is directly correlated with knowledge of health status. NHANES participants are asked directly about their perceived risk of diabetes, and this information can be used to test the applicability of the HBM. Specifically, perception of diabetes risk can be included in a statistical model to determine if this variable is a statistically significant predictor of consuming a healthy diet.

Definitions

The following definitions, mostly derived from the Merriam Webster Online Medical Dictionary and eMedicineHealth.com, relate to key terms used in the study:

• *Body mass index* (BMI): A measure of the amount of fat in the body based on the ratio of weight to height measured in kg/m2 (Body mass index, n.d.).

• *Diabetes*: A condition in which the body produces insufficient insulin to adequately control the amount of sugar in the blood. For purposes of this study, all references to “diabetes” will pertain to Type 2 diabetes and participants with Type 1 diabetes or gestational diabetes will be excluded (Diabetes, n.d).

• *Diagnosed diabetes*: For purposes of this study, diagnosed diabetes refers to self-reports of study participants that they were previously told by a doctor that they have diabetes, and measurements of their blood glucose levels confirm the diagnosis.

• *Dietary pattern*: Patterns of dietary intake depicting foods eaten in combination with other foods, allowing for a more accurate assessment of an individual’s diet as opposed to an analysis of individual food items, food groups, or nutrients (Hu, 2002).

• *Fasting blood glucose*: A measure of the amount of sugar in the blood after fasting overnight (normal range=70-100 mg/dL, diabetic range is >=126 mg/dL) (Fasting blood glucose, 2012).

• *Glucose intolerance (aka impaired glucose tolerance aka impaired fasting glucose):* Another term for prediabetes that describes a transition phase between normal blood glucose and diabetes (Impaired glucose tolerance, 2012).

• *Hemoglobin A1c (HbA1c)*: A measure of the average amount of sugar in the blood for the previous 2-3 months (Hemoglobin A1c, n.d.). HbA1c levels between 5.7-6.4% typically indicate prediabetes while levels greater than or equal to 6.5% typically indicate diabetes.

• *Oral glucose tolerance test (OGTT*): A test that measures the ability of the body to handle consumed glucose after at least 8 hours of fasting (Oral glucose tolerance test, 2012). OGTT levels greater than or equal to 200 mg/dL usually indicates diabetes (Sacks, 2011).

• *Prediabetes*: A transition phase between normal blood glucose and diabetes. Fasting blood glucose levels normally range from 70-100 mg/dL. The range for prediabetes is 100-125mg/dL. (Prediabetes, n.d.)

• *Type 2 diabetes mellitus (T2DM)*: A chronic disease characterized by an abnormally high level of glucose in the blood. The normal range is 70-100 mg/dL, and a level greater than or equal to 126 mg/dL usually indicates diabetes. (Type 2 diabetes, 2013).

• *Undiagnosed diabetes*: For purposes of this study, undiagnosed diabetes refers to self-reports of study participants that they were not previously told by a doctor that they have diabetes, and measurements of their blood glucose levels indicate that they have diabetes.

Assumptions

A major assumption of the study is that self-reported information collected in NHANES represents truthful and accurate information. This assumption is critical to the meaningfulness of the study given the study's reliance on self-reported data on diabetes diagnosis to distinguish individuals who are aware versus unaware of their diabetes status. Another assumption is that people with diabetes were selected from the same reference population as those with no history of diabetes and that each group had an equal probability of selection. These assumptions were necessary in the context of this study using secondary data analysis because these assumptions were inherit in the original study design.

Scope and Delimitations

This study seeks to compare the frequency of adherence to diabetes-associated dietary patterns among individuals in different stages of diabetes in order to address the research problem about limited knowledge of eating behaviors of persons unaware of their diabetes status. This specific aspect of the research problem was selected for investigation given the social change implications of identifying high-risk behaviors among unaware high-risk groups.

The target population for the study is U.S. adults aged 20 years and older. The primary reason for targeting this population is that Type 2 diabetes prevalence in the U.S. is highest among this group (CDC, 2014). Based on the assumption that children are unlikely to access nutritional health promotion messages targeted for adults, children will not be included in the study. Furthermore, the diets of children are more likely to reflect parental food choices rather than their own. For the purpose of this study, the study population will further be restricted to individuals who completed a dietary recall, laboratory testing for diabetes, and answered the questionnaire item on diabetes diagnosis by a doctor. Given the national representativeness of NHANES populations, findings from this study are likely generalizable to other subsamples of the U.S. population.

Limitations

This study may be vulnerable to certain threats to internal validity, such as selection bias, information bias, interviewer bias, and residual confounders.

There is a potential for selection bias because diabetes cases that completed a dietary recall and laboratory testing for diabetes may have a greater likelihood of selection than individuals with no history of diabetes, based on a greater probability of diabetes diagnosis associated with exposure to certain foods in the diet (Szklo & Nieto, 2014, p.133). Incidence-prevalence bias is another type of selection bias that occurs if confirmed diabetes cases are included in diabetes risk analyses (Szklo & Nieto, 2014, p.135). That is, the inclusion of diseased individuals in analyses regarding disease risk could lead to biased results. Selection bias may be reduced by ensuring that the participants with diabetes and those without diabetes originate from the same reference population or that their characteristics are as similar as possible (Szklo & Nieto, p. 26). Potential methods for verifying similar characteristics between diabetics and nondiabetics include comparing measures of central tendency and conducting chi-square analyses to check for significant associations between study variables by diabetes status.

Information bias and interviewer bias may also pose a threat to the internal validity of the study. One potential source of information bias in the study is response bias associated with inaccurate reports of healthy eating behavior or diabetes diagnosis by study participants. Specifically, participants may underreport their consumption of unhealthy foods or their diabetes diagnosis based on a perceived social undesirability associated with poor eating habits or poor health status. Interviewer bias occurs when nonverbal interviewer expressions or cues subsequently influence interviewee responses (Szklo & Nieto, 2014, p.119). This could also threaten the validity of the study by potentially increasing the likelihood of underreporting of unhealthy eating or diabetes status.

Biological and physiological measurements collected in the NHANES survey can be used to verify self-reported respondent information, and this would help to control for information bias (CDC, 2013). For example, self-reported diabetes diagnosis can be validated using biological measurements of blood glucose levels such as fasting blood glucose and HbA1c. In addition, the use of a standardized interview script (CDC, 2013) helps to control for interviewer bias and decrease the likelihood that interviewers would interject their personal views or other cues that could influence interviewee responses. Furthermore, a logistic regression model can be useful for controlling for potential confounders that may influence the association between dietary pattern adherence and diabetes status.

Residual confounders are variables not previously accounted for in the initial analytic procedure that may conceal the association between dietary patterns and diabetes status (Szklo & Nieto, 2014, pg.152). Potential residual confounders may include health insurance status, education level, and occupation. Individuals with health insurance may be at a greater advantage to receive recommendations about healthy eating from a physician or other health care provider compared to individuals with no health insurance. Educational level may also be a confounder given that individuals with more years of education completed may be more knowledgeable about diabetes prevention strategies than individuals with fewer years of education. Similarly, individuals in health-oriented occupations (e.g., medicine, nursing, nutrition) may be more knowledgeable about diabetes prevention strategies than individuals outside of the health care or health promotion industry.

Ethical concerns must also be considered with respect to the validity of the study. One potential concern with the NHANES survey is that respondents are asked to self-report sensitive health information via an in-person interview, which inhibits anonymity in collected responses. The most effective measure to ensure confidentiality of reported information is to remove all personal identifiers (e.g., names, date of birth) and to randomly assign a unique ID number to each respondent so that it is impossible to link the unique ID back to the respondent providing the information (CD, 2013). Another approach for protecting and maintaining confidentiality of reported information is to conduct group-level rather than person-level information, such as reporting the average age of diagnosed diabetes cases rather than listing all ages with corresponding frequencies, which could threaten the confidentiality of respondents reporting low-frequency ages. To ensure compliance with maintaining ethical standards of research, this study will undergo an approval process by an Institutional Review Board, per standard protocol of initiating new research with Walden University.

Significance

This study may contribute new information to the field of public health regarding the eating patterns of high-risk diabetes groups who are unaware of their disease status. This study will seek to advance the field of public health by applying the health belief model in a different context and providing scientific evidence of the impact of disease awareness on current dietary patterns. A potential social change implication from this study includes increased efforts to educate U.S. adults about specific dietary patterns associated with increased risk of diabetes that should be consumed less frequently. Furthermore, this research could ultimately inform new dietary behavior modification strategies for high-risk diabetes populations.

Summary and Transition

This chapter provided a general overview of prediabetes and undiagnosed diabetes as major public health concerns, including a summary of the most commonly-used diagnostic and screening tools available. This chapter also summarized the current state of knowledge of the association of diet and diabetes, including specific diets that are more likely to increase or decrease the risk of developing diabetes. Furthermore, this chapter introduced the research problem concerning limited knowledge of the relative importance of dietary patterns that influence the risk of diabetes and introduced several research questions and corresponding hypotheses. Chapter 2 will provide a more thorough review of the different dietary patterns associated with diabetes risk.

Chapter 2: Literature Review

Introduction

A current problem in the area of diabetes prevention is that there are multiple diets known to significantly influence diabetes risk, yet not much is known about how the relative risks of the diets compare. Existing investigations of the diet-diabetes association often comprise samples of patients who have knowledge of their diabetes status; conversely, few studies have investigated the diets of individuals in the early stages of diabetes, namely, those with prediabetes or those not yet diagnosed. A major assumption of the present study is that individuals who are unaware of their diabetes status are more likely to engage in risky eating behaviors than those who are aware of their status. That is, lack of awareness may significantly delay efforts to adopt healthier eating patterns. The purpose of this study is to examine the validity of this assumption and compare the adherence to diets known to increase diabetes risk between individuals who are knowledgeable versus unknowledgeable about their diabetes status. This study will determine if certain dietary patterns known to increase diabetes risk are more frequently consumed by those with undiagnosed prediabetes and undiagnosed T2DM than those with no history of diabetes. Findings from this study could provide new insights that, ultimately, could be used to help reduce the risk of diabetes and delay the progression of prediabetes to diabetes.

The current literature is filled with examples of dietary patterns significantly associated with diabetes risk. Individual dietary components, from foods to specific nutrients found within foods, may act singly or in an additive or multiplicative manner to influence blood sugar levels and ultimately contribute to the development or prevention of diabetes. A better understanding of how the different dietary patterns compare with respect to the risk of diabetes could lead to new insights about the dietary patterns that most significantly influence the risk of diabetes. In turn, this could improve current knowledge about the effects of specific food combinations and individual food groups on subsequent diabetes outcomes.

The following chapter presents a critical review of the literature to establish the current state of understanding of diet-diabetes associations. Specifically, this chapter highlights specific foods, food groups, and dietary patterns that are significantly associated with increased or decreased diabetes risk. A brief introduction to the initiation of the study is described in the section regarding the literature search strategy, and application of the health belief model as the theoretical foundation for the study is also discussed. This chapter also outlines different methodologies used by previous researchers addressing similar research questions and lists the strengths, limitations, and knowledge gaps associated with these studies that will be addressed in the present study.

Literature Search Strategy

A search for research articles pertaining to dietary patterns associated with diabetes began with a review of the PubMed, Cumulative Index of Nursing and Allied Health (CINAHL), EBSCO Academic Search Premier, Google Scholar, Science Direct, and MEDLINE databases available from the Walden University library. Additional efforts to retrieve relevant research articles included a review of the references listed at the end of other selected research articles. The keywords and search phrases used alone or in combination were as follows: "diabetes", "dietary patterns", "borderline diabetes", "prediabetes", "glucose intolerance", and "diet".

The selection of articles was restricted to those published in peer-reviewed journals within the past 10 years containing diet and diabetes-related search terms. Priority was given to articles with electronic full-text download capabilities. Search results were evaluated for content that specifically addressed the primary goals of the research. Selected articles were categorized into three broad groups based on their relevance to specific sections of the dissertation: background/introduction, literature review, and theoretical framework. Specifically, the background/introduction articles pertained to general information about diabetes as an important public health concern, methods for screening and diagnosing diabetes, the current state of knowledge of prediabetes and undiagnosed T2DM, and an overview of existing research on the association of diet and diabetes. The literature review articles pertained to existing research on specific diets significantly associated with increasing or decreasing the risk of diabetes, and the theoretical framework articles pertained to existing research supporting the theoretical framework of the dissertation. The three broad categories were further divided into subcategories depicting relevant themes common to multiple research studies. In some cases, there was limited current research on a given topic, such as the association of diet with prediabetes and undiagnosed T2DM, and this helped to support the problem statement regarding the gap in current knowledge. A review of the future research implications and research limitations described in the most recent research articles (published within the last 5 years) further supported the problem statement and the claim that the research problem was current and relevant.

Theoretical Foundation

The HBM is one of the most popular theories in the field of public health. Irwin M. Rosenstock initially proposed the theory in a 1966 publication describing health care use among ill populations (Glanz, Rimer, & Viswanath, 2008). Rosenstock proposed that psychological and physical factors could independently influence human behavior. Rosenstock presented a new way of thinking about health behavior, and his work is regarded as the first written documentation of what is now known as the HBM. Based on the HBM, multiple psychological and physical factors all work together to influence decisions about health behaviors; these factors include perceived risks, perceived barriers, and the severity of negative outcomes (Glanz & Bishop, 2010). Another tenet of the HBM is that self-perceived risks associated with a given behavior significantly influence an individual's willingness to modify their behavior (Glanz & Bishop, 2010).

The HBM was one of the first health behavior theories to suggest that health behavior is influenced by internal human thought processes (Glanz & Bishop, 2010), and the model serves as a conceptual framework for subsequent health behavior theories. The HBM may also provide a framework for diabetes prevention interventions aimed at identifying appropriate strategies for reducing diabetes risk factors among patients (Glanz & Bishop, 2010). One of the limitations of the HBM is that it does not account for different stages of readiness for behavior change. Moreover, given the influence of multiple psychological factors on health behavior, it may be difficult to discern the influence of one factor from another, making it difficult to effectively apply the theory for certain health behaviors (Dedeli & Fadiloglu, 2011). Despite these limitations, the HBM is important for public health research because it provides a framework for linking health behaviors with psychological processes. The theory provides a central foundation for subsequent health behavior theories, qualifying it as a leading theoretical model for public health prevention activities (Glanz & Bishop, 2010).

Consistent with the HBM, individuals who are knowledgeable about healthy eating and nutritional guidelines are more likely to adopt healthier diets as a result of feeling more confident about how to effectively implement a healthy dietary plan (Edman, Diamond, Wortman, & Carballo-Sayao, 2011). Similarly, individuals with diabetes who are more adherent to healthy dietary patterns are more likely to feel a greater sense of confidence in controlling their diabetes (Gherman et al., 2011). Based on the concepts of the HBM, healthy eating behavior stems from a unique way of thinking about one's ability to control health outcomes and one's perceptions of the risks associated with not adopting healthier behaviors (Sapp & Jensen, 1998; Harvey & Lawson, 2009).

The HBM relates to the present study given the idea that current healthy or unhealthy eating behavior may reflect an individual's self-perception of diabetes risk. In other words, if those with undiagnosed diabetes have higher dietary adherence scores for unhealthy eating patterns than those with diagnosed diabetes, then these differences may be attributed to differences in knowledge of recommended nutritional guidelines that is directly related to knowledge of current health status. One caution with applying the HBM concepts in research studies is that if is often difficult to use in a cross-sectional research context. For example, in the present study it would be difficult to ascertain subsequent eating patterns following diabetes diagnosis or to presume a cause and effect relationship using a cross-sectional research design. That is, it is unknown whether people's perceptions of the risks of unhealthy eating is a consequence of unhealthy eating behaviors, whether people adopt unhealthy eating behaviors as a consequence of their perceptions of unhealthy eating, or if potential biological factors mediate the relationship between perceptions and behaviors (Gherman et al., 2011). Furthermore, it is difficult to observe whether dietary patterns measured at a single point in time are consistent over a long duration period (Archer et al., 2004).

Literature Review Related to Key Variables and Concepts

An extensive review of the literature was conducted to synthesize current knowledge of diet-diabetes associations. Many of the reviewed studies described individual food groups associated with diabetes incidence or diabetes risk whereas others pertained to specific food group combinations or dietary patterns. There are pros and cons associated with studying dietary patterns as opposed to single food groups. Unlike single food group analyses, dietary pattern analysis captures synergistic and antagonistic effects of food combinations that reflect the cumulative effect of individual foods on diabetes risk (Erber et al., 2010; Fung, Schulze, Manson, Willett, & Hu, 2004). On the other hand, a limitation of dietary pattern analysis is the difficulty in separating the independent effects of food groups, specific foods, or particular nutrients that may play an important role in diet-diabetes associations. The selected articles were categorized into the following two broad themes: Individual food groups or dietary patterns associated with increased diabetes risk and Individual food groups or dietary patterns associated with decreased diabetes risk.

Individual Food Groups or Dietary Patterns Associated with Increased Diabetes Risk

Meat. Previous studies found a positive association between meat consumption and the risk of T2DM. A systematic review and meta-analysis of the effects of meat consumption on T2DM risk found that individuals who consumed a high intake of meat (defined as more than the average daily amount) were 1.17 times more likely to develop diabetes than those who consumed a low intake, and the risk was even higher when meats were divided into red meats (RR=1.21) and processed meats (RR=1.41) (Aune, Ursin, & Veierød, 2009). A prospective cohort study of over 16,000 European adults similarly found that a high consumption of red and processed meats significantly increased the incidence of T2DM (HR=1.08 and HR=1.12, respectively), and these results varied by gender, as the risk estimates were slightly lower in women (HR=1.06 and 1.08, respectively); poultry consumption also emerged as a significant risk factor for women (HR=1.20); see InterAct Consortium, 2013). Gender differences in the association of meat consumption and T2DM were also observed in a large prospective cohort study of Japanese American and Native Hawaiian participants. Specific findings revealed that men who consumed high quantities of meat were 1.40 times as likely and women were 1.22 times as likely to develop diabetes in comparison to those who did not consume high quantities of meat (Erber et al., 2010). The lower risk of T2DM in women in comparison to men was most likely due to a lower meat intake among women.

A recent prospective cohort study of over 40,000 African-American considered the setting of meat food preparation in the association of meat consumption and diabetes. The rationale for the research was that meat foods prepared in fast-food restaurants often contain higher cholesterol levels and larger portions sizes in comparison to foods prepared in a private home, thus, frequent consumption of fast-food meat-containing meals could significantly increase the risk of diabetes (Krishnan, Coogan, Boggs, Rosenberg, & Palmer, 2010). The results indicated that consumption of meat foods in a fast-food restaurant setting was significantly associated with increased risk of T2DM. Women in the study who consumed at least 2 fried chicken meals per week or at least 2 hamburger meals per week from a restaurant were 1.27 and 1.15 times as likely, respectively, to develop diabetes in comparison to those who reportedly consumed no meat-containing meals from a fast-food restaurant in the past year, adjusting for key demographics (age, BMI, family history of diabetes, education), lifestyle (e.g., television-viewing, physical activity level), dietary factors (e.g., consumption of other unhealthy foods), and BMI (Krishnan, Coogan, Boggs, Rosenberg, & Palmer, 2010). These results may relate more to the food preparation practices in fast-food settings, such as frying or adding fat to meats during cooking, as these methods are associated with increased diabetes risk (Archer et al., 2004).

One mechanism by which meat intake could increase the risk of T2DM is through the influence of total fat and saturated fat consumption on obesity, hyperglycemia, and other risk factors that are strongly associated with T2DM incidence (Aune, Ursin, & Veierød, 2009). Another mechanism is through the influence of heme iron, a major component of red meat, which could influence the metabolism of glucose and impede the insulin-producing function of the pancreas (Aune, Ursin, & Veierød, 2009; InterAct Consortium, 2013). In a systematic review of 31 research studies, heme iron from red meat—but not from other sources—was positively associated with T2DM, suggesting that other components of red meat besides the heme iron may explain the association with T2DM (Murakami, Okubo, & Sasaki, 2005). The association may be explained by the influence of nitrite, a commonly used meat preservative, which could be converted to nitrosamines in the stomach and impair the functioning of the pancreas to produce insulin (Aune, Ursin, & Veierød, 2009; InterAct Consortium, 2013).

High meat intake is often associated with an unhealthy lifestyle, including low physical activity, smoking, and consuming unhealthy foods (Aune, Ursin, & Veierød, 2009). As shown in previous studies, the positive association of meat consumption with diabetes risk persists after adjustment for the potential combined effects of meat with other unhealthy food groups (Murakami, Okubo, & Sasaki, 2005; Aune, Ursin, & Veierød, 2009; InterAct Consortium, 2013). This finding suggests that the elimination of meat food groups from the diets of individuals with no history of diabetes could significantly decrease the risk of developing diabetes, and it further suggests that a high adherence to dietary patterns that do not include meat food groups could significantly decrease diabetes risk.

Eggs. Egg consumption, like meat, is associated with greater T2DM risk. In a prospective cohort study of health professionals, men and women who consumed at least 7 eggs per week were 1.58 and 1.77 times as likely, respectively, to develop diabetes compared with those who reported no egg consumption (Djoussé, Gaziano, Buring, & Lee, 2009). Men diagnosed at baseline with diabetes who consumed at least 7 eggs per week were also twice as likely to develop cardiovascular disease compared with diabetic men who did not consume eggs (Hu et al., 1999). According to a recent systematic review, an increment of 4 eggs per week increased the risk of diabetes by 29% (pooled RR=1.68, 95% CI=[1.41-2.00]; see Li, Zhou, Zhou, & Li, 2013).

The association of egg consumption and diabetes risk may be explained by the saturated fat or cholesterol content of eggs. However, high egg consumption may also be correlated with the adherence to unhealthy dietary patterns, such as a high red and processed meat intake and a low fruits and vegetables intake (Hu et al., 1999; Li, Zhou, Zhou, & Li, 2013). Thus, given that eggs are commonly consumed in combination with other unhealthy foods or as an ingredient in composite foods, the negative health effects of other foods eaten in combination with eggs could overestimate the independent effect of eggs on adverse health events (Djoussé, Gaziano, Buring, & Lee, 2009).

White rice. White rice consumption is positively associated with an increased risk of T2DM. A prospective cohort study of US health professionals found that consuming 5 or more servings of white rice per week was associated with a 17% increase in diabetes risk (95% CI=[1.02, 1.36]; see Sun et al., 2010). A systematic review and meta-analysis of four prospective cohort studies of over 350,000 Asian and Western populations concluded that a 1-unit increase in daily servings of white rice was associated with an 11% increase in the relative risk of T2DM among consumers compared with non-consumers (95% CI=[1.08, 1.14]), and the risk was even higher when the study population was restricted to Chinese and Japanese groups (RR=1.55, 95% CI=[1.20, 2.01]; see Hu, Pan, Malik, & Sun, 2012). These findings suggest that white rice consumption may be a more significant risk factor for T2DM among populations of Asian ancestry, and stratification by ethnic groups in statistical analyses is essential for an accurate assessment of the association.

The positive association between white rice and T2DM likely reflects the high glycemic index and low levels of insoluble fiber and magnesium content of white rice. The glycemic index is a quantitative measure of how much a carbohydrate-containing food increases the amount of sugar in the blood (Diabets.org, 2015). White rice has a higher glycemic index than brown rice and whole grains, and the lower glycemic index of these two foods may explain their association with decreased diabetes risk (Sun et al., 2010; Hu, Pan, Malik, & Sun, 2012; Ye, Chacko, Chou, Kugizaki, & Liu, 2012). Compared with brown rice and whole grains, white rice is also lower in insoluble fiber and magnesium, two nutrients that are significantly associated with reduced T2DM risk (Hu, Pan, Malik, & Sun, 2012). Specifically, high-fiber foods significantly lower insulin levels by influencing digestive system processes such as gastric emptying and intestinal macronutrient absorption, and magnesium influences the function of insulin receptor proteins that are essential for maintaining appropriate insulin levels in the blood (Salmeron et al., 1997; Schulze et al., 2007).

Western dietary pattern. The Western dietary pattern is characterized by a high consumption of high-fat dairy products red and processed meats, refined grains, fried starchy foods, and sugary foods (Perry, 2002). Given the high intake of sugary foods, the Western diet is significantly associated with an increased likelihood of elevated HbA1c levels (Kerver, Yang, Bianchi, & Song, 2003). Recall that HbA1c is a marker of increased blood sugar and a strong precursor to the development of diabetes. Thus, the Western diet is also associated with a 60% increased risk of diabetes (RR=1.6, 95% CI=[1.3,1.9]), and combining the diet with low physical activity or obesity further increases the risk (Perry, 2002). In a prospective cohort study of nearly 70,000 women over the age of 35, adherence to the Western diet increased the risk of T2DM by 49% (RR=1.49, 95% CI=[1.26,1.76]), and the risk still remained high when the analysis was stratified by specific components of the diet, such as red meats (RR=1.26, 95% CI=[1.21,1.42]) and total processed meats (RR=1.38, 95% CI=[1.23,1.56]; see Fung, Schulze, Manson, Willett, & Hu, 2004). Given the attenuated increase in risk observed in the stratified analysis compared with the risk observed for the full diet, it is clear that meats alone do not fully account for the increased risk in diabetes associated with the Western diet; furthermore, it is important to consider other components of the diet to more fully understand diabetes risk associated with the Western diet.

Conservative dietary pattern. The conservative dietary pattern features a high consumption of red meats, whole milk, butter, and potatoes (Montenen et al., 2005). The relative risk of diabetes associated with high adherence to the conservative diet was found to be 1.49 (95% CI=[1.11, 2.00]) in a Finnish cross-sectional study of approximately 4,000 men and women aged 40-69 years (Montenen et al., 2005). However, it is difficult to find other published studies that consider the role of the conservative diet as a risk factor for diabetes. Thus, it is of interest to the present study to further investigate the association of this particular dietary pattern with diabetes risk, particularly within a population of U.S. adults.

Individual Food Groups or Dietary Patterns Associated with Decreased Diabetes Risk

Dairy. Dairy was the most frequently-cited protective food group identified in the literature, but its association with diabetes risk was inconsistent across multiple studies, leading to the conclusion that the association of dairy intake and diabetes risk remains unclear. First, in a meta-analysis of 3 prospective cohort studies of diary intake among US health professionals of European ancestry, total dairy was not found to be significantly associated with diabetes risk (Chen et al., 2014). Similarly, in a population-based case-cohort study of men and women from the United Kingdom, there was no significant association between total dairy intake and diabetes risk (O'Conner et al., 2014). However, other studies have reported an inverse association, that is, a decreased risk of diabetes following high dairy intake. In two prospective cohort studies of nondiabetic individuals, one daily serving of dairy was associated with a 9% reduced risk of T2DM (Choi et al., 2005), and, a 1-unit increase in daily servings of dairy was associated with a 4% lower risk of diabetes (Liu et al., 2006). Multiple studies have found that the risk of T2DM for dairy consumers is approximately 0.85 times the risk for non-dairy consumers, even if dairy foods are consumed at low levels (95% CI=[0.79-0.92]) (Elwood, Pickering, Givens, & Gallacher, 2010; Margolis et al., 2011; Tong, Dong, Wu, Li, & Qin, 2011). A systematic review and meta-analysis also concluded that an inverse association exists between total dairy product intake and T2DM risk (summary RR=0.93, 95% CI=[0.87,0.99]) (Aune, Norat, Romundstad, & Vatten, 2013), and the reported positive benefits of dairy consumption on diabetes risk may occur in a dose-response manner, for the higher the intake the lower the risk (Tong, Dong, Wu, Li, & Qin, 2011; Kalergis, Yinko, & Nedelcu, 2013). Perhaps distinguishing between low-fat and high-fat dairy products may help to resolve discrepant findings regarding the role of dairy intake on diabetes risk (Liu et al., 2006).

The association between specific dairy products and T2DM risk is also unclear. Some studies have shown that milk, cheese, and yogurt foods do not significantly influence diabetes risk (Aune, Norat, Romundstad, & Vatten, 2013; Elwood, Pickering, & Fehily, 2007) whereas others have found significant associations among specific dairy products. For example, yogurt intake was found to be a significant protective factor against the development of diabetes (RR=0.82, 95% CI=[0.70, 0.97], HR=0.83, 95% CI=[0.75,0.92]) (Liu et al., 2006; Margolis et al., 2011; Tong, Dong, Wu, Li, & Qin, 2011; Chen et al., 2014; O'Conner et al., 2014). Recommendations for future studies to reduce inconsistencies include controlling for more confounders and considering more subtypes of dairy food products.

Studies suggest that dietary calcium, vitamin D, protein, magnesium, and fat found in dairy foods may all play a role in the mechanism by which dairy intake influences diabetes risk. Calcium and vitamin D have been found to increase the production of insulin and reduce insulin resistance, both which help to reduce the risk of diabetes (Tong, Dong, Wu, Li, & Qin, 2011; Aune, Norat, Romundstad, & Vatten, 2013). Whey proteins and magnesium found in dairy foods may also protect against the development of diabetes by increasing insulin sensitivity and preventing weight gain. Calcium and whey proteins may also play a role in burning body fat, which reduces the risk of obesity which could ultimately lead to reduced diabetes risk (Kalergis, Yinko, & Nedelcu, 2013).

The role of dairy fat in the dairy-diabetes association is still unclear due to inconsistent findings across multiple studies (Kratz, Baars, & Guyenet, 2013), as some studies suggest no association between high-fat dairy products and diabetes risk (Margolis et. al 2011; Tong, Dong, Wu, Li, & Qin, 2011; Kalergis, Yinko, & Nedelcu, 2013; Chen et al., 2014) while multiple studies of low-fat dairy products have reported a decreased risk of diabetes (Choi et al., 2005; Liu et al., 2006; Margolis et al., 2011; Tong, Dong, Wu, Li, & Qin, 2011; Kalergis, Yinko, & Nedelcu, 2013; O'Conner et al., 2014). One explanation for the discrepant results is inconsistent adjustment for the strong influence of BMI on diabetes risk, as adjustment for BMI could minimize the beneficial effects of dairy fat on adiposity and thus, attenuate a potentially negative association between dairy fat intake and diabetes incidence (Kratz, Baars, & Guyenet, 2013).

Fruits and vegetables. Nutritional guidelines from the U.S. Department of Agriculture suggests that fruits and vegetables should comprise at least 50% of the foods consumed at every meal in order to receive proper nutrients for strengthening the immune system and reduce the risk of chronic diseases (CDC, 2011). A systematic review and meta-analysis of literature pertaining to fruit and vegetable consumption and diabetes risk revealed that green leafy vegetable intake was associated with a 14% reduction in diabetes risk, yet no significant reduction was observed for total vegetable, total fruit, or fruits and vegetables combined (Carter, Gray, Troughton, Khunti, & Davies, 2010). Green leafy vegetables contain magnesium, which is associated with reduced diabetes risk; and, they also contain antioxidants and omega 3 polyunsaturated fatty acids, which help to prevent adiposity and subsequent obesity (Carter, Gray, Troughton, Khunti, & Davies, 2010).

Fruit and vegetable intake may be measured according to the amount of daily servings, yet a more sensitive approach may be to consider biological markers such as plasma level C concentration (Carter, Gray, Troughton, Khunti, & Davies, 2010). Using this approach, Harding et al. (2008) found that a high plasma vitamin C level was significantly associated with a 62% reduction in diabetes risk (OR = 0.38, 95% CI=[0.28, 0.52]). Vitamin C may help reduce the risk of diabetes based on its antioxidant properties which help to maintain proper glucose metabolism. Findings from the Harding et al. (2008) study suggest that consuming even a small quantity of fruits and vegetables could protect against the development of diabetes, and the more fruits consumed the lower the risk.

Whole grains. Consumption of two servings per day of whole grains is associated with a 21% decreased risk ofT2DM in a prospective cohort of adult women (de Munter, Hu, Spiegelman, Franz, & van Dam, 2007), and general whole grain consumption was associated with a 26% reduction in T2DM based on a systematic literature review (Ye, Chacko, Chou, Kugizaki, & Liu, 2012). Whole grain foods include whole wheat, dark bread, oats, brown rice, rye, barley, and bulgur (Ye, Chacko, Chou, Kugizaki, & Liu, 2012). Potential mechanisms by which the inverse association with T2DM occurs is through the cereal fiber and magnesium found in whole grains, both which have been found to be significantly associated with reduced diabetes risk (de Munter, Hu, Spiegelman, Franz, & van Dam, 2007; Krishnan et al., 2007; Ye, Chacko, Chou, Kugizaki, & Liu, 2012). Another component of whole grains called lignans may also contribute to the inverse association given their antioxidant properties which could protect against the development of diabetes (de Munter, Hu, Spiegelman, Franz, & van Dam, 2007).

Furthermore, in comparison to refined grains, the intact structure of whole grains produces a lower glycemic index, which reduces the risk of diabetes (Ye, Chacko, Chou, Kugizaki, & Liu, 2012).

Other protective food groups. Other food groups associated with decreased diabetes risk include Nuts, Legumes, and Brown rice foods. Consumption of at least 1 serving of walnuts per week was associated with a 19% reduction in diabetes risk among a large prospective cohort of women over the age of 50 (RR=0.81, 95% CI=[0.70-0.94]), and this association may be explained by the polyunsaturated fatty acids found in nuts which protect against the development of diabetes (Pan, Sun, Manson, Willett, & Hu, 2013). However, a systematic review of literature found that increased walnut consumption may not significantly improve blood glucose levels of patients with diabetes (Wheeler et al., 2012). Similar findings suggest that legumes may significantly lower HbA1c levels in certain diabetic populations, but many studies did not indicate significant improvements in blood glucose levels among diabetic patients after increased consumption of legumes (Wheeler et al., 2012). High brown rice intake has been associated with an 11% reduction in diabetes risk (RR=0.89, 95% CI=[0.81-0.97]), and substituting brown rice for white rice is recommended for significant reduction in diabetes risk (Sun et al., 2010).

Mediterranean dietary pattern. The Mediterranean diet (MedDiet) features a high consumption of fruits, grains, legumes, nuts, olive oil, vegetables, moderate amounts of fish and wine, and low amounts of processed meats, red meats, and high-fat dairy products (Martínez-González et al., 2008; Salas-Salvadó et al., 2011). The diet is also generally characterized as having a high intake of dietary fibers and a high unsaturated fat: saturated fat ratio (primarily due to replacing saturated fats used in cooking with virgin olive oil; see Ben-Avraham, Harman-Boehm, Schwarzfuchs, & Shai, 2009; Esposito, Maiorino, Ceriello, & Giugliano, 2010). Adherence to the MedDiet is typically measured using an index score ranging from 0 to 1 that takes into account the daily intake of each food group included in the diet (Trichopoulou et al., 1995). MedDiet adherence is associated with a 0.41 point reduction in diabetes risk (95% CI=[0.19-0.87]) (Martínez-González et al., 2008; Ben-Avraham, Harman-Boehm, Schwarzfuchs, & Shai, 2009), and in a prospective cohort study of an initially health population, a two-point increase in adherence to the MedDiet was associated with a 35% reduction in diabetes risk (Martínez-González et al., 2008). In a systematic review of the association of the MedDiet with diabetes risk, multiple studies confirmed that the MedDiet was significantly associated with improvements in fasting glucose and HbA1c levels (Esposito, Maiorino, Ceriello, & Giugliano, 2010; Itsiopoulos et al., 2011), and multiple studies confirm that close adherence to the diet could reduce the incidence of diabetes by 35-83% (Esposito, Maiorino, Ceriello, & Giugliano, 2010; Salas-Salvadó et al., 2011).Furthermore, adherence to the MedDiet leads to lower all-cause mortality among diabetic patients, independently of the severity of diabetes (Bonaccio et al., 2015).

The dietary components of the MedDiet such as fibers, magnesium, and unsaturated fats may all play an influential role in the mechanism by which the inverse association with diabetes risk occurs (Ben-Avraham, Harman-Boehm, Schwarzfuchs, & Shai, 2009). Regarding unsaturated fats such as olive oil, multiple studies suggest that the monounsaturated fatty acids found in olive oil could help to protect against insulin resistance and lead to improved insulin sensitivity (Martínez-González et al., 2008; Esposito, Maiorino, Ceriello, & Giugliano, 2010).

Prudent dietary pattern. The Prudent diet includes high amounts of fruit and vegetables, low-fat dairy products, fish, pasta and rice (Perry, 2002). The prudent diet was associated with lower fasting blood glucose and a 56% reduced risk of diabetes among women over the age of 50 (Perry, 2002), yet the association was only moderately significant within a cohort of female nurses over the age of 30 (RR=0.86, 95% CI=[0.76,0.97]) (Fung, Schulze, Manson, Willett, & Hu, 2004). The prudent diet was also moderately associated with reduced diabetes risk in a cohort of adult Finnish men and women with no history of diabetes (RR=0.82, 95% CI=[0.76,0.97])(Montenen et al., 2005).

DASH dietary pattern. The Dietary Approaches to Stop Hypertension (DASH) diet is characterized by a high consumption of fruits, vegetables, low-fat dairy products, nuts, seeds, and whole grains and a low consumption of meat, poultry, eggs, fats, and oils (Liese, Nichols, Sun, D'Agostino, & Haffner, 2009). It has been widely recommended for reducing the risk of hypertension, yet multiple studies have also found that adhering to the diet significantly reduces the risk of diabetes (Liese, Nichols, Sun, D'Agostino, & Haffner, 2009). However, the association of DASH diet adherence with diabetes risk apparently varies by race, as Whites are more likely to see significant reductions in diabetes risk after adhering to the DASH diet than other racial groups (Liese, Nichols, Sun, D'Agostino, & Haffner, 2009). A cross-sectional study of US adults aged 20 years and older using NHANES data found that although adults with diabetes did not consistently adhere to the DASH diet, they did significantly adhere to certain aspects of the diet, such as a high fiber intake and a low saturated fat intake (Morton, Saydah, & Cleary, 2012). Limited adherence to the DASH diet may reflect a lack of education about the diet.

Previous Methods for Addressing the Research Problem

Following the review of evidence concerning diet-diabetes associations, selected articles pertaining to specific dietary patterns were further assessed for commonalities in research methodologies; particular attention was given to methods for collecting food intake data, identifying dietary patterns, measuring adherence to dietary patterns, and modelling diet-diabetes associations.

Food Intake Data Collection Methods

The most frequently-cited method for collecting food intake data was the use of a food frequency questionnaire to elicit participants' self-reported frequency of consumption and portion sizes of foods listed in the questionnaire. In some cases, the frequency of consumption was reported as a quantitative measure (Trichopoulou et al., 1995; Montenen et al., 2005; Brunner et al., 2008; Liese, Nichols, Sun, D'Agostino, & Haffner, 2009) and in other cases, the consumption frequency was captured using Likert-scale responses ranging from "Never" to "More than 6 times a day" (Fung, Schulze, Manson, Willett, & Hu, 2004; Martínez-González et al.,2008; Ortega et al., 2012). Other methods for collecting food intake data included in-person interviews (Morton, Saydah, & Cleary, 2012);, a food frequency questionnaire-dietary interview combined approach (Ben-Avraham, Harman-Boehm, Schwarzfuchs, & Shai, 2009);, and prospective, self-reported food diaries (Itsiopoulos et al., 2011).

Methods for Identifying Dietary Patterns

The most common approach for aggregating collected foods into food categories was the use of pre-defined food groups based on nutrient or culinary profiles (Kerver, Yang, Bianchi, & Song, 2003; Fung, Schulze, Manson, Willett, & Hu, 2004; Montenen et al., 2005; Martínez-González et al.,2008; Liese, Nichols, Sun, D'Agostino, & Haffner, 2009; Bonaccio et al., 2015). Following the formation of food groups, many researchers applied statistical methods such as factor analysis (Kerver, Yang, Bianchi, & Song, 2003; Fung, Schulze, Manson, Willett, & Hu, 2004; Montenen et al., 2005; Bonaccio et al., 2015) and cluster analysis (Brunner et al., 2008) to identify dietary patterns, whereas others used known dietary patterns in their investigations (Perry, 2002; Martínez-González et al.,2008; Itsiopoulos et al., 2011).

Diet Adherence Methods

Methods for measuring dietary pattern adherence include taking the sum of the frequency of consumption of individual food groups, using an index scoring system based on median consumption levels of the study sample, and using a scoring system based on recommended daily intake. The first method regarding summation of individual food group consumption data pertains to the results of factor analysis techniques in which the factor loadings of individual food groups comprising a specific dietary pattern are used to calculate weighted food intakes, and these weighted food intakes are summed together to produce the dietary pattern score (Kerver, Yang, Bianchi, & Song, 2003; Fung, Schulze, Manson, Willett, & Hu, 2004; Montenen et al., 2005). The second method for measuring dietary pattern adherence, first introduced by introduced by Trichopoulou et al. (1995), assigns a score of 1 for each protective food group (e.g., fruits, vegetables) that the participant consumes more than the median daily intake and for each non-protective food group (e.g., red meats) that the participant consumes less than the median daily intake; the adherence score is calculated based on the sum of the scores for each food group (Martínez-González et al.,2008; Liese, Nichols, Sun, D'Agostino, & Haffner, 2009; Bonaccio et al., 2015). The third method assigns scores to individual food groups based on recommended daily servings such that the highest points are assigned if the recommended serving was met and lower points are assigned proportionally (Ortega et al., 2012; Morton, Saydah, & Cleary, 2012).

Methods for Modelling Diet-Diabetes Associations

Statistical methods for modeling the diet-diabetes association include Cox proportional hazards, linear, and multiple logistic regression techniques. Cox proportional hazard models can assess the relative risk of diabetes over time by dietary adherence status, taking into account diabetes incidence and the time until its occurrence (Trichopoulou et al., 1995; Fung, Schulze, Manson, Willett, & Hu, 2004; Montenen et al., 2005; Brunner et al., 2008; Salas-Salvadó et al., 2011;Bonnacio et al., 2015). Linear regression methods consist of modeling the dietary pattern score as a function of diabetes status, controlling for covariates (Ortega et al., 2012), whereas multiple logistic regression methods consist of modeling diabetes status as a function of dietary pattern score, controlling for covariates (Liese, Nichols, Sun, D'Agostino, & Haffner, 2009).

Statistical models included dietary pattern score as either a continuous (Ortega et al., 2012) or a categorical variable grouped into tertiles (Liese, Nichols, Sun, D'Agostino, & Haffner, 2009), quartiles(Montenen et al., 2005), or quintiles (Perry, 2002; Kerver, Yang, Bianchi, & Song, 2003; Fung, Schulze, Manson, Willett, & Hu, 2004). Few studies included qualitative dietary pattern variables with values ranging from poor/low adherence to high adherence (Martínez-González et al.,2008; Bonnacio et al., 2015). The most frequently cited covariates included in statistical models were age, gender, ethnicity, education, family history of diabetes, smoking status, physical activity level, and BMI level.

Strengths and Weaknesses of Previous Studies

A major strength of the systematic reviews of evidence of the meat-diabetes association is that the combined statistical results from several research studies (e.g., pooled relative risk estimates) increased the statistical power to detect significant associations (Aune, Ursin, & Veierød, 2009). Several other reviewed studies also had the advantage of analyzing large samples, which increased the likelihood that the samples were representative of the broader populations of interest. Another advantage of many studies was the use of a prospective cohort design, which eliminated the potential for recall bias and inaccurate food recall data.

There were several limitations of the findings from the reviewed literature. One major limitation is the potential for inaccurate self-reporting of diabetes status and imprecise dietary assessments. Many studies restricted the study population to patients who self-reported their diabetes status, yet excluded those who may have been unaware of their diabetes status (InterAct Consortium, 2013). Also, many studies used food frequency diaries that may have been prone to misreporting of food intakes, and the intake for some food groups may have been underreported if the food group was a minor ingredient in a composite dish (e.g., eggs, whole grains; O'Conner et al., 2014). Secondly, many studies were unable to control for potential residual confounding due to BMI, as it was often unclear whether BMI served as a confounder or a mediator in the association of foods and food groups with T2DM risk (Erber et al., 2010; Kratz, Baars, & Guyenet, 2013). Residual confounding was also an issue in the dairy research studies, particularly given that consumers of dairy products could have been more likely than non-consumers to engage in healthful diet and exercise behavior, which could bias the study results (Kalergis, Yinko, & Nedelcu, 2013). Similarly, egg consumers could have been more likely than non-consumers to consume other unhealthy dietary patterns or to engage less often in physically active activities (Hu et al., 1999). Third, none of the selected articles regarding T2DM risk due to egg consumption evaluated the independent effects of whole-egg versus egg yolk or egg white consumption, which could have changed the results given that egg yolk consumption is associated with high cholesterol intake and unhealthy eating and egg white consumption is associated with healthy eating (Radzevičienė & Ostrauskas, 2012; Li, Zhou, Zhou, & Li, 2013). Fourth, for many studies, there was the potential lack of generalizability of results to the entire U.S. population, specifically among studies restricted to certain subgroups of the U.S. population or studies of non-U.S. populations. A fifth limitation associated with the systematic reviews and meta-analysis studies is that the results from multiple research articles were often heterogeneous in nature due to differences in dietary assessment methods, study populations, and dietary intake methods (Aune, Ursin, & Veierød, 2009), and the selected articles were likely prone to publication bias. A final limitation of the reviewed studies regarding adherence to dietary patterns is that the scores used to measure adherence often used arbitrary cutoff values, leading to imprecise measurements (Bonaccio et al., 2015).

Summary and Conclusions

Consumption of certain food groups such as meat, eggs, and white rice are significantly associated with increased T2DM risk, and these food groups may combine and interact within distinct dietary patterns such as the Western and Conservative dietary patterns to further increase the risk of T2DM. Similarly, some food types such as Dairy, Fruits and Vegetables, Whole Grains, Nuts, Legumes, and Brown rice may act independently or interact together to decrease the risk of T2DM. Future studies regarding the mechanism by which these food groups singly and additively influence diabetes risk could be beneficial for persons at risk of diabetes, persons already diagnosed with diabetes, and health professionals.

The findings from the review and synthesis of the literature provide a comprehensive assessment of what is currently known about diet-diabetes associations. It is currently known that meat food groups significantly increase the risk of T2DM both independently and combined with other food groups. Although this increased risk was consistent across racial groups and gender, differences in the relative risk of T2DM across racial groups and gender were likely due to differences in the frequency of consumption. Furthermore, consumption of meat foods in a fast-food restaurant may further increase the risk of T2DM for African-American women. The association of meat consumption and diabetes may be explained by individual meat components, including total and saturated fat, heme iron, and nitrites. Findings from the literature also suggest that consuming at least one egg per day is associated with increased diabetes risk, and the cholesterol and saturated fat content of eggs may explain this association. Daily white rice consumption is also significantly associated with increased diabetes risk, and the glycemic index of rice, insoluble fiber, and magnesium are potential contributing factors for the association.

Although the findings from multiple research studies regarding the role of dairy intake on diabetes risk were inconsistent, several studies support the notion that dairy intake significantly reduces the risk of T2DM, and the effect of dairy on diabetes risk likely happens in a dose-response manner. A closer look at low-fat dairy products and yogurt foods could help to further explain the inverse association. Furthermore, nutritional components such as calcium, vitamin D, protein, magnesium, and fat could play a significant role in the influence of dairy on diabetes risk. The inverse associations of whole grain, legumes, nuts, and brown rice consumption and diabetes risk may also be explained by dietary nutrients such as cereal fiber and magnesium. Fruits and vegetables also significantly lower the risk of diabetes in an apparent dose-response manner, yet green leafy vegetables appear to play the most critical role in the reduction in risk. Vitamin C levels may serve as a reliable proxy of the amount of fruit and vegetables consumed in the diet, and vitamin C intake is associated with a greater reduced risk of diabetes in comparison to green leafy vegetables and fruits (14% versus 62%, respectively) (Harding et al., 2008; Carter, Gray, Troughton, Khunti, & Davies, 2010).

Specific dietary patterns associated with increased diabetes risk include the Western and Conservative diets. Dietary patterns associated with reduced diabetes risk include the MedDiet, Prudent Diet, and DASH diet. Both the Western and Conservative diets feature a high consumption of red meats, high-fat dairy, and starchy foods, the Western diet additionally includes a high consumption of sugary foods. Although the protective dietary patterns all feature a high intake of fruits and vegetables, the MedDiet additionally features a high intake of unsaturated fats with a low consumption of meats and dairy products, while both the Prudent diet and DASH diets feature a high intake of low-fat dairy foods. The low-fat dairy feature of the DASH diet has been a strong argument for the adoption of the diet for those with hypertension given the association of low-fat dairy foods with lower blood pressure, and adoption of the diet could similarly benefit diabetic patients (Liu et al., 2006). Unlike the other protective diets, the Prudent diet combines rice and pasta whereas the DASH diet limits egg intake.

There are two key gaps in the literature regarding diet-diabetes association: 1) the most effective dietary strategy for reducing diabetes risk; and, 2) the dietary habits of persons with undiagnosed diabetes. The dietary strategy that is most effective for reducing the risk of diabetes and the diet associated with the greatest increase in diabetes risk is currently unknown. That is, the relative importance of specific dietary patterns associated with diabetes is still unclear. The present study will compare the odds of adherence to specific dietary patterns among different diabetes groups in order to further explore this area. Furthermore, there is limited research regarding the comparison of dietary habits of those with diagnosed versus undiagnosed diabetes. One study of Native American communities found that individuals with diagnosed diabetes typically adopted healthier eating patterns than those with no history of diabetes whereas those with undiagnosed diabetes adopted more unhealthy eating patterns than those with no history of diabetes, potentially suggesting that the diets of diabetics improved upon diagnosis (Archer et al., 2004). The present study will determine if similar differences in dietary habits among diagnosed versus undiagnosed diabetics is observed in a US population of adults aged 20 years and older. A related gap in the literature is whether the dietary patterns associated with diagnosed T2DM are independently associated with undiagnosed prediabetes and undiagnosed T2DM. A prospective cohort study of Spanish populations found that adherence to the MedDiet was significantly associated with undiagnosed diabetes (prediabetes and T2DM combined) (OR=0.88, 95% CI= [0.81,0.96], $p < 0.001$). The present study will investigate the independent association of several diabetes-associated dietary patterns with the risk of undiagnosed prediabetes and undiagnosed T2DM (Ortega et al., 2012).

Evidence from the literature provides insights into diet-diabetes associations, yet more research is needed regarding the association of diet and preliminary stages of diabetes. The present study is the first known study to consider the relative importance of established dietary patterns on the risk of diabetes. Chapter 3 outlines the cross-sectional approach for exploring this area of research and will explain in detail the study design, sample selection procedures, and analytic methods for addressing the primary research question of whether certain dietary patterns are more likely than others to be consumed by individuals with undiagnosed T2DM and undiagnosed prediabetes.

Chapter 3: Research Method

Introduction

The purpose of this study is to compare the odds of adherence to specific dietary patterns that are known to increase the risk of diabetes (i.e., Western and Conservative) or decrease (i.e., Mediterranean, Prudent, and DASH) the risk of diabetes. Specifically, this study will utilize data from NHANES to compare adherence to the different dietary patterns based on self-reported responses to a 24-hour dietary recall. Diet adherence will be measured by computing an adherence score similar to the methods of previous authors (Trichopoulou et al.,1995; Martínez-González et al., 2008; Bonaccio et al., 2015). This study will address the primary research question of whether there are statistically significant differences in the mean adherence to risky or protective dietary patterns among individuals with no diabetes, unknown diabetes risk (undiagnosed prediabetes or T2DM), and known diabetes risk (diagnosed prediabetes or T2DM). The study will also address the research question of whether there are significant differences in the odds of adherence to risky and protective dietary patterns, adjusting for covariates. Findings from the study will identify the most harmful food combinations associated with increased T2DM risk while also highlighting the most effective food combinations for reducing or preventing T2DM.

This chapter presents a quantitative approach for investigating the association of dietary patterns and the risk of undiagnosed diabetes. A detailed overview of the study design and rationale, target population, sample selection procedures, and analytical methods are described in detail. The chapter concludes with a discussion of potential threats to validity and ethical considerations.

Research Design and Rationale

The main independent variable of interest to the study is diabetes status, measured as a nominal variable with 5 categories: normal, undiagnosed prediabetes, diagnosed prediabetes, undiagnosed T2DM, and diagnosed T2DM. The primary dependent variables are the quantitative scores measuring adherence to specific dietary patterns, which include the Western, Conservative, Mediterranean, Prudent, and DASH diet adherence scores. Research suggests that age, gender, race, family history of diabetes, BMI level, and physical activity level significantly influence the risk of T2DM (CDC, 2014). These covariate, mediating, or moderating variables will be adjusted for when modeling the relationship between dietary patterns and diabetes status.

A quantitative research design is most appropriate for the study given the nature of the study variables (diet adherence scores and number of diabetes cases) and the general scope of the study, which involves quantifying variable relationships and identifying association patterns rather than making causal inferences about diet and diabetes outcomes (Rudestam & Newton, 2007). Moreover, this study seeks to generalize findings to larger populations given the use of a large representative sample of the U.S. population, thus, quantitative methods are most conducive to achieving this objective (Laureate Education, Inc., 2010). Specifically, this study will implement a cross-sectional research design, utilizing survey data from NHANES, a nationally representative survey that represents a snapshot of the behaviors, risk factors, and disease status of U.S. adults at a distinct point in time, a key feature of cross-sectional research designs (CDC, 2013). The primary advantages of cross-sectional research designs include large sample sizes and the ability to examine relationships between study variables without randomly assigning participants to different comparison groups, as the comparison groups are typically formed before the study begins (Laureate Education, Inc., 2010). However, these advantages are offset by limitations, as a large sample size may not necessarily guarantee that meaningful difference in comparison groups can be detected (Burkholder, n.d.), and a lack of randomized comparison groups could lead to unobservable factors that account for differences in comparison groups that are unrelated to the differences explained by the association of the independent and dependent variables in the study.

A cross-sectional research design was selected for this study for several reasons. First, the study seeks to draw conclusions about dietary risk factors for prediabetes and undiagnosed diabetes at a given point in time rather than drawing conclusions about the causes of these conditions over time, and this is consistent with a cross-sectional study design (Frankfort-Nachmias & Nachmias, 2008, p.116). Secondly, a cross-sectional design is the most common research design for studies using a survey data collection method (Frankfort-Nachmias & Nachmias, 2008, p.116), and given that this study will use national dietary, laboratory, examination, and questionnaire survey data from NHANES, this aligns with the cross-sectional research design. Moreover, previous NHANES studies exploring dietary patterns associated with disease risk have used a cross-sectional research design, and the use of the same study design would be consistent with previous research studies (Kant, Schatzkin, Harris, Ziegler, & Block, 1993).

Given that the NHANES dataset containing all study variables is readily available to the public (CDC, 2013), there are currently no known time constraints associated with this choice of study design. Using previously-collected survey data as the primary data source eliminates the need to recollect preexisting information while also allowing for multiple research questions to be addressed using a single source (Aponte, 2010). However, a potential resource constraint associated with the decision to use a secondary data source is that it removes the researcher from direct involvement in the data collection process and, consequently, the researcher has little control over the quality, reliability, or validity of the collected data. For example, information regarding measures of diabetes status and dietary intake used for the purposes of this study is restricted to the way in which questions regarding these topics were asked on the NHANES survey. Specifically, although participants report whether or not they have ever been told by a doctor that they have T2DM and the age at which they were first told by a doctor, they are not asked about the time period of their most recent diagnosis, which may influence the validity of diabetes-related research questions (CDC, 2013). That is, the omission of this information could present issues with distinguishing participants who are current versus past diabetics. However, the use of laboratory measurements of fasting plasma glucose and HbA1c in this study will help to clarify the distinction.

Methodology

Target Population

Defining the target population and devising a strategy for sample selection is often the first two steps for a quantitative research methodology. Considering the sample demographics, such as the geographic location, age, gender, and race/ethnicity of the study population, as well as the time period of interest are two key factors for establishing an appropriate target population (Frankfort-Nachmias & Nachmias, 2008, p.164). The NHANES target population consists of non-institutionalized civilian U.S. residents (CDC, 2013). This study will target a subset of the NHANES population, namely, U.S. adults aged 20 years and older who self-reported information about previous diabetes diagnosis by a doctor and completed a 24-hour dietary recall. Based on estimates from the U.S. Census Bureau, the approximate size of the population of U.S. adults aged 20 years and older is 200 million (U.S. Census Bureau, 2013). This population is an appropriate baseline selection for this study given the fact that adults aged 20 years and older have the highest prevalence of Type 2 diabetes in the country (CDC, 2014).

Children are excluded from the study based on the assumption that kids are less likely to choose which foods they consume on a daily basis and are less likely to initiate diet modification interventions. In other words, this study assumes that the diets of children would more than likely reflect the diets of adults, so the target population will be restricted to individuals who are more likely to make their own dietary choices. Furthermore, the interest of this study is to understand the potential role of diabetes knowledge on dietary habits, and given that adults are more likely than children to receive health promotion messages about dietary interventions to reduce diabetes risk, adults would be more directly impacted by the social change implications of the research and are, thus, a more appropriate target population than children.

More than 10,000 participants complete the NHANES survey each year (CDC, 2013), and this study will select the participants who self-reported their diabetes status and participated in both the dietary recall interview and the laboratory screening for diabetes (either the fasting blood glucose or HbA1c screening), which represents nearly 50% of the annual survey population. This study will combine survey results from the most recent NHANES data collection cycles, which were 2007-2008, 2009-2010, and 2011-2012.

To verify the representativeness of the final study sample, statistical analyses will be conducted to compare the demographics of the sample with the demographics of the non-selected NHANES population in order to confirm that there are no statistical differences in the characteristics of the individuals selected for the study and the individuals not selected for the study. The confirmation of non-statistically significant differences between the selected versus non-selected individuals would support the notion that the findings from the study based on the selected sample can be generalized to the rest of the population.

Sampling Procedures

The NHANES sampling procedure is described as multistage probability sampling design. The sampling process begins with selecting individual counties for participation in the study, and household clusters within counties are then selected based on homogenous household characteristics (CDC, 2013). Then, individual households are selected using probability proportional to size sampling, and the final step is to randomly select individuals within households (CDC, 2013). Although this type of multi-stage probability sampling may be more complex in comparison to other sampling methods, an advantage of this approach is that the resulting sample often meets the desired characteristics necessary for conducting the research study, and the method is often more efficient than other sampling methods (Trochim, 2006). For example, multistage sampling is used in the

NHANES survey in order to exclude certain institutionalized populations, such as members of the armed services, individuals residing in nursing homes or other healthcare institutions, and U.S. citizens who do not reside in the U.S. (CDC, n.d.).

In addition to multi-stage sampling, certain population subgroups such as non-Hispanic Blacks, Mexican-Americans, impoverished non-Hispanic Whites, adolescents, and senior citizens are oversampled, or selected in larger numbers than the actual number that exists in the population, in order to ensure appropriate representation of these groups (CDC, n.d.). Furthermore, a sampling weight is assigned to each participant based on the final probability of selection (given the county, household, and population subgroup from which the individual was selected). The sampling weights must be applied when computing national estimates in order to achieve unbiased results and to adjust for potential uncertainties in the sampling process (CDC, n.d.). Given the use of NHANES secondary data as the primary data source for the present study, the sampling approach for this study will be considered a multistage probability sampling design.

Although there are certain advantages of using a multistage probability sampling design, several limitations must also be considered. First, the use of this sampling approach may result in a non-representative sample given the exclusion of certain populations and the oversampling of certain subgroups, which may threaten the external validity of the study results (World Health Organization, 2013). The sample representativeness largely depends on the clustering stage in which homogenous subgroups are selected, and the sample size must often be doubled when using a clustering approach, which is hard to achieve in many cases (World Health Organization, 2013). One approach for mitigating this potential threat to external validity is to adopt the same sample sizes and effect sizes used in similar NHANES studies addressing similar research questions.

Another limitation of multi-stage sampling designs is that the national estimates obtained from the samples may be statistically unreliable if oversampling techniques and sample weights are not implemented. For example, if the survey was designed to capture frequently-reported characteristics of the general population, the collected survey data may not sufficiently capture unique characteristics that exist within the population, as persons with these unique characteristics may not be selected in sufficiently large numbers for adequate representation (Shapiro et al., 1999). NHANES controls for potentially unreliable statistical estimates by using oversampling and weighting techniques. Oversampling techniques in which population subgroups are selected in larger numbers than actually exists in the general population are useful to ensure that subgroups of the population are adequately represented (CDC, n.d.). Furthermore, sampling weights corresponding to each individual participant's probability of being selected for the sample are useful for producing unbiased national estimates (Ezzati-Rice & Murphy, 1995). This study will adopt the same sampling procedures inherit in the NHANES survey protocol, and sampling weights will be implemented for all statistical analyses to avoid biased national estimates of the prevalence of diagnosed diabetes, undiagnosed diabetes, and prediabetes.

The study sample will be drawn using the NHANES dataset available as a SAS downloadable file from the NHANES website (CDC, 2013). For each survey cycle, the study variables are available in five separate data files: Demographics, Questionnaire, Examination, Laboratory, and Dietary. The Demographic variables pertain to individual and household characteristics, and specific variables of interest to this study include age, gender, and race/ethnicity. The Questionnaire variables include self-reported information about various risk factors and health behaviors, including whether or not the participant was ever told by a doctor that they have diabetes, whether or not they were ever told that they have prediabetes, and their perceived risk of diabetes. The Examination and Laboratory variables pertain to objective measures of current health status. A specific Examination variable of interest to the study is BMI, and the Laboratory variables of interest include fasting plasma glucose and HbA1c. Finally, the Dietary data includes self-reported information regarding the foods and beverages consumed over the past 24 hours. This information will be used to determine exposure to specific food combinations and adherence to specific dietary patterns. Each of the five data files contain a common unique identifier for each participant known as the respondent sequence number. This unique identifier will be used to merge the files together into a master dataset containing all variables of interest. Then, the master dataset for each survey year will be combined together into one final analytic dataset. Any participant who is either less than 20 years old, has missing dietary information, has missing diabetes screening information, or who did not answer the question regarding diabetes diagnosis by a doctor will be excluded from the analysis.

Power Analysis

A power analysis was conducted to determine an appropriate sample size necessary to detect a meaningful effect resulting from the independent variables. G*Power software (version 3.1) is a popular power analysis tool that automatically calculates sample sizes based on a priori information provided by the end-user, such as the desired statistical test, level of significance, effect size, and power level (Buchner, Faul, & Erdfelder, n.d). Given the primary research objective of comparing the mean diet adherence scores between five diabetes groups (no diabetes, undiagnosed prediabetes, undiagnosed T2DM, diagnosed prediabetes, and diagnosed T2DM), a one-way ANOVA was selected as the desired statistical test for computing an appropriate sample size. Other input values for the G-power analysis included an alpha level of 0.05, a medium effect size of 0.25, and a standard power level of 0.80. Based on the G-Power results, a total sample size of 200 individuals (40 individuals in each of the five diabetes groups) would be required in order to achieve 81% power for the study. To verify the appropriateness of the sample size of each comparison group, the sample size of 40 can be compared with the sample size used in similar research studies comparing undiagnosed T2DM and prediabetes groups (Rudestam & Newton, 2007). To verify the representativeness of the sample, statistical analyses such as chi-square independence tests can be conducted in order to test the null hypothesis that the demographics of the study sample are not statistically different from the demographics of the non-selected population. The null hypothesis would be supported if the sample characteristics mirror the characteristics of the non-selected population, and the sample would be confirmed as a representative population with generalizable study findings.

Reliability and Validity of Data Source

NHANES data is used for computing national estimates of chronic disease prevalence and risk factors as well as for setting national benchmarks for physiological measurements (e.g., blood pressure, BMI, etc.) and nutritional recommendations, which speaks to its reliability for establishing official health knowledge for the U.S. (CDC, 2013). However, there are a few issues surrounding the validity and reliability of NHANES data. For example, it is now known that the amount of calories consumed in the American diet is significantly underreported in the NHANES survey, extremely limiting the ability to accurately estimate trends in caloric energy intake and trends in the prevalence of obesity in the U.S. (Archer, Hand, & Blair, 2013). There are also concerns about the reliability of self-reported health information by NHANES participants, as research shows that there is often inconsistent information reported in follow-up NHANES interviews conducted 1 month after the initial interview, as participants often report different self-rated health information in the second interview compared to the first interview (Zajacova & Dowd, 2011).

This concern is not applicable to the present study given that the present study will not seek to explore trends in dietary patterns over time but will instead consider patterns in eating behavior measured at a single point in time. Furthermore, to eliminate the possibility of analyzing discrepant food information reported on multiple days of the dietary interview, the analysis of dietary habits will be restricted to the foods consumed on the first day of the dietary interview.

Variable Definitions and Operationalization

Health information collected in NHANES consists of a combination of in-person questionnaire, dietary recall, body measurements, and laboratory screenings. The questionnaire consists of general questions about current health status, current health behaviors, and exposures to common disease risk factors. Separate sections of the questionnaire pertain to different health topics ranging from infectious diseases to chronic diseases, including diabetes. The dietary recall data collection is a separate component of the in-person interview and includes a detailed account of the foods consumed within the past 24 hours along with the amount and number of times the food was consumed (CDC, 2013). Finally, the body measurements and laboratory assessments include physical examinations and physiologic measures of metabolic processes, including HbA1c and fasting blood glucose assessments. Appendix A provides a list of all variables to be used in the study. The role of each variable as an independent, dependent, or covariate in the study is described below.

Independent variable. The diabetes section of the NHANES questionnaire includes a question regarding whether or not participants were ever told by a doctor or health professional that they have any of the following conditions: diabetes, impaired glucose intolerance, impaired fasting glucose, prediabetes or borderline diabetes, or an abnormally high blood sugar level that is not high enough to be considered diabetes (CDC, 2013). Laboratory assessments of fasting blood glucose and HbA1c levels are also available in addition to the self-reported diabetes information (CDC, 2013).

For the purpose of this study, information from both the self-reported and laboratory-based assessments of diabetes will be combined to define a total of five diabetes groups. The “no diabetes” group will consist of individuals with normal fasting blood glucose and HbA1c levels who reported that they were not previously told that they had diabetes or prediabetes. The undiagnosed prediabetes group will include individuals who were not previously told that they had diabetes or prediabetes but were considered prediabetic based on either the fasting blood glucose or HbA1c screening test. Similar to this group, the diagnosed prediabetes group will also consist of individuals with abnormally high fasting blood glucose or HbA1c levels, but this group will be distinguished from the undiagnosed prediabetes group based on self-reports of previous prediabetes diagnosis by a doctor or health care provider. Individuals who were not previously told by a doctor that they had diabetes but tested positive for diabetes on either the fasting blood glucose or HbA1c screening test will comprise the undiagnosed T2DM group. Similarly, individuals testing positive for diabetes on either the fasting blood glucose or HbA1c screening test who were previously told that they have diabetes will make up the diagnosed T2DM group.

For the purpose of conducting a one-way ANOVA analysis to address Research Questions 1 and 2, the diabetes variable will be represented as a nominal variable with five categories. Specifically, the first two research questions seek to determine if there is a significant difference in mean dietary pattern adherence scores among the different diabetes groups. Thus, for the purpose of these research questions, a quantitative dietary pattern adherence score would serve as the dependent variable and diabetes status would serve as the independent variable. A nominal variable with values of "No diabetes", "Unknown diabetes", and "Known diabetes" will also be created in order to distinguish diabetes cases who are aware versus unaware of their condition, and this variable will be used for addressing Research Question 5 regarding the role of diabetes awareness on eating habits.

Dependent variable. NHANES includes a detailed dietary recall in which participants are asked on two different occasions about the foods consumed within the last 24 hours. The amount of each food consumed as well as the source of the food (where the food was purchased) is also captured. NHANES also groups individual foods into distinct food categories, and these food categories will be used to assess adherence to certain dietary patterns. Dietary adherence scores will be calculated based on the methods described by Trichopoulou et al. (1995) that assigns 1 point to every protective food group (e.g., fruits, vegetables) that the participant consumes above the median daily intake and to every non-protective food group (e.g., red meats) that the participant consumes under the median daily intake. The sum of the individual food group scores will determine the final dietary adherence score for each dietary pattern, and separate independent variables pertaining to adherence to each dietary pattern will be created. Numeric dietary adherence scores will serve as dependent variables in one-way ANOVA analyses addressing Research Questions 1 and 2. Dichotomous variables will also be created for the dietary adherence scores using the median score as the cutoff value for defining low versus high diet adherence. These dichotomous variables are needed for the purpose of conducting multiple logistic regression analyses in addressing Research Questions 3 and 4 which seek to determine the odds of adherence to specific dietary patterns among the different diabetes groups, adjusting for covariates.

Covariates. NHANES captures participant demographics (e.g., age, gender, race/ethnicity) as well as body measurements (e.g., height, weight, BMI level) and health behaviors (e.g., smoking, physical activity). Participants are asked to report their current age in years on the NHANES questionnaire. For the purpose of this analysis, the numeric age variable will be recoded into a nominal variable with four distinct age groups: 20-30 years, 31-40 years, 41-50 years, and 51 years and older, as these groups represent increasing risk groups for diabetes. Variables for gender and race/ethnicity are collected as nominal variables with distinct categories, including “Other” and “Unknown”. A categorical variable for obesity will be defined based on BMI levels, where those with a BMI level>=30 Kg/m^2 would be considered obese, those with a BMI level between 25-30 Kg/m^2 would be considered “Overweight”, and those with a BMI level < 25 Kg/m^2 would be considered “Normal”. Interviewees are also asked if a close relative has ever been diagnosed with diabetes (CDC, 2013). A binary variable for family history of diabetes would be created based on whether or not the participant reported a family history of diabetes (1=family history of diabetes, 0=no family history of diabetes). Interviewees are also asked whether or not they are current smokers, and this dichotomous variable will serve as an additional covariate in the analysis. Finally, interviewees are asked about their engagement in moderate or vigorous daily physical activities. Respondents reporting moderate or vigorous daily physical activity will be considered physically active and those reporting no moderate or vigorous daily physical activity would be considered physically inactive.

Data Analysis Plans

The data analysis will consist of two components: descriptive analyses and hypothesis-testing outcomes. The descriptive analyses will be presented in a table that illustrates the mean and standard deviation of continuous variables and the frequency and percentage of categorical variables. These descriptive results may be divided by diabetes groups so that the characteristics of each diabetes population (no diabetes, prediabetes, and T2DM) can be directly compared. Further descriptive analyses comparing the study sample with the non-selected population will also be conducted using chi-square tests for independence. Data visualizations such as overlay plots showing diet adherence scores by each of the diabetes groups will also be created for graphical representation of the study population characteristics.

Hypothesis-testing analyses will consist of one-way ANOVA and regression analyses. Separate ANOVA analyses will be conducted for each dietary pattern (e.g., Western dietary pattern, Conservative dietary pattern), and the null hypothesis for each test will suggest that there is no significant difference in the man diet adherence score among the different diabetes groups. Separate multiple logistic regression analyses will be conducted with the dichotomized diet adherence score serving as the main dependent variable and a five-category variable for diabetes status serving as the main independent variable; each model will include age, gender, race/ethnicity, family history of diabetes, BMI, smoking status, and physical activity as covariates.

Threats to Validity

One potential threat to external validity is the lack of reliability or reproducibility of the study results. Reliability is a concept referring to the ability of a measure to repeatedly produce consistent results over time (Creswell, 2013, p.178). To test the reliability of a survey with multiple components such as the NHANES survey, a statistic known as Cronbach's alpha is often used for assessing the inter-item correlation of the survey items (Nakagami, Yamauchi, Noguchi, Maeda, & Nakagami, 2013). However, Cronbach's alpha statistic is often interpreted improperly, so additional reliability tests are recommended in most cases (Tavakol & Dennick, 2011). The test-retest method is another common reliability test that consists of administering a survey or other instrument to the same audience at two different time points to see if the second results are consistent with the first results (Yang et al., 2012). Given that the NHANES survey is administered every 2 years, one approach for testing the reliability of the study is to compare the dietary adherence scores across the 2007-2008, 2009-2010, and 2011-2012 NHANES study cycles. This study will adopt this approach for testing the reliability of the study, and if the dietary adherence scores are unreliable across different survey cycles, then only one survey cycle will be considered for the analysis.

The present study may be vulnerable to certain threats to internal validity. First, the study may not appropriately account for confounding variables, which are predictor variables that may conceal the association between diabetes status and diet adherence scores (Szklo & Nieto, 2014, p.152). For example, insurance status, education level, and occupation are potential confounders in the present study. NHANES participants are asked if they are currently covered by health insurance. Participants reporting that they do have health insurance are potentially more likely to receive healthy eating recommendations from a health care provider and to take appropriate steps to reduce their risk of developing diabetes in comparison to those who are uninsured, and this may influence the association of diabetes status and dietary adherence. NHANES participants are also asked to report their highest education level, and this could be a potential confounder given that individuals with a higher education level may be more knowledgeable about diabetes risk factors than individuals with a lower education level. Similarly, participants reporting health-oriented occupations (e.g., medicine, nursing, nutrition) may be more knowledgeable about diabetes prevention strategies than individuals outside of the health care and public health fields. These variables are currently excluded from the analysis given that they were not consistently included in the regression models of similar research studies or were not significantly associated with diabetes risk.

A third threat to internal validity may result from certain factors existing at the start of the study that may influence the differences observed between the five diabetes comparison groups. Examples of these types of "extrinsic" factors include geographic differences in eating habits and racial differences in diabetes incidence. Potential strategies for minimizing the potential influence of extrinsic factors is to statistically control for them in regression analyses or statistically test for significant associations between the dependent variable and the potential extrinsic variables (Marques & Lima, 2011). This study will statistically test for significant associations between undiagnosed T2DM and each of the following predictors: age, race, gender, family history of diabetes, BMI level, and physical activity level. Similar association tests will be conducting using undiagnosed prediabetes as the dependent variable.

Another potential threat to the validity of the study is selection bias, which may occur if diabetes cases have a greater probability of being selected for the study than non-diabetes cases (Szklo & Nieto, p.27), particularly if the diabetes cases were more likely to complete the dietary recall component of the NHANES interview than non-diabetes cases. To minimize this concern, chi-square independence tests will be conducted in order to verify that the characteristics of the diabetic cases match the characteristics of the non-diabetic cases, indicating no difference in the probability of selection for the study sample.

Information bias is another potential threat to the validity of the study that occurs when study participants are misclassified within the exposure or outcome groups (Szklo & Nieto, 2014, p. 110). An example of information bias that may occur in the study is the inaccurate reporting of foods consumed or current diabetes status resulting in an inaccurate dietary adherence score or a misclassification into one of the five diabetes groups. In-person interviews may be more vulnerable to information bias than other forms of data collection given the lack of anonymity in responses that may pertain to socially undesirable behaviors or sensitive health topics (Frankfort-Nachmias & Nachmias, 2008, p.219). Specifically, interviewers may inadvertently express certain nonverbal cues that could influence participants to respond differently than they would respond if providing an anonymous response, which could further contribute to misclassification of the participant into exposure or outcome groups (Szklo & Nieto, 2014, p. 119).

NHANES controls for information bias by collecting objective measures of health in addition to self-reported health information. For example, objective measures of fasting blood glucose and HbA1c levels can be used to verify self-reported diabetes information. Furthermore, the use of a standard interview script helps to ensure consistency in collecting self-reported information and prevents interviewers from interjecting their personal opinions or other influential cues during the interview (CDC, 2013).

Ethical Procedures

Given the use of a secondary dataset, ethical concerns related to recruitment processes and data collection activities are not applicable to this study. However, ethical considerations regarding breach of confidentiality are relevant to the study. Therefore, this study will seek IRB approval, which is an important first step for conducting any research study involving human subjects. IRB approval helps to ensure adherence to established ethical standards in research and protects both the researcher and the affiliated institution by verifying the beneficence of the research, validating the academic and professional integrity of the researcher, and removing the affiliated institution from potential legal ramifications associated with unethical research protocols (Rudestam & Newton, 2007). Research participants are also protected by IRB approval with respect to reduced risk of harm from the research and assurance of informed consent about all research elements (Endicott, 2010).

The present study will not directly collect information from human subjects but will use secondary data from the NHANES survey. Researchers using secondary data sources typically undergo an expedited IRB review process, as this process ensures that the stakeholders of the original data source are protected from potential misuse of the collected data (Walden University, 2012). The expedited review process for Walden University consists of completing an abbreviated version of the IRB application, which requests researchers to describe the nature of the study and describe any potential ethical concerns for the study (Walden University, 2012). Given the removal of personal identifiers from secondary data sources, research studies using secondary data pose minimal risks to participants. Information collected in the NHANES survey is protected in various ways, including the substitution of participant names with randomly-assigned ID numbers that cannot be traced back to the participant. To further minimize ethical risks to participants, the study methodology will consist of only group-level rather than person-level analyses of the diet-diabetes association.

Summary and Transition

This chapter described the methodology for addressing the research question regarding the association of dietary patterns and undiagnosed diabetes in U. S. adults aged 20 years and older. Using a cross-sectional study design and publicly available data from the NHANES, the data analysis plan includes the use of multiple logistic regression analysis with dietary adherence score and diabetes status as primary dependent and independent variables, respectively. The methods described in this chapter are consistent with previous studies addressing similar research questions.

The following chapter, Chapter 4, will present tabular and graphical displays of all study results, and these results may be of keen interest to both the public health and medical communities.

Chapter 4: Results

Introduction

The purpose of this quantitative research study was to compare the relative adherence to different dietary patterns known to influence the risk of T2DM among individuals in different stages of diabetes. The primary research question was whether there was a significant difference in the mean adherence to each diet among the different diabetes groups. The null hypothesis for this research question was that there was no difference in the mean adherence to each diet among the different diabetes groups, and the alternative hypothesis was that there was a significant difference in the mean adherence to each diet among the diabetes groups. A secondary research question was whether there was a significant difference in the odds of adherence to each diet among the different diabetes groups, after controlling for the covariates of age, race/ethnicity, gender, family history of diabetes, perceived risk of diabetes, physical activity level, BMI level, and smoking status. According to the null hypothesis for this research question, there is no significant difference in the odds of adherence to the diets among the different diabetes groups, and the alternative hypothesis suggested that there is a significant difference in the odds of adherence to the diets among the different diabetes groups. The final research question explored in this study was whether perceived diabetes risk and awareness of diabetes status (known versus unknown diabetes) were significantly associated with the odds of adherence to specific dietary patterns, controlling for covariates. The null hypothesis suggested that these variables were not significant predictors of the odds of adherence whereas the alternative hypothesis suggested that at least one of these variables was a significant predictor of the odds of adherence.

This chapter describes the results of descriptive and statistical analyses conducted to address the research questions described above. A summary of the characteristics of the study population is presented first, including a comparison of the study population with the non-selected sample in order to assess the representativeness of the selected study population. Next, the baseline demographics and descriptive statistics of the study sample are presented, followed by a detailed description of the statistical analyses conducted to address each of the research questions. Finally, the chapter concludes with a summary of the answers to the research questions and a brief preview of the next chapter.

Data Collection

Deviations from Data Collection Plans Described in Chapter 3

The initial data collection steps for the study included downloading the 2007-2012 NHANES survey data from the NHANES website, securely storing the data on a password-protected network drive, and preparing the data for the analysis, which included merging and recoding selected variables. For example, preparing the analytic dataset consisted of merging variables from the Demographics, Examination, Laboratory, Questionnaire, and Dietary Recall data files using the unique participant ID number common to all files. The next step included recoding several continuous variables, such as recoding the BMI continuous variable into a BMI categorical variable with values for “normal” (BMI level less than 25 Kg/m^2), “overweight” (BMI level between 25 and 30 Kg/m^2), and “obese”

(BMI level greater than or equal to 30 Kg/m^2). These initial steps were consistent with the methods described in Chapter 3.

Chapter 3 briefly described the approach for grouping the individual foods reportedly consumed by survey respondents into food groups and dietary patterns. To elaborate on this process, the food group categories originated from the United States Department of Agriculture's documentation of the MyPyramid Equivalents Database for USDA Survey Food Codes, which combines individual foods into broad food categories (and more refined subcategories) including fruits, grains, milk, meat and beans, oils, and vegetables (Friday & Bowman, 2006). I grouped the reported NHANES foods into the USDA food categories and then combined these food categories into the respective dietary patterns of interest to the study.

For each survey respondent, I determined dietary pattern adherence using the methods previously described by Trichopoulou et al. (1995), Martínez-González et al. (2008) and Bonaccio et al. (2015), which includes assigning a positive score based on consumption of protective/healthy foods above the sample median or consumption of risky/unhealthy foods below the sample median. I calculated separate diet adherence scores for each of the Conservative, DASH, Mediterranean, Prudent, and Western diets, selecting the diet with the highest score as the most adherent diet for a particular survey respondent. The scores corresponding to the most adherent diet were ultimately used in all subsequent analyses. For the purpose of running logistic regression models, I dichotomized the diet adherence scores using a cut-off value distinguishing high versus low adherence. This cut-off value was determined based on descriptive analyses of the percentile distributions of each diet. Specifically, a visual depiction of the percentile scores revealed that a vertical line drawn at the 75th percentile could appropriately divide the diet adherence scores into two distinct diet adherence groups. Thus, I selected the 75th percentile as the cut-off value for creating the dichotomous diet adherence variable, and this approach differed from the methods described in Chapter 3 which described the median score as the cut-off value for the dichotomy.

Baseline Descriptive Characteristics of the Sample

A total of 30,442 people participated in the NHANES study during the years 2007-2012. Of these 12,729 (41.8%) were excluded due to a reported age less than 20 years old. Another 5.7% of the initial population (n=1731) were excluded due to missing dietary recall information, and smaller fractions were excluded due to missing diabetes laboratory testing information (2.3%, n=706) or missing self-reported diabetes information (< 1%, n=6). Finally, 33 people (< 1%) were excluded due to non-adherence to any of the five dietary patterns of interest to the study. The final study sample consisted of 15,237 U.S. adults aged 20 years and older with available diabetes and dietary information.

There was approximately an even distribution of males and females in the study sample (49.1% versus 50.9%, respectively), of which 45.5% were non-Hispanic White, 20.6% were non-Hispanic Black, 15.6% were Mexican American, and 18.3% belonged to other race/ethnicity groups. The diabetes group comprising the greatest proportion of the study population was the no diabetes group (48.3%, n=7,357), followed by the unknown prediabetes group (31.3%, n=4,764) and the known diabetes group (9.6%, n=1,457). The majority of the study sample reported that they were non-smokers (82.4%, n=12, 556) , did not perceive that they were at an increased risk for diabetes (89.1%, n=13,537) and did not have a family history of diabetes (60.3%, n=9,187). Although nearly three-fourths of the study sample reported that they were physically active (72.6%, n=11, 067), the most frequently reported BMI category was "Obese" (36.8%, n=5, 61 2). Among the two unhealthy dietary patterns of interest to the study, the Western and Conservative diets, the mean adherence score was higher for the former diet (*M*=44.9, *SD*=19.7), and for the healthy dietary patterns of interest, the mean adherence score was highest for the Prudent diet (*M*=37.7, *SD*=15.0).

Table 1 compares the characteristics of the selected study sample and the non-selected adult population who were adherent to one of the dietary patterns of interest (n=705). This table also includes the chi-square p-value derived from testing the null hypothesis that there is no significant association between each study variable and the study inclusion status (1=included, 0=excluded). Although there were no significant differences in the age and gender distributions of the selected and non-selected population (p>.05), there were significantly more non-Hispanic White (45.5% versus 30.8%), Mexican American (15.6% versus 10.2%, respectively), and Other Hispanic (10.4% versus 8.5%) respondents included in the study sample ($p < .0001$). Moreover, a larger proportion of non-Hispanic Black respondents were represented in the non-selected population compared to the selected study sample (41.1% versus 20.6%). This difference is likely due to a large proportion of non-Hispanic Blacks with missing dietary recall data

Table 1

Selected and Excluded Population, Adults Aged 20 years and Older

Variable	Selected Study Population (N=15, 237)		Excluded Population (N=705)		Chi-square p-value
	Frequency	Percent	Frequency	Percent	
Age group	2525	16.6	139	19.7	0.0127
20-29 years	2576	16.9	126	17.9	
30-39 years	2597	17.0	91	12.9	
40-49 years	2442	16.0	102	14.5	
50-59 years	5097	33.5	247	35.0	
60+ years	2525	16.6	139	19.7	
Gender					
Female	7756	50.9	358	50.8	0.9494
Male	7481	49.1	347	49.2	
Race/ethnicity					
Non-Hispanic White	6937	45.5	217	30.8	0.0000
Non-Hispanic Black	3135	20.6	290	41.1	
Mexican American	2384	15.6	72	10.2	
Other Hispanic	1581	10.4	60	8.5	
Other Race	1200	7.9	66	9.4	
Diabetes status					
No diabetes	7357	48.3	590	83.7	0.0000
Unknown prediabetes	4764	31.3	0	0.0	
Known prediabetes	1074	7.0	113	16.0	
Unknown diabetes	585	3.8	2	0.3	
Known diabetes	1457	9.6	0	0.0	
Perceived risk of diabetes					
No	13578	89.1	652	92.5	0.0047
Yes	1659	10.9	53	7.5	
Family history of diabetes					
No	9187	60.3	432	61.3	0.6021
Yes	6050	39.7	273	38.7	
Physically active					
No	4170	27.4	253	35.9	0.0000
Yes	11067	72.6	452	64.1	
BMI category					
Normal	4551	29.9	240	34.0	0.0260
Overweight	5074	33.3	206	29.2	
Obese	5612	36.8	259	36.7	
Smoker					
No	12556	82.4	566	80.3	0.1491
Yes	2681	17.6	139	19.7	

Table 1 continued

Variable	Selected Study Population (N=15, 237)		Excluded Population (N=705)		Chi-square p-value
	Frequency	Percent	Frequency	Percent	
Diet adherence score*					
Conservative diet	35.8	17.7	53.5	16.7	0.0000
DASH diet	35.8	17.7	53.5	16.7	
Mediterranean diet	33.7	13.2	37.0	12.9	
Prudent diet	37.7	15.0	53.4	15.9	
Western diet	44.9	19.7	62.2	18.4	

* *Note.* Frequencies and percentages for diet adherence score replaced with means and standard deviations, respectively

(10%), missing diabetes diagnosis information (12%), or both (17%). The non-selected population was also significantly more likely than the selected study sample to report that they did not have diabetes (83.7% versus 48.3%, $p < .0001$), which corresponds to missing diabetes testing information or missing self-reported diabetes information that ultimately led to the exclusion of these cases. The non-selected sample was also significantly more likely to report a "Normal" BMI category (34.0% versus 29.9%, $p < .05$) and significantly higher adherence scores for each of the dietary patterns ($p < .0001$).

Results

Descriptive Analyses

Tables 2 and 3 present a summary of the study sample characteristics by each of the diabetes comparison groups. The no diabetes group comprised nearly half of the sample (48.3%) and included a higher proportion of young adults aged 20-29 years (27.6%) compared to the other diabetes groups. In contrast, the known diabetes group comprised approximately 10% of the sample and included a higher proportion of older

Table 2

*Study Population Characteristics (Covariate Variables), by Diabetes Status (*N = *15, 237)*

	Frequency (%)				
Variable	No Diabetes	Unknown Prediabetes	Known Prediabetes	Unknown Diabetes	Known Diabetes
Overall Sample	7357(48.3%)	4764(31.3%)	1074(7.0%)	585(3.8%)	1457(9.6%)
Age group	2031(27.6%)	405(8.5%)	48(4.5%)	21(3.6%)	20(1.4%)
20-29 years	1718(23.4%)	651(13.7%)	90(8.4%)	53(9.1%)	64(4.4%)
30-39 years	1335(18.1%)	851(17.9%)	172(16.0%)	89(15.2%)	150(10.3%)
40-49 years	922(12.5%)	891(18.7%)	201(18.7%)	118(20.2%)	310(21.3%)
50-59 years	1351(18.4%)	1966(41.3%)	563(52.4%)	304(52.0%)	913(62.7%)
60+ years					
Gender					
Female	4003(54.4%)	2202(46.2%)	606(56.4%)	245(41.9%)	700(48.0%)
Male	3354(45.6%)	2562(53.8%)	468(43.6%)	340(58.1%)	757(52.0%)
Race/ethnicity					
Non-Hispanic White	3573(48.6%)	2130(44.7%)	493(45.9%)	206(35.2%)	535(36.7%)
Non-Hispanic Black	1282(17.4%)	1033(21.7%)	273(25.4%)	145(24.8%)	402(27.6%)
Mexican American	1131(15.4%)	744(15.6%)	135(12.6%)	121(20.7%)	253(17.4%)
Other Hispanic	741(10.1%)	505(10.6%)	101(9.4%)	74(12.6%)	160(11.0%)
Other Race	630(8.6%)	352(7.4%)	72(6.7%)	39(6.7%)	107(7.3%)
Perceived risk of diabetes					
No	6620(90.0%)	4206(88.3%)	872(81.2%)	468(80.0%)	1412(96.9%)
Yes	737(10.0%)	558(11.7%)	202(18.8%)	117(20.0%)	45(3.1%)
Family history of diabetes					
No	4948(67.3%)	2966(62.3%)	478(44.5%)	304(52.0%)	491(33.7%)
Yes	2409(32.7%)	1798(37.7%)	596(55.5%)	281(48.0%)	966(66.3%)
Physically active					
No	1556(21.1%)	1370(28.8%)	387(36.0%)	220(37.6%)	637(43.7%)
Yes	5801(78.9%)	3394(71.2%)	687(64.0%)	365(62.4%)	820(56.3%)
BMI category					
Normal	2899(39.4%)	1153(24.2%)	197(18.3%)	80(13.7%)	222(15.2%)
Overweight	2508(34.1%)	1707(35.8%)	315(29.3%)	166(28.4%)	378(25.9%)
Obese	1950(26.5%)	1904(40.0%)	562(52.3%)	339(57.9%)	857(58.8%)
Smoker					
No	6052(82.3%)	3850(80.8%)	913(85.0%)	483(82.6%)	1258(86.3%)
Yes	1305(17.7%)	914(19.2%)	161(15.0%)	102(17.4%)	199(13.7%)

Table 3

*Study Population Characteristics (Dependent Variables), by Diabetes Status (*N = *15, 237)*

	Frequency (%)				
Variable	No Diabetes	Unknown Prediabetes	Known Prediabetes	Unknown Diabetes	Known Diabetes
Diet Adherence[a]					
Conservative Diet	1010 (13.7%)	666 (14.0%)	116 (10.8%)	94 (16.1%)	196 (13.5%)
DASH Diet	398 (5.4%)	252 (5.3%)	73 (6.8%)	28 (4.8%)	105 (7.2%)
Mediterranean Diet	2845 (38.7%)	1839 (38.6%)	408 (38.0%)	228 (39.0%)	558 (38.3%)
Prudent Diet	1748 (23.8%)	1126 (23.6%)	259 (24.1%)	126 (21.5%)	345 (23.7%)
Western Diet	2621 (35.6%)	1682 (35.3%)	351 (32.7%)	204 (34.9%)	475 (32.6%)
Diet Adherence Score[b]					
Conservative Diet	34.60(17.96)	37.54(17.89)	38.15(16.96)	34.84(14.76)	34.95(17.07)
DASH Diet	27.11(17.27)	31.63(16.07)	36.85(12.90)	30.71(10.52)	30.67(17.00)
Mediterranean Diet	33.13(13.52)	34.29(13.06)	34.75(12.18)	34.50(11.88)	33.63(12.85)
Prudent Diet	36.89(15.47)	38.50(14.63)	39.00(13.13)	36.64(12.30)	38.16(15.80)

[a] Adherence to a specific dietary pattern is defined as having a higher diet adherence score for the dietary pattern compared to the score for other dietary patterns; In some cases, respondents were adherent to more than one dietary pattern

[b] Frequencies and percentages for Diet Adherence Score replaced with means and standard deviations, respectively

adults aged 60 years and older (62.7%). The no diabetes and known prediabetes groups were predominantly female (54.4% and 56.4%, respectively), whereas the unknown prediabetes, unknown diabetes, and known diabetes groups were predominantly male (53.8%, 58.1%, and 52.0%, respectively). All groups were similar in that they were predominantly White (proportions ranging from 35.2% to 48.6%), and the majority were non-smokers (range from 80.8% to 86.3%) who were physically active (range from 56.3% to 78.9%) and did not perceive that they had a risk of diabetes (range from 80.0% to 96.9%). The known diabetes and known prediabetes groups more frequently reported that they had a family history of diabetes (66.3% and 55.5%, respectively), whereas the no diabetes and unknown prediabetes groups reported a family history of diabetes less frequently (32.7% and 37.7%, respectively). The no diabetes group had the lowest proportion of obese respondents (26.5%), whereas the known diabetes group had the highest proportion (58.8%).

Diet adherence patterns were similar across all groups. For the unhealthy dietary patterns, all groups were more adherent to the Western diet (proportions range from 32.6-35.6%) than the Conservative diet (proportions range from 10.8–16.1%). For the healthy dietary patterns, all groups reported adherence to the Mediterranean diet more frequently than the other dietary patterns (proportions ranging from 38.0- 39.0%) and reported adherence to the DASH diet less frequently than other diets (range from 4.8%- 7.2%).

Table 4 presents the percentiles of the diet adherence scores by diet and diabetes status. The diet adherence score percentiles for each dietary pattern were nearly identical across all groups, suggesting that there are no significant differences in the diet adherence score distributions among individuals in different stages of diabetes. However, for the three healthy diets, some individuals within the unknown prediabetes group were more adherent to the DASH and Mediterranean diets (maximum adherence score of 70% and 88.9%, respectively) than individuals in other diabetes groups, and individuals within the no diabetes group were more adherent to the Prudent diet (maximum adherence score of 100%). The results also indicate that individuals in the unknown prediabetes and known diabetes groups were more adherent to the unhealthy Conservative diet compared to individuals in the other diabetes groups (maximum adherence of 100% for each).

Table 4

Percentiles of Dietary Pattern Adherence Scores by Diet and Diabetes Status

	Percentiles							
	5th	25th	50th	75th	90th	95th	99th	100th
Conservative Diet								
No diabetes	0.0	25.0	25.0	50.0	50.0	75.0	75.0	75.0
Unknown prediabetes	25.0	25.0	25.0	50.0	50.0	75.0	75.0	100.0
Known prediabetes	25.0	25.0	25.0	50.0	50.0	75.0	75.0	75.0
Unknown diabetes	25.0	25.0	25.0	50.0	50.0	50.0	75.0	75.0
Known diabetes	0.0	25.0	25.0	50.0	50.0	50.0	75.0	100.0
DASH Diet								
No diabetes	0.0	20.0	30.0	40.0	50.0	50.0	60.0	60.0
Unknown prediabetes	0.0	20.0	30.0	40.0	50.0	50.0	60.0	60.0
Known prediabetes	20.0	30.0	40.0	50.0	50.0	50.0	70.0	70.0
Unknown diabetes	20.0	20.0	30.0	40.0	40.0	40.0	50.0	50.0
Known diabetes	0.0	20.0	30.0	40.0	50.0	60.0	60.0	70.0
Mediterranean Diet								
No diabetes	11.1	22.2	33.3	44.4	55.6	55.6	66.7	77.8
Unknown prediabetes	11.1	22.2	33.3	44.4	55.6	55.6	66.7	88.9
Known prediabetes	11.1	33.3	33.3	44.4	55.6	55.6	66.7	77.8
Unknown diabetes	11.1	33.3	33.3	44.4	44.4	55.6	66.7	77.8
Known diabetes	11.1	22.2	33.3	44.4	44.4	55.6	66.7	66.7
Prudent Diet								
No diabetes	16.7	33.3	33.3	50.0	50.0	66.7	66.7	100.0
Unknown prediabetes	16.7	33.3	33.3	50.0	50.0	66.7	66.7	83.3
Known prediabetes	16.7	33.3	33.3	50.0	50.0	66.7	66.7	83.3
Unknown diabetes	16.7	33.3	33.3	50.0	50.0	50.0	66.7	66.7
Known diabetes	16.7	33.3	33.3	50.0	50.0	66.7	66.7	83.3
Western Diet								
No diabetes	25.0	25.0	50.0	50.0	75.0	75.0	100.0	100.0
Unknown prediabetes	25.0	25.0	50.0	50.0	75.0	75.0	100.0	100.0
Known prediabetes	25.0	25.0	50.0	50.0	75.0	75.0	100.0	100.0
Unknown diabetes	25.0	25.0	50.0	50.0	75.0	75.0	100.0	100.0
Known diabetes	25.0	25.0	50.0	50.0	75.0	75.0	100.0	100.0

Figure 1 provides a visual representation of the diet adherence score percentile comparisons among the five comparison groups. The nearly identical percentile distributions are visually depicted by the overlapping scores at nearly all percentiles, with differences noted only at the 100th percentile, or maximum score. For example, some individuals within the unknown prediabetes group were 100% adherent to the Mediterranean diet, and individuals within the no diabetes group were 100% adherent to

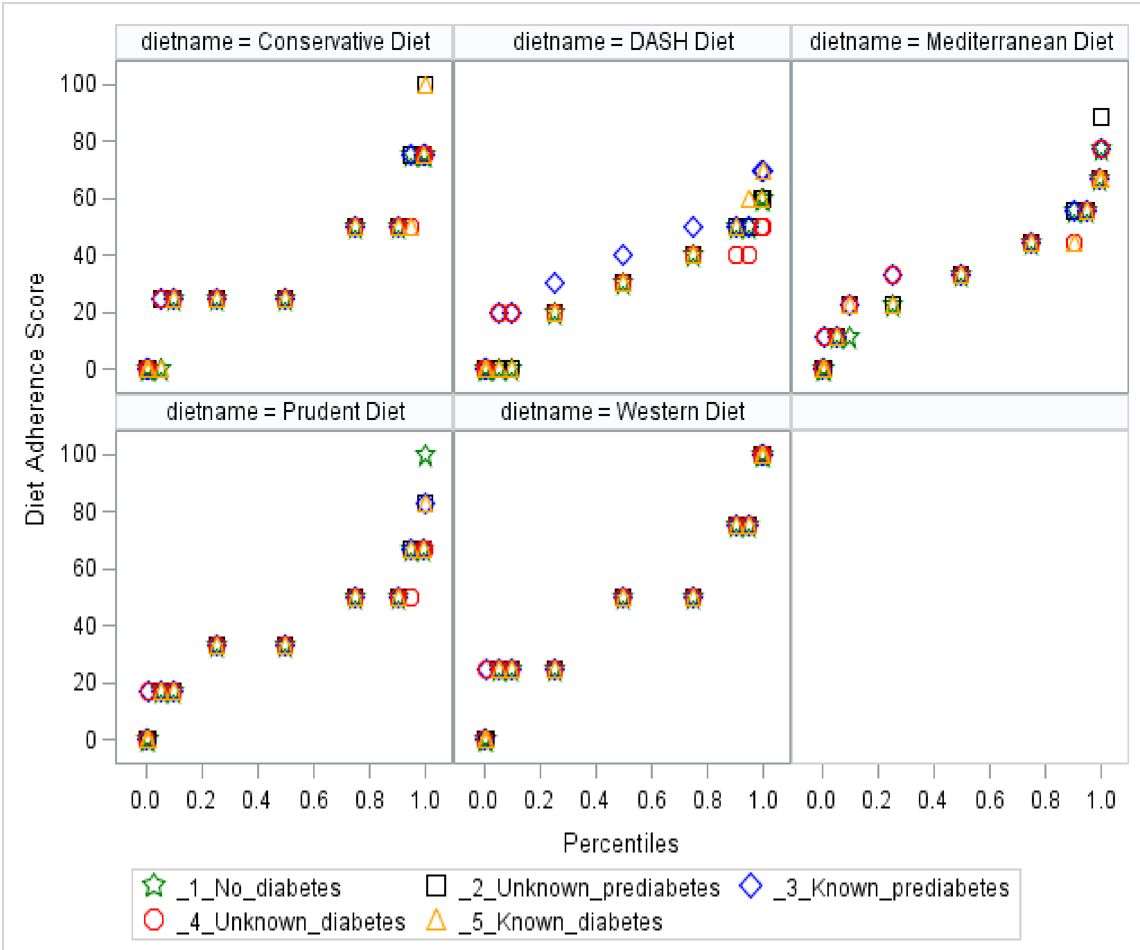

Figure 1. Dietary pattern adherence score percentiles among five diabetes groups. Diet adherence scores overlap at nearly all percentiles, reflecting nearly identical diet adherence patterns for each diet among the different diabetes groups.

the Prudent diet, which suggests that individuals in the earliest stages of diabetes may adhere more to the Mediterranean and Prudent diets than the DASH diet.

Figure 2 provides another comparison of the adherence score percentile distributions but examines the scores within rather than among the comparison groups. Differences in adherence to specific diets were noted for each of the groups, and a vertical line drawn at the 75th percentile for each graph could conceivably divide the

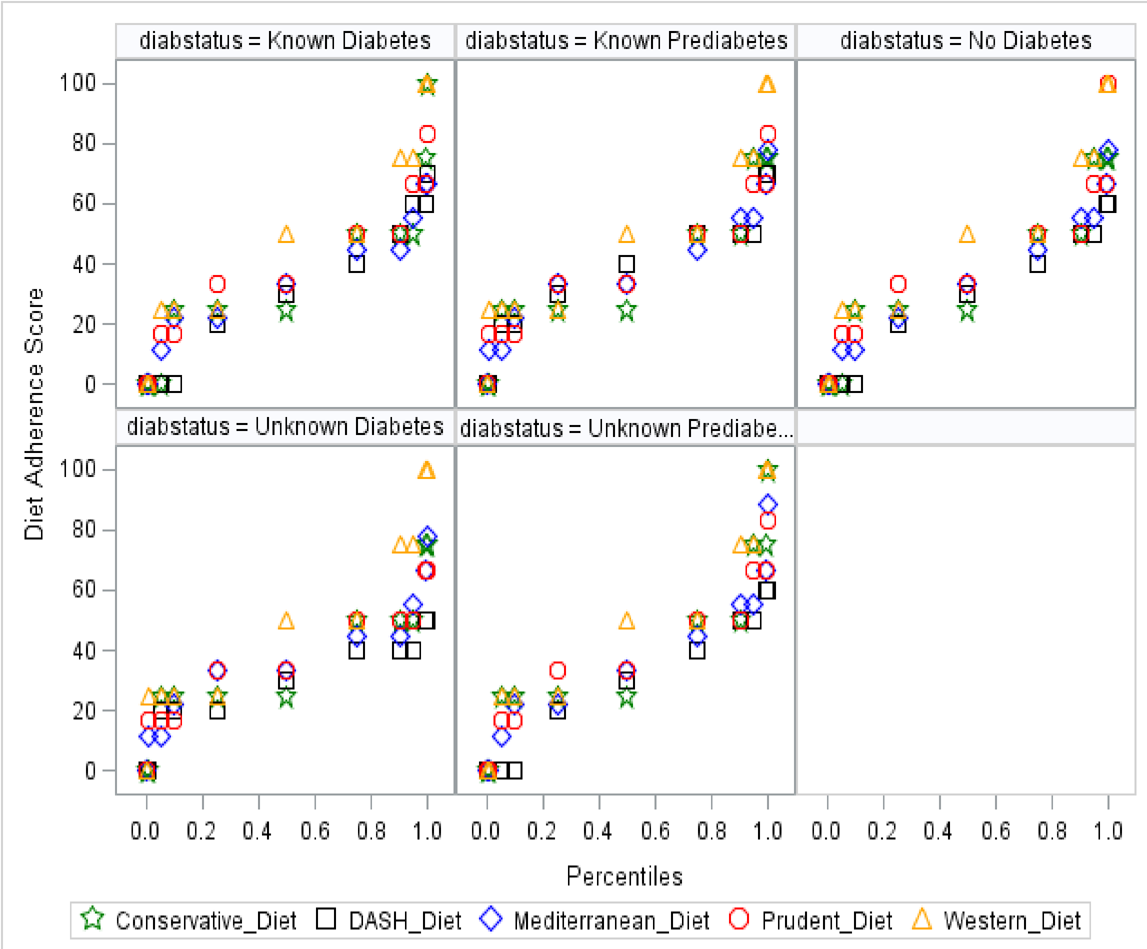

Figure 2. Dietary pattern adherence score percentiles within five diabetes groups. Individuals with known and unknown diabetes had high adherence scores for both the Western and Conservative diets, but individuals in the latter group adhered more to the Conservative diet. Individuals with known prediabetes had the highest adherence scores for the DASH and Prudent diets, whereas individuals with unknown prediabetes had the highest adherence scores for the Mediterranean diet.

scores into low versus high adherence. Within the known diabetes group, the median diet adherence score was highest for the Western diet, and both the Western and Conservative diets had the highest maximum adherence score within this group, indicating that some individuals within the known diabetes group were 100% adherent or consumed all food groups within these diets. The unknown diabetes group had a similar adherence score percentile distribution as the known diabetes group, but individuals within the former group appeared to have a greater affinity for the Western diet than the Conservative diet, as the scores for this diet were among the highest at every percentile, including the 100th percentile in which some individuals were 100% adherent, unlike any other diet. For the healthy dietary patterns, individuals within the known diabetes group had higher maximum adherence scores for the Prudent and DASH diets than individuals in the unknown diabetes group, but individuals in the latter group had a higher maximum adherence to the Mediterranean diet compared to the former group.

Individuals with prediabetes had similar diet adherence score percentile patterns as individuals with diabetes. Like the unknown and known diabetes groups, individuals within the known and unknown prediabetes groups had a greater affinity for the Western diet than other diets, as the scores for this diet were among the highest at every percentile. Contrary to the known diabetes group, individuals within the known prediabetes group were less adherent to the Conservative diet, as this diet had a lower maximum adherence score in comparison to the maximum score observed for the known diabetes group. Like the known and unknown diabetes groups, individuals within the known prediabetes group had higher maximum adherence scores for the Prudent and DASH diets than individuals within the unknown prediabetes group, but individuals in the latter group had a higher maximum adherence to the Mediterranean diet compared to the former group.

The preliminary findings from the percentile comparison analyses may provide new ideas about potential differences in dietary habits among individuals in different stages of diabetes, as adherence to a Western diet may be independent of diabetes status, whereas awareness of diabetes status may potentially influence the adherence to healthy dietary patterns, as individuals with known prediabetes and known diabetes adhere more to the Prudent and DASH diets than individuals with an unknown diabetes status. However, these findings were not based on inferential statistical analyses and must be interpreted with careful consideration.

Figure 3 depicts density curves of the overall pattern of diet adherence scores for each diabetes group. The adherence scores for all diets were normally distributed, and more distributional differences were observed for the Conservative diet than the Western diet. Specifically, there was a noticeably higher peak in the Conservative diet density curve for the unknown diabetes group, reflecting narrower tails and a smaller standard deviation compared to the Conservative diet density curves for the other diabetes groups. These findings suggest that individuals in different stages of diabetes have similar adherence patterns for the Western diet, yet those with unknown diabetes adhere to the Conservative diet more consistently (i.e., with less variation) than the other diabetes groups. Among the healthy diets, the adherence score distributions were very similar for the Mediterranean diet, but the mean adherence to the DASH diet was higher for the known prediabetes group (as seen in the shifted peak to the right) compared to the other groups, and individuals with unknown diabetes adhered more consistently to this diet compared to the other groups. Both the known prediabetes and unknown diabetes groups adhered more consistently to the Prudent diet than the other diabetes groups.

Figure 4 displays the overall pattern of diet adherence scores within diabetes groups. The distribution of scores for all diabetes groups were normally distributed,

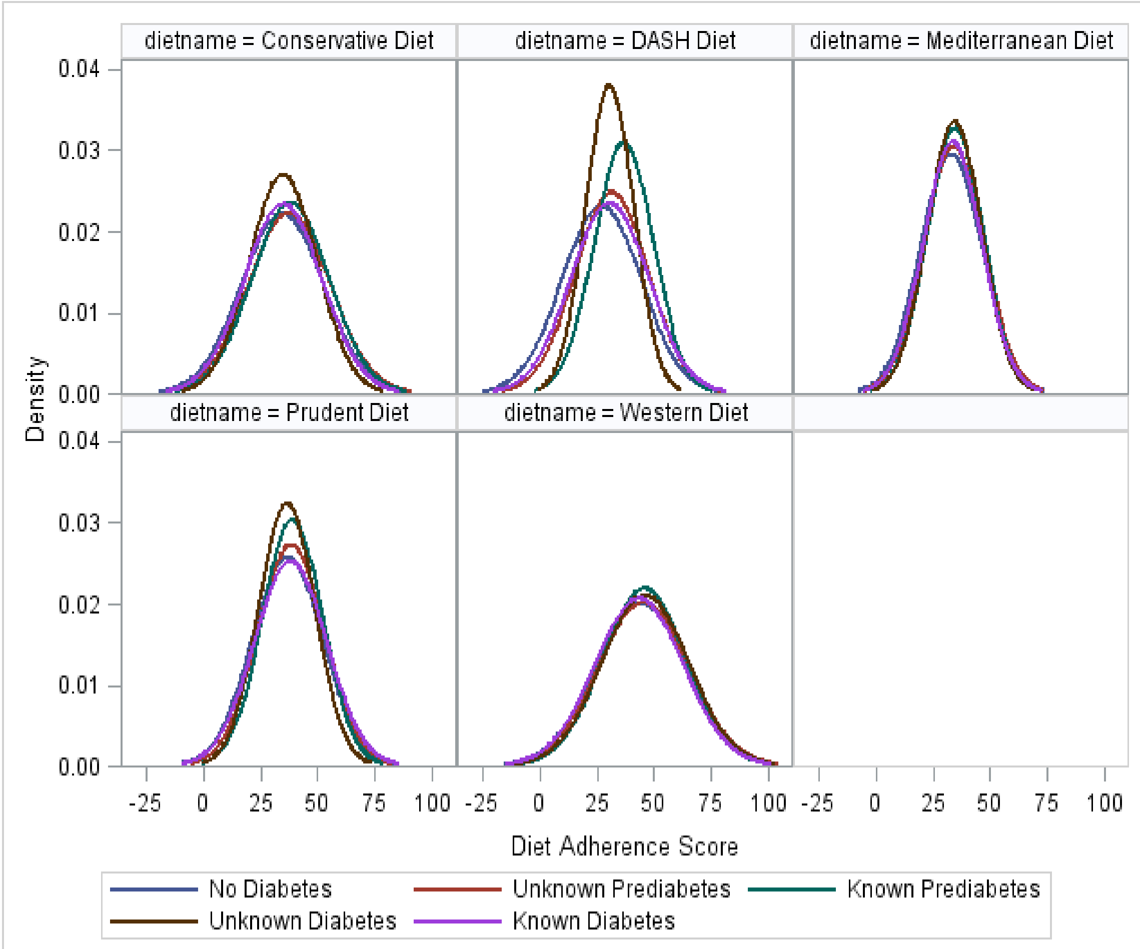

Figure 3. Density curves for diet adherence scores among five diabetes groups. The overall pattern of diet adherence scores among the diabetes groups was similar for the Western and Mediterranean diets. There was less variability in the Conservative diet adherence scores for the unknown diabetes group compared to the other groups. The mean adherence to the DASH diet was higher for the known prediabetes group, and individuals with unknown diabetes adhered more consistently to the DASH diet compared to the other diabetes groups. Individuals with known prediabetes and unknown diabetes adhered more consistently to the Prudent diet than the other diabetes groups.

and there were noticeable within-group differences in adherence score patterns. The mean adherence scores for the Western diet were higher than the mean scores for the Conservative diet for all diabetes groups. Among the healthy diets, all diabetes groups

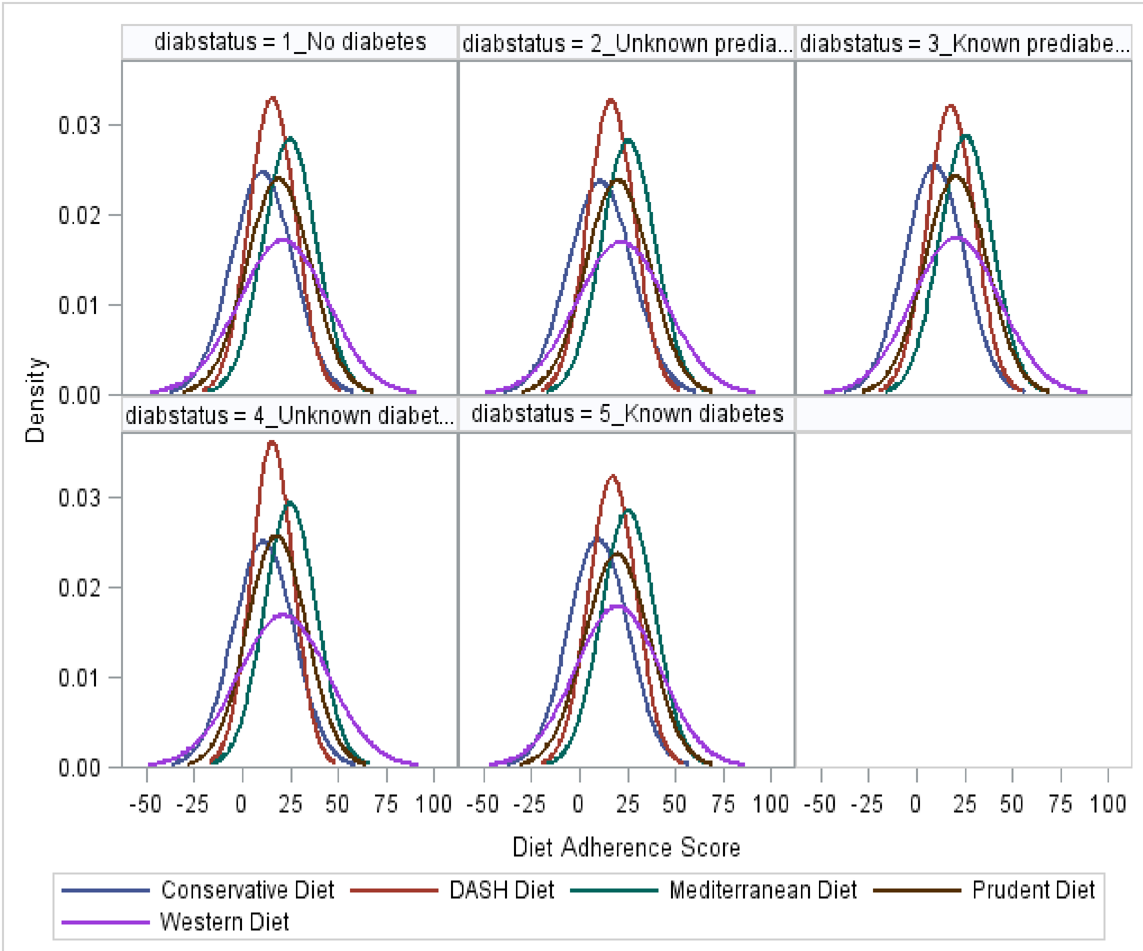

Figure 4. Density curves for diet adherence scores within five diabetes groups. All diabetes groups had a higher mean adherence to the Western diet compared to the Conservative diet. Among healthy diets, all diabetes groups had a higher mean adherence to the Mediterranean diet than the DASH and Prudent diets, but there was less variation in the scores for the DASH diet compared to the other diets.

had a higher mean adherence to the Mediterranean diet than the DASH and Prudent diets, possibly suggesting a greater affinity for this diet than the other healthy diets. However, the scores for the DASH diet were the most consistent and least variable among all diabetes groups.

In order to compare the distribution of scores by known versus unknown diabetes status, the known prediabetes and known diabetes groups were combined into a “known diabetes status” group and the unknown prediabetes and unknown diabetes groups were combined into an “unknown diabetes status” group. Figures 5 and 6 depict the percentile score comparisons among and within comparison groups, respectively, based on this new grouping. Figure 5 shows that, similar to the previous analysis of five comparison groups, adherence to the unhealthy diets was nearly the same across the three comparison groups. Percentile scores for the healthy dietary patterns were also similar at nearly every percentile, with differences observed only at the 100th percentile. Individuals within the no diabetes group had a higher maximum adherence score for the Prudent diet, whereas individuals within the unknown diabetes status and known diabetes status groups had a higher maximum adherence score for the Mediterranean and DASH diets, respectively. Figure 6 depicts within-group diet adherence score percentiles and shows similar results as the previous within-group analysis depicted in Figure 2. Namely, adherence to the Western diet was consistently high across all comparison groups, but the known and unknown diabetes status groups adhered more to the Conservative diet than the no diabetes group. Adherence to the DASH diet was higher among individuals within the known diabetes status group compared to individuals within the no diabetes and unknown diabetes status group.

Figures 7 and 8 are analogous to Figures 3 and 4 and compare the density curves for the diet adherence scores among and within diabetes groups, respectively, using the three-category diabetes grouping. Figure 7 shows that the overall pattern of diet

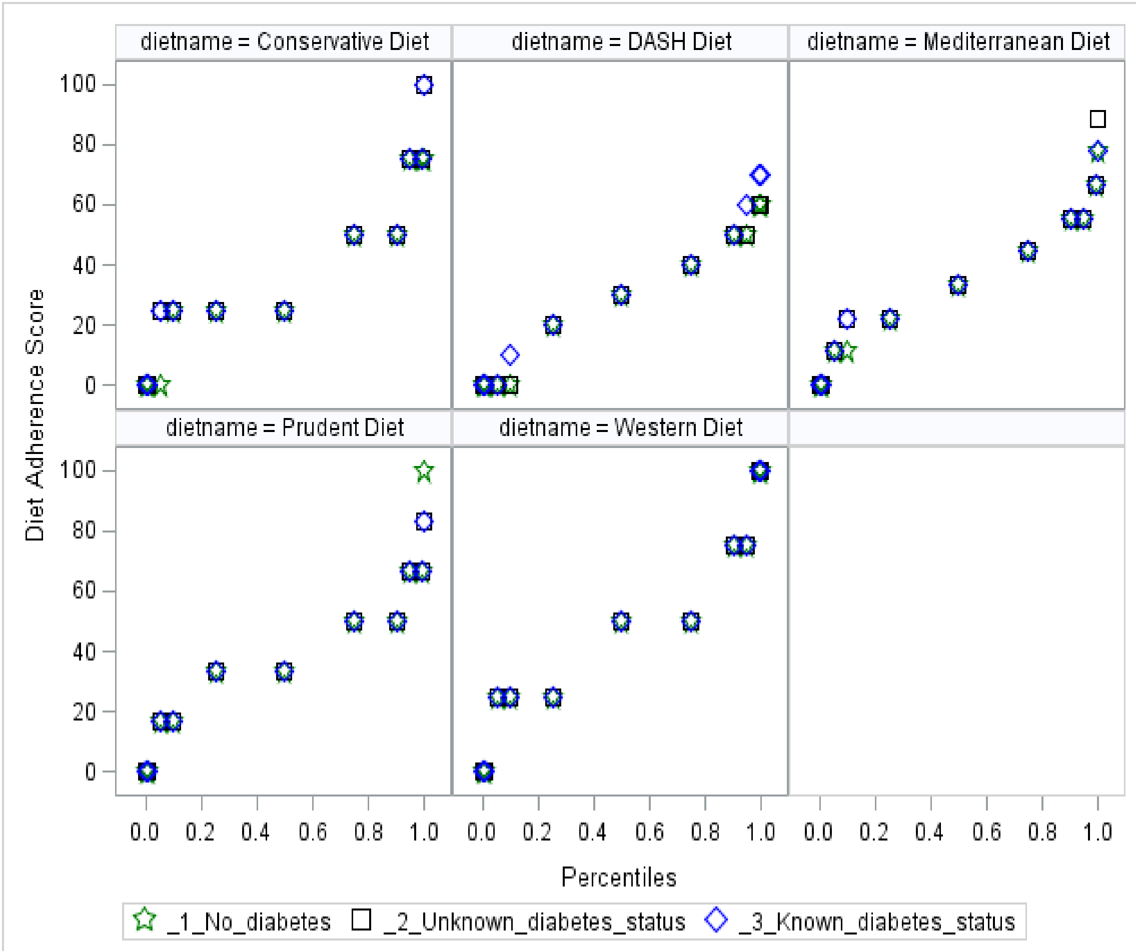

Figure 5. Dietary pattern adherence score percentiles by diabetes awareness. Percentile distributions were nearly the same for the unhealthy dietary patterns. Individuals with no diabetes, unknown diabetes, and known diabetes had the highest maximum adherence scores for the Prudent, Mediterranean, and DASH diets, respectively.

adherence scores was similar across the three groups, with very few observable differences among the unhealthy dietary patterns. For the healthy dietary patterns, individuals within the no diabetes group had lower mean adherence scores for the DASH diet compared to individuals with diabetes. Figure 8 highlights within-group differences in the overall pattern of diet adherence scores for each diabetes group. The results were identical to the previous findings from Figure 4, as all three groups had a higher mean

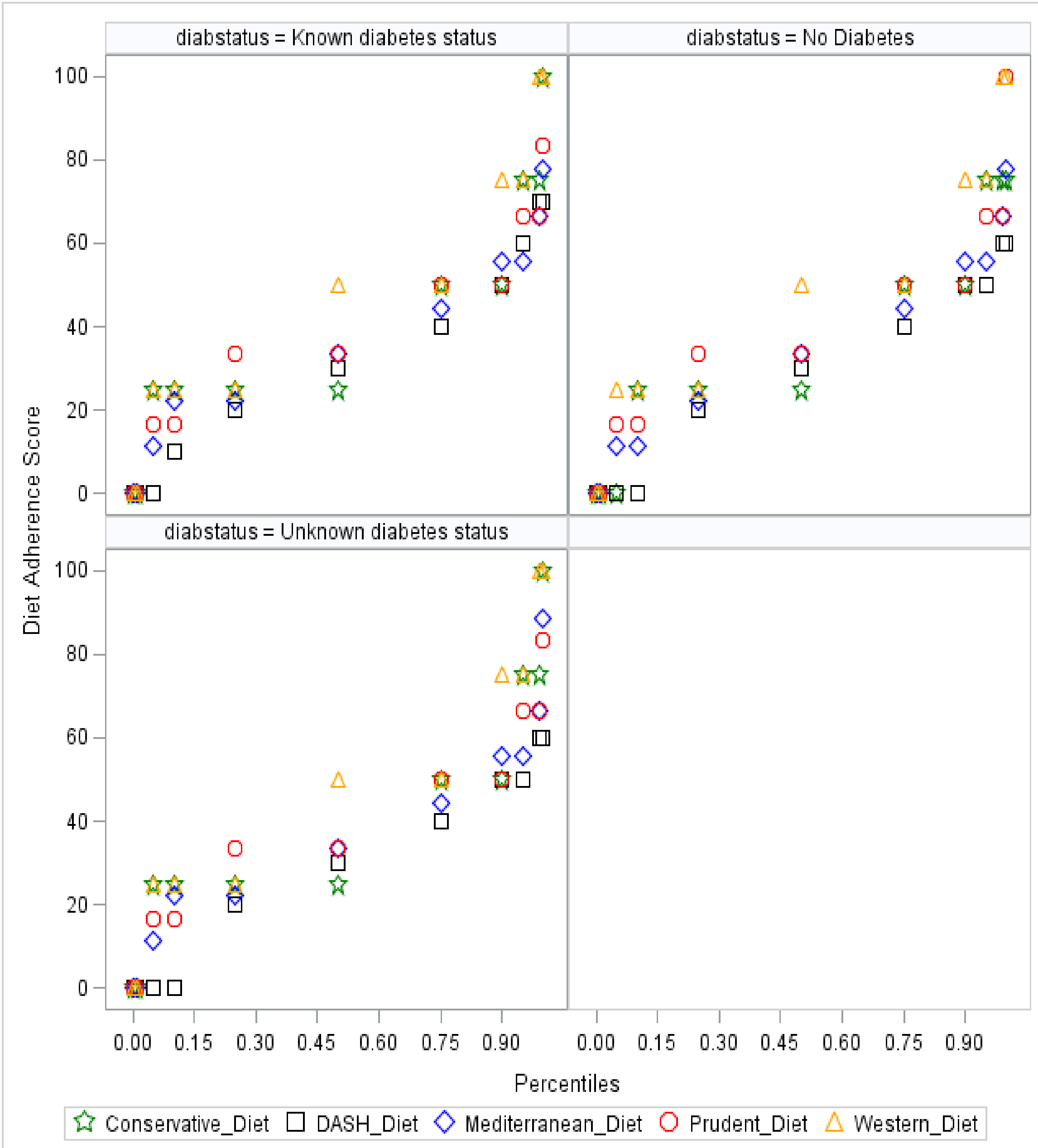

Figure 6. Dietary pattern adherence score percentiles within diabetes awareness groups. Individuals within all diabetes groups had consistently high adherence scores for the Western diet, but individuals with diabetes adhered more to the Conservative diet than individuals with no diabetes. Individuals within the known diabetes status group had higher adherence scores for the DASH diet than individuals within the no diabetes and unknown diabetes status group.

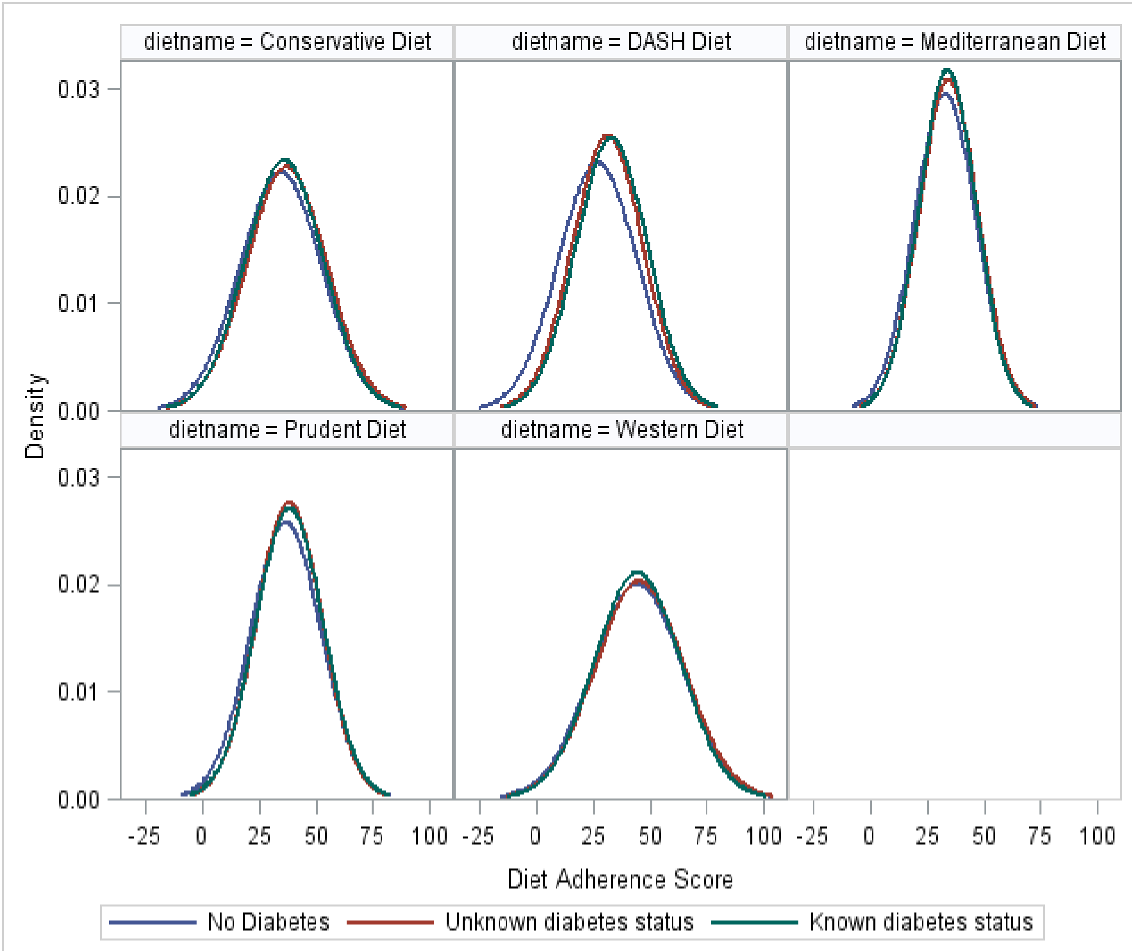

Figure 7. Density curves for diet adherence scores by diabetes awareness. The overall pattern of diet adherence scores for the unhealthy diets was similar among the three diabetes groups. Individuals within the no diabetes group were less adherent to the DASH diet than the other diabetes groups.

adherence to the Western diet compared to the Conservative diet. Among the healthy diets, all groups had a higher mean adherence to the Mediterranean diet than the DASH and Prudent diets, but there was less variation in the scores for the DASH diet compared to the other diets.

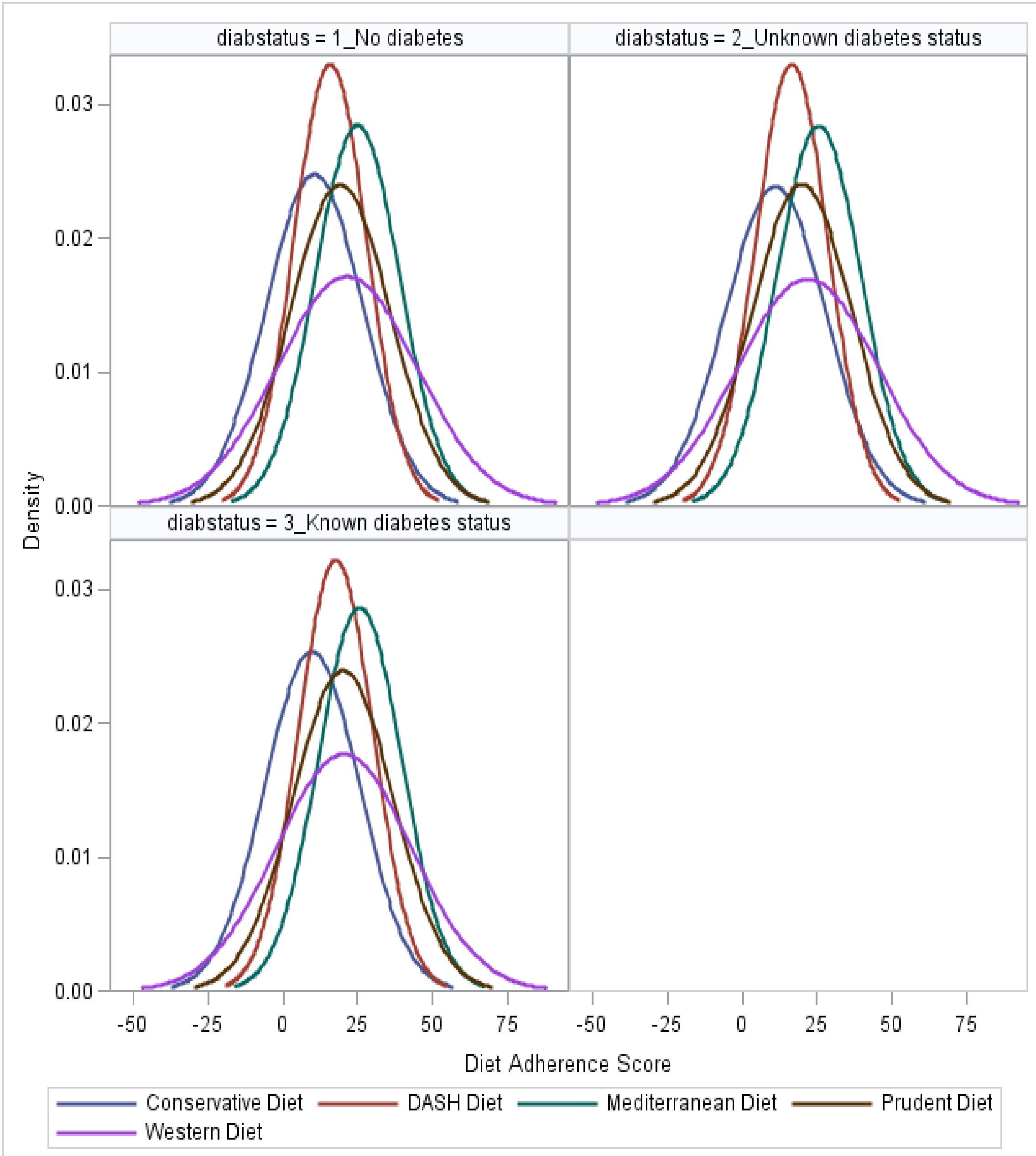

Figure 8. Density curves for diet adherence scores within diabetes awareness groups. All diabetes groups had a higher mean adherence to the Western diet compared to the Conservative diet. All diabetes groups had a higher mean adherence to the Mediterranean diet than the DASH and Prudent diets, but there was less variation in the scores for the DASH diet compared to the other diets.

Statistical Analyses

Tables 5 and 6 present the results of weighted one-way ANOVA analyses conducted in order to test the null hypothesis that there were no significant differences in the mean adherence to unhealthy dietary patterns among the five diabetes groups. Results for both the Conservative and Western diets indicate that there were significant differences in the mean adherence scores among the five comparison groups ($F(4, 15,236) = 6.45$, $p < .0001$ and $F(4, 15,236) = 3.19$, $p < .05$, respectively). Tables 7 thru 9 present similar results of weighted one-way ANOVA analyses conducted to test the null hypothesis that there were no significant differences in the mean adherence to healthy dietary patterns among the five diabetes groups. Statistically significant differences were noted for the DASH and Prudent diets ($F(4, 15,236) = 10.97$, $p < .0001$ and $F(4, 15,236) = 2.78$, $p < .05$, respectively), but the results for the Mediterranean diet were non-significant ($F(4, 15,236) = 1.51$, $p > .05$).

Post-hoc tests, shown in Tables 10 thru 14, revealed that the mean adherence to both the Conservative diet and Western diet was significantly lower for the no diabetes group compared to the unknown prediabetes group (mean difference= -1.53, 95% CI=[-2.37,-0.69] for Conservative diet and mean difference= -1.53, 95% CI=[-2.37,-0.69] for Western diet). The unknown prediabetes group also had a significantly higher mean adherence to the Conservative diet than the known diabetes group (mean difference= 1.57, 95% CI= [0.27, 2.87]). Compared to individuals with no diabetes, mean adherence scores for the DASH diet were significantly higher for individuals with unknown prediabetes (mean difference= -0.76, 95% CI= [-1.39,-0.12]), known prediabetes (mean

Table 5

Weighted One-Way Analysis of Variance of Dietary Pattern Adherence Score by Diabetes Status: Conservative Diet

Source	*df*	*SS*	*MS*	*F*	*p*
Model	4	95,990,154.21	23,997,538.55	6.45	0.0000
Error	15,232	56,712,344,435.62	3,723,236.90		
Corrected Total	15,236	56,808,334,589.83			

Table 6

Weighted One-Way Analysis of Variance of Dietary Pattern Adherence Score by Diabetes Status: Western Diet

Source	*df*	*SS*	*MS*	*F*	*p*
Model	4	95,104,029.54	23,776,007.39	3.19	0.0125
Error	15,232	113,465,162,747.82	7,449,130.96		
Corrected Total	15,236	113,560,266,777.37			

Table 7

Weighted One-Way Analysis of Variance of Dietary Pattern Adherence Score by Diabetes Status: DASH Diet

Source	*df*	*SS*	*MS*	*F*	*p*
Model	4	84,979,975.09	21,244,993.77	10.97	0.0000
Error	15,232	29,508,362,419.50	1,937,261.19		
Corrected Total	15,236	29,593,342,394.59			

Table 8

Weighted One-Way Analysis of Variance of Dietary Pattern Adherence Score by Diabetes Status: Mediterranean Diet

Source	*df*	*SS*	*MS*	*F*	*p*
Model	4	15,451,240.25	3,862,810.06	1.51	0.1973
Error	15,232	39,062,660,616.35	2,564,512.91		
Corrected Total	15,236	39,078,111,856.59			

Table 9

Weighted One-Way Analysis of Variance of Dietary Pattern Adherence Score by Diabetes Status: Prudent Diet

Source	*df*	*SS*	*MS*	*F*	*p*
Model	4	40,365,307.53	10,091,326.88	2.78	0.0254
Error	15,232	55,366,529,037.41	3,634,882.42		
Corrected Total	15,236	55,406,894,344.94			

Table 10

95% Confidence Intervals of Pairwise Differences in Mean Diet Adherence Score: Conservative Diet

Diabetes Status	M	SD	Unknown Prediabetes	Known Prediabetes	Unknown Diabetes	Known Diabetes
No Diabetes	10.59	0.25	-1.53 [-2.37,-0.69*]	-0.45 [-1.81,0.91]	-1.24 [-2.98,0.51]	0.04 [-1.18,1.25]
Unknown Prediabetes	12.12	0.35		1.08 [-0.21,2.37]	0.29 [-1.37,1.96]	1.57 [0.27,2.87*]
Known Prediabetes	11.04	0.67			-0.79 [-2.80,1.23]	0.49 [-1.38,2.35]
Unknown Diabetes	11.82	0.79				1.27 [-0.58,3.13]
Known Diabetes	10.55	0.52				

*An asterisk indicates that the 95% confidence interval does not contain zero and the difference in the mean diet adherence score is significant at the .05 level of significance

Table 11

95% Confidence Intervals of Pairwise Differences in Mean Diet Adherence Score: Western Diet

Diabetes Status	M	SD	Unknown Prediabetes	Known Prediabetes	Unknown Diabetes	Known Diabetes
No Diabetes	21.94	0.44	-1.50 [-2.74,-0.25*]	-0.71 [-2.66,1.24]	0.38 [-1.82,2.59]	0.14 [-1.91,2.19]
Unknown Prediabetes	23.44	0.46		0.79 [-1.24,2.82]	1.88 [-0.47,4.23]	1.64 [-0.52,3.79]
Known Prediabetes	22.65	0.98			1.09 [-2.12,4.30]	0.85 [-2.16,3.85]
Unknown Diabetes	21.56	1.04				-0.24 [-3.42,2.94]
Known Diabetes	21.80	0.98				

*An asterisk indicates that the 95% confidence interval does not contain zero and the difference in the mean diet adherence score is significant at the .05 level of significance

Table 12

95% Confidence Intervals of Pairwise Differences in Mean Diet Adherence Score: DASH Diet

Diabetes Status	M	SD	Unknown Prediabetes	Known Prediabetes	Unknown Diabetes	Known Diabetes
No Diabetes	15.87	0.25	-0.76 [-1.39,-0.12*]	-1.85 [-2.89,-0.81*]	-0.55 [-1.66,0.56]	-2.02 [-2.99,-1.05*]
Unknown Prediabetes	16.63	0.28		-1.10 [-2.21,0.01]	0.21 [-0.94,1.35]	-1.26 [-2.08,-0.45*]
Known Prediabetes	17.72	0.47			1.30 [-0.23,2.84]	-0.17 [-1.37,1.04]
Unknown Diabetes	16.42	0.52				-1.47 [-2.77,-0.17*]
Known Diabetes	17.89	0.41				

*An asterisk indicates that the 95% confidence interval does not contain zero and the difference in the mean diet adherence score is significant at the .05 level of significance

Table 13

95% Confidence Intervals of Pairwise Differences in Mean Diet Adherence Score: Mediterranean Diet

Diabetes Status	M	SD	Unknown Prediabetes	Known Prediabetes	Unknown Diabetes	Known Diabetes
No Diabetes	24.31	0.26	-0.48 [-1.23,0.28]	-0.93 [-2.08,0.21]	-0.14 [-1.98,1.69]	-0.16 [-1.69,1.37]
Unknown Prediabetes	24.79	0.33		-0.46 [-1.67,0.75]	0.33 [-1.58,2.25]	0.31 [-1.24,1.87]
Known Prediabetes	25.25	0.49			0.79 [-1.12,2.70]	0.77 [-0.75,2.30]
Unknown Diabetes	24.46	0.84				-0.02 [-2.04,2.01]
Known Diabetes	24.47	0.64				

*An asterisk indicates that the 95% confidence interval does not contain zero and the difference in the mean diet adherence score is significant at the .05 level of significance

Table 14

95% Confidence Intervals of Pairwise Differences in Mean Diet Adherence Score: Prudent Diet

Diabetes Status	M	SD	Unknown Prediabetes	Known Prediabetes	Unknown Diabetes	Known Diabetes
No Diabetes	19.43	0.37	-0.76 [-1.61,0.08]	-1.16 [-2.51,0.20]	0.52 [-1.13,2.17]	-0.96 [-2.36,0.43]
Unknown Prediabetes	20.19	0.37		-0.40 [-1.73,0.94]	1.28 [-0.27,2.82]	-0.20 [-1.40,0.99]
Known Prediabetes	20.59	0.61			1.68 [-0.04,3.39]	0.19 [-1.47,1.86]
Unknown Diabetes	18.92	0.70				-1.48 [-3.23,0.26]
Known Diabetes	20.40	0.63				

*An asterisk indicates that the 95% confidence interval does not contain zero and the difference in the mean diet adherence score is significant at the .05 level of significance

difference= -1.85, 95% CI= [-2.89,-0.81]), and known diabetes (mean difference= -2.02, 95% CI= [-2.99,-1.05]). Individuals with known diabetes also had higher adherence scores for the DASH diet compared to those with unknown prediabetes (mean difference= -1.26, 95% CI= [-2.08,-0.45]) and unknown diabetes (mean difference= -1.47, 95% CI= [-2.77,-0.17]).

Weighted univariable logistic regression analyses were performed in order to test the association of diabetes status and other covariates with the odds of a high adherence score for each dietary pattern. High adherence to a certain dietary pattern was defined as having a diet adherence score greater than or equal to the 75th percentile. Separate logistic regression analyses were conducted for each dietary pattern, and for each regression model, the known diabetes group was the referent group for the diabetes status independent variable. The odds of high adherence to the Conservative diet increased for those with unknown prediabetes (*OR*=1.22, p>.05) compared to those with known diabetes, but the increase was not statistically significant. Factors associated with significantly increased odds of high adherence to the Conservative diet included male gender (*OR*=1.81, $p <$ .0001) and current status as a smoker (*OR*=1.39, $p < .01$). The odds of high adherence to the Conservative diet was significantly decreased for non-Hispanic Blacks (*OR*=0.68, $p <$ .05), Mexican Americans (*OR*=0.75, $p < .05$), Other Hispanic (*OR*=0.55, $p < .05$), and Other Race (*OR*=0.41, $p < .05$) groups compared to non-Hispanic Whites. Like the Conservative diet, male gender was associated with a significant increase in the odds of high adherence to the Western diet (*OR*=1.49, $p < .01$), and some non-White race/ethnicity groups were significantly less likely than non-Hispanic Whites to adhere to the Western diet, but no further significant factors influencing the odds of high adherence to the Western diet were observed.

Consistent with the ANOVA analyses, individuals with unknown prediabetes and unknown diabetes were less likely than those with known diabetes to have a high adherence to the DASH diet, but the results were not statistically significant. Age greater than 49 years was associated with increased odds of high adherence to the DASH diet (*OR*=1.82 for age 50-59 years and *OR*=2.98 for age 60 years and older, $p < .05$), and both current status as a smoker (*OR*=0.40, $p < .01$) and non-White race/ethnicity (*OR*s ranged from 0.42 to 0.66, $p < .05$) were associated with a decreased odds of high adherence to the

DASH diet. Age greater than 29 years, non-White race/ethnicity, and being physically active were associated with significantly increased adherence to the Mediterranean diet, and these factors also significantly influenced the odds of adherence to the Prudent diet. No other statistically significant differences in high adherence to healthy dietary patterns among the five diabetes groups were observed.

Weighted multivariable logistic regression analyses were conducted to test the association of diabetes status with adherence to each of the dietary patterns controlling for other variables. Tables 15 thru 19 present side-by-side comparisons of the univariable and multivariable logistic regression results for each diet. Multivariable results for the unhealthy diets indicated that individuals with unknown prediabetes were more likely to have a high adherence to the Conservative diet compared to individuals with known diabetes, controlling for age, gender, race/ethnicity, perceived risk of diabetes, family history of diabetes, physical activity, BMI, and current status as a smoker (OR=1.15, p=.36), but this finding was not statistically significant. Male gender (OR=1.70, $p < .0001$) and current status as a smoker (OR=1.30, $p < .001$) were also significantly associated with an increased odds of high adherence to a Conservative diet, controlling for other variables. The odds of high adherence to the Western diet increased for all other diabetes groups compared to the known diabetes group, controlling for other variables, but these differences were not statistically significant. Male gender was also associated with a statistically significant increase in the odds of high adherence to the Western diet after controlling for other variables (OR=1.52, $p < .0001$).

Individuals with unknown diabetes were less likely to have a high adherence to the DASH diet compared to those with known diabetes after controlling for other variables, but this result was not statistically significant. No significant differences in adherence to healthy dietary patterns were observed among the five diabetes groups in the multivariable analyses. Age greater than 59 years was associated with significantly increased odds of adherence to the DASH diet (*OR*=2.65, $p < .001$), and age, male gender,

Table 15

Results of Univariable and Multivariable Weighted Logistic Regression Analyses: Conservative Diet Adherence

	Univariable Analysis					Multivariable Analysis				
	B	SE	Wald	p	OR [95% CI]	B	SE	Wald	p	OR [95% CI]
Age group										
20-29 years	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
30-39 years	-0.25	0.16	2.41	0.1209	0.78 [0.57,1.07]	-0.30	0.16	3.45	0.0634	0.74 [0.54,1.02]
40-49 years	-0.04	0.15	0.08	0.7776	0.96 [0.72,1.28]	-0.16	0.15	1.09	0.2956	0.86 [0.64,1.15]
50-59 years	0.03	0.17	0.02	0.8799	1.03 [0.73,1.45]	-0.13	0.18	0.49	0.4854	0.88 [0.61,1.26]
60+ years	-0.09	0.15	0.37	0.5429	0.91 [0.67,1.23]	-0.26	0.18	2.13	0.1445	0.77 [0.54,1.09]
Gender										
Female	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Male	0.59	0.08	50.35	0.0000	1.81 [1.54,2.13*]	0.53	0.09	38.25	0.0000	1.70 [1.44,2.01*]
Race/ethnicity										
Non-Hispanic White	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Non-Hispanic Black	-0.39	0.11	12.24	0.0005	0.68 [0.54,0.84*]	-0.41	0.12	11.92	0.0006	0.66 [0.52,0.84*]
Mexican American	-0.29	0.14	4.09	0.0430	0.75 [0.57,0.99*]	-0.31	0.15	4.52	0.0335	0.73 [0.55,0.98*]
Other Hispanic	-0.61	0.14	19.69	0.0000	0.55 [0.42,0.71*]	-0.61	0.13	20.72	0.0000	0.54 [0.42,0.71*]
Other Race	-0.90	0.28	10.32	0.0013	0.41 [0.23,0.70*]	-0.91	0.28	10.39	0.0013	0.40 [0.23,0.70*]
Diabetes status										
No diabetes	-0.13	0.15	0.74	0.3881	0.88 [0.65,1.18]	-0.21	0.17	1.57	0.2098	0.81 [0.59,1.12]
Unknown prediabetes	0.20	0.14	2.01	0.1567	1.22 [0.93,1.61]	0.14	0.15	0.85	0.3553	1.15 [0.86,1.53]
Known prediabetes	-0.11	0.22	0.24	0.6251	0.90 [0.58,1.39]	-0.06	0.22	0.07	0.7918	0.94 [0.61,1.46]
Unknown diabetes	-0.07	0.23	0.09	0.7687	0.94 [0.60,1.46]	-0.06	0.25	0.06	0.8011	0.94 [0.58,1.52]
Known diabetes	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Perceived risk of diabetes										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.29	0.14	4.44	0.0351	0.75 [0.57,0.98*]	-0.25	0.16	2.43	0.1193	0.78 [0.57,1.07]
Family history of diabetes										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.06	0.09	0.36	0.5458	0.94 [0.78,1.14]	0.01	0.10	0.02	0.8906	1.01 [0.83,1.24]
Physically active										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	0.21	0.09	5.64	0.0176	1.24 [1.04,1.47*]	0.13	0.09	2.11	0.1460	1.14 [0.96,1.36]
BMI level										
Normal	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Overweight	0.14	0.11	1.64	0.2010	1.15 [0.93,1.44]	0.08	0.11	0.53	0.4685	1.08 [0.87,1.34]
Obese	0.07	0.13	0.27	0.6011	1.07 [0.83,1.38]	0.05	0.14	0.11	0.7411	1.05 [0.80,1.37]
Smoker										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	0.33	0.10	11.18	0.0008	1.39 [1.15,1.68*]	0.26	0.10	7.73	0.0054	1.30 [1.08,1.57*]

*An asterisk indicates that the 95% confidence interval does not contain 1 and the odds ratio is significant at the .05 level of significance

Table 16

Results of Univariable and Multivariable Weighted Logistic Regression Analyses: Western Diet Adherence

	Univariable Analysis					Multivariable Analysis				
	B	SE	Wald	p	OR [95% CI]	B	SE	Wald	p	OR [95% CI]
Age group										
20-29 years	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
30-39 years	0.01	0.08	0.02	0.8820	1.01 [0.87,1.17]	0.00	0.08	0.00	0.9960	1.00 [0.85,1.17]
40-49 years	0.07	0.07	0.78	0.3768	1.07 [0.92,1.24]	0.02	0.08	0.04	0.8479	1.02 [0.86,1.20]
50-59 years	0.10	0.08	1.59	0.2072	1.11 [0.95,1.30]	0.02	0.10	0.05	0.8148	1.02 [0.85,1.23]
60+ years	0.06	0.08	0.61	0.4355	1.06 [0.91,1.24]	-0.05	0.10	0.27	0.6046	0.95 [0.78,1.16]
Gender										
Female	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Male	0.40	0.05	61.23	0.0000	1.49 [1.35,1.64*]	0.42	0.05	64.49	0.0000	1.52 [1.37,1.68*]
Race/ethnicity										
Non-Hispanic White	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Non-Hispanic Black	-0.24	0.07	11.63	0.0006	0.78 [0.68,0.90*]	-0.24	0.07	11.40	0.0007	0.78 [0.68,0.90*]
Mexican American	-0.67	0.08	72.22	0.0000	0.51 [0.44,0.60*]	-0.71	0.08	69.88	0.0000	0.49 [0.42,0.58*]
Other Hispanic	-0.12	0.11	1.20	0.2738	0.89 [0.72,1.10]	-0.13	0.11	1.46	0.2269	0.88 [0.71,1.09]
Other Race	-0.22	0.10	4.92	0.0266	0.80 [0.66,0.97*]	-0.24	0.10	5.60	0.0180	0.78 [0.64,0.96*]
Diabetes status										
No diabetes	0.02	0.09	0.07	0.7941	1.02 [0.86,1.21]	0.02	0.11	0.03	0.8689	1.02 [0.82,1.26]
Unknown prediabetes	0.13	0.10	1.77	0.1828	1.14 [0.94,1.39]	0.11	0.11	1.04	0.3085	1.12 [0.90,1.39]
Known prediabetes	0.09	0.13	0.51	0.4735	1.10 [0.85,1.42]	0.10	0.14	0.49	0.4830	1.10 [0.84,1.45]
Unknown diabetes	0.11	0.15	0.60	0.4375	1.12 [0.84,1.49]	0.10	0.15	0.38	0.5356	1.10 [0.81,1.49]
Known diabetes	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Perceived risk of diabetes										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	0.03	0.09	0.11	0.7448	1.03 [0.87,1.22]	0.08	0.11	0.63	0.4292	1.09 [0.88,1.34]
Family history of diabetes										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.04	0.05	0.50	0.4799	0.96 [0.87,1.07]	-0.01	0.06	0.03	0.8652	0.99 [0.88,1.11]
Physically active										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.03	0.07	0.20	0.6574	0.97 [0.85,1.11]	-0.12	0.07	2.77	0.0958	0.89 [0.77,1.02]
BMI level										
Normal	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Overweight	0.02	0.06	0.08	0.7804	1.02 [0.91,1.13]	-0.04	0.06	0.53	0.4674	0.96 [0.85,1.08]
Obese	-0.01	0.06	0.01	0.9294	0.99 [0.89,1.12]	-0.04	0.06	0.33	0.5669	0.96 [0.85,1.09]
Smoker										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	0.03	0.06	0.23	0.6327	1.03 [0.91,1.16]	-0.04	0.07	0.44	0.5072	0.96 [0.84,1.09]

*An asterisk indicates that the 95% confidence interval does not contain 1 and the odds ratio is significant at the .05 level of significance

Table 17

Results of Univariable and Multivariable Weighted Logistic Regression Analyses: DASH Diet Adherence

	Univariable Analysis					Multivariable Analysis				
	B	SE	Wald	p	OR [95% CI]	B	SE	Wald	p	OR [95% CI]
Age group										
20-29 years	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
30-39 years	0.17	0.27	0.43	0.5124	1.19 [0.71,2.00]	0.19	0.26	0.53	0.4668	1.21 [0.72,2.04]
40-49 years	0.36	0.29	1.62	0.2032	1.44 [0.82,2.52]	0.36	0.30	1.49	0.2227	1.43 [0.80,2.56]
50-59 years	0.65	0.30	4.77	0.0290	1.92 [1.07,3.46*]	0.61	0.33	3.53	0.0602	1.84 [0.97,3.49]
60+ years	1.09	0.22	24.40	0.0000	2.98 [1.93,4.60*]	0.98	0.27	13.08	0.0003	2.65 [1.56,4.50*]
Gender										
Female	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Male	-0.10	0.14	0.55	0.4575	0.90 [0.68,1.19]	-0.06	0.14	0.21	0.6478	0.94 [0.71,1.24]
Race/ethnicity										
Non-Hispanic White	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Non-Hispanic Black	-0.55	0.17	10.71	0.0011	0.58 [0.42,0.80*]	-0.39	0.19	4.25	0.0393	0.68 [0.47,0.98*]
Mexican American	-0.92	0.22	16.90	0.0000	0.40 [0.26,0.62*]	-0.72	0.23	10.28	0.0013	0.48 [0.31,0.75*]
Other Hispanic	-0.45	0.25	3.12	0.0773	0.64 [0.39,1.05]	-0.29	0.27	1.20	0.2723	0.75 [0.44,1.26]
Other Race	-1.11	0.41	7.33	0.0068	0.33 [0.15,0.74*]	-1.08	0.41	6.93	0.0085	0.34 [0.15,0.76*]
Diabetes status										
No diabetes	-0.31	0.28	1.21	0.2710	0.73 [0.42,1.27]	-0.08	0.31	0.06	0.8069	0.93 [0.50,1.70]
Unknown prediabetes	-0.09	0.28	0.12	0.7333	0.91 [0.53,1.56]	0.00	0.28	0.00	0.9965	1.00 [0.58,1.73]
Known prediabetes	-0.40	0.43	0.87	0.3515	0.67 [0.29,1.55]	-0.36	0.41	0.76	0.3836	0.70 [0.31,1.57]
Unknown diabetes	-0.30	0.47	0.39	0.5306	0.74 [0.30,1.88]	-0.14	0.48	0.08	0.7791	0.87 [0.34,2.25]
Known diabetes	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Perceived risk of diabetes										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.18	0.21	0.73	0.3942	0.83 [0.55,1.27]	-0.12	0.25	0.23	0.6279	0.89 [0.54,1.44]
Family history of diabetes										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	0.15	0.14	1.06	0.3040	1.16 [0.88,1.53]	0.26	0.15	2.96	0.0856	1.30 [0.96,1.76]
Physically active										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	0.14	0.15	0.84	0.3585	1.15 [0.85,1.55]	0.23	0.16	2.11	0.1462	1.26 [0.92,1.71]
BMI level										
Normal	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Overweight	0.02	0.21	0.01	0.9113	1.02 [0.68,1.54]	-0.11	0.21	0.31	0.5798	0.89 [0.59,1.34]
Obese	-0.33	0.19	3.20	0.0738	0.72 [0.50,1.03]	-0.48	0.18	7.05	0.0079	0.62 [0.43,0.88*]
Smoker										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.91	0.26	11.94	0.0006	0.40 [0.24,0.67*]	-0.87	0.27	10.44	0.0012	0.42 [0.25,0.71*]

*An asterisk indicates that the 95% confidence interval does not contain 1 and the odds ratio is significant at the .05 level of significance

Table 18

Results of Univariable and Multivariable Weighted Logistic Regression Analyses: Mediterranean Diet Adherence

	Univariable Analysis					Multivariable Analysis				
	B	SE	Wald	p	OR [95% CI]	B	SE	Wald	p	OR [95% CI]
Age group										
20-29 years	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
30-39 years	0.43	0.10	19.03	0.0000	1.54 [1.27,1.86*]	0.50	0.11	20.73	0.0000	1.64 [1.33,2.03*]
40-49 years	0.26	0.11	5.12	0.0237	1.29 [1.04,1.62*]	0.40	0.12	10.91	0.0010	1.49 [1.18,1.89*]
50-59 years	0.52	0.11	22.50	0.0000	1.68 [1.36,2.08*]	0.71	0.12	35.80	0.0000	2.04 [1.61,2.57*]
60+ years	0.48	0.10	24.37	0.0000	1.62 [1.34,1.97*]	0.73	0.12	34.81	0.0000	2.07 [1.62,2.63*]
Gender										
Female	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Male	0.12	0.06	3.60	0.0577	1.12 [1.00,1.27]	0.11	0.07	2.85	0.0916	1.12 [0.98,1.27]
Race/ethnicity										
Non-Hispanic White	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Non-Hispanic Black	0.24	0.09	7.68	0.0056	1.27 [1.07,1.50*]	0.41	0.09	20.84	0.0000	1.50 [1.26,1.79*]
Mexican American	0.52	0.07	50.50	0.0000	1.68 [1.45,1.93*]	0.70	0.08	85.13	0.0000	2.01 [1.73,2.33*]
Other Hispanic	0.05	0.12	0.20	0.6513	1.06 [0.83,1.34]	0.18	0.12	2.34	0.1258	1.20 [0.95,1.51]
Other Race	0.44	0.10	19.73	0.0000	1.55 [1.28,1.88*]	0.47	0.10	23.45	0.0000	1.61 [1.33,1.94*]
Diabetes status										
No diabetes	0.06	0.14	0.18	0.6698	1.06 [0.81,1.38]	0.10	0.17	0.31	0.5768	1.10 [0.78,1.55]
Unknown prediabetes	0.14	0.15	0.90	0.3438	1.15 [0.86,1.55]	0.11	0.17	0.42	0.5193	1.11 [0.80,1.55]
Known prediabetes	0.14	0.17	0.69	0.4077	1.15 [0.82,1.62]	0.17	0.18	0.85	0.3552	1.18 [0.83,1.70]
Unknown diabetes	-0.15	0.22	0.49	0.4824	0.86 [0.56,1.31]	-0.18	0.24	0.61	0.4350	0.83 [0.52,1.32]
Known diabetes	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Perceived risk of diabetes										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.16	0.11	2.14	0.1436	0.85 [0.69,1.06]	0.00	0.11	0.00	0.9685	1.00 [0.80,1.24]
Family history of diabetes										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.19	0.07	7.32	0.0068	0.83 [0.72,0.95*]	-0.19	0.07	7.13	0.0076	0.82 [0.72,0.95*]
Physically active										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	0.23	0.08	9.19	0.0024	1.26 [1.08,1.46*]	0.28	0.08	12.49	0.0004	1.33 [1.13,1.55*]
BMI level										
Normal	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Overweight	-0.05	0.08	0.35	0.5527	0.95 [0.82,1.12]	-0.14	0.08	2.65	0.1033	0.87 [0.74,1.03]
Obese	-0.34	0.09	15.16	0.0001	0.71 [0.60,0.85*]	-0.39	0.09	17.90	0.0000	0.68 [0.56,0.81*]
Smoker										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.24	0.12	3.92	0.0478	0.78 [0.61,1.00*]	-0.21	0.13	2.53	0.1116	0.81 [0.63,1.05]

*An asterisk indicates that the 95% confidence interval does not contain 1 and the odds ratio is significant at the .05 level of significance

Table 19

Results of Univariable and Multivariable Weighted Logistic Regression Analyses: Prudent Diet Adherence

	Univariable Analysis					Multivariable Analysis				
	B	SE	Wald	p	OR [95% CI]	B	SE	Wald	p	OR [95% CI]
Age group										
20-29 years	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
30-39 years	0.10	0.14	0.47	0.4919	1.10 [0.83,1.46]	0.13	0.15	0.72	0.3948	1.13 [0.85,1.52]
40-49 years	0.13	0.14	0.76	0.3822	1.13 [0.85,1.51]	0.18	0.15	1.34	0.2472	1.19 [0.89,1.61]
50-59 years	0.46	0.18	6.69	0.0097	1.59 [1.12,2.25*]	0.49	0.18	7.30	0.0069	1.64 [1.14,2.34*]
60+ years	0.68	0.15	21.38	0.0000	1.97 [1.48,2.63*]	0.68	0.15	19.39	0.0000	1.97 [1.46,2.66*]
Gender										
Female	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Male	0.13	0.07	3.18	0.0745	1.14 [0.99,1.31]	0.15	0.07	4.35	0.0370	1.16 [1.01,1.34*]
Race/ethnicity										
Non-Hispanic White	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Non-Hispanic Black	-0.28	0.09	9.09	0.0026	0.76 [0.63,0.91*]	-0.12	0.09	1.80	0.1802	0.89 [0.75,1.06]
Mexican American	-0.52	0.11	22.10	0.0000	0.59 [0.48,0.74*]	-0.38	0.11	11.38	0.0007	0.69 [0.55,0.85*]
Other Hispanic	-0.16	0.12	1.58	0.2091	0.86 [0.67,1.09]	-0.04	0.12	0.11	0.7366	0.96 [0.75,1.22]
Other Race	0.18	0.11	2.96	0.0854	1.20 [0.97,1.48]	0.24	0.10	5.23	0.0222	1.27 [1.03,1.55*]
Diabetes status										
No diabetes	-0.22	0.13	2.86	0.0910	0.80 [0.62,1.04]	-0.08	0.14	0.35	0.5565	0.92 [0.70,1.21]
Unknown prediabetes	-0.13	0.11	1.41	0.2353	0.88 [0.71,1.09]	-0.09	0.12	0.50	0.4801	0.92 [0.72,1.17]
Known prediabetes	0.00	0.20	0.00	0.9940	1.00 [0.68,1.48]	0.02	0.20	0.01	0.9100	1.02 [0.69,1.51]
Unknown diabetes	-0.38	0.20	3.43	0.0639	0.68 [0.46,1.02]	-0.32	0.22	1.99	0.1584	0.73 [0.47,1.13]
Known diabetes	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Perceived risk of diabetes										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.20	0.12	2.96	0.0853	0.82 [0.65,1.03]	-0.04	0.13	0.12	0.7341	0.96 [0.74,1.23]
Family history of diabetes										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.13	0.08	2.80	0.0943	0.88 [0.75,1.02]	-0.09	0.09	1.02	0.3114	0.92 [0.77,1.09]
Physically active										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	0.25	0.10	6.18	0.0129	1.28 [1.05,1.55*]	0.30	0.09	10.15	0.0014	1.35 [1.12,1.62*]
BMI level										
Normal	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Overweight	0.05	0.08	0.38	0.5389	1.05 [0.90,1.23]	-0.04	0.08	0.27	0.6046	0.96 [0.81,1.13]
Obese	-0.15	0.09	2.75	0.0974	0.86 [0.73,1.03]	-0.20	0.09	4.72	0.0298	0.82 [0.69,0.98*]
Smoker										
No	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Yes	-0.93	0.14	41.88	0.0000	0.40 [0.30,0.52*]	-0.88	0.14	38.13	0.0000	0.42 [0.32,0.55*]

*An asterisk indicates that the 95% confidence interval does not contain 1 and the odds ratio is significant at the .05 level of significance

and being physically active were associated with significantly increased odds of adherence to both the Mediterranean and Prudent diets after controlling for other variables ($p < .05$). Non-White race/ethnicity was associated with decreased odds of high adherence to all dietary patterns after controlling for other variables ($p < .05$), except the Mediterranean diet in which the odds of high adherence among Non-Whites was significantly increased ($p < .0001$).

Additional univariable and multivariable analyses were conducted to determine if knowledge of diabetes status and perceived risk of diabetes significantly influenced the odds of high adherence to a particular dietary pattern. The odds of high adherence to the unhealthy and healthy dietary patterns among individuals with a known diabetes status were compared to those with an unknown diabetes status and to those with no diabetes. The results showed that no statistically significant differences in dietary pattern adherence were observed based on knowledge of diabetes status. Furthermore, having a perceived risk of diabetes did not significantly influence the odds of adherence to healthy or unhealthy dietary patterns.

Table 20 provides a summary of the univariable and multivariable logistic regression analysis results for the association of high dietary pattern adherence and diabetes status. For each diabetes group, a comparison of the diet-specific univariable and multivariable odds ratios provides new insights about relative differences in the odds of adherence that may be attributed to diabetes awareness, given the known diabetes group as the reference group. For the no diabetes group, the Western diet was associated with increased odds of high adherence, unlike the Conservative diet, but this increase was not statistically significant. This finding suggests that diabetes awareness may play a larger role in the observed differences in adherence to this diet compared to other unhealthy diets. That is, differences in adherence to the Western diet between individuals with no diabetes and individuals with known diabetes may largely be explained by diabetes

Table 20

Comparison of Univariable and Multivariable Odds of High Adherence to Dietary Patterns Compared to Known Diabetes Group, By Diabetes Group

	Univariable		Multivariable	
	p	OR [95% CI]	p	OR [95% CI]
No diabetes				
Conservative Diet	0.3881	0.88 [0.65,1.18]	0.2098	0.81 [0.59,1.12]
DASH Diet	0.2710	0.73 [0.42,1.27]	0.8069	0.93 [0.50,1.70]
Mediterranean Diet	0.6698	1.06 [0.81,1.38]	0.5768	1.10 [0.78,1.55]
Prudent Diet	0.0910	0.80 [0.62,1.04]	0.5565	0.92 [0.70,1.21]
Western Diet	0.7941	1.02 [0.86,1.21]	0.8689	1.02 [0.82,1.26]
Unknown Prediabetes				
Conservative Diet	0.1567	1.22 [0.93,1.61]	0.3553	1.15 [0.86,1.53]
DASH Diet	0.7333	0.91 [0.53,1.56]	0.9965	1.00 [0.58,1.73]
Mediterranean Diet	0.3438	1.15 [0.86,1.55]	0.5193	1.11 [0.80,1.55]
Prudent Diet	0.2353	0.88 [0.71,1.09]	0.4801	0.92 [0.72,1.17]
Western Diet	0.1828	1.14 [0.94,1.39]	0.3085	1.12 [0.90,1.39]
Known Prediabetes				
Conservative Diet	0.6251	0.90 [0.58,1.39]	0.7918	0.94 [0.61,1.46]
DASH Diet	0.3515	0.67 [0.29,1.55]	0.3836	0.70 [0.31,1.57]
Mediterranean Diet	0.4077	1.15 [0.82,1.62]	0.3552	1.18 [0.83,1.70]
Prudent Diet	0.9940	1.00 [0.68,1.48]	0.9100	1.02 [0.69,1.51]
Western Diet	0.4735	1.10 [0.85,1.42]	0.4830	1.10 [0.84,1.45]
Unknown Diabetes				
Conservative Diet	0.7687	0.94 [0.60,1.46]	0.8011	0.94 [0.58,1.52]
DASH Diet	0.5306	0.74 [0.30,1.88]	0.7791	0.87 [0.34,2.25]
Mediterranean Diet	0.4824	0.86 [0.56,1.31]	0.4350	0.83 [0.52,1.32]
Prudent Diet	0.0639	0.68 [0.46,1.02]	0.1584	0.73 [0.47,1.13]
Western Diet	0.4375	1.12 [0.84,1.49]	0.5356	1.10 [0.81,1.49]
Known Diabetes				
Conservative Diet	--------	--------	--------	--------
DASH Diet	--------	--------	--------	--------
Mediterranean Diet	--------	--------	--------	--------
Prudent Diet	--------	--------	--------	--------
Western Diet	--------	--------	--------	--------

awareness, and diabetes awareness may play a larger role in the adherence to this diet than it does in the adherence to the Conservative diet. Among the healthy diets, the Mediterranean diet was the only diet associated with increased odds of adherence among the no diabetes group (although the increase was non-significant), and the DASH diet was associated with the greatest decrease in the odds of adherence compared to the other diets, suggesting that differences in adherence to these diets between the no diabetes and known diabetes groups may largely be explained by diabetes awareness, and diabetes awareness may play a larger role in the adherence to these diets than it does in the adherence to the other healthy diets.

The findings from the univariable and multivariable analyses for the known prediabetes group mirrored the findings of the no diabetes group, as individuals with known prediabetes were more likely to have a high adherence to the Western diet than the Conservative diet compared to those with known diabetes, and they were less likely to adhere to the DASH diet than the other healthy diets compared to those with known diabetes. The Western diet also stood out as the unhealthy diet that individuals with unknown diabetes were the most adherent, and the Prudent diet stood out as the diet in which individuals with unknown diabetes were the least adherent compared to those with known diabetes. Finally, the unknown prediabetes group were more adherent to the Conservative than the Western diet and, like the unknown diabetes group, were the least likely to adhere to the Prudent diet than the other healthy diets compared to individuals with known diabetes.

Summary and Transition

This chapter presented the results of descriptive and statistical analyses of the association of dietary pattern adherence and diabetes status among U.S. adults aged 20 years and older. Results of the descriptive analyses revealed that there were no major differences in adherence to the unhealthy Conservative and Western diets among individuals with no diabetes, unknown prediabetes, known prediabetes, unknown diabetes, and known diabetes. Furthermore, although there were no major observable differences in adherence to the healthy DASH, Mediterranean, and Prudent diets among the five diabetes groups, the descriptive results showed that, compared to the other diabetes groups, the individuals with unknown prediabetes were more adherent to the Mediterranean diet and those with no diabetes were more adherent to the Prudent diet.

A closer look at within-group differences in adherence to specific dietary patterns showed that the Western diet was a prominent diet among individuals with prediabetes and diabetes, regardless of known or unknown status. However, in comparing the healthy diets, individuals with known prediabetes and known diabetes were more likely to adhere to the Prudent and DASH diets, and those with unknown prediabetes and unknown diabetes were more likely to adhere to the Mediterranean diet. This difference in adherence to healthy dietary patterns was supported by subsequent analyses of known versus unknown diabetes status, as those with a known diabetes status were more likely to adhere to the DASH diet, and those with an unknown diabetes status were more adherent to the Mediterranean diet. However, these preliminary findings were based on visual depictions of the association of dietary adherence and diabetes status and were not based on inferential statistical analyses.

Weighted univariable one-way ANOVA analyses comparing the difference in mean adherence to dietary patterns among the five diabetes groups revealed that the unknown prediabetes group was more adherent to the unhealthy Conservative and Western diets compared to the no diabetes group. The unknown prediabetes group was also significantly more adherent to the Conservative diet than the known diabetes group. Among the healthy diets, the known diabetes group had a significantly higher mean adherence score for the DASH diet compared to the unknown prediabetes and unknown diabetes groups. These findings highlight the differences in eating habits of individuals with prediabetes and diabetes compared to those with no diabetes. The findings also suggest that there are significant differences in adherence to healthy and unhealthy dietary patterns between individuals with prediabetes and individuals with diabetes, and knowledge of diabetes status may significantly influence changes in eating habits.

Additional weighted univariable logistic regression analyses comparing the odds of high adherence to each diet among the five diabetes groups supported the findings from the one-way ANOVA analyses in that the unknown prediabetes group was more likely to adhere to the Conservative diet than the known diabetes group, however, the results were not statistically significant. Also, the unknown prediabetes and unknown diabetes groups were less likely to have a high adherence to the DASH diet compared to the known diabetes group, but these results were also not statistically significant. After adjusting for covariate factors, individuals with unknown prediabetes were still more likely to adhere to the Conservative diet and less likely to adhere to the DASH diet compared to the known diabetes group, but these differences were not statistically significant. In fact, no significant differences in adherence to dietary patterns among the five diabetes groups were observed in the multivariable analyses. Moreover, subsequent logistic regression analyses of differences in diet adherence patterns based on diabetes awareness and perceived risk of diabetes revealed that there were no significant differences in the adherence to unhealthy or healthy dietary patterns among individuals with a known versus unknown diabetes status, and having a perceived risk of diabetes also did not significantly influence the adherence to unhealthy or healthy dietary patterns.

A comparison of the multivariable results for each individual diet suggests that the Western diet was associated with the greatest differential in diet adherence patterns between individuals with known diabetes and individuals with unknown diabetes. However, the Conservative diet was associated with the greatest differential in diet adherence patterns between individuals with known diabetes and individuals with unknown prediabetes. The DASH diet was associated with the greatest differential in diet adherence patterns between individuals with known diabetes and individuals with known prediabetes. Furthermore, the Prudent diet stood out as the diet associated with the greatest differential in diet adherence patterns between individuals with known diabetes and individuals with unknown diabetes. Despite these observations of potentially noteworthy differences in dietary pattern adherence for certain diabetes groups, there were no statistically significant associations in either the univariable or multivariable analyses. The implications of these findings will be further discussed in the next chapter.

Chapter 5 presents a thorough discussion of the study findings, including a detailed interpretation of the study results, a discussion of how the study confirms and extends the findings of previous studies, a review of the limitations of the study, and recommendations for future studies. Chapter 5 also summarizes the answers to each of the research questions and the decisions regarding rejection or non-rejection of the null hypotheses. Finally, the significance and positive social change implications of the study are addressed.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this quantitative research study was to explore potential differences in adherence to certain diets known to influence the risk of diabetes among adults aged 20 years and older in different stages of diabetes, including no diabetes, unknown prediabetes, known prediabetes, unknown diabetes, and known diabetes. Using nationally representative data from the 2007-2012 NHANES survey, this study compared the mean diet adherence score and the odds of adherence to the Western and Conservative diets (known to increase the risk of diabetes) and the DASH, Mediterranean, and Prudent diets (known to decrease the risk of diabetes) among different diabetes groups. This study was conducted in order to determine if some diabetes groups were significantly more likely to adhere to certain diets more frequently than others, and if this affinity for certain diets ultimately leads to the identification of a “most risky” (i.e., most significantly associated with increased diabetes risk) or “most protective” (i.e., most significantly associated with decreased diabetes risk) diet for certain diabetes groups.

The primary research question of interest was if there was a significant difference in the mean adherence to healthy and unhealthy dietary patterns among individuals in different stages of diabetes. Results from the study indicated that the null hypothesis regarding no significant differences in the mean adherence to unhealthy dietary patterns was rejected given significant differences observed among certain diabetes groups. Specifically, individuals with unknown prediabetes had a significantly higher mean adherence to each of the unhealthy dietary patterns compared to individuals with no diabetes; those with undiagnosed prediabetes also had a significantly higher mean adherence to the Conservative diet compared to individuals with known diabetes. The null hypothesis regarding no significant differences in the mean adherence to healthy dietary patterns was also rejected given that individuals with known diabetes had a significantly higher adherence to the DASH diet than individuals with unknown prediabetes and unknown diabetes. These findings suggest that individuals in earlier phases of diabetes who are unaware of their prediabetes status may practice more unhealthy eating habits than those who are disease-free or who are aware of their disease status. Conversely, individuals who are aware of their disease status may practice more healthy eating habits than those who are unaware of their disease status. This finding lends support towards the idea that knowledge of disease status may significantly influence eating habits.

A secondary research question was whether the odds of adherence to healthy and unhealthy dietary patterns are significantly different among different diabetes groups, controlling for covariate factors. Findings from the univariable logistic regression analyses revealed that individuals with unknown prediabetes were more likely to have a high adherence to the unhealthy Conservative diet compared to those with known diabetes, and individuals with unknown prediabetes and unknown diabetes were less likely to have a high adherence to the healthy DASH diet compared to individuals with known diabetes. However, these findings were not statistically significant, even after controlling for other variables. Thus, the secondary null hypothesis, which stated that there was no significant difference in the odds of adherence to healthy and unhealthy dietary patterns among the diabetes groups, was not rejected.

Another secondary research question of interest to the study was whether diabetes awareness and perceived risk of diabetes were significantly associated with the odds of adherence to dietary patterns. Both variables were statistically non-significant in multivariable logistic regression analyses. Thus, the null hypothesis which suggested that these variables were not significant predictors of the odds of adherence to dietary patterns was not rejected.

Interpretation of the Findings

Findings Compared to Peer-reviewed Literature Described in Chapter 2

This study provides new insights into the dietary habits of individuals in different stages of diabetes, particularly those in the early stages of diabetes and those who are unaware of their diabetes status. This study found that two dietary patterns known to influence the risk of diabetes, the unhealthy Conservative Diet and the healthy DASH diet, were independently associated with undiagnosed prediabetes and undiagnosed diabetes, as individuals with these conditions had significantly higher mean adherence scores to the former diet and significantly lower mean adherence scores to the latter diet compared to individuals with known diabetes in univariable analyses. This study also extends previous findings that undiagnosed diabetes is significantly associated with decreased odds of adherence to the Mediterranean diet (Ortega et al., 2012) by providing new information that individuals with undiagnosed diabetes are also less likely to adhere to the DASH diet.

This study also supports previous findings suggesting that individuals with diagnosed diabetes adopt healthier eating patterns than those with no diabetes, and those with undiagnosed diabetes adopt more unhealthy eating patterns than those with no diabetes (Archer et al., 2004). Univariable analyses revealed that individuals with unknown prediabetes had a significantly higher mean adherence to the Conservative diet than those with no diabetes and those with known diabetes. Thus, in this study, those with known diabetes adopted healthier eating habits than those unaware of their diabetes status, and those unaware of their diabetes status adopted more unhealthy eating habits than those with no diabetes.

This study also provides new insights into the relative importance of specific dietary patterns associated with diabetes risk. A comparison of the unhealthy Western Diet and the unhealthy Conservative diet found that individuals who are unaware that they are in the early stages of diabetes are more likely to adhere to the Conservative diet than the Western diet, yet individuals with no diabetes and individuals who are aware that they are in the early stages of diabetes are more likely to adhere to the Western diet. Given the findings that awareness of diabetes status does not significantly influence adherence to specific dietary patterns, differences observed between the diabetes groups in adherence to the Western and Conservative diets suggest differences in dietary preferences that are unrelated to awareness of diabetes status.

The dietary preferences of individuals in different stages of diabetes may provide new insights into the role of specific food groups that comprise the dietary patterns. For instance, the greater affinity for the Conservative diet than the Western diet observed for the unknown prediabetes group may suggest that this group is more likely to consume a combination of whole milk, butter, potatoes, and red meat foods which are characteristic of the Conservative diet and may be less likely to combine sugary foods and refined grains which are characteristic of the Western diet. Furthermore, the greater affinity for the DASH diet observed for the known diabetes group may suggest that this group is more likely to consume a combination of fruits, vegetables, low-fat dairy, nuts, seeds, and whole grain foods which are characteristic of the DASH diet. However, observed differences in adherence to the diets may also be attributed to the gender and ethnic differences identified in the regression analyses.

This study confirms previous findings about the association of the DASH and Prudent diets with diabetes risk. Previous studies identified racial differences in the adherence to the DASH diet, as Whites were more likely than other racial groups to see positive reductions in diabetes risk after adhering to the DASH diet (Morton, Saydah, & Cleary, 2012). This study found similar racial differences in adherence to the DASH diet, as non-White race/ethnicity significantly decreased the odds of high adherence to the DASH diet in weighted logistic regression analyses. The Prudent diet was previously found to be only moderately associated with reduced diabetes risk within a cohort of female nurses over the age of 30 with no history of diabetes (Fung, Schulze, Manson, Willett, & Hu, 2004), and another study also reported a moderate association between Prudent diet adherence and reduced diabetes risk within a cohort of adult Finnish men and women with no history of diabetes (Montenen et al., 2005). This study similarly found a moderate association between the no diabetes status and adherence to the Prudent diet, as those with no diabetes were most likely to adhere to the Mediterranean diet, the least likely to adhere to the DASH diet, and moderately adhered to the Prudent diet.

Interpretation of the Findings in the Context of the Theoretical Framework

The theoretical framework for this study was the health belief model, and the underlying concept was that an individual's dietary preferences are influenced by self-perceived risk of disease or other negative health consequences associated with modifiable risk factors such as diet. According to the health belief model, individuals with undiagnosed diabetes are more likely to adhere to unhealthy eating habits than those with known diabetes due to the latter groups' greater perception of the negative health consequences associated with unhealthy eating. This study found that having a perceived risk of diabetes was not a significant predictor of adherence to healthy dietary patterns. Also, no statistically significant differences in the adherence to healthy dietary patterns were observed between those with undiagnosed versus diagnosed diabetes after controlling for other variables. Thus, the findings from this study were not consistent with the tenets of the health belief model, potentially suggesting that other confounding factors not considered in the study may have influenced the association between dietary pattern adherence and diabetes status.

Given the cross-sectional nature of the study, it is difficult to discern whether adherence to dietary patterns preceded or followed the diagnosis of prediabetes or diabetes. That is, persons with a diabetes diagnosis might be induced to adhere to better diets, yet they may also have an affinity for unhealthy diets which contributed to the initial diagnosis of diabetes. Thus, it is difficult to directly apply the health belief model or to establish that the knowledge of diabetes or the perceived risk of diabetes was a contributing or causal factor in the decision to adhere to certain dietary patterns.

Study Limitations

This study was subject to several limitations in the study design and methodology. First, the cross-sectional nature of the NHANES study design allows for only one time point for data collection. Thus, it is difficult to determine if the observed dietary pattern adherence findings are consistent over time or represent the longitudinal eating patterns of individuals in different stages of diabetes. Secondly, as previously mentioned, it is difficult to directly apply the tenets of the health belief model to this cross-sectional study, as it is uncertain whether the adoption of unhealthy dietary patterns is a predictor or an outcome of diabetes diagnosis, and the role of perceived health risks in the association of dietary pattern adherence and diabetes status remains unclear. Third, given that NHANES collects data from the non-institutionalized U.S. population (e.g., excludes individuals residing in nursing homes, prisons, college/universities, etc.), the present study cannot be generalized to the entire adult U.S. population but rather to the noninstitutionalized adult U.S. population. Furthermore, a selection bias may exist in the present study given the exclusion of a significantly large proportion of non-Hispanic Blacks due to missing diabetes information, dietary recall data, or both, which potentially limits the generalizability of the study findings to all non-institutionalized non-Hispanic Blacks in the United States. However, this limitation was mitigated by appropriately applying statistical weights in the statistical analyses. Fourth, the self-reported dietary data and information regarding previous diabetes diagnosis by a doctor were subject to recall and response biases which may have resulted in inaccurate diabetes status classifications and diet adherence scores.

One of the major methodological limitations of the study was the subjective nature of measuring the diet adherence dependent variable. Diet adherence score calculations reflected the consumption of a unique combination of distinct food groups at a specific point in time, but given that some food groups were included in multiple diets (e.g., fruits and vegetables were included in the DASH, Mediterranean, and Prudent diets) individuals could potentially adhere to more than one diet. Thus, the diet with the highest adherence score was selected for each individual, but more than one diet could be selected for individuals with tied maximum adherence scores for multiple diets. Another limitation of the diet adherence score calculation was the subjective nature of selecting a cutoff value for dichotomizing the scores for purposes of the binary logistic regression analyses. The 75th percentile was selected as the cutoff value based on the visual depiction of the distribution of percentile scores, however, as cautioned in the work of Bonaccio et al. (2015), an arbitrary cutoff value for categorizing diet adherence scores may lead to imprecise measurements of dietary adherence.

Another methodological limitation of the study was the classification of individuals into the five diabetes groups. A major goal of the study was to determine if awareness of diabetes status influences the adoption of healthier eating habits and if people who are aware that they are in the early stages of diabetes or actually have diabetes are more likely to adhere to heathy dietary patterns than those who are unaware or have no history of diabetes. The use of a five-category diabetes status variable in this study allowed for direct comparisons of diet adherence patterns between individuals with no diabetes, known prediabetes, unknown prediabetes, known diabetes, and unknown diabetes. However, this level of categorization may potentially mystify the independent effects of diabetes awareness and stage of diabetes on diet adherence patterns. That is, in order to more appropriately address the major goal of the study, perhaps separate analyses comparing diet adherence scores of individuals with prediabetes versus diabetes and individuals with known versus unknown diabetes is needed in order to better distinguish the effects of diabetes stage and diabetes awareness. The rationale for distinguishing diabetes stage and diabetes awareness is that individuals with unknown prediabetes and known prediabetes may share similar eating habits that are unobserved when these groups are separated into two different groups, and the same argument could be made for individuals with unknown and known diabetes. Moreover, although this study included a separate analysis of "known diabetes status" versus "unknown diabetes status", individuals with known prediabetes were combined with the known diabetes group and those with unknown prediabetes were combined with the unknown diabetes group, but these groupings may not have been appropriate given the combination of individuals in different stages of diabetes. An alternative approach for analyzing the effect of diabetes awareness may be to consider only known versus unknown diabetes and to remove the prediabetes cases from the analysis.

In addition to the methodological limitations concerning the dependent and independent variables, there were also limitations with the statistical analysis. First, this study used a binary logistic regression approach to determine if there were significant differences in the odds of adherence to specific dietary patterns among individuals in different stages of diabetes, controlling for covariates. Dichotomous diet adherence score variables were created for the purposes of conducting the analysis, yet, as previously mentioned, these dichotomous scores were based on subjective criteria. An alternative approach for the analysis would be to use multinomial logistic regression, which can better accommodate nominal dependent variables. The use of multinomial logistic regression requires mutually exclusive categories of the dependent variable (Starkweather & Moske, 2011), which may have been accomplished by creating diet adherence categories based on tertiles, quartiles, or quintiles of the diet adherence score distributions. However, given the interest of comparing low versus high diet adherence scores and the ease of interpreting dichotomous versus multinomial odds ratios, a binary logistic regression approach was selected for the purpose of this study.

A second limitation of the statistical analysis was that the potential confounding effects of education level, insurance status, occupation, and disease co-morbidities were not effectively accounted for, as these variables were excluded from the analysis given that they were not consistently included in the regression models of previous studies. Differences in adherence to the DASH diet between individuals with known diabetes and individuals with unknown prediabetes may partially be explained by one or more of these variables. For example, individuals with known diabetes may have a higher prevalence of hypertension and, thus, may be more knowledgeable about the DASH diet which is directly targeted for individuals with hypertension. Alternatively, a greater awareness of the DASH diet among individuals with known diabetes may also be attributed to a higher education level, greater access to health care or health information, or a greater presence in health-oriented occupations.

Recommendations

Several recommendations for improving the study design and methodology stem from the findings and limitations of this study. First, a longitudinal study of the association of dietary patterns and diabetes status is recommended. Specifically, a prospective cohort study of adults aged 20 years and older with no history of diabetes should be conducted such that the participants' adherence to the different dietary patterns can be measured over time, and the relative risk of diabetes associated with the different dietary patterns can be assessed at the end of the study. Ideally, this prospective cohort study should measure diabetes status based on a combination of self-reported diagnosis and laboratory-based measures such as HbA1c and fasting blood glucose.

One methodological recommendation would be to perform separate analyses for the stage of diabetes and awareness of diabetes. For example, the present study considered five stages of diabetes: no diabetes, unknown prediabetes, known prediabetes, unknown diabetes, and known diabetes. Two alternative ways to classify diabetes status could be to use three categories for the stage of diabetes with values for "no diabetes", "prediabetes", and "diabetes" or to use a three-category variable for diabetes awareness with values for "no diabetes", "unknown diabetes", and "known diabetes". Another methodological recommendation would be to use multinomial logistic regression which can better accommodate a nominal dependent variable for dietary adherence. The nominal diet adherence variable could represent tertiles, quartiles, or quintiles of diet adherence scores, similar to the categorical diet adherence scores used in other studies (Perry, 2002; Kerver, Yang, Bianchi, & Song, 2003; Fung, Schulze, Manson, Willett, & Hu, 2004; Montenen et al., 2005; Liese, Nichols, Sun, D'Agostino, & Haffner, 2009). Finally, future analyses should consider the use of factor analysis or cluster analysis methods to identify unique dietary patterns frequently consumed by individuals with prediabetes and unknown diabetes. Differences in the adherence to these patterns among individuals in different stages of diabetes could be explored in an effort to identify potentially new dietary patterns not previously observed in a population of individuals with known diabetes.

Implications

Given the knowledge that the unknown prediabetes group adheres more to the Conservative diet more than the Western diet, this presents new opportunities for encouraging reduced adherence to the Conservative dietary pattern in diabetes prevention efforts targeted for individuals with unknown prediabetes. Furthermore, although individuals with undiagnosed prediabetes were less adherent to the DASH diet compared to those with no diabetes and known diabetes, this group was the least adherent to the Prudent diet, suggesting that these two diets are less frequently consumed among this group. This finding provides new opportunities for encouraging increased adherence to the DASH and Prudent diets among individuals with undiagnosed prediabetes.

This study extends knowledge of covariate factors associated with increased odds of adherence to healthy and unhealthy dietary patterns. Male gender was significantly associated with increased odds of high adherence to both the Conservative and Western diet, and age 50 years and older was significantly associated with increased odds of high adherence to the DASH, Mediterranean, and Prudent diets after controlling for other variables. In addition, Non-White race/ethnicity was associated with increased odds of high adherence to the Mediterranean diet. These findings highlight demographic differences in the adherence to dietary patterns associated with diabetes risk that are independent of diabetes status, presenting new opportunities for more targeted dietary interventions to help reduce the risk of diabetes within these demographic groups. For instance, future diabetes prevention interventions should encourage adult males to avoid Western and Conservative dietary patterns, which both consist of red, processed meats and high-fat dairy products. Future interventions should also encourage adults between the ages of 20-49 to adhere more to healthy dietary patterns such as the DASH, Mediterranean, and Prudent diets, which consist of a high consumption of fruits and vegetables.

Summary and Conclusion

This study is one of the first studies to consider the relative importance of healthy and unhealthy dietary patterns that influence the risk of diabetes. By combining self-reported and laboratory-based diabetes information, this study provided a unique look into the eating habits of individuals in five different stages of diabetes, which included no diabetes, unknown prediabetes, known prediabetes, unknown diabetes, and known diabetes. The central research question of interest to the study was whether there was a significant difference in the mean adherence to healthy and unhealthy dietary patterns among individuals in the five diabetes stages. The null hypothesis suggesting that there is no significant difference in the mean adherence to healthy and unhealthy dietary patterns was rejected given that individuals with unknown prediabetes were significantly more likely to adhere to the unhealthy Conservative diet than individuals with no diabetes and known diabetes. Also, individuals with known diabetes were significantly more likely to adhere to the healthy DASH diet than individuals with unknown prediabetes and those with known diabetes. After considering the odds of high adherence to specific dietary patterns and adjusting for the additional covariates of age, race/ethnicity, gender, family history of diabetes, perceived risk of diabetes, physical activity level, BMI category, and smoking status, the association between dietary pattern adherence and diabetes status was non-significant. However, some covariate factors such as male gender and current status as a smoker were associated with a significant increase in the odds of high adherence to unhealthy dietary patterns, and other covariate factors such as older age, non-Hispanic White race/ethnicity and being physically active were associated with a significant increased odds of high adherence to healthy dietary patterns. Thus, these factors may explain more of the variation in dietary pattern adherence than diabetes status.

The findings from this study provide new insights into the independent association of unknown prediabetes and Conservative diet adherence as well as the independent association of known diabetes and DASH diet adherence. The positive social change implications from these findings include new opportunities for educating individuals with unknown prediabetes about the negative health consequences of adopting a Conservative diet and educating individuals with known diabetes about the benefits of the DASH diet. Furthermore, given that males were significantly more likely than females to adhere to the Conservative diet and older individuals were more likely to adhere to the DASH diet, males with unknown prediabetes and older adults with known diabetes may require more targeted nutritional intervention strategies to promote better eating habits within these groups.

Future studies of the association between dietary pattern adherence and diabetes status should consider major changes to the research design and methodology used in this study. First, a prospective cohort design should be used in order to allow for multiple time points for collecting food intake data and laboratory-based diabetes information. Secondly, a multinomial regression analysis should be conducted in order to assess the association of a nominal diet adherence dependent variable with diabetes status, controlling for multiple covariate factors. Finally, more advanced statistical analyses should be considered that would allow for more robust variable selection criteria for the variables included in the final regression model.

This research will continue beyond the completion of a dissertation study and extends further than the fulfillment of doctoral degree requirements. Immediate next steps for continuing this work include disseminating preliminary dissertation findings to the internal Walden community by submitting the work to ProQuest UMI and publishing the dissertation within Walden's database of completed dissertations and theses. Another next step would be to implement several recommendations for improving the study methodology, including reconsidering the covariate variables included in the logistic regression models, adding interaction terms to the regression models, and using multinomial rather than binomial logistic regression. Next, the findings from the updated, improved study would be disseminated to external audiences via national conferences, such as the American Public Health Association (APHA) annual conference, or peer-reviewed journal publications, such as the American Journal of Public Health. Finally, long-term plans for continuing this work include collaborating with other diabetes researchers to implement a prospective cohort study that would more appropriately assess longitudinal adherence to dietary patterns over time and its association with diabetes status. This collaborative work may ultimately lead to innovative findings, such as the discovery of new dietary patterns that are uniquely associated with prediabetes or undiagnosed diabetes.

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Appendix A: List of NHANES Study Variables

Original Variable Name	Description	Values	Recoded Variable Name	Recoded Values
NHANES Demographics Dataset				
RIAGENDR	Gender	1=Male, 2=Female, Null=Missing	Gender	1=Male, 2=Female, Null=Unknown
RIDRETH1	Race/ethnicity	1=Mexican American, 2=Other Hispanic, 3=Non-Hispanic White, 4=Non-Hispanic Black, 5=Other Race--Including Multi-Racial, Null=Missing	Race	Same as original, except Null=Unknown
RIDAGEYR	Age in years	Continuous	Agegroup	20-29 years, 30-39 years, 40-49 years, 50-59 years, 60 years and older
RIAGENDR	Gender	1=Male, 2=Female, Null=Missing	Gender	1=Male, 2=Female, Null=Unknown
NHANES Questionnaire Dataset				
DIQ010	Doctor told you have diabetes	1=Yes, 2=No, 3=Borderline, 7=Refused, 9=Don't know, Null=Missing	Doctolddiab	If DIQ010=1 then Yes, otherwise No
DIQ160	Ever told you have prediabetes	1=Yes, 2=No, 7=Refused, 9=Don't know, Null=Missing	Doctoldprediab	IF DIQ060=1 OR DIQ010=3 then Yes, otherwise No
DIQ170	Ever told at risk	1=Yes, 2=No,	Perceivedrisk	If original

	for diabetes	7=Refused, 9=Don't know, Null=Missing		variable=1 then Yes, otherwise No
PAQ605	Vigorous work activity	1=Yes, 2=No, 7=Refused, 9=Don't know, Null=Missing	Pa_vigwork	If original variable=1 then Yes, otherwise No
PAQ620	Moderate work activity	1=Yes, 2=No, 7=Refused, 9=Don't know, Null=Missing	Pa_modwork	If original variable=1 then Yes, otherwise No
Original Variable Name	Description	Values	Recoded Variable Name	Recoded Values
PAQ635	Walk or bicycle	1=Yes, 2=No, 7=Refused, 9=Don't know, Null=Missing	Pa_walkorbike	If original variable=1 then Yes, otherwise No
PAQ650	Vigorous recreational activity	1=Yes, 2=No, 7=Refused, 9=Don't know, Null=Missing	Pa_vigrec	If original variable=1 then Yes, otherwise No
PAQ665	Moderate recreational activity	1=Yes, 2=No, 7=Refused, 9=Don't know, Null=Missing	Pa_modrec	If original variable=1 then Yes, otherwise No
SMQ040	Do you now smoke cigarettes?	1=Yes, 2=No, 7=Refused, 9=Don't know, Null=Missing	Smokenow	If original variable=1 then Yes, otherwise No
MCQ300c	Close relative had diabetes	1=Yes, 2=No, 7=Refused, 9=Don't know, Null=Missing	Famhistory	If original variable=1 then Yes, otherwise No

NHANES Dietary Recall Dataset

DR1IFDCD	USDA Food Code (Food ID)	Continuous	USDAFoodCode	Same as original
DRXFCSD	Short food code description	Various text values	ShortFoodCodeDesc	Same as original
DRXFCLD	Long food code description	Various text values	LongFoodCodeDesx	Same as original

DR1IGrms	GramWeight of Food	Continuous	GramWeightofFood	Same as original
		NHANES Exam Dataset		
BMXBMI	BMI level	Continuous	BMI	If BMXBMI >=30 then Obese, otherwise non-obese
		NHANES Laboratory Dataset		
LBXGH	Glycohemoglobin	Continuous	HbA1c	Same as original
LBXGLU	Fasting glucose (mg/dL)	Continuous	FBG_mgdl	Same as original
LBDGLUSI	Fasting glucose (mmol/L)	Continuous	FBG_mmolL	Same as original