ABSTRACT

Title of Document: ASSOCIATIONS OF HEALTH MARKERS, PERCEPTIONS, AND LIFESTYLE BEHAVIORS WITH DIET QUALITY INDICES AND TYPE 2 DIABETES STATUS IN U.S. ADULTS

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There is growing evidence that adherence to healthful dietary patterns reduces the risk of type 2 diabetes (T2DM). The Healthy Eating Index 2010 (HEI-2010) and the Alternate Healthy Eating Index 2010 (AHEI-2010) are recognized as assessment tools for measuring dietary quality. This research had three main objectives: 1) Determine whether the AHEI-2010 provides a more accurate assessment of dietary quality than the HEI-2010 in relation to diabetes status; 2) Examine the relationship between diabetes status and discrepancies between perceived diet quality (PDQ) and measured diet quality (MDQ) (using total HEI-2010 and AHEI-2010 scores, respectively); 3) Examine the relationships between selected lifestyle behaviors independently, and in combination with other lifestyle behaviors, and dietary quality (using total HEI-2010 and AHEI-2010 scores) by diabetes status. Data from the National Health and Nutrition Examination Survey (NHANES) 2007-2010 were used to analyze participants age 20 years and older (n = 4097). Overall, the total HEI-2010 and AHEI-2010 scores for the sample indicate that U.S. adults need dietary improvement (mean total HEI-2010 score = 47.3 ± 0.4; mean total AHEI-2010 score

= 38.2 ± 0.4). Diabetics had higher total HEI-2010 and AHEI-2010 scores compared to prediabetics and nondiabetics, but did not have better health markers. Results indicate no predictive value of total HEI-2010 and AHEI-2010 scores (OR = 1.00, $p > 0.05$) in relation to diabetes status. In addition, the associations between diabetes status and discrepancy scores (for both HEI-2010 and AHEI-2010) were not significant after adjusting for perceived health status ($p > 0.05$). However, there were significant associations between individual lifestyle behaviors and total HEI-2010 and AHEI-2010 scores by diabetes status ($p < 0.05$). In addition, the combined Lifestyle Behaviors score was a significant predictor of total HEI-2010 and AHEI-2010 scores ($p < 0.05$) by diabetes status. In conclusion, these findings suggest that dietary quality, measured with HEI-2010 or AHEI-2010 is associated with health markers, perceptions, and lifestyle behaviors, all of which can influence the development of T2DM. Findings of this research have implications for developing more successful strategies to improve compliance with dietary guidelines and evidence-based recommendations for disease management and prevention.

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Dedication

I dedicate this dissertation to my family, friends and colleagues from whom I received encouragement and support throughout this academic journey. I could not have done this without you.

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Chapter 1: Introduction

In the United States (U.S.), diabetes is the 7th leading cause of death (Heron, 2011). Type 2 diabetes (T2DM) accounts for at least 90% of all diabetes cases (Maxwell & Wood, 2011). Unhealthful dietary intake is an essential risk factor for T2DM and many other chronic diseases (Wang et al., 2014). Therefore, adopting a healthful diet is an important strategy to prevent diabetes and other adverse health outcomes and optimize long-term health (Wang et al., 2014). For that reason, it is important to examine the factors that may contribute to non-adherence to a healthy diet in order to better understand the association between overall diet quality and diabetes. More importantly, the results of this research may contribute to the development of more effective policies and interventions aimed at primary and secondary prevention of T2DM through adequate nutrition counseling on evidence-based dietary recommendations. A better understanding of the factors that can influence dietary choices and health outcomes may lead to the development of successful strategies that help improve compliance to dietary guidelines, healthy food choices, lifestyle behaviors, individual health awareness, and ultimately, improve health outcomes and disease prevention in the U.S. adult population.

Diabetes remains widespread in the U.S. and its prevalence and incidence have been increasing across several demographic subgroups including age, sex, and ethnicity. More recent data from NHANES indicate that 37% of U.S. adults age 20 years or older had prediabetes in 2009-2012 (51% of those age 65 years or older) and 12.3% had diagnosed and undiagnosed diabetes (Centers for Disease Control and Prevention, 2014a). Diabetes prevalence also increases with age, and varies considerably by ethnicity. The age-adjusted prevalence of diabetes is highest among American Indians/Alaska Natives (15.9%), followed by non-Hispanic blacks (13.2%), Hispanics (12.8%), Asian Americans (9.0%) and non-Hispanic whites (7.6%) (Centers for Disease Control and Prevention, 2014a).

Nutrition research has traditionally focused on single nutrients in relation to health and/or disease outcome (Nicklas, Carol, Fulgoni, & others, 2014). Recently however, scientists have acknowledged the complex synergistic interactions among foods in relation to health. This has led to a growing interest in looking at dietary patterns, given that individuals generally consume food as a relative mix with other food items (i.e., mixed dishes) (Nicklas et al., 2014). Index-based analysis is one of the most recent methods in dietary pattern analysis. It involves the calculation of dietary-quality scores based on a numerical scoring system defined on the basis of a *priori* knowledge originated from recommended diets or dietary guidelines (Jacques & Tucker, 2001; Reedy et al., 2010). The calculated score represents an estimate of the degree to which an individual's actual diet conforms to a recommended diet, or dietary guidelines. A given index includes the most important dietary components of a particular diet and then scores compliance with those components on the basis of a rubric developed for that index (Huffman, Zarini, Mcnamara, & Nagarajan, 2011). There are several dietary indices currently in use to assess overall diet quality. The most recognized index of dietary quality is the Healthy Eating Index (HEI), which is a tool designed to measure compliance with the key diet-related recommendations of the *Dietary Guidelines for Americans* (DGA) (McGuire, 2011; Patricia M. Guenther et al., 2013). Another popular dietary index tool is the Alternate Healthy Eating Index

(AHEI), which is a modification of the original HEI. It uses foods and nutrients to capture additional information on diet quality, focusing especially on foods that may lower the risk of metabolic diseases further (Chiuve et al., 2012). It is useful to examine the total scores for each index and the relationships among individual components and health or disease outcomes, such as diabetes (T2DM).

Chapter 2: Literature Review

2.1 Diabetes Epidemic in the United States

Diabetes remains widespread in the U.S. and its prevalence and incidence have been increasing across several demographic subgroups including age, sex, education, and ethnicity. Between 1980 and 1994, there was a 16% increase in diabetes prevalence (Geiss, 1999), and a 33% increase in the 8-year period between 1990 and 1998 (Mokdad et al., 2000). Projections for the U.S. suggest that the number of individuals age $\geq$ 20 years with either diagnosed or undiagnosed diabetes will increase from 13.9 million in 1995 to almost 22 million in 2025 (King, Aubert, & Herman, 1998). However, these projections only reflect the anticipated total number of people with diabetes (diagnosed and undiagnosed) through applying age- and sex-specific prevalence rates without taking into account changes in ethnic composition of the population (Boyle et al., 2001). In general, diagnosed diabetes is when an individuals' diabetes status is self-reported based on information obtained from a doctor or a primary care physician. Undiagnosed diabetes is when there is no self-report or record of an individuals' diabetes status by a primary care practice.

Boyle et al. (2001) combined age-, sex-, and ethnicity-specific diagnosed diabetes prevalence rates from 1980–1998 National Health Interview Survey (NHIS) data with Bureau of Census population demographic projections, to project the number of people with diagnosed diabetes in the U.S. through 2050 accounting for changes in demographics and diabetes prevalence rates. Sensitivity analyses suggest that the number of Americans with diagnosed diabetes will increase 165%, from 11 million in 2000 (prevalence of 4.0%) to 29 million in 2050 (prevalence of 7.2%). By 2050, there will be an additional 18 million people with diagnosed diabetes in the U.S. alone, and 37% of this increase will be due to changes in the age, sex, and ethnic composition of the population, 27% will be due to population growth, and 36% will be due to changes in prevalence rates. It also expected that African-Americans and the elderly (age ≥ 75 years) will experience the most rapid growth in the number of people with diabetes (Boyle et al., 2001).

A more recent study by Geiss et al. (2014) used 1980-2012 NHIS data (n = 664,969) for adults age 20 to 79 years to estimate and examine long-term trends in the incidence and prevalence rates of diagnosed diabetes for the overall civilian, non-institutionalized, U.S. population and for demographic subgroups defined by age, sex, ethnicity, and educational level. Self-reported diabetes diagnosis was used to estimate prevalence (i.e., percentage of the population with the disease); a duration of less than a year was used to estimate incidence (i.e., rate of new cases in the past year). Joinpoint regression analysis (also known as piecewise linear regression) was used to determine the annual percentage change (APC) in prevalence and incidence of diagnosed diabetes. Joinpoint regression determines the number of linear segments needed to describe a trend and identifies points at which linear trends change; the points at which a segment begins and ends; the annual percentage change (APC) for each segment; and whether the APC is significantly different from zero (Geiss et al., 2014). Results indicate that the APC for age-adjusted prevalence and incidence of diagnosed diabetes did not change substantially during the 1980s (prevalence APC = 0.2, $p = 0.69$; incidence APC = -0.1, $p = 0.93$), but suggest that it doubled each year from 1990 to 2008 (prevalence APC = 4.5, $P < 0.001$; incidence APC = 4.7, $P < 0.001$) before leveling off with no significant change from 2008 to 2012 (prevalence APC = 0.6, $p = 0.64$; incidence APC = -5.4, $p = 0.09$) (Geiss et al., 2014). However, prevalence and incidence rates of diabetes have continued to increase among some demographic subgroups. Pairwise z-tests and post hoc comparisons of APCs between demographic subgroups were conducted for the most recent trend period (2008-2012). The incidence rates among non-Hispanic blacks and Hispanic adults have continued to increase at rates significantly greater than for non-Hispanic white adults ($P < 0.05$). In addition, the rate of increase in prevalence was higher for adults who had a high school education or less compared with those who had more than a high school education ($P < 0.05$) (Geiss et al., 2014).

The authors discussed multiple reasons for the doubling of diabetes prevalence and incidence during 1990-2008. These include aging of the population, improved survival rates, growth of minority populations at increased risk, and increased risk factors such as obesity and sedentary lifestyle (Geiss et al., 2014). Moreover, the authors mentioned that changes in total dietary intake and portion size, and the qualitative changes in the diet (i.e., increased consumption of refined carbohydrates, added sugars) over recent decades are major factors in the increase of obesity prevalence. They suggest that the increase in diabetes prevalence coincides with the increase in obesity in the U.S. (Geiss et al., 2014). Their conclusions support the findings from another population-based study, which indicates that increased adiposity is a major factor in increasing diabetes incidence (Fox, 2006).

Between 2008 and 2012, the rate of increase in diabetes prevalence slowed, which the authors suggested may be due to a slower rate of increase in obesity (a major risk factor for T2DM) in the U.S., with no change in the prevalence of obesity among adults since 2003-2004 (Ogden, Carroll, Kit, & Flegal, 2013; Flegal, Carroll, Kit, & Ogden, 2012). Moreover, the authors contemplated from previous studies that this slowing in the growth of obesity and diabetes appears to be coexisting with declines in overall caloric intake, food purchases, and excess energy intake (Ford & Dietz, 2013; Ng, Slining, & Popkin, 2014). However, the authors have not further discussed the possible reasons for continued increase in diabetes prevalence and incidence among demographic subgroups (i.e., ethnicity and education level). Overall, this study suggests that there has been an overall plateauing of prevalence and incidence of diagnosed diabetes since 2008 (Geiss et al., 2014). Nevertheless, diabetes remains a widespread problem, especially among some demographic subgroups, and it has a significant impact on the U.S. healthcare system.

2.2 Assessment of Dietary Quality

Over the years, there have been various attempts to make the concept of diet quality more objective, quantifiable, and measureable (Preedy, Hunter, & Patel, 2013). Measuring dietary quality can be complex because it is usually undertaken to evaluate dietary patterns (Preedy et al., 2013). For that reason, there is lack of consensus in defining the term “diet quality” because it has been defined and used in different ways in the literature (Coulston, Boushey, & Ferruzzi, 2013). In general, dietary patterns can be categorized “empirically” or “theoretically” (Preedy et al., 2013). Empirically defined dietary patterns uses an “*a posteriori*” approach, where statistical methods such as factor and cluster analyses are used to generate patterns from food consumption data (data-driven). Theoretically defined dietary patterns use an “a *priori*” approach in developing dietary indices or scores, which are made up of nutritional variables (include foods and/or nutrients) based on current nutrition knowledge. These variables are summed to provide an overall measure of diet quality (Preedy et al., 2013).

The measurement of diet quality has evolved. Several different scoring indices are currently in use. They are increasingly being used to examine epidemiological associations between dietary intake and nutrition-related health outcomes (Wirt & Collins, 2009). Scoring indices assess both the quality and the variety of the entire diet, enabling examination of associations between whole foods and health status, rather than just single nutrients. Diet quality is measured by scoring food patterns in terms of how closely they align with national dietary guidelines and evidence-based recommendations (Wirt & Collins, 2009). There are several pre-defined diet quality scores that have been validated by relating the index to health outcome. Two of them have gained strong recognition: Healthy Eating Index (HEI) and the Alternate Healthy Eating Index (AHEI).

2.2.1 The Healthy Eating Index (HEI)

The Healthy Eating Index (HEI) was first developed in 1995 by the USDA Center for Nutrition Policy and Promotion (CNPP) to assess and monitor the dietary status of Americans. Every five years, the HEI has been updated to reflect current guidelines. The first revision in 2006 produced the HEI-2005. It was followed by a second revision in 2012 (which produced the HEI-2010) to reflect the 2010 DGA (McGuire, 2011; Patricia M. Guenther et al., 2013). In general, the HEI is a measure of diet quality in relation to federal dietary guidance. It is used to monitor the quality of American diets; to examine relationships between diet and health-related outcomes and between diet cost and diet quality; to determine the effectiveness of nutrition intervention programs; and to assess the quality of food assistance packages, menus, and the U.S. food supply ("Healthy Eating Index," n.d.).

The main features of the HEI-2010 were maintained from the HEI-2005: 1) diet quality is assessed from two perspectives: adequacy (dietary components to increase) and moderation (dietary components to decrease); 2) the scoring standards are density-based such that the relative mix of foods is evaluated; and 3) the standards for the maximum score are the least-restrictive (easiest to achieve) recommendations among those that vary by energy level, sex, and/or age (Patricia M. Guenther et al., 2013). The HEI-2010 score captures all dietary components rather than a selected list of nutrients/food groups and also reflects the most up-to date evidence on the components of a healthy diet (Bernstein, Bloom, Rosner, Franz, & Willett, 2010).

The HEI-2010 is made up of 12 components: 9 adequacy components and 3 moderation components. The 9 adequacy components are: Total Fruit, Whole Fruit (forms other than juice), Total Vegetables, Greens and Beans (dark-green vegetables and beans and peas), Whole Grains, Dairy (all milk products and soy beverages), Total Protein Foods, Seafood and Plant Proteins, and Fatty Acids (ratio of poly- and monounsaturated fat to saturated fat). The 3 moderation components are: Refined Grains, Sodium, and Empty Calories (all calories from solid fats & added sugars plus calories from alcohol beyond a moderate level). For most components, higher intakes result in higher scores; however, for Refined Grains, Sodium, and Empty Calories, lower intake levels result in higher scores because lower intakes are more beneficial (Patricia M. Guenther et al., 2013). For all components (adequacy and moderation), higher scores reflect better diet quality because the moderation components are scored such that lower intakes receive higher scores (P. M. Guenther et al., 2014). Seven components are each scored on a 0 to 5 scale, with intermediate values scored proportionally. These components are: Total fruit, whole fruit, total vegetables, greens and beans, total protein foods, and seafood and plant proteins. Five other components are scored on a 0 to 10 scale, with intermediate values scored proportionally. These components include: whole grains, dairy, fatty acids, refined grains, sodium, and empty calories. The individual component scores are summed to arrive at a single score between 0 and 100. Higher scores indicate a higher quality diet. Scores above 80 indicate a "good" diet, while scores below 51 indicate a "poor" diet. A HEI score between 51 and 80 is considered as "needing dietary improvement" (Bowman, Lino, & Basiotis, 1998; Patricia M. Guenther et al., 2013; P. M. Guenther et al., 2014).

The main objective of the dietary guidelines is to promote healthy eating in the general population (Willett, 2012). The HEI score is a quantitative measure of the overall healthfulness of diets. In the literature, the HEI has been evaluated among individuals with chronic disease (i.e., diabetes, CVD, cancer) with mixed results. Some studies have shown that higher HEI scores are associated with only a small reduction in risk of major chronic disease (i.e., fatal or nonfatal CVD or nontraumatic death) (McCullough et al., 2002a). Other studies have shown moderate inverse associations between HEI score and chronic disease risk (i.e., CVD) (de Koning et al., 2011; Schwingshackl & Hoffmann, 2015a). Therefore, McCullough and colleagues developed the Alternate Healthy Index (AHEI) in 2002 as a way to improve on the ability to predict chronic disease risk based on diet. The AHEI has different components and focuses on foods and nutrients that have been linked to chronic disease risk (McCullough et al., 2002; Chiuve et al., 2012). The most recent U.S. dietary guidelines (DGA 2015) have somewhat moved in the direction suggested by the AHEI. Further evaluation and modification of the guidelines should improve the quality of the dietary guidelines and subsequently, the quality of advice to the public and the value of government food programs for improving health (Willett, 2012)**.**

2.2.2 The Alternate Healthy Eating Index (AHEI)

The Alternate Healthy Eating Index (AHEI) is another index used by researchers to measure diet quality based on current scientific knowledge on foods and nutrients that are predictive of chronic disease risk (Chiuve et al., 2012). The AHEI food and nutrient groups were chosen and scoring decisions were made "*a priori*", on the basis of discussions with nutrition researchers (McCullough et al., 2002a). The AHEI incorporates some aspects of the HEI (i.e., both the HEI and AHEI assign points for high intake of fruit and vegetables), but it also provides quantitative scoring for qualitative USDA recommendations (i.e., the AHEI assigns a certain number of points for choosing more fish, poultry, and whole grains) (Bernstein et al., 2010). Some of the features that set the AHEI apart from the original HEI and other indices include attention to fat quality (i.e., trans fats, omega-3), inclusion of moderate alcohol intake, sugar-sweetened beverages and fruit juice, red-to-white meat ratio, nuts and legumes, and duration of multivitamin use (Huffman, Zarini, et al., 2011).

Originally, the AHEI was scored on the basis of data from the Food Frequency Questionnaire (FFQ). Before 2010, the AHEI was comprised of 9 components, including some components from the original HEI (i.e., fruits and vegetables). Eight of the nine components contributed from 0 to 10 points to the total score. A score of 0 represents not meeting the dietary intake found to decrease risk of chronic disease, whereas a score of 10 represents perfect adherence. Intermediate intakes were scored proportionately from 0 to 10. Duration of multivitamin use was scored either 2.5 (nonuse) or 7.5 (use $\geq$ 10 y). To calculate the AHEI score, component scores were summed so that the composite index ranged from a minimum score of 2.5 (worst eating pattern) to a maximum of 87.5 (best eating pattern) (McCullough et al., 2002a; Bernstein et al., 2010). Since the creation of the AHEI in 2002, substantial evidence has emerged to support the role of additional dietary factors in the development of chronic disease. Thus, Chiuve et al. (2012) created the AHEI-2010, a new measure of diet quality that incorporates current scientific evidence on diet and health (Chiuve et al., 2012). The AHEI-2010 has been validated against major chronic disease risk, mortality, and biomarkers of inflammation and endothelial function (Doell, Folmer, Lee, Honigfort, & Carberry, 2012; Belin et al., 2011; Akbaraly et al., 2011; Teresa T. Fung et al., 2005).

The AHEI-2010 was developed based on a comprehensive review of the relevant literature and discussions with other nutrition researchers to identify foods and nutrients that have been associated consistently with lower risk of chronic disease in clinical and epidemiologic investigations, including information from the original HEI (Chiuve et al., 2012; Wang et al., 2014). The AHEI-2010 is based on 11 components: six components for which higher intakes are better [vegetables, fruit, whole grains, nuts and legumes, long chain omega-3 fatty acids (FA) that include docosahexaenoic acid and eicosapentaenoic acid, and Polyunsaturated Fatty Acids (PUFA)], one component for which moderate intake is better (alcohol), and four components that must be limited or avoided (sugar sweetened drinks and fruit juice, red and/or processed meat, trans fats, and sodium). Each component is scored on a 0 to 10 point scale. The component scores are summed to obtain the total AHEI-2010 score, which can range from 0 (non-adherence) to 110 (perfect adherence). Higher scores represent healthier diets (Bernstein et al., 2010; Wang et al., 2014; Varraso et al., 2015). Table 1 summarizes the component and criteria scoring for the two diet quality indices: the Healthy Eating Index (HEI-2010) and the Alternate Healthy Eating index (AHEI-2010) (Wang et al., 2014).

Table 1. Alternate Healthy Eating Index (AHEI-2010) and Healthy Eating Index (HEI-2010) Components and Criteria for Scoring

	AHEI-2010			HEI-2010		
	Maximum Score	Criteria: Score of 0	Criteria: Maximum Score	Maximum Score	Criteria: Score of 0	Criteria: Maximum Score
Total fruit	...	...	...	5	0	≥0.8 cups/1000 kcal
Whole fruit[a]	10	0	≥4 servings/d	5	0	≥0.4 cups/1000 kcal
Total vegetables[b]	10	0	≥2.5 cups/d	5	0	≥1.1 cups/1000 kcal
Greens and beans	...	...	...	5	0	≥0.2 cups/1000 kcal
Whole grains[c]	10	0	Women: 75 g/d; Men: 90 g/d	10	0	≥1.5 oz/1000 kcal
Dairy				10	0	≥1.3 cups/1000 kcal
Sugar-sweetened beverages and fruit juice	10	≥8 oz/d	0	...	...	...
Nuts and legumes	10	0	≥1 oz/d	...	...	...
Red and/or processed meats[d]	10	≥1.5 servings/d	0	...	...	...
Fatty acids	...	...	...	10	(PUFAs + MUFAs)/SFAs ≤1.2	(PUFAs + MUFAs)/SFAs ≥2.5
trans Fat	10	≥4% of energy	≤0.5% of energy	...	...	...
Long-chain (ω-3) fats (EPA + DHA)	10	0	250 mg/d			
PUFAs	10	≤2% of energy	≥10% of energy	...	...	...
Alcohol	10	Women: ≥2.5 drinks/d; Men: ≥3.5 drinks/d	Women: 0.5-1.5 drinks/d; Men: 0.5-2.0 drinks/d	...	...	...
Total protein foods	...	...	...	5	0	≥2.5 oz/1000 kcal
Seafood and plant proteins	...	...	...	5	0	≥0.8 oz/1000 kcal
Refined grains	...	...	...	10	≥4.3 oz/1000 kcal	≤1.8 oz/1000 kcal
Sodium	10	Highest decile	Lowest decile	10	≥2.0 g/1000 kcal	≤1.1 g/1000 kcal
Empty calories[e]	...	...	...	20	≥50% of energy	≤19% of energy
Total	110			100		

Abbreviations: DHA, docosahexaenoic acid; ellipses, not applicable; EPA, eicosapentaenoic acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

[a] Whole fruit excludes juice. For AHEI-2010, 1 serving is 1 medium piece of fruit or 0.5 cups of berries.

[b] For AHEI-2010, total vegetables excludes potatoes and juices.

[c] For AHEI-2010, whole grains include brown rice, popcorn, and any grain food with a carbohydrate to fiber ratio no more than 10:1.

[d] For AHEI-2010, 1 serving is 4 oz of unprocessed meat or 1.5 oz of processed meat.

[e] Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.

Source: Wang et al. (2014) Trends in Dietary Quality Among Adults in the United States, 1999 Through 2010. *JAMA Internal Medicine*, *174*(10), 1587. http://doi.org/10.1001/jamainternmed.2014.3422

A recent study by Wang et al. (2014) used NHANES data to investigate changes in diet quality (measured by AHEI-2010) from 1999 to 2010 in the U.S. adult population overall and within socioeconomic subgroups (Wang et al., 2014). The analytic population included 29,124 adults age 20 to 85 years. Multivariate linear regression analysis was used to examine the association between the mean adjusted AHEI-2010 scores over time within socioeconomic subgroups. Covariates for the models included total energy intake, sex, age group, poverty income ratio (PIR), education, ethnicity, and household size. Results showed that the energy-adjusted mean AHEI-2010 score increased from 39.9 (low adherence) in 1999 to 2000 to 46.8 (intermediate adherence) in 2009 to 2010 (linear trend $P < 0.001$). Among socioeconomic subgroups, family income and education level (indicators of socioeconomic status, or SES) were positively associated with diet quality. In addition, there was a modest improvement in dietary quality (as measured by AHEI-2010) among U.S. adults over that period of time (1999-2010), but the improvement was greater among persons with higher (SES) and healthier body mass index (BMI). Most importantly, more than half of the improvement was attributable to a reduction in trans fat intake (Wang et al., 2014). Despite some improvement in dietary quality, the authors concluded that nearly the entire U.S. population fell short of meeting federal dietary recommendations and there was a need for further improvement (Wang et al., 2014).

2.3 Dietary Quality and Type 2 Diabetes Risk

The role of adherence to predefined dietary patterns in the development of T2DM has been of great interest. Although obesity and lack of adequate physical activity are major risk factors, certain dietary factors (i.e., unhealthful dietary intake) and overall diet quality may also contribute to an increased risk of T2DM (Fung et al., 2007; Qiao et al., 2014). Several cross-sectional and prospective studies have examined the relationship between diet quality indices and T2DM. These studies are difficult to compare because they used different diet quality indices and controlled for different possible confounders that may modify the association. Recently, however, comparison between diet quality indices in relation to T2DM has become more popular.

2.3.1 Comparison of the HEI and AHEI in Cross-Sectional Studies

Limited cross-sectional studies have compared the HEI and AHEI in relation to T2DM. Huffman et al. (2011) examined the relationship between dietary quality indices, as measured by the HEI-2005 and the AHEI-2005 and 10-year predicted CHD risk in Cuban Americans with and without T2DM. Pearson's correlations were used to identify associations between HEI-2005 and AHEI-2005 scores with 10-year CHD risk and other potential covariates (energy intake, WC, PA). Results indicated that only the AHEI-2005 score was significantly and negatively correlated with the 10-year CHD risk score ($r = -0.227$, $P < 0.001$) for participants with T2DM (Huffman, Zarini, et al., 2011). Hierarchical linear regression (HLR) models were used to determine whether HEI or AHEI could predict 10-year CHD risk. After controlling for confounding variables, the HLR indicated that the AHEI explained 1.7% of the variation in 10-year CHD risk ($F_{(1,353)} = 6.24$, $P < 0.013$). Diabetes status explained an additional 1.4% of the variability ($F_{(1,352)} = 5.30$, $P = 0.020$). Finally, diabetes status moderated the association between AHEI-2005 and 10-year CHD risk ($F\ (1,351) = 4.44$, $P = 0.036$, $R^2 = 1.2\ \%$). An association between AHEI-2005 and 10-year CHD risk was found for participants with T2DM ($\beta = -0.244$, $SE = 0.049$, $P = 0.001$). The model predicted that, on average, for every unit increase in the AHEI-

2005 score, there would be a 0.24 point reduction in the 10-year CHD risk score among participants with T2DM. No significant association was found between HEI-2005 score and CHD risk among Cuban Americans without T2DM (β = -0.025, SE = 0.048, P = 0.737). In conclusion, the authors recommended the use of AHEI as an assessment tool to identify and modify dietary patterns as a means of decreasing CHD risk among individuals with T2DM (Huffman, Zarini, et al., 2011).

A similar study by Huffman et al. (2011) examined the differences in diet quality between African Americans (AA) and Haitian Americans (HA) with and without T2DM using the HEI-2005 and the AHEI-2005. The study included both male and female AA and HA participants with self-reported T2DM, age ≥ 35 years, not pregnant or lactating, without thyroid disorders or coronary heart disease (CHD), not undergoing chemo- or radiation therapy, and without major psychiatric disorders. A comparison group of participants without T2DM was selected using the same criteria, except that they were free of diabetes. The final sample consisted of 471 participants (n = 225 AA, n = 246 HA) for whom all data were available for analysis.

Results showed significant differences in dietary patterns of AA and HA by diabetes status using the HEI-2005 and AHEI-2005. The mean HEI-2005 score was higher for HA than AA, at 66.4 ± 11.6 and 56.3 ±12.5 (P < 0.001), respectively. Similarly, the mean AHEI-2005 was higher for HA as compared to AA, at 51.4 ± 12.6 and 42.4 ±12.6 (P < 0.001), respectively. Individuals with T2DM had higher HEI-2005 scores compared to those without T2DM, at 63.4 ±12.5 and 59.5 ± 13.3 (P < 0.001), respectively (Huffman, De La Cera, et al., 2011). General linear models suggested significant effects of ethnicity and diabetes status on total HEI-2005 score (dependent variable). Unadjusted HEI-2005 scores were higher in HA than for AA ($P < 0.001$) and for persons with T2DM as compared to without T2DM ($p = 0.001$). These relationships were maintained when controlling for demographic characteristics and diabetes status in multivariate models (diabetes status, ethnicity, gender, age, and education). All of these predictors were statistically significant ($P < 0.05$). In addition, individuals with T2DM had higher HEI-2005 scores than those without T2DM ($\beta = 3.90$ (1.78, 6.01), SE = 1. 08, $P < 0.001$). This final model explained 24.3% of the variance in HEI-2005 scores ($F_{(6,464)} = 26.1$, $P < 0.001$, adj. $R^2 = 0.243$) (Huffman, De La Cera, et al., 2011). General linear models also suggested significant associations with total AHEI-2005 score (dependent variable). Individuals with T2DM had lower AHEI-2005 scores than those without T2DM ($\beta = -9.73$ (16.3, − 3.19), SE = 3. 33, $p = 0.004$) after final adjustments (ethnicity, gender, ethnicity by gender, age, and education). The final model ($F_{(11,459)} = 8.71$, $P < 0.001$) explained 15.3% of the variance in AHEI-2005 score (adj. $R^2 = 0.153$). Overall, the authors concluded that there are ethnic differences in terms of dietary pattern consumption (as measured by HEI-2005 and AHEI-2005 scores), which strengthen the need to consider ethnicity in health studies (Huffman, De La Cera, et al., 2011).

2.3.2 Comparison of the HEI and AHEI in Prospective Studies

Several prospective studies have compared the HEI and AHEI in relation to T2DM. Results from a recent meta-analysis of cohort studies, with follow-up time ranging from 5 to ≥ 24 years, show that diets of the highest quality (compared highest vs. lowest quintile scores), as assessed by the HEI, AHEI, and DASH, are associated with a significant risk reduction for all-cause mortality, T2DM and other chronic diseases (i.e., cardiovascular disease, cancer) (P < 0.05) (Schwingshackl & Hoffmann, 2015b). In addition, diets that score highly on the HEI, AHEI, and DASH are associated with a significant reduction in the risk of T2DM (22%, P < 0.05) (Schwingshackl & Hoffmann, 2015b).

Koning et al. (2011) evaluated the relationship between the HEI, AHEI, and other diet-quality scores (DASH, aMED, RFS) with risk of T2DM in a cohort of men from the Health Professionals Follow-Up Study. Cox proportional hazards models were used to test associations between quintiles of diet-quality scores and T2DM using time-varying covariates and continuous intervals. Diet-quality scores and dietary covariates (coffee, total energy) were calculated as cumulative averages at each time point. Other covariates were updated at each time point. These included smoking, physical activity, coffee intake, total energy intake, BMI, and family history of T2DM. Of the diet-quality scores measured, results showed that the mean HEI-2005 score was 67.4 (SD 9.8) (HEI score = 51-80, needing dietary improvement) while the mean AHEI-2005 score was 44.2 (SD 11.2) (AHEI score = 17.0-44.0, low adherence) (Akbaraly et al., 2010). There were 2,795 cases of T2DM over 20 years of follow-up (733,291 person-years). After multivariate adjustment, the AHEI-2005, aMED, and DASH scores were significantly associated with decreased T2DM risk (P < 0.01), while the HEI-2005 score and the Recommended Food Score (RFS) were not significant (P > 0.05). In conclusion, the authors found that several diet-quality scores (including the AHEI-2005 score) were inversely associated with T2DM. The authors concluded that public health messages should focus on improving diet quality in overweight and obese individuals to prevent the greatest number of T2DM cases (de

Koning et al., 2011).

Another recent prospective study by Jacobs et al. (2015) evaluated the association between the HEI-2010, AHEI-2010, and two other diet quality indices (including the aMED and DASH) and risk of T2DM among white individuals, Japanese-Americans and Native Hawaiians using data from the Multiethnic Cohort (MEC) in Hawaii. The study sample consisted of 89,185 participants age 45-75 years, of which 11,217 are incident cases of diabetes (T2DM) (Jacobs et al., 2015).

The authors used Cox proportional hazards regression to assess the association between the four diet quality indices and risk of T2DM at each follow up. The follow-up time was calculated as the time between the date of the baseline questionnaire and the date of diagnosis of diabetes, the date of death or the last date when diabetes status was available. The models were stratified by age and adjusted for ethnicity, physical activity, smoking status, years of education, total energy intake and BMI (Jacobs et al., 2015). For each diet quality index (i.e., HEI-2010, AHEI-2010), individual dietary components were divided into five sex-specific categories using the lowest category as reference category (C1, lowest index category; C5, highest index category). In addition, the total diet quality score for each index was computed as a continuous variable (total score for each index, divided by its SD) (Jacobs et al., 2015).

Results showed significant inverse associations of the AHEI-2010 with risk of T2DM in men and women of all ethnicities combined (score points in men: C5 73–101 vs. C1 25–56; score points in women: C5 47–100 vs. C1 30–58; 12% risk reduction, respectively). However, the significant risk estimate per 1 SD of the continuous AHEI-2010 score (calculated as total AHEI-2010 score/SD) suggested a trend in in white men [HR = 0.90; 95% C.I. (0.85, 0.95)], white women [HR = 0.92; 95% C.I. (0.86, 0.98)], and Native Hawaiian women [HR = 0.93; 95% C.I. (0.87, 0.99)]. In contrast, the categorized HEI-2010 score (C5 76-100 vs. C1 21-57) was not significantly associated with risk of T2DM, while the continuous HEI-2010 score (calculated as total HEI-2010 score/SD) showed a significant inverse trend only in white men [HR = 0.94; 95% C.I. (0.89, 0.99)] (Jacobs et al., 2015). Overall, the authors concluded that higher diet quality scores (i.e., HEI-2010 and AHEI-2010 scores) are associated with risk reduction in T2DM (particularly in white individuals), but this may not indicate true ethnic differences. These could be the result of diverse eating patterns or biological differences in metabolism in these populations (Jacobs et al., 2015).

In general, there is some evidence from cross-sectional and prospective studies of an inverse association between diet quality indices (including the HEI & AHEI scores) and T2DM. However, most of the literature supports the AHEI-2010 as a better index than the HEI-2010 because it captures additional food components (i.e., red and/or processed meat, alcohol intake, nuts & legumes, long-chain fats) that are not found in the HEI-2010 and may be associated with the risk of metabolic diseases (including T2DM) (Huffman, Zarini, et al., 2011; Wang et al., 2014). Therefore, using both the HEI-2010 and AHEI-2010 in relation to T2DM will provide more information about overall diet quality based on key food groups that reflect the components of a healthy diet. This is essential for dietary counseling in clinical and public health settings that aims to evaluate and improve diet quality for the prevention and progression of diabetes.

2.4 Perceptions and Dietary Quality

In recent years, concerns about dietary behavior have grown in the U.S. due to strong evidence that unhealthful diets can have profound and long-term effects on health. In addition, there is greater awareness that an unhealthy diet can increase the risk of adverse health outcomes, including obesity and diabetes (T2DM). Despite changes in dietary recommendations aimed at chronic disease prevention, intake of nutrient-dense foods remains suboptimal among U.S. adults (Powell-Wiley, Miller, Agyemang, Agurs-Collins, & Reedy, 2014). Also, people may not consider the nutritional value of foods in their food choices. People may prefer qualities such as taste, variety, and convenience over nutrition in their food consumption decisions (Bishow, Blaylock, & Variyam, 1998). Currently, there is increasing interest in understanding individuals' perceptions of their own dietary behavior.

There are very limited studies in the literature that have examined the relationship between perceived diet quality (PDQ) and measured diet quality (MDQ). Variyam et al. (2001) was one of the first to measure consumers' overall diet quality (using HEI-1995) and compare it with self-perceived diet quality using the 1989–90 CSFII-DHKS data. The purpose of the study was to assess the degree of consumer misperception regarding one's own diet quality and to identify factors associated with such misperception. Dietary misperception of respondents was classified using Brug et al.'s classification based on categories of perceived and measured diet quality (HEI-1995 score) into three groups: optimists, realists, and pessimists (J. Brug, P.A.

Assema, G. Kok, T. Lenderink, 1994). Results showed that almost 40% of household meal planners or preparers perceived their diets to be of higher quality than their actual diets, as measured using HEI-1995 (Variyam, Shim, & Blaylock, 2001). Another 40% of the respondents were realists, which means that they accurately assessed the quality of their diets. The remaining 20% were pessimists, which means that they perceived their diets to be worse than they actually were. The optimists had a mean HEI-1995 score of 60.6, which was significantly different from the mean HEI-1995 score of realists (66.2) and pessimists (68.6). Based on the USDA's grading scale, an HEI score of 51 to 80 is classified as "needing dietary improvement" (Bowman et al., 1998). This implies that many U.S. adults have inaccurate perceptions and need improvement in quality of their diets (Variyam et al., 2001).

Despite continuous efforts to promote public awareness and knowledge of existing dietary guidelines, major discrepancies continue to exist between the recommendations and individuals' actual dietary behavior (Variyam et al., 2001). This could be attributed to various environmental or socioeconomic factors (i.e., limited access to health foods) that promote this disconnect between perceived and actual dietary behavior. Moreover, psychosocial barriers (i.e., inadequate social support, perceived behavioral control or general knowledge of appropriate dietary habits) are known to influence people's perceptions of their diet quality (Shaikh, Yaroch, Nebeling, Yeh, & Resnicow, 2008).

A more recent study of U.S. adults by Powell-Wiley et al. (2014) used 2005-2006 NHANES data to compare PDQ and MDQ using a nutrient-based DASH index score. The study sample (n = 4419) included non-Hispanic White, non-Hispanic Black and Mexican-Americans individuals age 19 years or older with reliable 24-hour dietary recall data and non-missing responses for the survey question about PDQ from the 2005–2006 NHANES. Participants rated their diet quality on a 5-point Likert scale and PDQ scores were generated (low, medium, high). The DASH index score is composed of nine-targeted nutrients. For some nutrients, greater consumption leads to higher scores (i.e., protein, fiber, Mg, Ca and K); for others, lower consumption leads to higher scores (i.e., total fat, saturated fat, Na and cholesterol). Higher scores indicate greater adherence to the DASH diet. The component scores are summed to obtain an overall DASH index score. A DASH index score of 9 points represents optimal adherence to the DASH dietary pattern. An index score of 0 is classified as suboptimal relative to the targets of the DASH diet pattern. A total DASH index score of approximately ≥ 4.5 points was considered accordant with the DASH dietary pattern (Mellen, Gao, Vitolins, & Goff, 2008). The authors used a single 24-hour dietary recall to estimate DASH index scores (range 0–9 points) by assigning 0, 0.5 or 1 point (optimal) for nine target nutrients: total fat, saturated fat, protein, cholesterol, fiber, calcium, magnesium, potassium and sodium. Results indicate that 33% of U.S. adults perceived their diet as excellent or very good (high PDQ). These individuals were more likely to be older, non-Hispanic Whites, with higher levels of education and income, and with normal BMI. In terms of energy intake, adults with high PDQ consumed the least amount of kilojoules (8820.3 ± 137.8) as compared to those with medium (9317.3 ± 192.6) or low PDQ (9523.6 ± 228.6) (Powell-Wiley et al., 2014). Participants with high PDQ also had higher

DASH scores than those who had medium or low PDQ (mean score: 3.0 (SD 0.1) v. 2.6 (SD 0.04) v. 2.5 (SD 0.1) points, P-trend = 0.0002); however, none of the average DASH index scores across the three PDQ levels reflected the targets of the DASH diet pattern (score ≥ 4.5 points). In addition, adults with high PDQ had greater adjusted mean intake for saturated fat than the DASH target recommendations (10.5% (SE 0.2) v. 6.0% of energy), cholesterol [141.3 (SE 4.3) v. 71.4 mg/4184 kJ (1000 kcal)], and sodium [1595.5 (SE 36.6) versus 1143.0 mg/4184 kJ (1000 kcal)]. In conclusion, the study found that despite having relatively higher DASH index scores, U.S. adults who perceived their diets as of the highest quality still did not meet recommendations for dietary intake based on individual nutrient components and total DASH index scores. The authors suggest that PDQ should be considered as a potential psychosocial barrier to improving dietary habits in U.S. adults (Powell-Wiley et al., 2014).

2.5 Lifestyle Behaviors and Dietary Quality

Numerous epidemiological studies have shown that T2DM is largely preventable through diet and lifestyle modifications. In addition, individual dietary and lifestyle factors (i.e., physical inactivity, smoking, alcohol consumption) in the development of T2DM in diverse populations have been implicated. However, few studies have investigated these factors simultaneously (Hu, 2011). Moreover, lifestyle modification involves altering long-term dietary and physical activity habits, and maintaining new behavior(s) throughout life. Lifestyle modification is commonly recommended to treat various chronic diseases, including obesity and T2DM. However, there are other lifestyle factors that may possibly be associated with the progression of T2DM that have not been clearly examined. Some of these factors include the effect of dietary supplement intake and sleep quality (i.e., sleep duration) and their association with dietary quality in people with and without T2DM.

2.5.1 Physical Activity

Individually, both dietary behavior and physical activity predict health outcomes among adults. However, there is limited understanding of the potential combined influence of dietary and physical activity behaviors on health outcomes (Loprinzi, Smit, & Mahoney, 2014). Loprinzi et al. (2014) examined the association between objectively measured physical activity (using an ActiGraph accelerometer to objectively measure physical activity and sedentary patterns) and dietary behavior (measured by HEI-2005 scores) and their combined effect on health. The authors used 2003-2006 NHANES data to examine the association between physical activity and dietary behavior, and their potential combined effect on biomarkers (i.e., total cholesterol) and physical health (i.e., waist circumference) (Loprinzi et al., 2014). Logistic regression analysis was also used to examine the association between lifestyle groups (independent variable) and biological/health markers. Results showed that compared with those who consumed a healthy diet (HEI-2005 score above 60^{th} percentile) and were physically active (referent group), participants who consumed an unhealthy diet and were inactive were 3.7 times more likely to have a high waist circumference ($\geq$ 102 cm for men and $\geq$ 88 cm for women) ($P < 0.001$), 62% more likely to be hypertensive [OR= 1.62 (1.23-2.14), $p = 0.001$], 43% more likely to have an elevated CRP level (> 0.3 mg/dl) [OR= 1.43 (1.17-1.74), $p = 0.001$], 89% more likely to have an elevated homocysteine value (>10.4 μmol/L for women and >11.4

μmol/L for men) (OR = 1.89 [1.35-2.65), p = 0.001], and 2.4 times more likely to have metabolic syndrome [OR = 2.40 (1.42- 4.07), p = 0.003]. Overall, the findings of the study indicate a relationship between objectively measured physical activity and dietary behavior. Also, individuals who consume a healthy diet (HEI-2005 score above 60^{th} percentile) and engage in regular physical activity (150 minutes of moderate-intensity or 70 minutes of vigorous-intensity per week or some combination of the two) have better health outcomes than those who engage in either behavior alone (Loprinzi et al., 2014).

2.5.2 Alcohol Consumption

Excessive alcohol consumption and unhealthy dietary intake are known to be associated with various chronic diseases (i.e., CVD, cancers of the colorectum and upper GI tract, and alcohol-related liver disease). However, little is known about the association between alcohol consumption, nutrient intakes, and diet quality and their combined associations with chronic disease, even though each one is individually associated with chronic disease (Lieber, 2000; Imperatore, 2004; American Institute for Cancer Research & World Cancer Research Fund, 2007). Breslow et al. (2010) examined associations between alcoholic beverage consumption (i.e., drinking status, drinking level), nutrient intakes, and diet quality (measured by HEI-2005 scores) among U.S. adults using 1999-2006 NHANES data. Multiple linear regression analysis was also used to analyze the association between drinking status, drinking levels, and diet quality. Results showed the diet quality of Americans (as measured by HEI-2005 scores) was relatively poor on average when compared to the recommendations of the 2005 DGA, regardless of drinking status. Among men, the total HEI-2005 scores did not differ significantly by drinking status (HEI-2005 scores 53.6 – 57.8 out of a maximum score 100). Among women, however, diet quality scores were significantly lower among current drinkers (total HEI-2005 score = 58.9) than never drinkers (total HEI-2005 score = 63.2) ($P < 0.05$). For drinking levels, results showed that among men who currently drank, diet quality scores declined significantly from total HEI-2005 score 55.9 to 41.5 with increasing number of drinks per day, on average ($P < 0.05$). Similarly, results showed that among women who currently drank, HEI-2005 scores declined significantly from 59.5 to 51.8 as the number of drinks per day increased, on average ($P < 0.05$). In conclusion, the findings of the study suggest that the HEI-2005 is a useful indicator of diet quality according to drinking status and drinking levels. In addition, the authors found that increased alcohol consumption was associated with a decline in total diet quality (measured by the HEI-2005 scores), apparently due to higher energy intake from alcohol as well as other differences in food choices. They recommended that educational messages focus on the chronic disease risk associated with high consumption of alcoholic beverages and poor food choices, including excessive energy intake (Breslow, Guenther, Juan, & Graubard, 2010).

2.5.3 Dietary Supplementation

Most of the literature examines single nutrients (through supplement intake) in relation to T2DM risk. However, studies evaluating the association between dietary supplementation, diet quality, and T2DM are few. Anders et al., (2015) used 2007-2008 NHANES data to estimate whether and to what extent dietary supplementation impacts the diet quality (measured by HEI-2010 scores) and/or BMI outcomes among individuals with diabetes. The author hypothesized that people with diabetes who take nutrition supplements, (presumably make an effort to actively improve their diet quality) will have higher HEI-2010 scores and lower BMI scores than those individuals who do not take dietary supplements. The authors used Propensity Score Matching (PSM) to quantify the possible relationships between supplement intakes (as treatment group), diet quality (measured by HEI-2010 scores) and obesity status (BMI) among diabetic patients. PSM is a statistical matching technique used to estimate the effect of a treatment, policy, or other intervention by controlling for other known characteristics of the treatment group that may affect the outcome within observational datasets. It is widely used in health-related research when randomized controlled trial methods are not feasible ("Propensity score matching," 2015).

Results showed that the frequency of intake of supplements among individuals with diabetes does not lead to measurable improvements in diet quality. However, the authors did find significant differences in BMI status outcomes between individuals with diabetes who reported taking dietary supplements compared to those who did not report taking dietary supplements ($P < 0.05$). Matching results suggest that regular dietary supplement consumption is associated with significantly lower BMI outcomes of almost 1 kg/m^2. This suggests that these individuals lead healthy lifestyles (as part of diabetes management) and seem to be concerned about their general well-being (Anders & Schroeter, 2015). So far, this was the only up-to-date study that attempted to determine the role of dietary supplementation on diet quality and obesity among individuals with diabetes. Therefore, more studies are needed to understand the role of dietary supplementation and diet quality in people with and without diabetes.

2.5.4 Sleep Quality

There are various factors of modern lifestyle that contribute to the increasing obesity and diabetes epidemic. For that reason, a better understanding of the factors that predispose individuals to chronic disease is necessary to improve public health (Grandner, Jackson, Gerstner, & Knutson, 2013). Physical inactivity and unhealthy dietary intake (i.e., highly palatable processed foods) are the most common factors that contribute to weight gain, which leads to obesity and T2DM. However, another potential risk factor that is of great interest is sleep adequacy (i.e., insufficient or excessive sleep duration) (Chao et al., 2011; Grandner et al., 2013). Sleep adequacy can be broadly defined as a combination of sufficient sleep duration and sleep quality (Buxton et al., 2009). Epidemiological studies have demonstrated that inadequate sleep duration and compromised sleep quality (independent of other known contributing factors) increase the risk of weight gain leading to obesity as well as other chronic disease (Buxton et al., 2009). In addition, short sleep duration has been shown to be associated with diabetes, cardiovascular disease (CVD), psychiatric illness, and performance deficits. Similarly, long sleep duration is also associated with poor physical and mental health (Chao et al., 2011; Grandner et al., 2013). Therefore, the role of a healthy diet in habitual sleep duration represents a largely unknown pathway linking sleep and health (Grandner et al., 2013).

There is growing evidence that inadequate sleep could be a risk factor for diabetes (T2DM) (Chao et al., 2011). Experimental studies have shown that sleep deprivation causes a decrease in glucose tolerance and compromises insulin sensitivity (VanHelder, Symons, & Radomski, 1993; Spiegel, Knutson, Leproult, Tasali, & Van Cauter, 2005). Although the mechanisms by which sleep duration and diabetes risk are related are not fully understood, it has been suggested that habitually short sleep durations could lead to insulin resistance by increasing sympathetic nervous system activity, raising evening cortisol levels, and decreasing cerebral glucose utilization (Spiegel et al., 2005). Over time, the increased burden on the pancreas from insulin resistance can compromise β-cell function and lead to T2DM (Grandner et al., 2013).

Limited studies have examined the association between habitual sleep duration and dietary behavior. Grandner et al. (2013) evaluated the association between habitual sleep (i.e., sleep duration) and dietary intake (i.e., overall diet, single nutrients) using 2007-2008 NHANES data. Multinomial logistic regression analysis was used to examine the effect of dietary intake (total energy intake, protein, carbohydrates, fats, vitamins, minerals, caffeine, alcohol) on sleep duration. Results showed that very short sleep durations (< 5 hours) were associated with decreased intake of protein (g) [74.4 ± 54.9], carbohydrates (g) [236 ± 157], sugars (g) [115 ± 105], dietary fiber (g) [13.2 ± 10.1], and fat (g) [79.4 ± 67.6], relative to normal sleep (7–8 hours) (reference group) ($P < 0.05$). Short sleep (5–6 hours) was associated with decreased dietary fiber (g) [15.9 ± 10.9]. Long sleep (9+ hours) was associated with decreased intake of protein (g) [72.8 ± 44.6], carbohydrates (g) [225 ± 120], sugars (g) [101± 69], dietary fiber (g) [14.2 ± 8.7], and fat (g) [74.7 ± 48.0] ($P < 0.05$). In analyses adjusted for variables related to overall diet (i.e., number of foods, energy intake, typical vs. usual intake, following special diet), the only association that remained was decreased protein [RR = 0.46 (95% C.I. 0.30–0.71)] and carbohydrates

[RR = 0.46 (95% C.I. 0.29–0.75)] in the very short (< 5 hours) sleep group ($P < 0.05$). Overall, the authors found several nutrient variables were associated with short and/or long sleep duration, which may be explained by differences in food variety. They suggest that future studies should assess whether these nutrients or other causes such as appetite dysregulation and/or sleep duration have physiologic effects on sleep regulation. This will allow a better understanding of the complex relationship between diet and sleep and the potential role of diet in the relationship between sleep and obesity and other cardiometabolic risks (Grandner et al., 2013).

2.6 Rationale

Chronic diseases associated with dietary intake rank among the leading causes of morbidity and mortality in the U.S. (Hiza, Casavale, Guenther, & Davis, 2013). In addition to diabetes, poor diet is thought to increase risk for cardiovascular disease, hypertension, osteoporosis, and some types of cancer (Hiza et al., 2013). While there is growing evidence that poor diet quality increases T2DM risk, there is still a controversy on whether HEI-2010 or AHEI-2010 score is more strongly associated with T2DM. Moreover, there are no studies to-date that have used both the HEI-2010 and AHEI-2010 scores as measures of dietary quality and examine their associations with T2DM in a representative sample of U.S. adults. In addition, there is limited information on the degree to which health markers (including biomarkers) could potentially modify the associations between HEI-2010 and AHEI-2010 and T2DM.

Over the last 20 years, awareness of the relationship between diet and health has increased in the U.S. (Gregory, Smith, & Wendt, 2011). The development of national dietary recommendations has been aimed at chronic disease prevention, but major discrepancies continue to exist between recommended and actual dietary behavior (Variyam et al., 2001). There are no studies to date that have looked at whether or not there is a discrepancy between perceived and measured diet quality in U.S. adults with and without T2DM.

Lastly, although landmark studies have shown that healthy lifestyle changes play a major role in preventing or delaying the onset of T2DM, there are no studies to-date, of the contribution of lifestyle behaviors (i.e., physical activity, smoking status, alcohol consumption, sleep duration, on a special diet, supplement use) to diet quality in people with and without T2DM.

This research included objective measures (i.e., anthropometrics and biomarkers of health) that may modify the association between diet quality and T2DM in a representative sample of U.S. adults. Also, this research was the first to evaluate the relationship between PDQ and MDQ in adults with and without T2DM in order to determine areas of focused nutrition education in public health interventions targeting dietary habits. In addition, there has been little focus in examining the knowledge, attitude, and beliefs/perceptions in relation to dietary quality in national surveys. Therefore, this research was one of the few studies that examined the variables related to perception, knowledge, and attitude that are available in NHANES. Finally, this research was the first to consider the impact of several lifestyle behaviors (i.e., physical activity, sleep adequacy, on a special diet, supplement use) and their role in diet quality among U.S. adults, age 20 years and older, with and without T2DM using NHANES 2007-2010.

2.7 Research Questions

1) What are the relationships between dietary quality (using HEI-2010 and AHEI-2010 scores), health markers, and diabetes status (nondiabetes, prediabetes, T2DM) in U.S. adults?
    - Is there a significant association between dietary quality (using HEI-2010 and AHEI-2010 scores) and diabetes (T2DM) status after adjusting for health markers and sociodemographic and lifestyle characteristics?
    - Is the total AHEI-2010 score more strongly associated with diabetes (T2DM) status than the total HEI-2010 score?
2) What are the relationships between perceived dietary quality (PDQ) and measured dietary quality (MDQ) in U.S. adults with and without diabetes (T2DM)?
    - Is diabetes status (nondiabetes, prediabetes, T2DM) significantly associated with the discrepancy in perceived and measured dietary quality (using HEI-2010 and AHEI-2010 scores)?
    - Which measured index (HEI-2010 or AHEI-2010) is associated with a greater discrepancy in perceived and measured dietary quality?
    - What are the factors (including general nutrition knowledge, attitudes about diet/weight, and sociodemographic characteristics) that are associated with the discrepancy between PDQ and MDQ?
3) What are the relationships between a selection of lifestyle behaviors, dietary quality (using HEI-2010 and AHEI-2010 scores), and diabetes status in U.S. adults?

- Are these selected lifestyle behaviors (smoking status, self-reported alcohol consumption, physical activity, on a special diet, sleep duration, supplement use) independently, and in combination, significantly associated with dietary quality (using HEI-2010 and AHEI-2010 scores)?
- Does the association between selected lifestyle behaviors and dietary quality (using HEI-2010 and AHEI-2010 scores) differ by diabetes status (nondiabetes, prediabetes, T2DM)?

2.8 Objectives

1) To determine whether there were relationships between two measures of dietary quality, the HEI-2010 and AHEI-2010 and diabetes status (nondiabetes, prediabetes, T2DM).
2) To examine the relationships between the HEI-2010 and AHEI-2010 and health markers (including biomarkers).
3) To determine the strength of the relationships between the HEI-2010 and AHEI-2010 with diabetes status while controlling for health markers, lifestyle and demographic factors.
4) To determine whether there were relationships between diabetes status (nondiabetes, prediabetes, T2DM) and discrepancy of PDQ and MDQ (for each total HEI-2010 and AHEI-2010 scores)
5) To identify the factors (i.e., sociodemographic, lifestyle, perceived health, attitudes, and knowledge) associated with discrepancy of PDQ and MDQ in U.S. adults with and without T2DM

6) To determine the strength of the relationships between diabetes status and HEI-2010 and AHEI-2010 discrepancy scores while controlling for sociodemographics, perceived health status, and attitudinal factors
7) To determine whether the HEI-2010 or AHEI-2010 was associated with greater discrepancy in PDQ and MDQ.
8) To examine the independent association between selected individual lifestyle behaviors and dietary quality (using HEI-2010 and AHEI-2010 scores) and determine whether the associations are different by diabetes status groups (nondiabetes, prediabetes, T2DM).
9) To examine the association between combined Lifestyle Behaviors score and dietary quality (using HEI-2010 and AHEI-2010 scores) and determine whether the association differs by diabetes status groups (nondiabetes, prediabetes, T2DM).
10) To determine the strength of the relationships between selected individual lifestyle behaviors and Lifestyle Behaviors score with dietary quality (using HEI-2010 and AHEI-2010 scores) while controlling for demographic and health characteristics.

Chapter 3: Methods

3.1 Survey Description

The National Health and Nutrition Examination Survey (NHANES) is a program of the National Center for Health Statistics (NCHS), which is a part of the Centers for Disease Control and Prevention (CDC). Data collection for NHANES starts with health interviews in the household, followed by physical examinations held in a mobile examination center (MEC). The health interview is administered to survey participants by a trained survey technician. It includes a comprehensive questionnaire designed to gather data on demographic, socioeconomic, dietary behavior and health-related questions. The MEC is specifically designed and equipped to allow for physical examinations and the collection of blood samples; it ensures standardized conditions for data collection. The medical examination consists of a physical exam, dental exam, biochemical analysis (blood and urine laboratory tests), dietary assessment (i.e., 24-hour recall), and other diagnostic-testing procedures performed by qualified medical personnel (i.e., physicians, nurses or medical technicians) (MEC In-Person Dietary Interviewers Procedures Manual, 2008). All NHANES data collection, including the household interview and MEC, are automated and recorded online with automated data edit and consistency checks, and built-in quality control checks to reduce data entry errors ("NHANES - NHANES 2009-2010 - General Information about Examination Data," n.d.).

3.2 Sample Design

Participants for the NHANES surveys are selected using a complex, stratified multistage probability cluster sampling designed to ensure that the sample is representative of the civilian, non-institutionalized U.S. population. The sampling frame does not include persons living in nursing homes, members of the armed forces, institutionalized persons, or U.S. nationals living abroad ("NHANES - About the National Health and Nutrition Examination Survey," n.d.). Differences in sample size and design should be considered when making comparisons across different

NHANES cycles (National Center for Health Statistics (U.S.), 2013b). For example, the sample design of 2007-2010 NHANES is different than the sample designs of earlier continuous NHANES (1999-2006) cycles, especially with regard to oversampling of demographic subgroups of the population. The most significant change is that, starting in 2007, all Hispanic persons are targeted for oversampling rather than just Mexican Americans. Because of the difference in methodology, it is important for the analyst to be cautious when combining 2007-2010 with 1999-2006 NHANES cycles and when producing estimates for Hispanic subgroups. As a result of these design changes, NCHS strongly recommends that researchers not calculate estimates for all Hispanic persons for survey periods prior to 2007 or for non-Mexican American Hispanic subgroups in any survey cycle between 1999 and 2010 (National Center for Health Statistics (U.S.), 2013b). Otherwise, aberrant results in subgroup estimates (and estimates of sampling error) may be obtained as a result of the differences in oversampling between the two sample designs. However, this is not of concern in this study since no detailed analysis was conducted for the Hispanic or Mexican American populations. The sample weights in NHANES should provide representative estimates for all populations (including Hispanics). The research is intended to have policy implications for the broader U.S. population. Therefore, the results of this study focused on issues that are generalizable to the U.S. adult population rather than to a specific subgroup. Table 2 provides a summary of the change in the oversampling of subgroups during the 1999-2006 and 2007-2010 continuous NHANES (National Center for Health Statistics (U.S.), 2013a).

Table 2. Comparison of oversampled subgroups during 1999-2006 and 2007-2010 NHANES

1999 – 2006 NHANES	**2007-2010 NHANES**
Mexican-American persons	Hispanic persons
Black persons	Non-Hispanic black persons
White and Other persons at or below 130% of the federal poverty level (beginning in 2000)	Non-Hispanic white and Other persons at or below 130% of the federal poverty level
White and Other persons age 70 and over	Non-Hispanic white and Other persons age 80 and over
Adolescents age 12-19	

Source: National Center for Health Statistics (U.S.) (Ed.). (2013). *National health and nutrition examination survey: analytic guidelines, 1999-2010*. Hyattsville, Maryland: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics.

During the 2007-2010 NHANES survey period, oversampling was carried out for Hispanic persons, non-Hispanic black persons, and non-Hispanic white and other persons at or below 130% of the federal poverty level, and for non-Hispanic white and other persons age 80 and over. There was also a change in the NHANES sample design; a key change between 2007-2010 NHANES and 2011-2014 NHANES was that Asians (i.e., Far East, Southeast Asia, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam) were also oversampled in addition to the ongoing oversampling of Hispanics, non-Hispanic blacks, older adults, and low income white and other persons. Because Asians were included as an additional oversampled subgroup, this lead to changes in sample size for the already categorized demographic subgroups. In the 2011-2012 NHANES, the increase in the Asian sample size resulted in a decrease in the percent examined for non-Hispanic whites, Mexican Americans, and Other ethnic groups (given that the total sample size in any year is fixed due to operational constraints) (National Center for Health Statistics (U.S.), 2013). Consequently, sample sizes for other demographic subgroups went down. Moreover, changes in sample design can cause the NHANES weights to be somewhat variable. Therefore, when combining subgroups for analysis over multiple cycles of NHANES (with different sampling designs), can lead to a wider range of weights and increased variance in the analytic results. This will mostly be the case when combining 2011-2012 data with earlier cycles because of the change in how Asians are sampled (National Center for Health Statistics (U.S.), 2013). In the 2011-2012 analytic guidelines, it is noted that the largest sample weights in the 2011-2012 survey cycle data are larger than the largest weights in previous years. Therefore, NCHS suggests that it would be better to not to combine 2011-2012 data with earlier cycles, but wait for it to combine it with 2013-2014 NHANES cycle when it becomes available (National Center for Health Statistics (U.S.), 2013).

Although data are released in 2-year cycles, the accumulation of at least 4 years of data is needed in order to increase the precision of survey estimates (smaller sampling error) (National Center for Health Statistics (U.S.), 2013b). Therefore, for the purpose of this study, NHANES data from 2007-2008 and 2009-2010 cycles were combined because these cycles have the same sample design and the variables of interest are only available in these two-cycles. Also, this increased sample size and analytic options. More importantly, combining cycles with the same sample design will ensure that the NHANES weights are consistent within each cycle to prevent increased variance in the analytic results.

3.3 Use of Sample Weights

The purpose of NHANES is to enable analyses representative of the civilian non-institutionalized U.S. population (National Center for Health Statistics (U.S.), 2013a). Since NHANES has a complex survey design, appropriate sample weights must be used in the analysis to obtain proper estimates and standard errors of estimates. NHANES assigns a sample weight to each sampled individual. The sample weights can be considered as measures of the number of persons the particular sample observations represent in the population. Weighting is used to adjust for unequal probabilities of selection (given that some groups were oversampled), non-response at various stages (i.e., in-home interview, MEC), and post-stratification, to match the 2000 U.S. Census population. When unequal selection probability is applied, sample weights are used to produce unbiased national estimates (National Center for Health Statistics (U.S.), 2013b). When sampling weights are used, estimates based on NHANES data are considered to be representative of the U.S. civilian non-institutionalized population (National Center for Health Statistics (U.S.), 2013a).

The CDC website provides multiple sets of weights in the data release files. Two major sets of survey weights are the household interview weight (WTINT2YR) and the MEC examination weight (WTMEC2YR). Additional sets of weights are included for the 24-hour dietary recalls sample (WTDRD1; WTDR2D), the fasting sample (WTSAF2YR), and the oral glucose tolerance test (OGTT) sample (WTSOG2YR) are computed. It is extremely important to use the correct sample weight for analysis; the selection of weights depends on the variables being used. NCHS recommends applying the weight of the smallest subpopulation in the analysis, also known as the "least common denominator" approach (National Center for Health Statistics (U.S.), 2013a). As a start, the variables of interest must be examined. Then the variable that was collected on the smallest number of persons is considered the least common denominator (LCD), and the sample weight that applies to that variable is the appropriate one to use for that particular analysis (National Center for Health Statistics (U.S.), 2013a). Afterwards, the selected sample weight must be modified based on the NCHS recommendation to take into account the combination of NHANES cycles being analyzed (National Center for Health Statistics (U.S.), 2013a). Since this research is interested to examine the dietary behaviors in adults with and without T2DM, either the OGTT subsample or the fasting subsample weights are appropriate to use because they are found to be the LCD in the dataset (as recommended by NCHS). However, the fasting subsample weight was applied throughout the analyses (instead of the OGTT subsample weight) because the OGTT subsample weight excluded individuals already diagnosed with diabetes and are taking insulin or oral medications. The purpose of this research was to include these individuals as part of the classification for T2DM. The 4-year fasting subsample weight was constructed by combining the 2-year weights for the 2007-2008 and 2009-2010 cycles using the formula: WTSAF4YR = 1/2 * WTSAF2YR (available online: https://www.cdc.gov/nchs/tutorials/nhanes/SurveyDesign/Weighting/intro.htm).

3.4 Study Sample

For this research, the study sample included all men and women who are 20 years and over, who participated in both the health interview and MEC, who self-reported as non-pregnant at the examination, who have complete and reliable 24-hour diet recall data, and a BMI ≥ 18.5 kg/m^2.

The 2007-2010 NHANES has a total sample size N = 20,686 participants. For the present study, the exclusion criteria were individuals age less than 20 years old (n = 8,533), participated in the health interview only (n = 387), self-reported being pregnant at the examination (n = 195), did not have reliable 24-hour diet recall (n = 2,011), and have BMI < 18.5 kg/m^2 (n = 244). From these exclusions, the sample size was reduced to n = 9316 participants. However, since the fasting subsample weight was applied throughout the analysis, the sample size was further reduced to n = 4550 participants. Also, participants who had fasting subsample weight with a value of zero were excluded from the analysis (n = 453). The final analytic cohort included n = 4097 participants. Figure 1 provides a summary of the study sample with the inclusion and exclusion criteria of participants in 2007-2010 NHANES cycles.

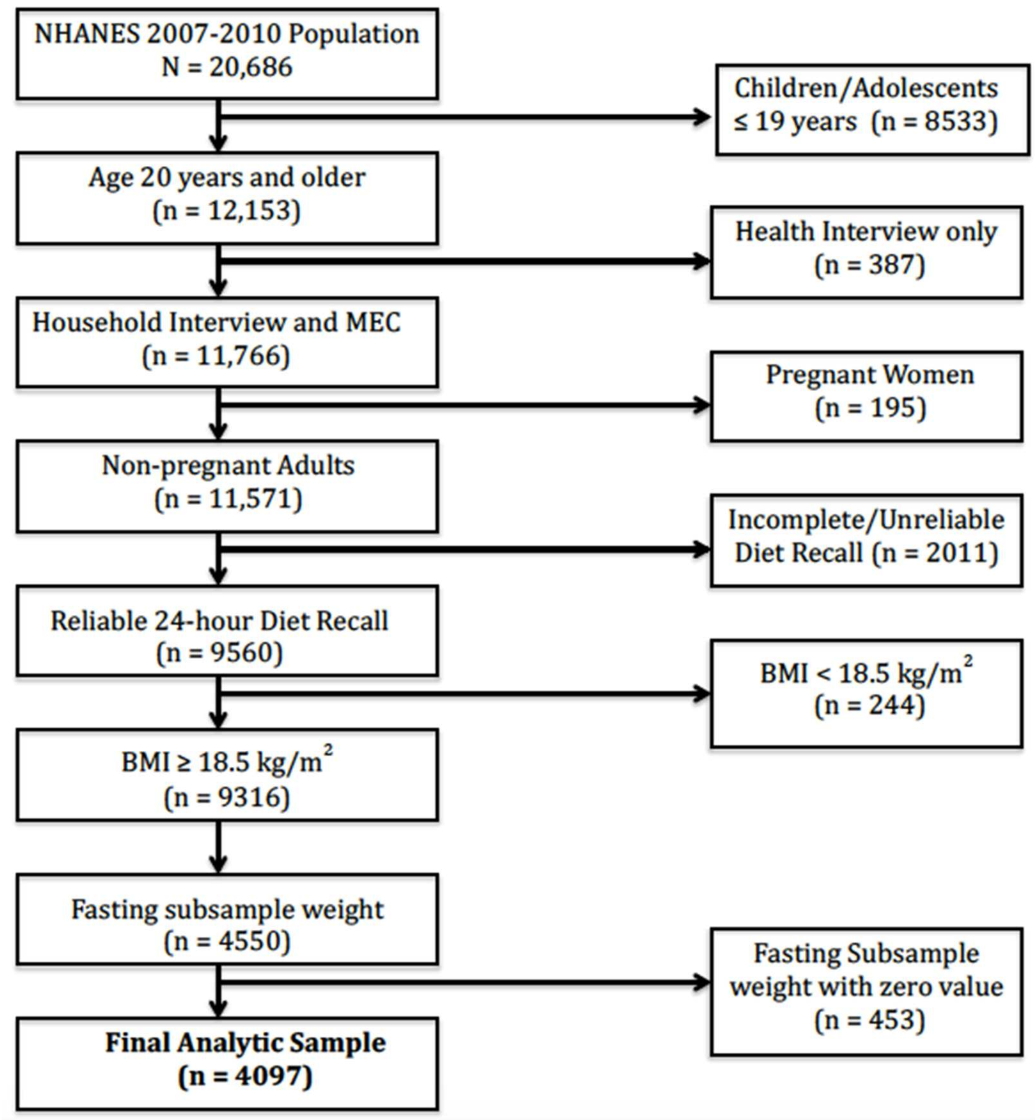

Figure 1. Study Sample using NHANES 2007-2010

3.5 Variables of Interest

The variables of interest were extracted from the Demographic, Dietary, Laboratory, and Questionnaire data files available on the CDC website. For the purpose of this study, datasets from the 2007–2008 and 2009–2010 NHANES cycles were combined because these are the only two-year cycles that contain the Flexible Consumer Behavior Survey (FCBS) module. The module was first released in 2007 and was developed in collaboration with the Economic Research Service (ERS) of the USDA. It is designed to collect information on people's perceptions, attitudes, knowledge and beliefs about nutrition and food choices. Other variables such as general health markers and lifestyle behaviors were also extracted to determine their associations with dietary quality and diabetes status.

3.5.1 Primary Outcome and Predictor Variables

3.5.1.1 Definition of Type 2 Diabetes status (T2DM)

Type 2 diabetes (T2DM) status was defined using the data files from the Diabetes and Prescription Questionnaires and some biomarkers from the Laboratory data. The cut-offs for the laboratory biomarkers was based on the 2017 Standards of Medical Care from the American Diabetes Association (ADA) for diabetes diagnosis (American Diabetes Association (ADA), 2017). Diabetes (T2DM) status was constructed using an approach similar to what is used in other data briefs and publications using NHANES data (Centers for Disease Control and Prevention, 2014a; Kramer et al., 2010; Menke, Casagrande, Geiss, & Cowie, 2015; Steeves et al., 2015). T2DM status was defined based on two conditions: diagnosed and undiagnosed diabetes. Diagnosed diabetics were defined as those who answered "yes" to the question: "Other than during pregnancy, have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?" and those who reported taking diabetes medication (i.e., Metformin) during the interview. Undiagnosed diabetics were defined as fasting plasma glucose $\geq$ 126 mg/dL, or HbA1c $\geq$ 6.5% among participants who did not report a previous diabetes diagnosis during the interview. In addition, total number of adults with T2DM (total diabetes) was calculated as the sum of individuals with diagnosed and undiagnosed diabetes. Since NHANES did not collect information on type of diabetes, individuals diagnosed with diabetes prior to age 30 and continuous users of insulin were excluded to minimize the number of respondents with type 1 diabetes (T1DM) (Jarvandi et al., 2012). Prediabetics were defined as fasting plasma glucose of 100 – 125 mg/dL, HbA1c 5.7 – 6.4 %, or an answer of "yes" to the question "Have you ever been told by a doctor or other health professional that you have prediabetes?" or an answer of "borderline" to the question "Other than during pregnancy, have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?" Participants who did not meet the definition for T2DM and prediabetes were categorized as non-diabetic since they have normal values that correspond to fasting plasma glucose < 100 mg/dL and HbA1c < 5.7% (William T. Cefalu, MD et al., 2017).

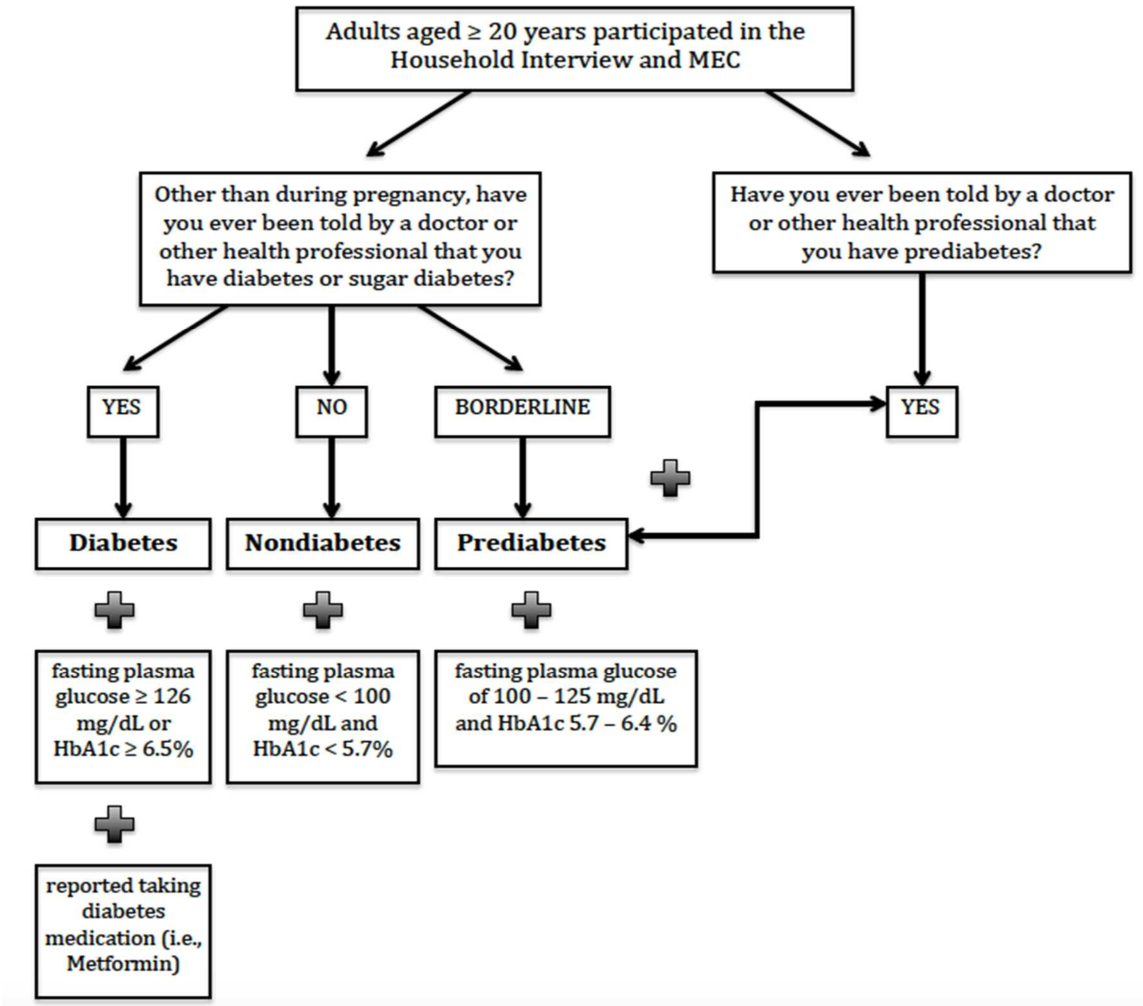

Figure 2. Classification of Diabetes Status using NHANES 2007-2010

3.5.1.2 Scoring of Diet Quality Indices

Based on the evidence provided in the literature, this research study used the Healthy Eating Index-2010 (HEI-2010) and the Alternate Eating Index-2010 (AHEI-2010) to measure dietary quality in U.S. adults with and without T2DM. The HEI-2010 and AHEI-2010 scores were calculated using the methodology outlined in Wang et al (2014) since this was the only study to-date that computed the diet quality scores for both the HEI-2010 and AHEI-2010 using NHANES data (Wang et al., 2014).

In NHANES, study participants were administered two 24-hour recalls in the 2007–2008 and 2009–2010 cycles. The first day of the dietary recall was administered in-person at the mobile examination center (MEC) and conducted by trained interviewers using USDA's Automated Multiple-Pass Method (AMPM). The second day of dietary recall was administered via telephone interview, approximately three to 10 days after the MEC exam ("NHANES Dietary Web Tutorial - Dietary Data Overview," n.d.). Although two 24-hour recalls were collected in 2007-2010, only data from the first in-person dietary recall were used to calculate the HEI-2010 and AHEI-2010 scores in order to ensure consistency in dietary methodology. Moreover, results based on a single 24-hour dietary recall are sufficient to estimate population means, which is the intent of our proposed research. This is because the effects of random errors associated with dietary recall (i.e., day–to-day variability) are assumed to cancel out if days of the week are evenly represented (Ahluwalia, Dwyer, Terry, Moshfegh, & Johnson, 2016). After the effects of random errors are averaged out, a single 24-hour recall can produce reasonable estimates of mean usual dietary intake of population subgroups or for examining trends over time (Ahluwalia, Dwyer, Terry, Moshfegh, & Johnson, 2016). The mean of 1-day intakes from the weighted study population has been shown to be a reasonably accurate estimate of the mean of the usual intake distribution of the population (Willett, 2012; Ahluwalia, Dwyer, Terry, Moshfegh, & Johnson, 2016; Krebs-Smith, Guenther, Subar, Kirkpatrick, & Dodd, 2010). In addition, using the first-day 24-hour dietary recall is consistent with the most recent literature on diet quality scores (i.e., HEI-2010) that uses NHANES (Powell-Wiley et al., 2014; Nicklas et al., 2014; Agarwal, Fulgoni, & Berg, 2015).

Healthy Eating Index (HEI-2010) Scores

For calculation of the Healthy Eating Index, the SAS code established by the USDA CNPP was used to compute the HEI-2010 scores. The Food Pattern Equivalents Database (FPED), which is found on the USDA website (available online: http://www.ars.usda.gov/Services/docs.htm?docid=23869), along with the total nutrients file from NHANES were used to compute the HEI-2010 scores. The FPED converts foods and beverages in the Food and Nutrient Database for Dietary Studies (FNDDS) to 37 USDA Food Patterns (FP) components reported by each respondent on the 24-hour dietary recall (day 1) in NHANES. It is used to transform individual food and nutrient intakes into cup, ounce, grams, or teaspoon equivalents of food and beverage intakes compared with the Dietary Guidelines for Americans 2010, which helps calculate the HEI scores of different food groups (Ahluwalia, Dwyer, Terry, Moshfegh, & Johnson, 2016).

Alternate Healthy Eating Index (AHEI-2010) Scores

The AHEI was originally designed for use with Food Frequency Questionnaire (FFQ) data. However, previous studies have used 24-hour dietary recall data from NHANES to compute the AHEI-2010 scores (Wang et al., 2014; Cindy W. Leung, Epel, Ritchie, Crawford, & Laraia, 2014; C. W. Leung et al., 2012). In general, the continuous NHANES surveys (since 1999) only collect 24-hour recalls to assess dietary intake. Some of the earlier NHANES cycles included an expanded FFQ but it was not used for the specific NHANES cycles used for this study (2007-2008; 2009-2010).

Comparison between HEI-2010 and AHEI-2010 scores

As shown in table 1, there are similarities and differences between the AHEI-2010 and the HEI-2010. Both indices contain whole fruit, total vegetables (excluding potatoes for the AHEI), whole grains, and sodium as components for scoring. However, the scoring units for each index are different; HEI-2010 scores use ounces, cups, or gram equivalents per 1000 calories (density-based approach), while some of the units for the AHEI-2010 score use number of servings per day. To calculate AHEI component scores, food intake in grams or ounces was converted into serving equivalents (C. W. Leung et al., 2012). Another difference is that the maximum score for the total AHEI-2010 is 110 while the maximum score for the total HEI-2010 score is 100 (see **Table 1**). This study used a modified AHEI-2010 score with a maximum of 100 points by excluding the trans fat component because trans fat is unavailable in the NHANES dietary files (C. W. Leung et al., 2012). This approach is similar to the approach used by Leung et al (2012) (C. W. Leung et al., 2012).

Public Policy and Trans Fat Intake

Public policy change has played a central role in the large reduction in trans fat intake (Wang et al., 2014). Increasing awareness of the dangers of trans fat consumption over the last 20 years (Brownell & Pomeranz, 2014) prompted the U.S. Food and Drug Administration to issue a rule in 2003 requiring that processed foods report trans fat content on the food label (available online: http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInfomation/LabelingNutrition/ucm053479.htm). The rule has led to food companies reformulating foods to reduce trans fat content in response to labeling requirements (Doell et al., 2012; Brownell & Pomeranz, 2014; Wang et al., 2014). Since the initial rule was published, the public has become more aware of the risks of trans fat consumption, and the FDA has proposed a new rule that would require the complete removal of trans fat from the food supply. The FDA gave the food industry and manufacturers three years (until year 2018) to remove artificial trans fat from the food supply (available online: https://www.washingtonpost.com/national/health-science/fda-moves-to-ban-trans-fat-from-us-food-supply/2015/06/16/f8fc8f18-1084-11e5-9726-49d6fa26a8c6_story.html). Some state and local governments have also taken action to reduce the use of trans fat in restaurants and other food outlets. For example, New York City passed a law in 2006 banning the use of artificial trans fat in restaurant foods, and the state of California did the same in 2008 (Brownell & Pomeranz, 2014). Therefore, trans fat intake is likely to have decreased over the last 10 years, regardless of individual consumption decisions, because of the apparent success of public policy efforts to reduce the amount of trans fat available in the food supply. This research focuses primarily on individual food consumption decisions and behavior. It seems likely that trans fat intake will continue to be reduced over time even without efforts to modify individual behavior.

Datasets to Construct the AHEI-2010 Food Groups

AHEI-2010 scores were computed using a methodology similar to that used by Wang et al (2014) and Leung et al (2012) (C. W. Leung et al., 2012; Wang et al., 2014). Data from the USDA Food and Nutrient Database for Dietary Studies (FNDDS) was used to identify foods and food groups from the NHANES individual foods file. The FNDDS is a food composition database that assigns codes to all foods and beverages reported by participants during their 24-hour dietary recall interviews, and it is updated for each NHANES cycle (Ahluwalia, Dwyer, Terry, Moshfegh, & Johnson, 2016). The FNDDS was used to process the NHANES dietary recall data that are included in the dietary data files. The individual foods file, which is a component of the NHANES dietary data files, provides detailed information about the types and amounts of individual foods reported by each participant, as well as amounts of nutrients from each food (available online: http://wwwn.cdc.gov/Nchs/Nhanes/2007-2008/DR1IFF_E.htm for 2007-2008 cycle and http://wwwn.cdc.gov/Nchs/Nhanes/2009-2010/DR1IFF_F.htm for 2009-2010 cycle). In addition, the Individual Foods file for each cycle contains two supporting files: Food Code Description file (DRXFCD_E; DRXFCD_F) and Modification Code Description file (DRXMCD_E; DRXMCD_F). The Food Description file includes complete descriptions (up to 200 characters) for each USDA food code identified in the Individual Foods file. The Modification Code Description file includes descriptions for each modification code identified in the Individual Foods files. For this research, the Individual Foods file and the Food Description file (for the 2007-2008 and 2009-2010 cycles) were used to prepare the dataset to construct and classify the AHEI-2010 food groups.

Classification of the AHEI-2010 Food Groups

The Individual/Foods/Food Description file of NHANES contains the foods and beverages (represented by food codes) consumed by the participants. Using that file, each food and beverage item was identified by going through the food codes and was assigned to a new AHEI-based food group. This research used two references to identify the individual foods and beverages and classified them into AHEI food groups: 1) the supplementary table provided by Wang et al (2014) and Leung et al (2012) (C. W. Leung et al., 2012; Wang et al., 2014) (see **Appendix 1**); and 2) the USDA food-coding scheme (Ahuja et al., 2012). The supplementary table was used to identify foods and beverages that correspond to each AHEI food group. It contains the inclusion and exclusion of foods and beverages for each AHEI category. In addition, the supplementary table contains the serving size (in grams) for each AHEI category (see **Appendix 1**). The USDA food-coding scheme provides an outline of the food codes (representing food and beverage items) used in NHANES (Ahuja et al., 2012). It was used as a reference to categorize individual foods and beverages into AHEI food groups (Ahuja et al., 2012). After creating the AHEI food groups, a SAS program was written to calculate the AHEI-2010 scores.

The AHEI-2010 is made up of several major food groups: 1) total vegetables, 2) whole fruit, 3) whole grains, 4) sugar-sweetened beverages and fruit juice, 5) nuts and legumes, 6) red and/or processed meat, and 7) alcohol. Each AHEI food group contains foods and beverages corresponding to USDA food groups (see **Appendix 1**). Each USDA food group is made up of food codes indicating specific food or beverage items (see **Appendix 2**). Each food or beverage item is represented with an 8-digit food code. The first digit of each USDA food code represents one of nine major commodity groups. In addition, the first digit always indicates the major food group to which the item belongs. Table 3 shows the major USDA food groups and their first digit numerical codes.

Table 3. USDA Food Code First Digits and Major Commodity Groups

Identifier	Description
1	Milk and milk products
2	Meat, poultry, fish, and mixtures
3	Eggs
4	Legumes, nuts, and seeds
5	Grain products
6	Fruits
7	Vegetables
8	Fats, oils, and salad dressings
9	Sugars, sweets, and beverages

Source: NHANES dietary tutorial.
Available online: https://www.cdc.gov/nchs/tutorials/Dietary/SurveyOrientation/ResourceDietaryAnalysis/Info2.htm

Subsequent digits (second, third, and sometimes fourth) of a food code identify increasingly specific subgroups within the nine major groups. The remaining digits identify specific foods (or beverages) in a numerical sequence. The 8-digit food code was used to identify and combine USDA food codes representing similar foods into AHEI food groups. Tables 4-9 show the classification for each AHEI food group using USDA food codes (also see **Appendix 1-2**).

TOTAL VEGETABLES

Vegetables have a first digit code of 7 and are divided into subcategories with USDA food codes. Each of the subcategories was assigned either a full- or half-weight to calculate AHEI total vegetables. Of these subcategories, dark-green vegetables, deep-yellow vegetables, tomatoes (raw and cooked), and other vegetables (raw and cooked) were assigned as a full-weight; tomato mixtures, tomato sandwiches, vegetables with sauces, vegetable soups, and baby foods were assigned as half-weight. Excluded foods were potatoes and starchy vegetables, tomato juices, tomato sauces, olives, pickles, and relishes (see **Appendix 2**). The subcategories for total vegetables using USDA food code are shown in **Table 4**.

Table 4. AHEI classification for Total Vegetables using USDA food code

Food Code	Food Group	AHEI weight	Exclusion
71	White potatoes and Puerto Rican starchy vegetables		Excluded from AHEI
72	Dark-green vegetables	Full weight Half weight	
73	Deep-yellow vegetables	Full weight Half weight	
74	Tomatoes and tomato mixtures	Half weight	Tomato juices Tomato sauces
75	Other vegetables	Full weight	Yeast and yeast extract spread from vegetables Olives, pickles, relishes
76	Vegetables and mixtures mostly vegetables baby food	Half weight	
77	Vegetables with meat, poultry, fish	Half weight	

As outlined in **Table 4**, specific food items related to vegetables (first digit code '7') were identified using 8-digit food codes. For example, a USDA food code of 72302000 indicates 'dark-green vegetables' from the two digits code ('72') (see **Table 4**). The three digit code ('723') further indicates 'dark-green vegetable soups' as a subcategory specified in the USDA food-coding scheme (see **Appendix 2**). The remaining digits ('02000') indicate a specific food item, in this case, 'broccoli soup.' For purposes of the AHEI classification for total vegetables, dark-green vegetable soups were assigned a half-weight for scoring purposes.

WHOLE FRUIT

Fruits have a first digit code of 6 and are divided into subcategories with USDA food codes. Each of the subcategories was assigned either a full- or half-weight to calculate total AHEI whole fruit. Of these subcategories, citrus fruits, dried fruits, other fruits, berries, and fruit mixtures were assigned as a full-weight; mixtures with non-fruits and baby food mixtures were assigned as half-weight. Excluded foods are juices, fruit desserts and fruit-flavored puddings (see **Appendix 2**). Furthermore, since the purpose of this research was to examine the association between dietary behavior and disease outcome (i.e., people with and without T2DM), a more stringent rule was applied to classify fruit. For example, any individual foods described as "added sugar," "heavy syrup," or "light syrup" were re-classified as fruit desserts. Therefore, no weights were applied to these individual foods. However, individual foods described as "non-specified as sweetened, unsweetened" or "waterpack" were assigned a full-weight. The subcategories for fruit using USDA food code are shown in **Table 5**.

Table 5. AHEI classification for Whole Fruit using USDA food code

Food Code	Food Group	AHEI weight	Exclusion
61	Citrus fruits, juices	Full weight	Fruit desserts
62	Dried fruits	Full weight	Fruit desserts
63	Other fruits	Full weight Half weight	Other fruit desserts
67	Fruits and juices baby food	Half weight	Fruit desserts and fruit-flavored puddings and yogurt

			desserts baby food

As outlined in **Table 5**, specific food items related to fruits (first digit code '6') were identified using 8-digit food codes. For example, a USDA food code of 63107010 indicates 'other fruit' from the two digits code ('63') (see **Table 5**). The remaining digits ('107010') indicate a specific food item, in this case, 'raw banana.' For purposes of the AHEI classification for whole fruit, other fruits were assigned a full-weight for scoring purposes.

WHOLE GRAINS

Grain products have a first digit code of 5 and are divided into subcategories with USDA food codes. Each of the subcategories was assigned either a full- or half-weight to calculate into AHEI whole grains. Of these subcategories, brown rice, popcorn, individual foods described as "whole wheat," "bran," "oatmeal," or "rye," and any grain food with a carbohydrate to fiber ratio ≤ 10:1 were assigned as a full-weight. The 10-to-1 rule for "total carbohydrates" to "fiber" ratio was applied through the search for the nutrient contents of each individual food to determine whether or not a food subgroup would be classified as a whole grain. The USDA's super tracker (Food-A-Pedia) website was used to look up nutrition information for specific foods (available online: https://www.supertracker.usda.gov/foodapedia.aspx). Excluded foods are meat substitutes, mainly cereal protein. The subcategories for whole grains using USDA food code are shown in **Table 6**.

Table 6. AHEI classification for Whole Grains using USDA food code

Food Code	Food Group	AHEI weight	Exclusion
50	Flour and dry mixes	Full weight	Not specified as "whole wheat"
51	Yeast breads, rolls	Full weight	
52	Quick breads	Full weight only for food items containing carbohydrate-to-fiber ratio ≤ 10:1	
54	Crackers and salty snacks from grain products	Full weight	Not specified as "whole wheat"
55	Pancakes, waffles, French toast, other grain products	Full weight only for food items containing carbohydrate-to-fiber ratio ≤ 10:1	Not specified as "whole wheat"
56	Pastas, cooked cereals, rice	Full weight only for food items containing carbohydrate-to-fiber ratio ≤ 10:1	Not specified as "whole wheat," "oatmeal," "brown rice," or "bulgur"
57	Cereals, not cooked or NS as to cooked	Full weight only for food items containing carbohydrate-to-fiber ratio ≤ 10:1	
58	Grain mixtures, frozen plate meals, soups	Full weight only for food items containing carbohydrate-to-fiber ratio ≤ 10:1	Not specified as "whole wheat," or "brown rice"
59	Meat substitutes, mainly cereal protein		Excluded from AHEI

As outlined in **Table 6**, specific food items related to 'grain products' (first digit code '5') were identified using 8-digit food codes. For example, a USDA food code of

51201010 indicates 'yeast bread, rolls' from the two digits code ('51') (see **Table 6**). The three digits code ('512') further indicate 'Whole wheat breads, rolls' as a subcategory specified in the USDA food-coding scheme (see **Appendix 2**). The remaining digits ('01010') indicate a specific food item, in this case, '100% whole wheat bread.' For purposes of the AHEI classification for whole grains, whole wheat bread rolls were assigned a full-weight for scoring purposes.

SUGAR-SWEETENED BEVERAGES AND FRUIT JUICE

Sugar-sweetened beverages and fruit juice are divided into two subgroups: sugar-sweetened beverages (SSBs) and 100% fruit juice (see **Appendix 1**). Sugar-sweetened beverages and fruit juice have first digit codes of 6 and 9 and are divided into subcategories. Each of the subcategories was assigned either a full- or half-weight to calculate AHEI sugar-sweetened beverages and fruit juice. Of these subcategories, citrus fruit juices, fruit juices and nectar, vegetable and fruit juice blend (specified as 100% juice), and nonalcoholic beverages described as "presweetened," "sweetened," "with sugar," or "flavored," were assigned as a full-weight; fruit juices baby food, and nonalcoholic beverages described as "reduced sugar sodas," "low sugar," or "sugar free" were assigned a half-weight. The subcategories for sugar-sweetened beverages and fruit juice using USDA food code are shown in **Table 7**.

Table 7. AHEI classification for Sugar-sweetened beverages and fruit juice using USDA food code

Food Code	Food Group	AHEI weight	Exclusion

61	Citrus fruits, juices	Full weight	
64	Fruit juices and nectar	Full weight	
67	Fruit and juices baby food	Half weight	
*78	Mixtures mostly vegetables without meat, poultry, fish	Full weight only for USDA food code 78101000 as part of 100% fruit juice	Excluded from AHEI
92	Nonalcoholic beverages	Full weight Half weight	Not specified as "sweetened," or "presweetened," or "presweetened with sugar" or "reduced sugar sodas," or "low sugar," or "sugar free"
94	Water, noncarbonated	Full weight only for items specified as "sweetened" or "flavored" water	Excluded from AHEI

**Note*: The individual food code 78101000 corresponds to vegetable and fruit juice blend, 100% juice, with high vitamin C plus added vitamin E and vitamin A.

As outlined in **Table 7**, specific food items related to 'sugars, sweets, and beverages' (first digit code '6' and '9') were identified using 8-digit food codes. For example, a USDA food code of 92410315 indicates 'nonalcoholic beverages' from the two digits code ('92') (see **Table 7**). The three digits code ('924') further indicate 'Soft drinks, carbonated' as a subcategory specified in the USDA food-coding scheme (see **Appendix 2**). The remaining digits ('10315') indicate a specific beverage, in this case, 'soft drink, cola type, reduced sugar.' For purposes of the AHEI classification for sugar sweetened beverages and fruit juice, nonalcoholic beverages were assigned a half-weight for scoring purposes.

NUTS AND LEGUMES

Nuts and legumes are divided into several subgroups: nuts/legumes/seeds, nut butters, tofu, and soy milk (see **Appendix 1**). Nuts and legumes have a first digit code of 4 and are divided into subcategories with USDA food codes. Each of the subcategories was assigned either a full- or half-weight to calculate total AHEI nuts and legumes. Of these subcategories, seeds and seed mixtures (food code '43') were assigned as a full-weight; legumes (food code '41') and nuts/ butters/mixtures (food code '42') were generally assigned as a full-weight but specific food items within each category were assigned a half-weight (see **Appendix 1 and 2**). For legumes category, frozen plate meals with legumes (food code '415') and soups with legumes (food code '416) were assigned a half-weight. For nuts/butters/mixtures category, nut butter sandwiches (food code '423') were assigned a half-weight (see **Appendix 2**). Excluded foods are meat substitutes, coconut beverages, and carob products. The subcategories for nuts and legumes using USDA food code are shown in **Table 8**.

Table 8. AHEI classification for Nuts and Legumes using USDA food code

Food Code	Food Group	AHEI weight	Exclusion
41	Legumes	Full weight [food code: 411, 412, 413] Half weight [food code: 415 and 416]	Soybean derived products Meat substitutes, mainly legume protein Meat substitute sandwiches
42	Nuts, nut butters, and nut mixtures	Full weight [food code: 421 and 422] Half weight [food	Coconut beverages

		code: 423)	
43	Seeds and seed mixtures	Full weight	
44	Carob products		Excluded from AHEI

As outlined in **Table 8**, specific food items related to 'legumes, nuts, and seeds' (first digit code '4') were identified using 8-digit food codes. For example, a USDA food code of 41101120 indicates 'legumes' from the two digits code ('41') (see **Table 8**). The three digits code ('411') further indicate 'dried beans' as a subcategory specified in the USDA food-coding scheme (see **Appendix 2**). The remaining digits indicate a specific food item, in this case, 'White beans, dry, cooked, fat not added in cooking.' For purposes of the AHEI classification for nuts and legumes, legumes were assigned a full-weight for scoring purposes.

RED AND/OR PROCESSED MEAT

Red and/or processed meat are divided into three subgroups: beef, pork, and processed meat. Red and/or processed meat have a first digit code of 2 and are divided into subcategories with USDA food codes. Each of the subcategories was assigned either a full- or half-weight to classify into AHEI red and/or processed meat. Of these subcategories, beef, pork, sausages, lunchmeats, and meat spreads were assigned as a full-weight; beef baby food, pork baby food, potted meat, meat with nonmeat items, and frozen and shelf-stable plate meals were assigned as half-weight. Excluded foods are organ meats, poultry and fish. The subcategories for red and/or processed meat using USDA food code are shown in **Table 9.**

Table 9. AHEI classification for Red and/or processed meat using USDA food code

Food Code	Food Group	AHEI weight	Exclusion
21	Beef	Full weight Half weight for baby food	
22	Pork	Full weight Half weight for baby food	
25	Organ meats, sausages, and lunchmeats, and meat spreads	Full weight Half weight for potted meat	Organ meats Chicken and turkey frankfurters
27	Meat, poultry, fish with nonmeat items	Half weight	Poultry and fish
28	Frozen and shelf-stable plate meals, soups, and gravies with meat, poultry, fish base; gelatin and gelatin-based drinks	Half weight	Poultry and fish

As outlined in **Table 9**, specific food items related to 'meat, poultry, fish, and mixtures' (first digit code '2') were identified using 8-digit food codes. For example, a USDA food code of 21101000 indicates 'beef' from the two digits code ('21') (see **Table 9**). The three digits code ('211') further indicate 'beef steak' a subcategory specified in the USDA food-coding scheme (see **Appendix 2**). The remaining digits ('01000') indicate a specific food, in this case, 'Beef steak, not specified as to cooking method, not specified as to fat eaten.' For purposes of the AHEI classification for red and/or processed meat, beef was assigned a full-weight for scoring purposes.

ALCOHOL

Alcoholic beverages have a first digit code of 9 and are divided into subcategories with USDA food codes. Each of the subcategories was assigned either a full- or half-weight to calculate consumption of AHEI alcohol. Of these subcategories, beer and ales, wine, distilled liquors, and Cordials and liqueurs were assigned a full-weight; cocktails were assigned a half-weight. The subcategories for alcohol using USDA food code are shown in **Table 10.**

Table 10. AHEI classification for Alcohol using USDA food code

Food Code	Food Group	AHEI weight
931	Beers and ales	Full weight
932	Cordials and liqueurs	Full weight
933	Cocktails	Half weight
934	Wines	Full weight
935	Distilled liquors	Full weight

As outlined in **Table 10**, specific food items related to 'sugars, sweets, and beverages' (first digit code '9') were identified using 8-digit food codes. For example, a USDA food code of 93301110 indicates 'cocktails' from the three digits code ('933'). The remaining digits ('01110') indicate a specific beverage, in this case, 'Martini.' For purposes of the AHEI classification for alcohol, cocktails were assigned a half-weight for scoring purposes. This means that the AHEI counts the intake of cocktails as half a serving of alcohol (since cocktails are also made up of a mixture of other ingredients).

3.5.2 Secondary Outcome and Predictor Variables

3.5.2.1 Health Markers

Examination and Laboratory procedures are conducted at the MEC. In NHANES, these markers are obtained through following standardized protocols reported in the Examination and Laboratory Procedures Manual (Laboratory Procedures Manual, 2009). This research analyzed the lipid profile, blood pressure, and C-reactive protein as a marker of inflammation. These biomarkers were examined as predictor variables in the regression models.

Lipid Profile

In NHANES, lipid profile is the main element of the CVD laboratory component. The data is used to monitor the status of hyperlipidemia and the success of the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATPIII). For that reason, it is important to examine the lipid profile due its association with heart disease and stroke, which are leading causes of death in people with T2DM (Imperatore, 2004). Lipid profile such as total cholesterol (TC), HDL cholesterol (HDL-C), LDL cholesterol (LDL-C), and triglycerides (TG) were included in the analysis. Since 2007, there were changes in the instruments used to measure lipid profile. Serum TC, HDL-C, and TG were measured using Roche Modular P chemistry analyzer. This instrument used enzymatic method to determine these markers. The concentration of TC was determined through the conversion of esterified cholesterol to cholesterol by the enzyme cholesterol esterase. Subsequently, the resulting cholesterol is acted upon by cholesterol oxidase to produce cholest-4-en-3-one and hydrogen peroxide (Laboratory Procedures Manual, 2009). The NCEP-

ATPIII recommends desirable TC to be less than 200 mg/dL [5.2 mmol/L] (Pasternak, 2002). The HDL-C concentration is also determined enzymatically by cholesterol esterase and cholesterol oxidase (Laboratory Procedures Manual, 2009). The NCEP-ATPIII recommends raising low HDL-C from less than 35 mg/dL to less than 40 mg/dL [<1.03 mmol/L] for men and less than 50 mg/dL for women [<1.30 mmol/L] (Pasternak, 2002). Similarly, TG concentration was determined through conversion of free glycerol to glycerol-3-phosphate (G3P) by the enzyme glycerol kinase. The enzyme glycerol phosphate oxidase helps to express G3P to produce dihydroxyacetone phosphate and hydrogen peroxide (Laboratory Procedures Manual, 2009). According to the NCEP-ATPIII, the normal level of TG should be less than 150 mg/dl [< 1.7 mmol/L] (Pasternak, 2002). LDL-C was calculated from measured values of TC, HDL-C, and TG based on the Friedewald formula: [LDL-cholesterol] = [total cholesterol] – [HDL-cholesterol] – [triglycerides/5] where all values are expressed in mg/dL. The calculation is valid for TG less than or equal to 400 mg/dL (Laboratory Procedures Manual, 2009).

Blood Pressure

Hypertension and T2DM frequently occur together; they are two of the leading risk factors for heart disease and strokes (Cheung & Li, 2012). For hypertension screening, participants had to do blood pressure testing at the MEC. Protocols of NHANES requires participants to rest quietly and be in a sitting position for five-minutes (Health Tech/Blood Pressure Manual, 2009). After that, the blood pressure readings were obtained using a standard mercury sphygmomanometer. The majority of participants had at least three consecutive readings for each systolic and diastolic blood pressure. A fourth reading was taken in case the previous blood pressure measurement is interrupted or incomplete. For that reason, this study only used the first three readings to calculate the average blood pressure (systolic and diastolic). The fourth reading is not included because of many missing values.

C-Reactive Protein

C-reactive protein (CRP) is considered one of the best measures of the acute-phase response to an infectious disease or other cause of tissue damage and inflammation ("NHANES 2007-2008," n.d.; "NHANES 2009-2010," n.d.). CRP can also be used as a marker of the body's response to inflammation from chronic conditions (i.e., arthritis) and environmental exposure agents (i.e., tobacco smoke) ("NHANES 2007-2008," n.d.; "NHANES 2009-2010," n.d.). In NHANES, the Nephelometry method was used to measure CRP and was quantified by latex-enhanced nephelometry. CRP concentrations were calculated by using a calibration curve. A Behring Nephelometer was used to perform these assays for quantitative CRP determination. The Center for Disease Control/ American Heart Association (CDC/AHA) recommends CRP level less than 0.1 mg/dL to be classified as "low risk". CRP is considered elevated as level of more than 0.3 mg/dL indicates "high risk" of developing CVD in adults (Pearson, 2003).

3.5.2.2 Perceived and Measured Diet Quality

Variables related to perception were extracted from the Diet Behavior & Nutrition and the Flexible Consumer Behavior Survey follow-up for adults. This module was only collected in NHANES during the 2007-2010 cycles. It provides personal interview data for participants on various dietary related consumer behavior topics. Self-perception of dietary quality was assessed based on responses to the Question "In general, how healthy is your overall diet?" Possible responses to the question were based on a 5-point Likert scale: Excellent, Very Good, Good, Fair, and Poor. Similar to the approach used by Powell et al. (2014), this variable was used to calculate discrepancy in Perceived Diet Quality (PDQ) and Measured Diet Quality (MDQ) (using total HEI-2010 and AHEI-2010 scores) (Powell-Wiley et al., 2014).

Calculation of Discrepancy Scores

As previously mentioned, PDQ was based on the question asked in NHANES, "In general, how healthy is your overall diet?" Possible responses were based on a 5-point scale (1 = 'excellent', 2 = 'very good', 3 = 'good', 4 = 'fair', 5 = 'poor'). MDQ was based on using the total HEI-2010 and AHEI-2010 scores as indices to measure objective (or actual) diet quality. The total HEI-2010 and AHEI-2010 scores are continuous variables and need to be converted to ordinal variables to compare with PDQ and calculate discrepancy scores. The criterion-referenced method was used to establish cut-offs for total HEI-2010 and AHEI-2010 as follows: (80-100 ='excellent'; 60- <80 = 'very good'; 40- <60 = 'good'; 20- <40 = 'fair'; 0- <20 = 'poor').

Discrepancy scores were calculated as the difference between PDQ and MDQ. There were two measures used to estimate MDQ using first total HEI-2010 score and then total AHEI-2010 score: MDQ-HEI2010 and MDQ AHEI2010. The present study analyzed discrepancy scores in three ways: 1) the magnitude (absolute value) of the difference between PDQ and MDQ; 2) the magnitude and direction of the difference between PDQ and MDQ; and 3) the direction of the difference between PDQ and MDQ. The first approach looks only at the magnitude of the difference between perceived and measured (objective) diet quality [abs (discrepancy score = perceived score – objective score) (MDQ-HEI2010 and MDQ-AHEI2010)] regardless of the direction of the difference. The second approach takes into account both the magnitude and the direction of the difference [discrepancy score = perceived score – objective score (MDQ-HEI2010 and MDQ-AHEI2010)] and can take on positive or negative values. Positive values indicate that participants under rate and negative values indicate that they over rate their own diet. Analysis using this approach had sparse cells because the magnitude of the difference between PDQ and MDQ were in the 1 to 2 point range. Therefore, collapsing extreme sized values to get reasonable groups would reduce the analysis of direction only. This research applied the third approach that looks at only the direction of the difference between PDQ and MDQ by collapsing differences into three groups: positive, negative, and zero. Some studies refer to over raters as "optimists", under raters as "pessimists", and matchers as "realists" (J. Brug, P.A. Assema, G. Kok, T. Lenderink, 1994; Variyam, Shim, & Blaylock, 2001). The direction of discrepancy scores was categorized as over raters, under raters, and matchers.

3.5.2.3 Lifestyle Behaviors

Lifestyle behaviors variables were extracted from the Laboratory module and Questionnaires data in NHANES, including questions on Alcohol use, Dietary, Physical Activity, and Sleep Disorders. The following variables were used as measures of lifestyle: 1) Smoking status (demographics file), 3) Self-Reported

Alcohol Consumption, 4) Physical Activity (minutes of moderate and/or vigorous recreational activities per week or the combination of the two), 5) On a special Diet (yes/no), 6) Supplement intake in the past 30 days (yes/no), and 6) Sleep Adequacy (hours of sleep). These variables were used to examine the relationships of individual lifestyle behaviors and Lifestyle Behaviors score with dietary quality (using HEI-2010 and AHEI-2010) by diabetes status.

Individual Lifestyle Behaviors

Alcohol Consumption

The present study examined self-reported alcohol consumption from the Alcohol Use Questionnaire of NHANES. The Alcohol Use Questionnaire focuses on lifetime and current use of alcohol (defined as consumption within the past 12 months) and was not specific to type of alcohol consumed. In this study, self-reported alcohol consumption was based on the average alcoholic drinks reported per day in the past 12 months. Participants where asked "In the past 12 months, on those days that you drank alcoholic beverages, on the average, how many drinks did you have?" Participants who reported zero drinks were defined as nondrinkers. Participants were defined as drinkers if they reported consuming any amount of alcohol, including moderate (Female: 1 drink; Male: 1-3 drinks) or heavy (Female: > 1 drink; Male: > 3 drinks), otherwise classified as "no" for nondrinkers.

Sleep Adequacy

Epidemiological studies have shown that inadequate sleep (short sleep duration) can be a potential risk factor for T2DM (M.-P. St-Onge et al., 2016). The

Sleep Disorders questionnaire of NHANES contains a set of questions on sleep habits and disorders. This study evaluated sleep adequacy based on participants reporting the number of hours of sleep at night (self-reported sleep duration). Participants were asked "How much sleep do you usually get at night on weekdays or workdays?" Participants' responses ranged from 1 to 11 hours. Participants who reported sleeping 12 or more hours were coded together as a category. Previous studies have defined adequate sleep as participants reporting 7-8 hours of sleep at night (Grandner, Jackson, Gerstner, & Knutson, 2013; Beydoun et al., 2014). Adequate sleep was defined by assigning a "1" to individuals who slept at least 7 hours at night and "0" to those who did not (< 7 hours).

<u>On a special diet</u>

The dietary interview component at the MEC gathered detailed dietary intake information from NHANES participants. In one of the questions, participants were asked: "Are you currently on any kind of diet, either to lose weight or for some other health-related reason?" Responses were coded as "yes" or "no." Participants who responded "yes" were further asked to specify the type of diet that they followed. Participants mentioned the following types of diets: weight loss/low calorie diet, low fat/low cholesterol diet, low salt/low sodium diet, sugar free/low sugar diet, low fiber diet, high fiber diet, diabetic diet, weight gain/muscle building diet, low carbohydrate diet, high protein diet, and other special diets, but many respondents had missing values. Therefore, this study only used the general question related to being on a special diet as an indicator of participants' intent to change their diets.

Supplement Intake

The Total Dietary Supplements component of NHANES was used to evaluate dietary supplement intake. NHANES asked participants to report any dietary supplements taken in the preceding month. The full question was: "Have you used or taken any vitamins, minerals or other dietary supplements in the past month? Include those products prescribed by a health professional such as a doctor or dentist, and those that do not require a prescription." Participants' responses to the question were coded as "yes" or "no."

Smoking Status

Analysis of smoking status was based on several questions in the NHANES Smoking Questionnaire. Smoking status was categorized based on the responses of two questions. First, participants were asked if they had smoked at least 100 cigarettes or other tobacco use in their lives. Possible responses were "yes" or "no." Second, participants who answered "yes" to the previous question were further asked if they were currently smoking cigarettes. The response categories were: every day, some days, or not at all. Based on participants' responses, participants were classified as nonsmokers, current smokers, and former smokers. Participants who said "no" to having smoked 100 cigarettes during their lifetimes were classified as nonsmokers. Participants who said "yes" to having smoked at least 100 cigarettes in their lives and who reported now smoking either "everyday" or "some days" were classified as smokers. Those who said "yes" to having smoked at least 100 cigarettes in their lives and reported "not at all" to current smoking were classified as former smokers.

Physical Activity

The NHANES Physical Activity questionnaire was used to evaluate the frequency, duration, and intensity of recreational physical activity. This study used the 2008 Physical Activity Guidelines for Americans as the standard (Leavitt, n.d.). The Guidelines call for 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity per week or some combination of the two (Leavitt, n.d.). This study estimated total reported minutes of moderate and vigorous physical activity per week by multiplying the reported minutes of activity per day by the reported number of days of activity per week. To account for the combination of moderate and vigorous physical activity, vigorous intensity was multiplied by 2 before being added to moderate intensity. Therefore, participants could meet guidelines if they engaged in at least 150 minutes of moderate plus 2 × vigorous intensity of physical activity per week (Paul D. Loprinzi, Ellen Smit , Sara Mahoney, 2014).

Lifestyle Behaviors score

The present study created a total Lifestyle Behaviors score to examine the effect of a combination of individual lifestyle behaviors in relation to dietary quality (using HEI-2010 and AHEI-2010 scores). A total Lifestyle Behaviors score variable was constructed using participants' responses to six selected individual lifestyle behaviors: 1) self-reported alcohol consumption, 2) sleep adequacy, 3) on a special diet, 4) supplement intake, 5) smoking status, and 6) physical activity adequacy. Individuals received 1 point for each positive lifestyle behavior: sleep adequacy, on a special diet, supplement intake, and physical activity. Smoking and alcohol consumption were reverse-scored. Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status. The total Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors (Maximum score = 6 points).

3.5.3 Additional Analytic Variables

3.5.3.1 Sociodemographic and Economic Characteristics

During the household interview, sociodemographic and economic information were obtained from the Demographics Questionnaire. The variables include age, sex, ethnicity, marital status, education level, Poverty Income Ratio (PIR), and number of people in the family (family size). For categorical variables, ethnicity was categorized as Mexican American, non-Hispanic White, non-Hispanic Black, and other (including other Hispanic). Educational status was categorized into four levels: less than high school, high school diploma, some college education, or college graduate and above. Marital status was categorized as current married/partner, former married or never married. Additional variables were obtained from different questionnaires of NHANES. These variables include smoking status, Adult Food Security category, and health insurance coverage. All of the variables mentioned were used describe the study sample and explored as potential covariates in regression models.

In NHANES, the Smoking Questionnaire contains several questions related to smoking status. In the present study, smoking status was categorized based on the responses of two questions. First, participants were asked whether they had smoked at least 100 cigarettes in their life. Possible responses to the question are either "yes" or "no." Second, participants who answered "yes" to the previous question were further asked whether they now smoke cigarettes. Possible responses to the question are: every day, some days, or not at all. Based on the response to these questions, this study categorized smoking status as nonsmoker, current smoker, and former smoker. Nonsmokers were categorized if participants responded “no” to having smoked 100 cigarettes during their lifetime. Current smokers were categorized as those who responded “yes” to having smoked at least 100 cigarettes in their life and reported now smoking either “everyday” or “some days.” Former smokers were categorized as those who responded “yes” to having smoked at least 100 cigarettes in their life and reported “not at all” to now smoking.

Previous studies have shown that adult food security status is inversely associated with dietary quality (lower HEI-2005 and AHEI-2010 scores) in lower-income U.S. adults (Cindy W. Leung et al., 2014). In addition, several studies have shown that food insecurity is strongly associated with T2DM (Seligman, Bindman, Vittinghoff, Kanaya, & Kushel, 2007; Berkowitz, Baggett, Wexler, Huskey, & Wee, 2013; Montgomery, Lu, Ratliff, & Mezuk, 2017). In NHANES, the Food Security Questionnaire contains several questions related to food security status. This study used the Adult Food Security variable to determine food security status in U.S. adults. Adult Food Security category was constructed based on the number of affirmative responses for 10 items in the questionnaire. These items could be used to characterize the overall food security status for the adults in the household. Adult Food Security Category was classified as follows: 1 = Adult full food security: no affirmative response in any of these items; 2 = Adult marginal food security: 1-2 affirmative responses; 3 = Adult low food security: 3-5 affirmative responses; and 4 = Adult very low food security: 6-10 affirmative responses.

In NHANES, the Health Insurance questionnaire contains several questions related to health insurance coverage, type of insurance coverage, coverage of prescription drugs, and uninsured during the past 12 months. This study only used the question related to health insurance coverage. This include health insurance obtained through employment or purchased directly as well as government programs like Medicare and Medicaid that provide medical care or can help pay medical bills. Participants were asked whether they are covered by health insurance or some other kind of health care plan. Possible responses to the question are "yes" and "no."

3.5.3.2 Medical History

General Health Status and Comorbidities

The CDC website provide information on participants' general health status and presence of comorbidities. In NHANES, the Current Health Status Questionnaire provides personal interview data on overall health assessment. **Self-reported health status** was assessed based on the question "would you say your health in general is…." Possible responses to the question are: excellent, very good, and good, fair, and poor. This variable was used as a covariate in the regression models. Additionally, people with T2DM often have other chronic conditions and presence of comorbidities (Leavitt, n.d.;Weaver, Ashby, & Kamimura, 2017). The Medical Conditions Questionnaire provides self-reported personal interview data on a broad range of health conditions for U.S. adults. Self-reported diagnosis of chronic diseases associated with T2DM was extracted from the questionnaire and a co-morbidity score was created based on the participants' response. Similar to Loprinzi et al (2015), a **co-morbidity score** (range: 0–15) variable was created by summing the number of physician-diagnosed comorbidities, including overweight, high blood pressure, high cholesterol, heart attack, coronary heart disease, congestive heart failure, angina, stroke, thyroid problems, liver conditions, asthma, arthritis, chronic bronchitis, emphysema, and cancer/malignancy (Loprinzi, 2015). This variable was also used as a covariate in the regression models.

Depression Status

Depression has shown to be associated with metabolic risk factors and T2DM (Wang, Lopez, Bolge, Zhu, & Stang, 2016). The Mental Health-Depression Screener Questionnaire was used to evaluate depression status. NHANES used the Depression Screener (DPQ) questions from the Patient Health Questionnaire (PHQ-9), which is a version of the Prime-MD diagnostic instrument. A Depression score variable was created by summing the responses to a 9-item screening tool, which asks participants to choose responses about the frequency of depressive symptoms during the previous 2 weeks, where "0" means not at all and "3" means nearly every day. Depression severity can be defined by several cut points from the total score that ranges from 0-27 (Kroenke, Spitzer, & Williams, 2001). Depression score with PHQ-9 score 5-9 was characterized as mild depression, PHQ-9 score 10-14 as moderate depression, PHQ-9 score 15-19 as moderately severe, and PHQ-9 score ≥ 20 as severe depressive symptoms (Kroenke et al., 2001; Loprinzi, 2015).

3.5.3.3 Anthropometric Measurements

Obesity continues to be one of the most important modifiable risk factors for the prevention of T2DM and its related comorbid conditions (Kramer et al., 2010). NHANES collect body measurements to estimate the prevalence of overweight and obesity in the U.S. population. The anthropometric measurements were used to evaluate health and dietary status, disease risk, and body composition trends in U.S. adults (Anthropometry Procedures Manual, 2009). In NHANES, the Examination data contains the body measures files including anthropometric measurements. This study used Body Mass Index (BMI) and Waist Circumference (WC) as variables to measures weight status and adiposity. All survey participants were eligible for the body measurement component with no specific exclusions. All body measurements were collected at the MEC by trained health technicians.

Body Mass Index (BMI)

Body Mass Index (BMI) was calculated for participants using weight in kilograms divided by height in meter squared. In NHANES, both weight and height are collected through following standardized protocols as explained in the Anthropometry Procedures Manual (Anthropometry Procedures Manual, 2009).

Weight

Participants were weighed in kilograms using a digital floor scale and measured to the nearest 0.1 kilogram. To obtain accurate weight measurement, each participant had to wear the standard MEC examination gown, which consisted of a disposable shirt, pants and slippers. Only underpants beneath the gown were allowed while taking the measurement. Participants stood in the center of the scale platform, hands at sides and looking straight ahead (Anthropometry Procedures Manual, 2009).

Height

Participants were directed to stand on a stadiometer platform. To obtain accurate height measurement, each participant was asked to remove any hair ornaments, jewelry, buns, or braids from the top of the head, stand up straight against the backboard with the body weight evenly distributed, and place both feet flat on the platform with the heels together and toes apart. While standing on the platform, the back of the head, shoulder blades, buttocks, and heels had to be in contact with the backboard (Anthropometry Procedures Manual, 2009).

Based on the National, Heart, Lung, and Blood Institute (NHLBI) standards, BMI values are used to screen for weight categories: underweight [< 18.5 kg/m^2], healthy weight [18.5-24.9 kg/m^2], overweight [25.0-29.9 kg/m^2], obesity class I [30.0-34.9 kg/m^2] obesity class II [35.0-39.9 kg/m^2] and obesity class III [≥ 40 kg/m^2] (NATIONALINSTITUTESOFH, 2007). This study excluded underweight participants since people with T2DM are more likely to be normal, overweight, or obese. BMI was used as a continuous variable in regression models.

Waist Circumference (WC)

A high waist circumference (WC) is associated with an increased risk for T2DM, dyslipidemia, hypertension, and CVD among individuals with a BMI in a range between 25 and 34.9 kg/m^2 (Koh-Banerjee et al., 2004). Although BMI is commonly used in clinical practice to measure weight status, WC is an important measure to examine across diabetes status since it can provide a better estimate of increased abdominal fat even in the absence of a change in BMI (Menke, Muntner, Wildman, Reynolds, & He, 2007). NHANES follows standardized protocols to measure WC (Anthropometry Procedures Manual, 2009). Participants had to gather their gown shirt above the waist, cross the arms, and place the hands on opposite shoulders. The pants and underclothing had to be lowered below the waist. After that, a steel measuring tape was used to the nearest 0.1 cm at the high point of the iliac crest during minimal respiration (Anthropometry Procedures Manual, 2009). Based on the NHLBI standards, WC values are used to screen participants for abdominal obesity using sex-specific cut-offs: WC >102 for men and WC > 88 for women are classified as abdominally obese (NATIONALINSTITUTESOFH, 2007). Adults with WC values above the sex-specific cut-offs (in conjunction with BMI 25-34.9 kg/m^2) are considered to have increased T2DM risk and other chronic diseases (i.e., HTN, CVD) (available online: https://www.nhlbi.nih.gov/health-pro/guidelines/current/obesity guidelines/e_textbook/txgd/4142.htm). This study used WC as a continuous variable in regression models.

3.5.3.4 General Nutrition Knowledge

Variables related to general nutrition knowledge were extracted from the Flexible Consumer Behavior Survey follow-up for adults. A knowledge score was created by summing the responses to 7 questions related to having general knowledge about dietary guidelines. Because the Dietary Guidelines are updated regularly, the questions in NHANES 2007-2010 primarily reflect the 2005 Dietary Guidelines (e.g. “MyPyramid”). However, knowledge of dietary guidelines, even if it is not related to the most recent dietary guidelines, can serve as a proxy for general nutrition knowledge. The seven questions assess whether participants are able to identify the correct number of servings recommended for each food group based on the MyPyramid guidelines (available online: http://www.foodpyramid.com/mypyramid/). These food groups include fruits, vegetables, milk, ounces of meat/beans, ounces of grains, ounces of whole grains, and calories needed per day. Since the suggested number of servings for each food group varies depending on the target calorie level (which is determined based on a person's age and physical activity level), a reference level of 2000 calories was used as the cut-off for each suggested food group. For example, participants who answered 3 cups of milk, 2 cups of fruit, 2.5 cups of vegetables, 8 ounces of meats/beans, 6 ounces of grains, and 3 ounces of whole grains (MyPyramid recommends that at least 50% of the grains should be whole grain) and to identify that adults need about 1,000 – 2,500 calories per day receive 1 point for each of these questions. Participants who answer any other values for each of these food groups, or say "don't know" receive 0 points. Then the points for each question are added to compute an overall knowledge score (Total = 7 points).

3.5.3.5 Attitudes about diet and body weight

Variables related to attitudes changing current diet and body weight were extracted from the Flexible Consumer Behavior Survey follow-up for adults. There are only three questions available in NHANES that are used to assess attitudes. The first question is related to fatalistic attitudes about body weight. Participants are asked, "some people are born to be fat and some thin; there is not much you can do to change this?" The second question is related to attitudes about changing diet. Participants are asked, "There is no reason for me to make changes to the things I eat?” Responses to these questions are based on a 5-point Likert Scale: Strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, and strongly disagree. The third question was related to the importance of nutrition. Participants were asked, “How about "nutrition"? When you buy food from a grocery store or supermarket, how important is "nutrition"? ” Responses to these questions are based on a 5-point Likert Scale: Very important, somewhat important, not too important, and not all important. These variables were examined as potential factors that affect the discrepancy between PDQ and MDQ.

3.6 Statistical Analysis

According to NHANES 1999-2010 Analytic Guidelines, software packages such as SAS (survey procedure), SUDAAN, and STATA can be used for variance estimation since they do not assume a simple random sample for computing variances. Data sets from NHANES 2007–2008 and 2009–2010 cycles were combined according to the NHANES analytic guidelines (National Center for Health Statistics (U.S.), 2013b). In this study, data preparation for the 2007-2010 NHANES data, including extracting, merging, appending, sorting, creating variables, and exploratory analysis was performed using SAS 9.3 software (SAS Institute Inc, Cary, NC). SAS 9.3/9.4 and STATA 14.1/14.2 versions (StataCorp, College Station, TX) were also utilized for descriptive and inferential statistics (i.e., regression modeling) that incorporated the complex sampling design. The stratum variable (SDMVSTRA), the primary sampling unit variable (SDMVPSU), and the appropriate sample weights (fasting subsample weights) were applied to all the analyses to account for the complex survey design, unequal probabilities of selection, non-response and oversampling of demographic subgroups of the population. As recommended in the NHANES analytic guidelines, the 4-year fasting weight was constructed by assigning one-half of the 2-year weight for each survey cycle (2007-2008 and 2009-2010) and was used throughout the analysis (National Center for Health Statistics (U.S.), 2013a). Taylor Series Linearization (TSL) methods were used for variance estimation.

Univariate analyses were performed for all variables. Weighted frequencies and percentages were obtained for categorical variables. These included sociodemographic characteristics (i.e, sex, ethnicity, education), diabetes status, discrepancy scores, lifestyle behaviors, general nutrition knowledge, depression status, and attitudinal variables. Weighted means ± standard errors of the means (SEMs) were obtained for continuous variables including HEI-2010 and AHEI-2010 scores, anthropometric measurements (BMI and WC), biomarkers (i.e., lipid profile), presence of comorbidities (comorbidity score), and Lifestyle Behaviors score.

Bivariate analyses were performed to examine associations among categorical and continuous variables. For categorical variables, the design-adjusted Rao-Scott chi-square test was used to assess relationships among: 1) participants' sociodemographic characteristics and by diabetes status groups (nondiabetes, prediabetes, T2DM); 2) consumption of HEI-2010 and AHEI-2010 food/nutrient groups across diabetes status; 3) participants' characteristics related to sociodemographics, lifestyle and health, depression, attitude, and nutrition knowledge by discrepancy scores groups (under raters, matchers, over raters); 4) selected lifestyle behaviors by diabetes status groups; and 5) demographic characteristics by

Lifestyle Behaviors score (categorized as low and high). Some of the categorical variables were re-classified by combining some groups to minimize sparse cells.

For continuous variables, linear regression was used to calculate Least-square means (LSMs) (and the standard errors of the LSMs). LSMs were computed to determine differences in the following: 1) total and sub-component HEI-2010 and AHEI-2010 scores by diabetes status groups; 2) health markers by diabetes status groups; 3) health markers by quartiles of total HEI-2010 and AHEI-2010 scores; 4) total and sub-component HEI-2010 and AHEI-2010 scores by discrepancy score groups; 5) total and sub-component HEI-2010 and AHEI-2010 scores across discrepancy scores by diabetes status groups; 6) total HEI-2010 and AHEI-2010 scores across individual lifestyle behaviors (categorized as "yes" and "no") and Lifestyle Behaviors score (categorized as low and high); and 7) total and sub-component HEI-2010 and AHEI-2010 scores across Lifestyle Behaviors score (categorized as low, medium, and high). For ease of presentation of the data, non-transformed LSMs were presented with p-values associated with transformed variables. Bonferroni corrections for multiple comparisons (0.05/number of variables) were applied to obtain the effective p-values for the models.

Logistic regression analysis was performed to examine the associations between 1) dietary quality (using total HEI-2010 and AHEI-2010 scores and diabetes status, and between 2) diabetes status and discrepancy scores (calculated for each total HEI-2010 and AHEI-2010 scores). STATA 14.1/14.2 software was used to perform multinomial logistic regression for nominal outcome variables with three levels: 1) diabetes status (nondiabetes, prediabetes, T2DM) and 2) discrepancy score.

Discrepancy scores were calculated as the difference between perceived (self-rated) and measured diet quality [discrepancy score = perceived score – measured score (calculated for each total HEI-2010 and AHEI-2010 scores)]. Individuals were assigned to one of three groups based on their discrepancies score: 1) under raters; 2) over raters; and 3) matchers. The STATA command (mlogitgof) was executed after fitting the models to assess the goodness-of-fit for multinomial logit modeling (Fagerland & Hosmer, 2013). Multivariate linear regression analyses were performed to examine the associations between lifestyle behaviors and dietary quality (using total HEI-2010 and AHEI-2010 scores) overall and by diabetes status. SAS 9.3/9.4 was used to perform the regression analysis within diabetes status groups (nondiabetes, prediabetes, T2DM) as a class variable using the Domain statement. Separate models were performed for individual lifestyle behaviors and Lifestyle Behaviors score. All analyses were two-tailed, and results were considered statistically significant if $p < 0.05$.

3.6.1 Confounders in the Multivariate Models

Research Question #1

Is there a significant association between total HEI-2010 score and diabetes status?

Figure 3. Association of total HEI-2010 score with Diabetes Status

Is there a significant association between total AHEI-2010 score and diabetes status?

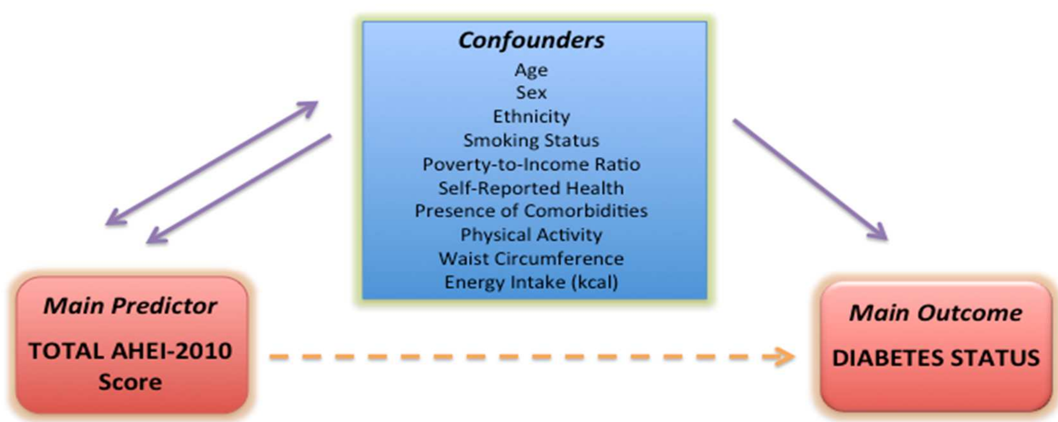

Figure 4. Association of total AHEI-2010 score with Diabetes Status

Multinomial logistic regression was used to examine the association between dietary quality (using total HEI-2010 and AHEI-2010 scores) and diabetes status (nondiabetes, prediabetes, diabetes) while controlling for health markers, lifestyle and demographic factors. Energy intake was included as a covariate for the AHEI-2010 because, unlike HEI-2010, it does not adjust for energy intake. Separate models were performed for total HEI-2010 and AHEI-2010 scores. In order to determine the presence of effect modifiers, several interaction terms were tested for each of the models. These included WC × total HEI-2010 score, WC × total AHEI-2010 score, age × physical activity, physical activity × total HEI-2010 score, and physical activity × total AHEI-2010 score. These two-way interaction terms were not statistically significant and therefore were dropped from the models.

Research Question #2

Is diabetes status significantly associated with HEI-2010-based discrepancy scores?

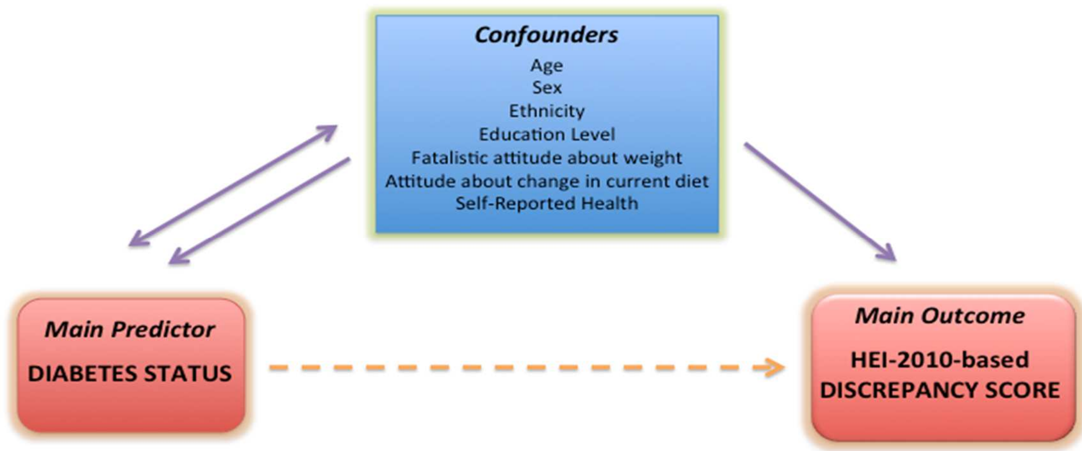

Figure 5. Association of diabetes status with HEI-2010 Discrepancy score

Is diabetes status significantly associated with AHEI-2010-based discrepancy scores?

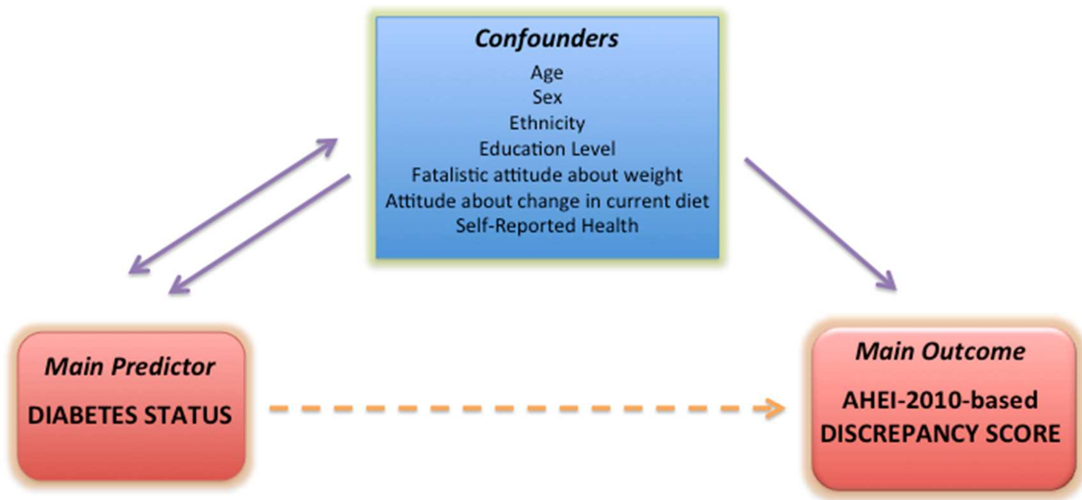

Figure 6. Association of diabetes status with AHEI-2010 Discrepancy score

Multinomial logistic regression was used to examine the association between diabetes status and discrepancy scores (under raters, over raters, and matchers) while controlling for sociodemographics, perceived health status, and attitudinal factors. Discrepancy scores were calculated separately for HEI-2010 and AHEI-2010. The models were run separately for HEI-2010-based and AHEI-2010-based discrepancy scores.

<u>Research Question #3</u>

Are selected individual lifestyle behaviors independently associated with total HEI-2010 score by diabetes status?

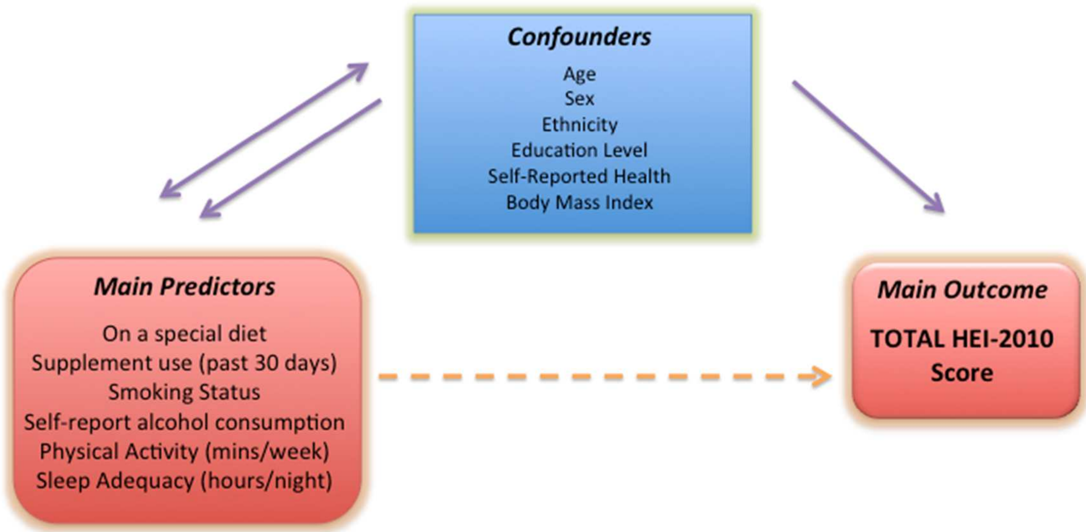

Figure 7. Association of individual lifestyle behaviors with total HEI-2010 score

Are selected individual lifestyle behaviors independently associated with total AHEI-2010 score by diabetes status?

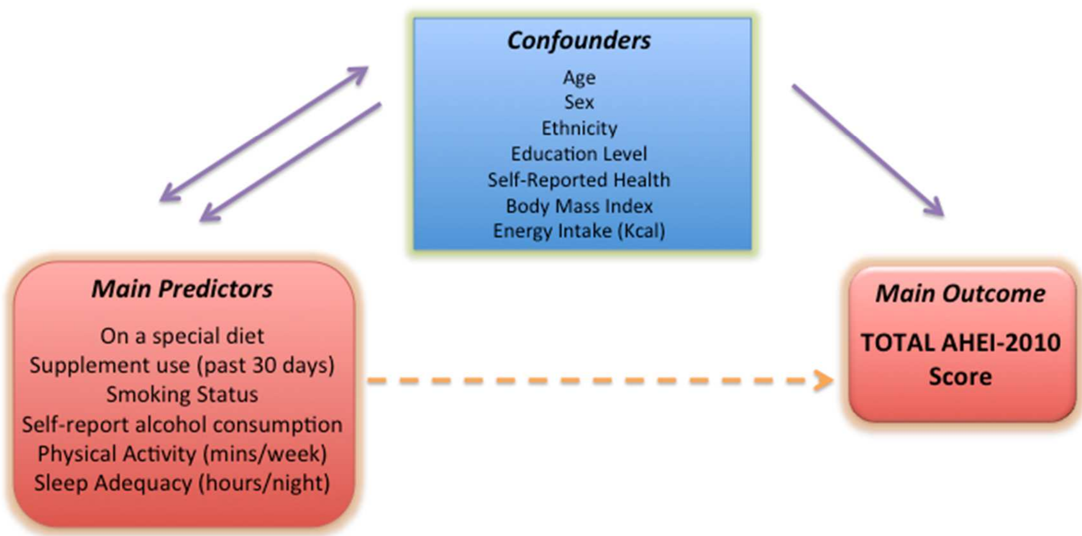

Figure 8. Association of individual lifestyle behaviors with total AHEI-2010 score

Multivariate linear regression was used to examine the associations between individual lifestyle behaviors and dietary quality (using total HEI-2010 and AHEI-2010 scores) after adjusting for demographic and health characteristics. Energy intake was included as a covariate for the AHEI-2010 because, unlike HEI-2010, it does not adjust for energy intake. The regression analyses were performed within diabetes status groups (nondiabetes, prediabetes, T2DM). Separate models were performed for total HEI-2010 and AHEI-2010 scores.

Are selected lifestyle behaviors in combination associated with total HEI-2010 score by diabetes status?

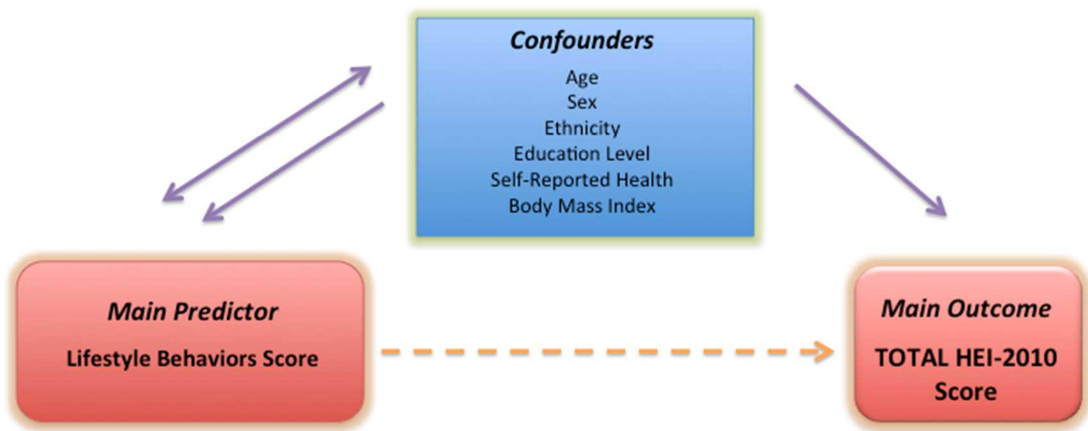

Figure 9. Association of Lifestyle Behaviors score with total HEI-2010 score

Are selected lifestyle behaviors in combination associated with total AHEI-2010 score by diabetes status?

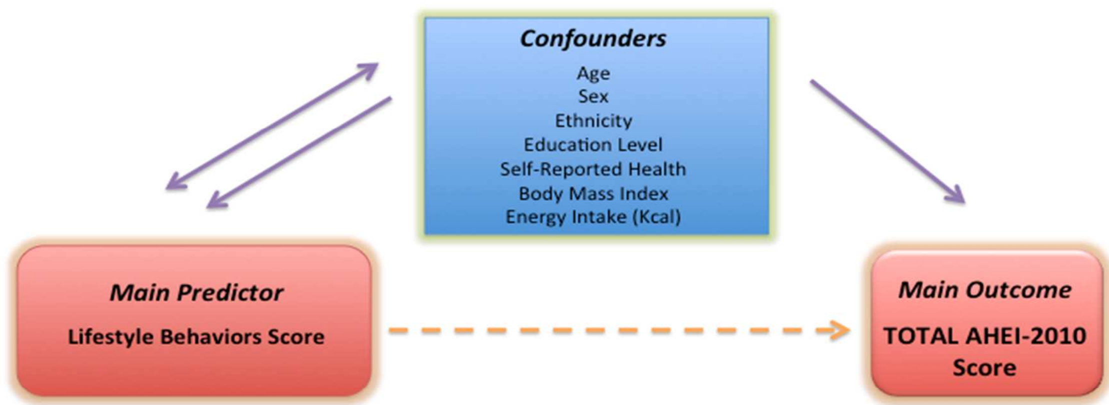

Figure 10. Association of Lifestyle Behaviors score with total AHEI-2010 score

An aggregate Lifestyle Behaviors score was created by assigning 1 point for each behavior (self-reported alcohol consumption and smoking status were reverse-scored), and summing the points for each individual. Multivariate linear regression was used to examine the association between Lifestyle Behaviors score and dietary quality (using total HEI-2010 and AHEI-2010 scores) after adjusting for demographic and health characteristics. Energy intake was included as a covariate for the AHEI-2010 because, unlike HEI-2010, it does not adjust for energy intake. The regression analyses were performed within diabetes status groups (nondiabetes, prediabetes, T2DM). Separate models were performed for total HEI-2010 and AHEI-2010 scores.

Chapter 4: Results

4.1 Healthy Eating Index versus Alternate Healthy Index in Relation to Diabetes Status and Health Markers in U.S. Adults

Abstract

Background: There is growing evidence that adherence to healthful dietary patterns reduces the risk of type 2 diabetes (T2DM). The Healthy Eating Index 2010 (HEI-2010) and Alternate Healthy Eating Index 2010 (AHEI-2010) are recognized as tools to assess dietary quality. Both indices are similar in some of their food and nutrient components. However, the AHEI-2010 reflects a critique of the HEI-2010 and incorporates distinct components that are predictive of chronic disease risk. It remains to be determined whether the AHEI-2010 or the HEI-2010 is preferably recommended as means to assess dietary quality in people with T2DM.

Objective: To determine whether the Alternate Healthy Eating Index 2010 (AHEI-2010) provides a more accurate assessment of dietary quality than the Healthy Eating Index 2010 (HEI-2010) in relation to type 2 diabetes (T2DM), while controlling for health markers, sociodemographic and lifestyle factors.

Methods: This study used a representative sample of U.S. adults 20+ years of age (n = 4097) in the 2007-2010 National Health and Nutrition Examination Survey (NHANES). Total HEI-2010 and the AHEI-2010 were used as measures of dietary quality and were calculated using data from the first 24-hour dietary recall. Health markers evaluated include anthropometrics, blood pressure, lipid and inflammatory

markers, and presence of co-morbid diseases. Least Squares Means were computed to determine differences across diabetes status (nondiabetes, prediabetes, T2DM) for total and sub-component HEI-2010 and AHEI-2010 scores, and to determine differences across total HEI-2010 and AHEI-2010 quartiles for health markers. Covariate-adjusted logistic regression was used to examine the association between total HEI-2010 and AHEI-2010 scores and diabetes status.

Results: Overall, HEI-2010 (mean total score = 47.3 ± 0.4) and AHEI-2010 (mean total score = 38.2 ± 0.4) both indicate that U.S. adults need improvement in dietary pattern. However, individuals with the highest total HEI-2010 and AHEI-2010 scores in the sample had significantly better health marker values compared to those with the lowest scores ($p < 0.01$). Diabetics showed higher HEI-2010 and AHEI-2010 scores compared to prediabetics and nondiabetics but did not have better health markers. There were significant differences in some of the sub-component HEI-2010 and AHEI-2010 scores across T2DM status ($p < 0.01$). For HEI-2010 component scores, diabetics had highest consumption (highest score) of total protein foods and lowest consumption (highest score) for empty calories. For AHEI-2010 component scores, diabetics had the lowest consumption (highest score) for sugar-sweetened beverages and fruit juice, sodium, and alcohol (lowest score). In addition, diabetics had the highest consumption (lowest score) for red and/or processed meats. However, neither total HEI-2010 nor AHEI-2010 scores were significantly associated with diabetes status ($p > 0.05$). Results suggest that neither index was clearly superior to the other in terms of its predictive ability in relation to T2DM.

Conclusion: Neither total HEI-2010 nor AHEI-2010 scores performed better in terms of their relationship with diabetes status. However, the significant relationships between 1) T2DM status and health markers and 2) between HEI-2010 and AHEI-2010 scores and health markers suggest that diet has some influence on T2DM. In addition, neither index performed better than sociodemographic characteristics, which could point to unmeasured genetic differences. More research is needed to investigate the role of genetics in the development of T2DM. Lastly, the HEI-2010 and AHEI-2010 were not developed specifically for use in assessing dietary quality in diabetics. Future research is needed to improve diet quality assessment among individuals with T2DM.

Keywords: NHANES, HEI-2010, AHEI-2010, Diabetes Status, Health Markers

Introduction

Diabetes is a serious clinical and public health concern in the United States. Type 2 diabetes mellitus (T2DM) accounts for the majority of all cases of diabetes in adults (up to 95%). T2DM continues to be prevalent despite public health efforts to develop effective policies and interventions. It is estimated that about 12.3% of U.S. adults age 20 years and older had diagnosed or undiagnosed diabetes (Centers for Disease Control and Prevention, 2014). T2DM is associated with an increased risk of serious complications including cardiovascular disease (CVD) and is a primary risk factor for coronary heart disease (CHD) (Wu, Huang, Lei, & Yang, 2016). In 2009-2012, an analysis of data from the National Health and Examination Survey (NHANES) found that about 37% of U.S. adults age 20 years and older (51% of those age 65 years or older) had prediabetes. People with prediabetes had high fasting plasma glucose (FPG) or hemoglobin A1c (HbA1c) levels, but these blood values were not high enough yet for a diagnosis of T2DM (Centers for Disease Control and Prevention, 2014a). However, prediabetes increases the risk of developing T2DM, heart disease, and stroke in the future. Estimates from the Centers for Disease Control and Prevention (CDC) suggest that about 15-30% of people with prediabetes will develop T2DM within five years (Centers for Disease Control and Prevention, 2014b). Therefore, lifestyle interventions to improve diet are an important strategy to prevent T2DM and other adverse health outcomes, and optimize long-term health (Wang et al., 2014).

Diet quality indices are increasingly being used to examine epidemiological associations between dietary intake and nutrition-related health outcomes (Wirt & Collins, 2009). Diet quality indices score individual food consumption patterns in terms of how closely they align with national dietary guidelines and evidence-based recommendations. Scoring indices assess both the quality and the variety of the entire diet, enabling examination of associations between total food consumption and health status, rather than just single nutrients or foods (Nicklas, O'Neil, & Fulgoni, 2012). There are several pre-defined diet quality scores that have been validated by relating the index to health and/or outcome. Two of them have gained strong recognition: Healthy Eating Index (HEI) and the Alternate Healthy Eating Index (AHEI).

The Healthy Eating Index-2010 (HEI-2010) is a measure of diet quality in relation to the 2010 Dietary Guidelines for Americans (DGA 2010) (Patricia M Guenther et al., 2014). The main objective of DGA 2010 is to promote healthy eating in the general population (Willett, 2012). The HEI-2010 score captures key nutrients and food groups that reflects current evidence on the dietary components that are healthful (Adam M. Bernstein, Bloom, Rosner, Franz, & Willett, 2010). Another popular tool used to measure dietary quality is the Alternate Healthy Eating Index-2010 (AHEI-2010), which is based on evidence-based recommendations that incorporates additional components that focus on foods and nutrients to predict the risk of chronic disease (McCullough et al., 2002; Stephanie E Chiuve et al., 2012). The most recent U.S. dietary guidelines (DGA 2015) have somewhat moved in the direction suggested by the AHEI (Willett, 2012). Therefore, it is useful to utilize the HEI-2010 and AHEI-2010 indices to examine their association with health or disease outcomes, such as T2DM.

The HEI-2010 and AHEI-2010 are useful tools measure adherence to dietary guidelines and evidence-based recommendations. The HEI-2010 and AHEI-2010 are similar in some aspects. For example, both indices capture consumption of fruits, vegetables, whole grains, and sodium. However, the AHEI-2010 reflects a critique of the HEI-2010 and incorporates distinct features. For example, the AHEI-2010 pays more attention to fat quality (i.e., intakes of omega-3 fats and polyunsaturated fats), promotes intake of nuts and legumes, recommends to limit intake of red meat and processed meats and avoid added sugars (i.e., sugar-sweetened beverages and fruit juice), and considers moderate alcohol intake (Male: 0.5-2.0 drinks/day; Female: 0.5-1.5 drinks/day) as beneficial to health regardless of disease status (i.e., diabetes). Both HEI-2010 and AHEI-2010 complement one another in terms of evaluating essential foods groups and nutrients. Therefore, it is useful to utilize the HEI-2010 and AHEI-

2010 as tools to assess dietary quality and examine their association with lifestyle behaviors by diabetes status.

Several prospective studies have evaluated HEI-2010 and AHEI-2010 scores in relation to T2DM (McCullough et al., 2002; Teresa T. Fung, Mccullough, Dam, & Hu, 2007; Lawrence De Koning et al., 2011; Stephanie E Chiuve et al., 2012; Qiao et al., 2014; Jacobs et al., 2015; Schwingshackl & Hoffmann, 2015). Results from a recent meta-analysis of 15 cohort studies, with follow-up time ranging from 5 to ≥ 24 years, show that diets of the highest quality (compared highest vs. lowest quintile scores), as assessed by the HEI, AHEI, and DASH, are associated with a significant risk reduction for all-cause mortality, T2DM and other chronic diseases (i.e., cardiovascular disease, cancer) ($P < 0.05$) (Schwingshackl & Hoffmann, 2015). In addition, diets that score highly on the HEI, AHEI, and DASH are associated with a significant reduction in the risk of T2DM (22%, $P < 0.05$) (Schwingshackl & Hoffmann, 2015). In these studies, the HEI-2010 (and HEI-2005) has been evaluated among individuals with chronic disease (including T2DM) with mixed results. Some studies have shown moderate inverse associations and some showed no association with regards to the HEI-2010 and T2DM risk (McCullough et al., 2002; Lawrence De Koning et al., 2011; Schwingshackl & Hoffmann, 2015). However, the AHEI-2010 has demonstrated to be more strongly associated with chronic disease, including T2DM (McCullough et al., 2002; Stephanie E Chiuve et al., 2012; Jacobs et al., 2015; Täger, Peltner, & Thiele, 2016).

While there is growing evidence from prospective studies that high scores on the HEI or AHEI (corresponds to healthy dietary pattern) are inversely associated risk reduction of chronic disease, it remains unclear on whether the HEI-2010 or AHEI-2010 is preferable as a tool for dietary assessment in people with T2DM. Therefore, an improved understanding of the relationships between dietary pattern and health outcomes will help identify the appropriate tool to assess dietary quality for diabetes management and subsequently, decrease the risk of CHD and other diabetes-related complications.

This study hypothesized that the AHEI-2010 is more strongly associated with T2DM than the HEI-2010 dietary pattern. To our knowledge, this was the first study that compared the HEI-2010 and AHEI-2010 scores and their associations with diabetes status in a representative sample of U.S. adults. Moreover, there is limited understanding of the differences of individuals' dietary behavior at different stages of disease development. For that reason, this study defined diabetes status into three categories: nondiabetes, prediabetes, and T2DM. This study was interested in looking at differences in dietary quality, and how they are associated with the stages of disease development. Furthermore, few studies have investigated the relationship between dietary pattern and physiological health markers. A better understanding of the biological basis of health markers (i.e., lipid profile) in relation to diet may better explain the differences in metabolism of individuals with and without chronic disease. In addition, this may provide an insight to develop more effective treatments for diabetes.

The main objectives of this study were three-fold: 1) To determine whether there were relationships between two measures of dietary quality, the HEI-2010 and AHEI-2010 and diabetes status (nondiabetes, prediabetes, T2DM); 2) To examine the relationships between the HEI-2010 and AHEI-2010 and health markers (including biomarkers); 3) To determine the strength of the relationships between the HEI-2010 and AHEI-2010 with diabetes status while controlling for health markers, lifestyle and demographic factors. All analyses were based on data from the 2007-2010 National Health and Nutrition Examination Survey (NHANES).

Participants and Methods

Survey Design

The NHANES is an ongoing cross-sectional survey that collects information on the health and nutritional status of the U.S. population ("National Health and Nutrition Examination Survey Overview," n.d.). The sample is representative of the civilian, non-institutionalized U.S. population because the participants are selected using complex, stratified multistage probability cluster sampling design (Curtin, Mohadjer, & Dohrmann, 2010). The CDC website provides complete details of the NHANES including study design, implementation, datasets, analytic considerations, and other documentations such as consent and operation manuals ("National Health and Nutrition Examination Survey Overview," n.d.).

Study Sample

The present study combined data from NHANES 2007-2008 and 2009-2010 to increase sample size. The study sample (n = 4,097) was limited to adults age ≥ 20 years who participated in both the health interview and medical examination, self-reported as non-pregnant at the examination, had complete and reliable 24-hour diet recalls, a Body Mass Index (BMI) ≥ 18.5 kg/m^2, and fasting glucose measures during the morning examination session. NHANES is in compliance with federal law and follows stringent protocols and procedures that ensure confidentiality and protect participants' identity ("NHANES - NHANES Participants - Eligible Participants," 2017). A formal institutional review board approval was not required since this study was based on secondary analysis and did not contain any personal identifiers (University of Maryland, n.d.).

Exposure and Outcome Variables

Estimation of Dietary Quality

This study utilized the Healthy Eating Index-2010 (HEI-2010) and the Alternate Eating Index-2010 (AHEI-2010) as the main exposure variables to assess dietary quality. The HEI-2010 and AHEI-2010 were calculated using the dietary intake data available in NHANES. Dietary intake information was obtained from two 24-hour dietary recall interviews. The first recall was administered in-person at the Medical Examination Center (MEC) by trained interviewers using USDA's Automated Multiple-Pass Method (AMPM). The second recall was administered via telephone interview, approximately 3 to 10 days after attending the MEC (MEC In-Person Dietary Interviewers Procedures Manual, 2008). For reasons of methodology, interpretation, and comparability with other dietary surveys[1], this study used only data from the in-person recall (day 1) to calculate the HEI-2010 and AHEI-2010 scores. The use of the first day recall is recommended for most statistical analyses

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[1] Personal communication with Dr. Joseph Goldman, who is a biostatistician at Food Surveys Research Group, Agricultural Research Service, USDA. 10300 Baltimore Ave. Bldg. 005, Room 102, BARC-West Beltsville, MD 20705.

because the two dietary recalls cannot be considered as independent of one another. Combining them would underestimate the within-person variation and complicate the interpretation of the results. Furthermore, the use of two different methods to collect data (in-person for the first vs. telephone for the second) could affect participants' responses and introduce bias. The varying length of time between recalls (3 to 10 days) may also introduce bias. Therefore, using the in-person (day 1) recall ensures consistency in dietary methodology and yields estimates that are most comparable with other dietary surveys. Additionally, this analysis was limited to dietary recall data reported to be complete and reliable by the National Center for Health Statistics staff (MEC In-Person Dietary Interviewers Procedures Manual, 2008).

Healthy Eating Index-2010 (HEI-2010)

The HEI-2010 was developed by the United States Department of Agriculture (USDA) Center for Nutrition Policy and Promotion (CNPP) as a tool to measure compliance with the 2010 Dietary Guidelines for Americans. In addition, the HEI-2010 is used to monitor the quality of American diets and examine relationships between diet and health-related outcomes (P. M. Guenther et al., 2014). The HEI-2010 is made up of 12 components: 9 components assess dietary adequacy (foods that people should consume more of) and 3 components assess moderation (foods that people should consume less of). For the moderation components, higher scores are associated with lower levels of consumption. The 9 adequacy components are: Total Fruit, Whole Fruit (forms other than juice), Total Vegetables, Greens and Beans (dark-green vegetables and beans and peas), Whole Grains, Dairy (all milk products and soy beverages), Total Protein Foods, Seafood and Plant Proteins, and Fatty Acids (ratio of poly- and monounsaturated fat to saturated fat). The 3 moderation components are: Refined Grains, Sodium, and Empty Calories (all calories from solid fats & added sugars plus calories from alcohol beyond a moderate level) (P. M. Guenther et al., 2014). Seven components were each scored on a 0 to 5 scale and the five other components are each scored on a 0 to 10 scale, with intermediate values scored proportionally. The component scores were summed to obtain total HEI-2010 scores. Higher scores indicate a higher quality diet. Scores above 80 indicate a "good" diet, while scores below 51 indicate a "poor" diet. An HEI score between 51 and 80 is considered as "needing dietary improvement" (Patricia M Guenther et al., 2014). The Food Pattern Equivalents Database (FPED) was used to construct and calculate the HEI-2010 scores and the SAS code was downloaded from the USDA CNPP website (United States Department of Agriculture. Center for Nutrition Policy and Promotion., 2013).

Alternate Healthy Eating Index-2010 (AHEI-2010)

The AHEI-2010 was developed by researchers at the Harvard School of Public Health as an alternative measure of diet quality to identify future risk of diet-related chronic disease (C. W. Leung et al., 2012; Leung, Epel, Ritchie, Crawford, & Laraia, 2014; Wang et al., 2014). The AHEI was originally developed on the basis of the Food Frequency Questionnaire (FFQ). However, previous studies have used 24-hour dietary recalls to compute the AHEI-2010 scores from NHANES (C. W. Leung et al., 2012; Cindy W. Leung, Epel, Ritchie, Crawford, & Laraia, 2014; Wang et al., 2014). In general, the continuous NHANES (since 1999) only collect 24-hour recalls to assess dietary intake. For that reason, this study applied the methodology used

Wang and colleagues (2014) to calculate the AHEI-2010 scores since the 2007-2010 NHANES only contain 24-hour recalls for measuring dietary intake. The AHEI-2010 consists of 11 components: six components for which higher intakes are better [vegetables, fruit, whole grains, nuts and legumes, long chain omega-3 fatty acids (FA) that include docosahexaenoic acid and eicosapentaenoic acid, and Polyunsaturated Fatty Acids (PUFA)], one component for which moderate intake is better (alcohol), and four components that must be limited or avoided [sugar sweetened drinks and fruit juice, red and processed meat, trans fats, and sodium]. Each component was scored on a 0 to 10 point scale. The component scores were summed to obtain the total AHEI-2010 score, which can range from 0 (non-adherence) to 110 (perfect adherence). Higher scores represent healthier diets (A. M. Bernstein, Bloom, Rosner, Franz, & Willett, 2010; Varraso et al., 2015). However, this study constructed a modified AHEI-2010 score by excluding the trans fat component because trans fat is unavailable in the NHANES dietary files (C. W. Leung et al., 2012). Therefore, the maximum total AHEI-2010 score was rescaled from 110 points to 100 points (excluding trans fat) similar to the approach used in a previous study (C. W. Leung et al., 2012). The NHANES individual foods file was used to estimate servings of food to construct the AHEI-2010 food groups. The USDA food-coding scheme was used as a reference to categorize each individual food (represented by food codes) into groups (Ahuja et al., 2012). In addition, this study used the supplementary table provided by Wang and colleagues (2014) to identify the foods and beverages that correspond to each AHEI food component (i.e., sugar-sweetened beverages, nuts and legumes, red and/or processed meats) (C. W.

Leung et al., 2012; Cindy W. Leung, Epel, Ritchie, Crawford, & Laraia, 2014; Wang et al., 2014). The NHANES total nutrients file was used to estimate the intake of nutrients (i.e., PUFA, long-chain omega-3 fats, sodium) as components of the AHEI. After creating the AHEI food and nutrient components, a SAS code was constructed to calculate the AHEI-2010 scores.

Diabetes Status

T2DM status was the main outcome variable. The definition of T2DM was on the calculation of diagnosed and undiagnosed diabetes. Diagnosed diabetics were defined as those who answered "yes" to the question: "Other than during pregnancy, have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?" or who reported taking diabetes medication (i.e., Metformin) during the interview. Undiagnosed diabetics were defined as individuals with a fasting plasma glucose (FPG) $\geq$ 126 mg/dL, or HbA1c $\geq$ 6.5% who did not report a previous diabetes diagnosis during the interview. The sum of individuals with diagnosed and undiagnosed diabetes was computed to obtain the total number of adults with T2DM. Individuals diagnosed with diabetes prior to age 30 and continuous users of insulin were excluded to minimize the number of respondents with type 1 diabetes (T1DM) (Jarvandi et al., 2012; Demmer, Zuk, Rosenbaum, & Desvarieux, 2013). Pre-diabetics were defined as those with FPG of 100 – 125 mg/dL, HbA1c 5.7 – 6.4 %, or an answer of "yes" to the question "Have you ever been told by a doctor or other health professional that you have prediabetes?" or an answer of "borderline" to the question "Other than during pregnancy, have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?" Participants who did not meet the definition for T2DM or pre-diabetes (FPG < 100 mg/dL and HbA1c < 5.7%) were categorized as non-diabetic (William T. Cefalu, MD et al., 2017).

Demographic and Health Characteristics

Demographic and health information were obtained from the household interview component of NHANES. Self-reported sociodemographic characteristics are explored as potential covariates. These included age, sex, ethnicity, education level, marital status, poverty-to-income ratio, adult food security category, and family size. Additional health and lifestyle factors that were considered to potentially influence diabetes included smoking status, and physical activity, self-reported health, and health insurance coverage.

Health Markers

Several health markers were evaluated in the analysis. These include Body Mass Index (BMI), Waist Circumference (WC), triglycerides (TG), total cholesterol, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), TG/HDL-C ratio, C-reactive protein (CRP), insulin, systolic and diastolic blood pressures, and presence of comorbidities (comorbidity score). Measurements of height, weight, WC, and blood pressure (systolic and diastolic) were obtained in the MEC according to the NHANES protocols (MEC Interviewers Procedures Manual, 2009). BMI is calculated as body weight (in kilograms) divided by height (in meters) squared (Anthropometry Procedures Manual, 2009). Data on physiological markers was obtained from laboratory testing of participants who attended the MEC; participants were randomly assigned to morning or afternoon sessions (Laboratory

Procedures Manual, 2009). Venous blood was drawn to obtain lipid profile, CRP, insulin, and plasma glucose from fasting and non-fasting participants. Morning session participants had to fast for ≥ 8.5 hours and were tested for LDL-C, triglycerides, insulin, and blood glucose. Afternoon session participants did not fast, and were tested only for total cholesterol and HDL-C. Therefore, not all participants have values for all laboratory tests (Laboratory Procedures Manual, 2009). This study limited the analysis to participants who provided fasting measures (i.e., serum LDL-C, insulin, and plasma glucose) by applying the nonzero fasting subsample weights (Laboratory Procedures Manual, 2009; National Center for Health Statistics (U.S.), 2013a). Blood pressure testing was also performed at the MEC. The majority of participants had four readings each for systolic and diastolic blood pressures (Health Tech/Blood Pressure Manual, 2009). This study only used the first three readings to calculate the average blood pressure (systolic and diastolic). The fourth reading was not included because it had a large number of missing values. Presence of comorbidities was evaluated using the medical conditions questionnaire. A comorbidity score (range: 0–15) was computed based on the sum of self-reported physician-diagnosed comorbidities that tend to co-occur with T2DM (Loprinzi, 2015; Lin et al., 2015; Weaver, Ashby, & Kamimura, 2017). These comorbidities included overweight, high blood pressure, high cholesterol, heart attack, coronary heart disease, congestive heart failure, angina, stroke, thyroid problems, liver conditions, asthma, arthritis, chronic bronchitis, emphysema, and cancer/malignancy (Lin et al., 2015; Weaver, Ashby, & Kamimura, 2017).

Statistical Analysis

Data were analyzed using SAS 9.3 (SAS Institute Inc, Cary, NC) and STATA 14.1 (StataCorp, College Station, TX) to adjust the variances for the complex sample design of NHANES. To account for the complex multistage design, the 4-year fasting sample weight was used throughout the analysis in order to include participants who are already diagnosed with diabetes and taking insulin or oral medications. The fasting subsample weights (WTSAF2YR) for both cycles were used to construct a 4-year fasting weight as suggested in the NHANES analytic guidelines (National Center for Health Statistics (U.S.), 2013a).

SAS (release 9.3) was the primary tool used in data preparation, cleaning, and analysis. The design-adjusted Rao-Scott chi-square test (PROC SURVEYFREQ) was used to compare participants' sociodemographic characteristics as well as consumption of HEI-2010 and AHEI-2010 food/nutrient groups by diabetes status. Linear regression (PROC SURVEYREG) was used to determine differences in total and sub-component HEI-2010 and AHEI-2010 scores across diabetes status (nondiabetes, prediabetes, diabetes) by calculating the Least-square means (LSMs). Least-square means (and the standard errors of the LSMs) were also calculated to determine differences in health markers across diabetes status and quartiles of total HEI-2010 and AHEI-2010 scores. For ease of presentation of the data, non-transformed LSMs were presented with p-values associated with transformed analyses. The covariates used for the LSMs were sex, ethnicity, age, poverty-to-income ratio, physical activity, and energy intake. Bonferroni correction for multiple comparisons (0.05/number of variables) was applied to obtain the effective p-values for the models. Binary logistic regression (PROC SURVEYLOGISTIC) was used to obtain predicted probabilities, which were then used to create a classification table showing the percentage of individuals correctly classified as to diabetes status based on each model specification. A cut-off of 0.5 was used to determine the predicted probability of T2DM. A predicted probability of 0.5 or greater indicated having T2DM and less than 0.5 indicated not having T2DM. Several models were developed using various predictors (including dietary quality, sociodemographics, health markers and lifestyle behaviors) with different specifications of diabetes status being categorized as a dichotomous outcome variable. Prediabetes is a risk factor for T2DM. Many people with prediabetes will eventually develop T2DM if interventions are not started early. Therefore, T2DM status was dichotomized by collapsing prediabetes with diabetes as the event and nondiabetes as the nonevent to determine whether or not the disease has occurred. All analyses had statistical significance set at $p < 0.05$.

STATA (release 14.1) software was used to perform multinomial logistic regression (svy: mlogit) to examine the association between dietary quality (using total HEI-2010 and AHEI-2010 scores) and diabetes status. T2DM status was used as a nominal outcome variable with three levels: nondiabetes, prediabetes, and diabetes. This categorization of T2DM status was specified in order to observe differences in the association of the HEI-2010 and AHEI-2010 scores among these subgroups. Separate models were specified for total HEI-2010 and AHEI-2010 scores after adjusting for sociodemographics, health markers, and lifestyle behaviors. The

STATA command (mlogitgof) was executed after fitting the models to assess the goodness-of-fit for multinomial logit modeling (Fagerland & Hosmer, 2013).

Multivariate Models

Theoretical models of Dietary Quality and Diabetes

This study attempted to produce a model to explain the relationship between dietary quality (using total HEI-2010 and AHEI-2010 scores) and diabetes status including covariates on a theoretical basis rather than primarily relying on statistical significance. The covariates were selected based on previous studies of the association between dietary quality and T2DM. Covariates such as age, sex, ethnicity, smoking status, physical activity, WC, and energy intake appear consistently in regression models of previous studies (Teresa T. Fung et al., 2007; Lawrence De Koning et al., 2011; Qiao et al., 2014; Jacobs et al., 2015). For that reason, predictors such as smoking status and physical activity were included in the models regardless of their statistical significance. Additional covariates such as self-reported health, poverty-to-income ratio, and presence of comorbidities were included since they had significant or marginally significant relationships with the probability of having diabetes (and prediabetes). Energy intake was included as a covariate for the AHEI-2010 because it is based on absolute amount of intake whereas the HEI-2010 already adjusts for energy intake using the density-based approach (amounts consumed per 1,000 calories). In addition, several interaction terms were tested: these included WC × total HEI-2010 score, WC × total AHEI-2010 score, age × physical activity, physical activity × total HEI-2010 score, and physical activity × total AHEI-2010 score. These two-way interaction terms were not statistically significant and therefore were dropped from the models.

Classification of Diabetes Status using Predicted Probabilities

The next step was to specify models that represented different types of factors (including total and sub-component HEI-2010 and AHEI-2010 scores, sociodemographics, health markers, and health behaviors) and examine how well each model performed in correctly classifying participants by diabetes status. Sixteen binary logistic regression models were constructed to produce the predicted probabilities. For instance, as part of the model specification, this study sought to assess the predictive power of sociodemographics, health markers, and dietary quality individually and together (using HEI-210 and AHEI-2010 scores) by determining the percentage of the sample correctly classified as to diabetes status based on each of these factors. By identifying the contribution of these factors, this would provide a better guide to improve clinical practice in terms of prevention, treatment, and management of diabetes. Also, this study explored the predictive ability of the total and sub-component scores HEI-2010 and AHEI-2010 score in correctly classifying diabetes status. Only the sub-component scores for the HEI-2010 and AHEI-2010 that were significant in the bivariate analysis were included in the multivariate models ($p < 0.05$). For the HEI-2010, the sub-components included were total protein foods, refined grains, sodium, and empty calories. For the AHEI-2010, the sub-components included were sugar-sweetened beverages and fruit juice, red and/or processed meat, alcohol, and sodium. Knowing the predictive ability of these sub-components would provide more targeted dietary interventions for treating diabetes.

One of the major differences between the HEI-2010 and AHEI-2010 is the treatment of alcohol consumption. The HEI-2010 counts alcohol intake as part of empty calories (threshold exceeds moderate level more than 13 grams/1,000 kcal). However, the AHEI-2010 counts alcohol intake as a separate category where moderate drinking is a part of a healthful dietary pattern. The AHEI-2010 scoring methodology as reported by Wang et al. (2014) is non-linear and assigns higher scores to moderate alcohol drinkers than to nondrinkers (Wang et al., 2014). Moderate alcohol drinkers (Male: 0.5-2.0 drinks/day; Female: 0.5-1.5 drinks/day) received the maximum score of 10 points, while nondrinkers received 2.5 points. This method of scoring severely penalizes nondrinkers. Therefore, this study explored two alternative approaches to scoring nondrinkers: 1) a deduction of 2.5 points from the maximum instead of 7.5; or 2) no penalty. Nondrinkers received the maximum score of 10 points, and scores declined as alcohol consumption increased. Each of these approaches was used to create modified AHEI-2010 scores. These modified alcohol scores were used in the multivariate analysis to determine whether there was a difference in their predictive ability compared to the original scoring of alcohol (score of 2.5 points for nondrinkers).

Results

Characteristics of the participants

The NHANES 2007-2010 analytic sample included 4097 individuals ≥ 20 years of age. Data indicate that the majority of individuals were 20-39 years (about 35.1%) and 45-59 years (about 39.1%). Approximately half of the sample was female (about 51.4%) and the other half was male (about 48.6%). The majority of individuals were non-Hispanic Whites (about 70.8%), about one-third had a college education or better (about 30.2%), and the majority were currently married (about 65.1%). More than one-third (40.8%) of individuals were considered to have income above the poverty level (≥ 3.50). The majority of participants (about 81.1%) were classified as having "full" food security and almost half (about 48.2%) lived in households of 1-2 persons. In terms of lifestyle characteristics, more than half of individuals were nonsmokers (about 55.7%), and almost half of individuals (about 45.9%) did not meet recommended physical activity levels. The vast majority of individuals were covered by health insurance (about 82.1%), and self-reported their health as "very good" (about 31.9%) or "good" (about 33.8%). In terms of diabetes status, about 46.1% of the participants in the sample were classified as "prediabetic" and 12.5% are "diabetic" (**Table 11**).

Table 12 shows that the majority of sociodemographic characteristics were significantly associated with diabetes status ($p < 0.01$), with the exception of food security ($p > 0.05$). Individuals with prediabetes and diabetes were older, were more likely to be male, and reported themselves as currently married ($p < 0.01$). T2DM was strongly associated with educational level and other sociodemographics. The majority of diabetics reported having high school diploma (about 29.1%) and some college education (about 26.8%). Individuals with lower educational attainment were more likely to be diabetic than nondiabetic (i.e., about 25.1% vs. 12.9% with less than high school, respectively). Among ethnic minority groups, non-Hispanic blacks were more likely to become diabetic (about 15.7%). Nonsmokers were more likely to be diabetic than current and former smokers (about 49.5% vs. 13.5% vs. 36.9%, respectively).

For self-reported health, individuals who rated their health as "good" (about 36.9%) or "fair" (about 32.3%) were more likely to be diabetic. Similarly, prediabetes was strongly associated with sociodemographics. Individuals with higher educational attainment were more likely to be prediabetic than diabetic (i.e., 28.2% vs. 18.9% with college graduate or above education, respectively). Among ethnic minority groups, non-Hispanic blacks were more likely to be prediabetic (about 10.3%). Individuals with poverty-to-income ratio above 3.50 were more likely to become prediabetic (about 40.5%). Former smokers were more likely to be prediabetic than current smokers (about 27.9% vs. 19.2%, respectively). For self-reported health, individuals who rated their health as "very good" (about 31.9%) or "good" (about 37.1%) were more likely to be prediabetic. The majority of participants (including nondiabetics) in the sample did not engage in any physical activity. About 63.9% of diabetics and 47.2% of prediabetics were not physically active.

Consumption of HEI-2010 and AHEI-2010 food and nutrient groups in servings

Results show that for the HEI-2010 food/nutrient groups, the majority of participants in the sample reported inadequate consumption of total fruit, whole fruit, total vegetables, greens and beans, whole grains, and seafood and plant proteins. However, over half of the participants reported excessive consumption of refined grains (58.5%) and sodium (83.8%) (**Supplemental Table 1)**. For the AHEI-2010 food/nutrient groups, the majority of participants in the sample reported inadequate consumption of whole fruit, total vegetables, whole grains, nuts and legumes, and alcohol (**Supplemental Table 2**).

HEI-2010 food and nutrient groups by diabetes status

Table 13 shows significant differences in consumption of whole grains, dairy, seafood and plant proteins, refined grains, and empty calories across diabetes status categories ($p < 0.01$). To compare individuals meeting the criteria for consumption (in servings), nondiabetics were most likely to meet HEI-2010 criteria (as recommended by DGA 2010) for the adequacy components, including whole grains (19.6%), diary (54.8%), and seafood and plant proteins (43.8%). Diabetics were most likely to meet HEI-2010 criteria for the moderation components, including refined grains (12.7%) and empty calories (20.9%).

AHEI-2010 food and nutrient groups by diabetes status

Table 14 shows significant differences in consumption of sugar-sweetened beverages and fruit juice, red and/or processed meats, alcohol, and sodium across diabetes status groups ($p < 0.01$). To compare individuals meeting the criteria for consumption (in servings), diabetics were most likely to meet AHEI-2010 criteria (evidence-based recommendations) for sugar-sweetened beverages and fruit juice (28.9%). Nondiabetics were most likely to meet AHEI-2010 criteria for red and/or processed meats (45.2%) and alcohol (20.1%). There were significant differences in sodium consumption across diabetes status categories ($p < 0.05$). However, the AHEI-2010 scoring for sodium did not identify a specific threshold that individuals should not exceed compared to HEI-2010.

HEI-2010 and AHEI-2010 total and components scores

Results show that the mean total HEI-2010 score in the sample is 47.3 ± 0.4, which indicates the need for dietary improvement in the population. For the adequacy components, at least half of the participants were far from achieving the maximum score. Whole fruit had the lowest mean score followed by the mean scores for greens and beans and seafood and plant proteins. For the moderation components (reverse-scored), at least half of the participants had moderately higher mean scores for refined grains and empty calories, which means they had lower intake of these food groups (**Supplemental Table 5)**.

Similarly, the mean total AHEI-2010 score in the sample was 38.2 ± 0.4, which indicates non-adherence to a healthful dietary pattern in the population. For the component scores, at least half of the participants were far from achieving the maximum scores. Nuts and legumes had the lowest mean score followed by the mean scores for long-chain omega-3 fats and total vegetables. For the components that were reverse-scored (a higher score corresponds to lower intake), red and/or processed meat had the highest mean score followed by the mean score for sodium and sugar-sweetened beverages (**Supplemental Table 6)**.

HEI-2010 total and components score by diabetes status

Table 15 shows the HEI-2010 components and total scores by diabetes status. The total HEI-2010 score was highest for individuals with diabetes (mean score = 48.8 ± 0.6). However, these differences across diabetes status were not statistically significant ($p > 0.05$). Interestingly, there were significant differences in some of the component scores across diabetes status including total protein foods, refined grains, sodium, and empty calories ($p < 0.01$). For the adequacy components, diabetics had the highest score (corresponding to highest intake) for total protein foods (mean score = 4.4 ± 0.06) compared to prediabetics and nondiabetics. For the moderation components, diabetics had the highest score (corresponding to lowest intake) for empty calories (mean score = 12.5 ± 0.3) compared to prediabetics and nondiabetics. However, prediabetics had the highest score for refined grains (mean score = 6.3 ± 0.1) and for sodium (mean score = 4.4 ± 0.07) compared to diabetics and nondiabetics ($p < 0.01$).

AHEI-2010 total and components score by diabetes status

Table 16 shows the AHEI-2010 components and total scores by diabetes status. The total AHEI-2010 score was highest for diabetics (mean score = 39.1 ± 0.7). However, these differences across diabetes status were not statistically significant ($p > 0.05$). Interestingly, there were significant differences in some of the component scores across diabetes status including sugar-sweetened beverages and fruit juice, red and/or processed meats, alcohol, and sodium ($p < 0.01$). Diabetics had the highest score (corresponding to lowest intake) for sugar-sweetened beverages and fruit juice (mean score = 3.3 ± 0.2) and sodium (mean score = 6.1 ± 0.2) compared to prediabetics and nondiabetics. In addition, diabetics had the lowest score (corresponding to highest intake) for red and/or processed meat (mean score = 5.9 ± 0.2). Diabetics had the lowest score (corresponding to lowest intake) for alcohol (mean score = 2.8 ± 0.07) compared to prediabetics and nondiabetics.

Health Markers and HEI-2010 and AHEI-2010 scores

There was a significant linear trend between the quartiles of total HEI-2010 and AHEI-2010 scores and health markers (**Tables 17 and 18**). With increasing HEI-2010 and AHEI-2010 scores, there was a significant linear decrease in BMI, WC, triglycerides, TG/HDL cholesterol ratio, and presence of comorbidities ($p < 0.01$). Also, there was a significant linear increase in HDL cholesterol across quartiles of HEI-2010 and AHEI-2010 scores ($p < 0.01$) (**Tables 17 and 18**). In addition, the mean concentration of LDL cholesterol and mean systolic blood pressure significantly decreased with increased total AHEI-2010 score ($p = 0.0406$ and $p = 0.0109$, respectively) (**Table 18)**.

Health Markers and Diabetes Status

Table 19 shows the covariate-adjusted health markers of participants by diabetes status. The majority of health markers were significantly associated with diabetes status after adjusting for age, sex, ethnicity, smoking status, poverty-to-income ratio, physical activity level, and energy intake ($p < 0.001$). Compared with prediabetics and nondiabetics, diabetics had significantly higher mean BMI, WC, triglycerides, TG/HDL cholesterol ratio, insulin, mean systolic blood pressure, and total co-morbidities ($p < 0.001$). However, prediabetics had significantly higher mean total cholesterol and LDL cholesterol ($p < 0.001$) compared to nondiabetics (and diabetics). There were no significant differences in C-reactive protein across diabetes status groups ($P > 0.05$).

Association between HEI-2010 and AHEI-2010 scores and Diabetes Status

Results from the multinomial logistic models show that the odds ratios for total HEI-2010 and AHEI-2010 scores is equal to 1, which means that they have no predictive value for diabetes status. Contrary to the study hypothesis, the models suggest that the AHEI-2010 does not seem to perform better than the HEI-2010 in terms of its association with T2DM. However, the overall design-adjusted Wald test shows that the predictors most strongly associated with diabetes (and prediabetes) include age, sex, ethnicity, self-reported health, WC, and presence of comorbidities ($p < 0.05$). Specifically, both models suggest that males (females as the reference group) had significantly higher odds of being prediabetic or diabetic compared to nondiabetic ($p < 0.001$). Using non-Hispanic whites as the reference group, Mexican Americans significantly had the highest odds of being pre-diabetic and diabetic compared to nondiabetic ($p < 0.001$). In addition, participants who self-rated their health as "fair" or "poor" had significantly higher odds of being diabetic than participants who self-rated their health as "very good" or "good." For continuous variables, both models show that a one-unit increase in age and a one-unit increase in total comorbidity score were significantly associated with higher relative odds of being diabetic compared to nondiabetic ($p < 0.001$). Results from the goodness-of-fit had p-value > 0.05, which indicates that the data fits the model well (HEI-2010 model: p = 0.396; AHEI-2010 model: p = 0.590) (**Tables 20 and 21**).

Table 22 shows the classification of diabetes status using predicted probabilities. Results show that the model with only sociodemographic characteristics (Model 1) classified the largest percentage of the sample correctly with respect to diabetes status (about 65.1% correct classification) and lower percentages of false positive (about 24.2%) and false negative (about 10.7%). The model with only the health markers (Model 2) also classified the majority of respondents correctly (about 63.3% correct classification). However, the models with only the HEI-2010 and AHEI-2010 scores (total and sub-components) only classified about 52% of the sample correctly (Model 5, 6, 7, 11, 12, and 13). This means that dietary quality alone (using both total and sub-component HEI-2010 and AHEI-2010 scores) is not a good predictor of diabetes status. Interestingly, the model with dietary quality and other health behaviors (i.e., smoking status, and physical activity) increased predictive ability slightly, with about 54% of the sample correctly classified diabetes (Model 3 and 4). The AHEI-2010 score did not perform any better than the HEI-2010 score in terms of predicting or explaining diabetes.

Discussion

The results of present study were not consistent with the results of earlier cross-sectional studies that compared the HEI and AHEI scores in relation to T2DM. The main result of this study was that the AHEI-2010 did not to perform better than the HEI-2010 in terms of its relationship with diabetes status. This was in contrast with the results of a cross-sectional study by Huffman and colleagues that examined the relationship between the HEI-2005 and the AHEI-2005 scores and 10-year predicted CHD risk in Cuban Americans with and without T2DM (Huffman, Zarini, Mcnamara, & Nagarajan, 2011). The authors performed hierarchical linear regression models and used diabetes status as one of the covariates to predict CHD risk. They found that for every unit increase in the AHEI-2005 score, there was a 0.24-point reduction in the 10-year CHD risk score among participants with T2DM. However, they did not find a significant association between HEI-2005 score and CHD risk among participants without T2DM (Huffman, Zarini, et al., 2011). Another similar study by Huffman and colleagues assessed the relationships of the HEI-2005 and AHEI-2005 among Haitian Americans (HA) and African Americans (AA) with and without T2DM (Huffman, De La Cera, et al., 2011). The authors used general linear models to examine diabetes status (T2DM, no T2DM) as the independent variable and the HEI-2005 and AHEI-2005 as the dependent variables. They found that the HEI-2005 score was significantly higher among diabetics (T2DM) compared to nondiabetics after controlling for age, gender, ethnicity, and education. However, the difference in AHEI-2005 scores among diabetics and nondiabetics was not significant (Huffman, De La Cera, et al., 2011).

There are several possible ways to interpret the apparent inconsistencies between the results of these earlier cross-sectional studies and the present study. First, this study used total the HEI and AHEI scores based on the 2010 dietary guidelines and evidence-based recommendations rather than the 2005 guidelines. Second, this study and the earlier studies focused on different outcomes. This study used logistic regression to examine diabetes status as the dependent variable and the HEI-2010 and AHEI-2010 scores as the independent variables. Third, this study used differences in the HEI-2010 and AHEI-2010 by diabetes status and did not further assess the health risks of diabetics. The AHEI-2010 is based on current knowledge of dietary factors that mainly contribute to CVD (i.e., myocardial infarction, angina, stroke, transient ischemic attack, and revascularization) (McCullough et al., 2002; Stephanie E Chiuve et al., 2012). T2DM is associated with increased risk of CVD and is an independent risk factor for CHD (Huffman, Zarini, et al., 2011; Wu et al., 2016). This may indicate that the AHEI-2010 would be more applicable among diabetic individuals with pre-existing CVD conditions.

Some prospective studies have found significant inverse associations between the HEI-2010 and AHEI-2010 scores and risk of T2DM (McCullough et al., 2002;

Teresa T. Fung, Mccullough, Dam, & Hu, 2007; Lawrence De Koning et al., 2011; Stephanie E Chiuve et al., 2012; Qiao et al., 2014; Jacobs et al., 2015). The association was found to be stronger for the AHEI-2010 than for the HEI-2010 in relation to T2DM. These studies found that greater adherence to the AHEI-2010 dietary pattern was associated with 23-36% risk reduction in T2DM (Teresa T. Fung, Mccullough, Dam, & Hu, 2007; Lawrence De Koning et al., 2011). However, the present study did not confirm earlier findings of significant association of the HEI-2010 nor the AHEI-2010 in relation to T2DM. A possible reason could be differences in how diet was assessed (i.e., 24-hour recall vs. FFQ) to calculate the HEI-2010 and AHEI-2010 scores. This study used a single 24-hour dietary recall to calculate the HEI-2010 and AHEI-2010 scores. Therefore, measuring dietary quality based on one or even two days of intake may not serve as a good predictor of chronic disease (i.e., diabetes) that takes years to develop. However, assessing dietary quality based on habitual or usual intake may serve as a better predictor. It might be possible to find a significant relationship with diabetes status if the HEI-2010 and AHEI-2010 scores were calculated based on the FFQ since it is designed to evaluate usual dietary intake. NHANES uses the 24-hour recall rather than the FFQ to capture food intake. This study attempted to replicate the methods from previous studies that used the 24-hour dietary recalls to compute the HEI-2010 and AHEI-2010 scores from NHANES (C. W. Leung et al., 2012; Cindy W. Leung, Epel, Ritchie, Crawford, & Laraia, 2014; Wang et al., 2014; Nicklas et al., 2014; Agarwal, Fulgoni, & Berg, 2015). NHANES is currently considered to be the best source of valid and reliable data on dietary intake.

Additionally, there is inconsistency in modeling decisions and specification when examining the association between diet and disease (i.e., T2DM). In epidemiology, some studies attempt to specify models that are parsimonious while other studies control for a large number of variables. When variables are intercorrelated (as socioeconomic and demographic characteristics often are), this can lead to multicollinearity if multiple variables are entered into the model. In the present study, the AHEI-2010 score did not provide any improvement over the HEI-2010 in terms of predicting or explaining T2DM (and prediabetes) after adjusting for potential covariates. A possible reason is the interrelationships among the covariates that are included in the multivariate models (i.e., health markers and lifestyle characteristics). For instance, smoking status was significantly associated with physical activity, body size (as measured by WC), and presence of comorbidities (as measured by total comorbidity score). Also, dietary quality (using the total HEI-2010 and AHEI-2010 scores) seemed to be related to the other predictors, which makes it difficult to construct a definitive model that determines the effect of dietary quality alone in relation to diabetes status. The predicted probabilities suggest that the models specified for only the HEI-2010 and AHEI-2010 scores (total and sub-components) classified the least percentage of the sample correctly (about 52% correct classification) with respect to diabetes status compared to the other factors (i.e., sociodemographics, health markers). Classification of diabetes status did not improve when adding more variables to the models possibly because of the interrelationships among the variables. In addition, the percentage of false negative (i.e., when results indicate a person does not have the disease but actually does have the disease) increases when adding more variables to the models. Therefore, the true predictive value of dietary quality (using HEI-2010 and AHEI-2010) is not observed in relation to diabetes status. Diet is a complex exposure variable. There are numerous factors that influence diet, which in turn can have an impact on disease development (i.e., T2DM). This calls for more consistency in model specification, and maybe alternative approaches, to examine the relationship between diet and disease.

Both the HEI-2010 and AHEI-2010 scores indicated that U.S. adults need improvement in dietary pattern (mean total HEI-2010 score = 47.3 ± 0.4; mean total AHEI-2010 score = 38.2 ± 0.4). Diabetics appeared to have more healthful dietary patterns (as shown by higher total scores) compared to prediabetics and nondiabetics. It is likely that diabetics are receiving more regular health care than other groups. Diabetics (diagnosed) with regular doctor visits are more closely followed and receive nutrition counseling and are taught self-management skills to improve their health.

The HEI-2010 and AHEI-2010 individual food and nutrient component scores can provide more insight about dietary quality, which would allow more flexibility to tailor dietary intervention among individuals with diabetes (T2DM). This study found significant differences in the sub-component HEI-2010 and AHEI-2010 scores across diabetes status. Some of the food and nutrient groups in the HEI-2010 and AHEI-2010 were aligned with one another in terms of protein and carbohydrate intake. For example, diabetics had the highest intake of total protein foods (corresponding to highest score) in the HEI-2010, which was consistent with their having the highest intake of red and/or processed meat (corresponding to lowest score) in the AHEI-

2010. Similarly, diabetics had the lowest intake of empty calories (corresponding to highest score) in the HEI-2010, which was consistent with their having the lowest intakes of alcohol (corresponding to lowest score) and sugar-sweetened beverages and fruit juice (corresponding to highest score) in the AHEI-2010. It seems that diabetics are consuming food groups that are higher in protein and lower in carbohydrates and fats than other groups.

A possible explanation is that individuals with T2DM receive regular care and are counseled to avoid consuming excessive carbohydrates. As part of diabetes self-management, they are being taught to monitor their carbohydrate intake through carbohydrate counting, or "carb counting," which is a meal planning technique for managing blood glucose levels in balance with medication or insulin intake and physical activity (William T. Cefalu, MD et al., 2017). In addition, diabetics are more likely to consume a low-fat diet as recommended by the American Diabetes Association (ADA) and American Heart Association (William T. Cefalu, MD et al., 2017; Sacks et al., 2017). As a result, the decrease in carbohydrate or fat intakes involves a compensatory increase in protein intake.

High protein diets such as the Atkins, South Beach, and Paleo diets are recommended weight reduction methods because protein reduces hunger, improves satiety, and increases thermogenesis (Hamdy & Horton, 2011). Also, when combined with a reduction in calories, high protein diets enhance weight reduction while maintaining lean muscle mass (Hamdy & Horton, 2011). Several studies have shown the benefits of a modest increase in dietary protein intake among diabetic individuals with normal renal function (Parker, Noaks, Luscombe, & Clifton, 2002; Brinkworth, Noakes, Parker, Foster, & Clifton, 2004; O., 2008). Higher dietary protein consumption has a favorable effect on CVD risk factors among individuals with T2DM. It is associated with reduction in HbA1c, total serum cholesterol, LDL cholesterol, triglycerides, blood pressure, and C-reactive protein. It is also associated with an increase in HDL cholesterol (Parker et al., 2002; Brinkworth et al., 2004; O., 2008). In clinical practice, overweight and obese patients with T2DM and normal renal function are often advised to increase absolute protein intake to 1.5–2 g/kg of body weight (or 20–30% of total caloric intake) during weight reduction (Hamdy & Horton, 2011). However, the ADA recommends that dietary protein not exceed between 1 and 1.5 g/kg of body weight (or 15-20% of total caloric intake) (William T. Cefalu, MD et al., 2017). Despite the potential health benefits, high protein intake may have adverse long-term effects on renal function in individuals with diabetes (as well as in healthy individuals).

The present study demonstrated that diabetics (T2DM) consumed less sugar and alcohol compared to prediabetics and nondiabetics. The HEI-2010 and AHEI-2010 differ in how they assess the intakes of sugar and alcohol in the diet. In HEI-2010, sugar and alcohol intake were summed and counted as empty calories. Empty calories are composed of all calories from solid fats, added sugars, and alcohol intake beyond a moderate level (more than 13 g /1,000 calories). In the AHEI-2010, sugar and alcohol are considered to be separate categories. Additionally, AHEI-2010 considers moderate alcohol intake (Male: 0.5-2.0 drinks/day; Female: 0.5-1.5 drinks/day) as part of a healthful dietary pattern. This means that individuals with moderate alcohol intake received higher scores than non-drinkers (10 points versus

2.5 points). This method of scoring severely penalized nondrinkers, especially for diabetics. In this sample, the percentage of individuals with alcohol component scores above 2.5 points (drinkers) was approximately 7.7% for nondiabetics, 7.9% for prediabetics, and 1.0% for diabetics. This is likely to be due to the nutrition education and counseling that is typically provided to diagnosed diabetics. As part of diabetes self-management, the ADA recommends that individuals with diabetes (both type 1 and type 2) reduce or minimize alcohol consumption (William T. Cefalu, MD et al., 2017), because alcohol intake (especially on an empty stomach) lowers blood glucose and causes hypoglycemia. In addition, many alcoholic beverages contain added sugars, which can lead to excess calories and elevated triglycerides, increasing the risk of heart disease (William T. Cefalu, MD et al., 2017). In this sample, diabetics seemed to minimize alcohol or not drink it at all, which is consistent with diabetic self-management. This suggests that the HEI-2010 may be a better tool for assessing diet quality than the AHEI-2010 for individuals with T2DM.

Despite the differences in construction of these indices to assess diet, both the HEI-2010 and AHEI-2010 have similar components of a healthful dietary pattern. Overall, the pillars of a healthy diet include higher intakes of fruits, vegetables, whole grains, nuts, legumes, unsaturated fats (i.e., PUFA), and lower intakes of sodium, sugar (i.e., sugar-sweetened beverages) and red and processed meats (Cespedes et al., 2016). Currently, the DGA 2015 does not recommend adherence to a single diet plan to achieve healthy eating patterns, but recommends instead that individuals consume specific food groups that are healthful (USDA and DHHS, n.d.). Similarly, the ADA recommends that individuals with diabetes consume from various food groups that are high in fiber (i.e., whole grains, vegetables) and avoid foods and/or beverages that contain added sugars to meet metabolic goals such as glucose, HbA1c, lipid levels, and blood pressure (William T. Cefalu, MD et al., 2017).

Strengths and Limitations

Strengths of this study include the use of a large, nationally representative sample of U.S. adults with reliable estimates of dietary intake. Therefore, the findings are generalizable and have implications for the development of effective policies to improve health and/or disease outcomes. NHANES is the only national survey that currently provides complete dietary intake through utilizing the AMPM to screen 24-hour dietary recalls that are valid and reliable. NHANES has a long history of collecting nutrition data (since the 1960s) and continues to incorporate improvements to refine their dietary methodology.

However, this study also has some limitations: First, NHANES is a cross-sectional study design and therefore, the results cannot support causal inferences about the relationships between HEI-2010 and AHEI-2010 and diabetes status. Second, this study used a single 24-hour dietary recall to calculate the HEI-2010 and AHEI-2010 scores, which may not reflect individuals' habitual or usual intake. In addition, the 24-hour recall may be subject to measurement error because it relies on participants' ability to recall and accurately self-report dietary intake, which may lead to under- or over- reporting. Lastly, NHANES does not explicitly collect information on the type of diabetes (i.e., T1DM or gestational), which may lead to misclassification. However, this study used the available information in NHANES to construct a diabetes classification variable based on using a combination of self-reported and laboratory measured attributes to minimize misclassification.

Conclusion

In conclusion, HEI-2010 and AHEI-2010 were used as predictors of T2DM, and neither was significant, either alone or in combination with sociodemographic characteristics, health markers, and lifestyle behaviors. However, there were some significant differences in the means of the sub-component HEI-2010 and AHEI-2010 scores by diabetes status. In addition, there were significant positive relationships between the HEI-2010 and AHEI-2010 scores and health markers. Individuals with higher total HEI-2010 and AHEI-2010 scores had better health marker values compared to those with lower diet quality scores. Although total HEI-2010 and AHEI-2010 were not significant predictors of T2DM as expected, the role of diet should not be dismissed as a potential factor in the development of T2DM. There are factors that point to a role of diet in the development of T2DM: the significant differences in means of health markers across HEI-2010 and AHEI-2010 scores, and the significant differences in means of health markers (i.e., BMI, WC) by diabetes status. These findings indicate that diet has some influence on T2DM development, leading to the conclusion that better tools are needed to assess dietary intake in diabetics and to better understand the role of diet in T2DM risk.

The main finding of the present study is that diet alone did not have strong predictive ability with respect to T2DM. Neither the HEI-2010 nor the AHEI-2010 performed better than sociodemographics alone as predictors of T2DM. Some sociodemographic characteristics are likely to be associated with genetic differences. This study was not able to assess the impact of genetics, but there has been some recent research investigating the role of genetic factors in the development of T2DM, but this area of inquiry is still in its early stages (Lyssenko & Laakso, 2013; Läll, Mägi, Morris, Metspalu, & Fischer, 2017). In addition, the HEI-2010 and AHEI-2010 were not specifically designed as tools to assess dietary quality in diabetics. Future research is needed to develop an index based on relevant dietary components that contribute to T2DM. This will provide better utility for dietary assessment in diabetics in clinical and community settings.

Table 11. Characteristics of the study sample (Age ≥ 20, N = 4097)

Characteristic	(n)	*n* (%)
Age (in years)	4097	
20 - 39		1231 (35.1)
40 – 59		1395 (39.1)
60 – 79		1211 (21.4)
80+		260 (4.4)
Sex	4097	
Male		1946 (48.6)
Female		2151 (51.4)
Race/Ethnicity	4097	
Mexican American		739 (8.0)
Non-Hispanic White		2027 (70.8)
Non-Hispanic Black		699 (10.6)
Other		632 (10.6)
Education Level	4091	
Less than high school		1119 (17.4)
High School diploma		965 (23.5)
Some College education		1113 (28.8)
College Graduate or Above		894 (30.2)
[a]**Marital Status**	4096	
Current Married		2508 (65.1)
Former Married		946 (17.9)
Never Married		642 (17.0)
Smoking Status	4097	
Nonsmoker		2259 (55.7)
Current smoker		773 (18.4)
Former smoker		1065 (25.9)
[b]**Physical Activity**	4097	
None		2193 (45.9)
Insufficient		620 (17.3)
Sufficient		1284 (36.8)
Poverty-to-Income Ratio	4097	
<1.30		1478 (24.6)
1.30-3.49		1459 (34.6)
≥3.50		1160 (40.8)
Number of people in household	4097	
1-2		1867 (48.2)
3-4		1399 (35.7)
5-6		591 (12.6)
7+		240 (3.5)
Self-Reported Health	4096	
Excellent		539 (16.9)
Very Good		1094 (31.9)
Good		1453 (33.8)
Fair		814 (14.2)
Poor		196 (3.1)
Covered by Health Insurance	4093	
Yes		3130 (82.1)
No		963 (17.9)
Adult Food Security Category	4065	
Full		2984 (81.1)

Marginal		419 (7.6)
Low		403 (7.1)
Very Low		259 (4.2)
Diabetes Status	4056	
Nondiabetic		1436 (41.4)
Prediabetic		1905 (46.1)
Diabetic		715 (12.5)

Values are proportions *n* (%) for categorical variables.
*Data source***:** Adults 20+ years of age participating in 2007-2010 NHANES.Analyses adjusted for complex survey design and using fasting subsample weights.
[a]Marital status was defined as current married/partner, former married (including widowed/divorced/separated), and never married.
[b]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans.

Table 12. Sociodemographic Characteristics of U.S. adults (Age ≥ 20 years) by Diabetes Status

Characteristic	(n)	[a]Diabetes Status						
		Nondiabetes (n = 1436)		**Prediabetes** (n = 1905)		**Diabetes** (n = 715)		***p* trend**
	4056	*n*	%	*N*	%	*n*	%	
Age								**<.0001**
20 - 39		731	53.2	448	26.7	34	5.1	
40 – 59		459	34.9	704	43.3	219	38.2	
60 – 79		199	9.9	614	24.9	388	46.5	
80+		47	1.9	139	5.1	74	10.1	
Sex	4056							**<.0001**
Male		554	40.4	997	54.6	375	52.9	
Female		882	59.6	908	45.4	340	47.1	
Race/Ethnicity	4056							**0.0049**
Mexican American		255	7.8	338	8.0	136	8.2	
Non-Hispanic White		720	71.2	978	72.0	309	65.1	
Non-Hispanic Black		221	9.5	310	10.3	163	15.7	
Other		240	11.4	279	9.7	107	10.9	
Education Level	4050							**<.0001**
Less than high school		302	12.9	536	19.1	263	25.1	
High School diploma		311	20.2	459	25.1	188	29.1	
Some College education		428	30.7	501	27.6	172	26.8	
College Graduate or Above		395	36.1	405	28.2	90	18.9	
Marital Status	4055							**<.0001**
Current Married		832	62.0	1217	68.1	439	65.2	
Former Married		253	13.4	462	19.3	218	26.9	
Never Married		351	24.6	226	12.5	57	7.9	
Smoking Status	4056							**<.0001**
Nonsmoker		876	60.6	1008	52.9	353	49.5	
Current smoker		282	18.9	375	19.2	108	13.5	
Former smoker		278	20.4	522	27.9	254	36.9	
[b]**Physical Activity**	4056							**<.0001**
None		654	38.6	1020	47.2	489	63.9	
Insufficient		230	17.2	293	18.0	94	15.5	
Sufficient		552	44.1	592	34.8	132	20.6	
Poverty-to-Income Ratio	4056							**<.0001**
<1.30		494	23.0	705	25.7	259	25.2	
1.30-3.49		498	32.9	649	33.8	300	43.6	
≥3.50		444	44.1	551	40.5	156	31.2	
Number of people in household	4056							**<.0001**
1-2		527	40.5	923	52.1	400	59.2	
3-4		549	40.1	625	33.6	214	29.3	
5-6		265	15.5	251	11.1	67	7.9	
7+		95	3.9	106	3.1	34	3.5	
Self-Reported Health	4055							**<.0001**
Excellent		280	23.3	224	14.1	32	6.0	
Very Good		457	37.4	535	31.9	97	15.6	
Good		481	29.2	719	37.1	242	36.9	

Fair		184	8.8	351	13.9	262	32.3	
Poor		34	1.4	75	3.0	82	9.2	
Covered by Health Insurance	4052							**0.0031**
Yes		1039	80.1	1455	82.1	604	88.1	
No		396	19.9	447	17.9	111	11.9	
Adult Food Security Category	4024							0.2948
Full		1045	82.3	1375	79.8	544	83.8	
Marginal		162	7.5	189	7.9	64	6.5	
Low		129	6.5	202	7.6	60	5.9	
Very Low		86	3.7	123	4.7	45	3.8	

Values are column percents *n* (%) for categorical variables by diabetes status. Statistical differences were assessed using design-based Rao-Scott F adjusted X^2 statistic.

Bolded values are significantly different $p < 0.01$.

[a]Diabetes status was defined from self-report of participants in the diabetes questionnaire and from the laboratory biomarkers using the cut-offs based on the 2014 Standards of Medical Care from the American Diabetes Association (ADA) for diabetes diagnosis.

[b]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans.

Table 13. Consumption (in servings) of HEI- 2010 Food and Nutrient groups in servings among U.S. adults (Age ≥ 20 years) by Diabetes Status

Food/Nutrient Group	Consumption *n* (%)			*p* trend
	Nondiabetes (n = 1436)	**Prediabetes** (n = 1905)	**Diabetes** (n = 715)	
Total fruit (cup eq.)				0.7491
Inadequate	409 (28.4)	531 (26.9)	204 (29.2)	
Intermediate	417 (29.7)	534 (29.9)	231 (31.6)	
Meeting Criteria	610 (41.9)	840 (43.0)	280 (39.2)	
Whole fruit (cup eq.)				0.4435
Inadequate	1072 (72.9)	1388 (71.9)	533 (72.7)	
Intermediate	177 (13.5)	214 (11.9)	81 (12.9)	
Meeting Criteria	187 (13.6)	303 (16.1)	101 (14.5)	
Total vegetables (cup eq.)				0.5785
Inadequate	62 (4.0)	99 (4.2)	30 (4.2)	
Intermediate	557 (38.0)	669 (34.3)	270 (35.5)	
Meeting Criteria	817 (57.9)	1137 (61.5)	415 (60.4)	
Greens and beans (cup eq.)				0.5426
Inadequate	932 (65.8)	1272 (68.6)	479 (67.7)	
Intermediate	135 (8.7)	141 (7.4)	54 (6.9)	
Meeting Criteria	369 (25.5)	492 (24.0)	182 (25.4)	
Whole grains (oz. eq.)				**0.0379**
Inadequate	680 (43.1)	952 (49.4)	320 (41.9)	
Intermediate	499 (37.3)	640 (33.5)	291 (41.7)	
Meeting Criteria	257 (19.6)	313 (17.1)	104 (16.4)	
Dairy (cup eq.)				**<.0001**
Inadequate	64 (3.9)	103 (4.7)	40 (4.3)	
Intermediate	650 (41.4)	966 (46.8)	407 (56.2)	
Meeting Criteria	722 (54.8)	836 (48.4)	268 (39.5)	
[a]**Fatty acids**				0.2587
Inadequate	150 (10.1)	222 (12.7)	75 (11.6)	
Intermediate	1011 (71.0)	1285 (68.2)	490 (68.5)	
Meeting Criteria	275 (18.9)	398 (19.0)	150 (19.9)	
Total protein foods (oz. eq.)				0.7266
Inadequate	18 (1.2)	27 (1.4)	8 (1.3)	
Intermediate	245 (15.5)	305 (14.4)	113 (12.6)	
Meeting Criteria	1173 (83.3)	1573 (84.2)	594 (86.2)	
Seafood and Plant proteins (oz. eq.)				**0.0460**
Inadequate	602 (38.9)	810 (40.9)	348 (47.3)	
Intermediate	261 (17.3)	364 (19.4)	115 (15.4)	
Meeting Criteria	573 (43.8)	731 (39.6)	252 (37.3)	
Refined grains (oz. eq.)				**0.0002**
Intermediate	430 (30.2)	567 (29.4)	259 (36.9)	
Meeting Criteria	137 (8.9)	230 (12.3)	92 (12.7)	
Excessive	869 (60.9)	1108 (58.3)	364 (50.4)	
[b]**Sodium (mg)**				0.2981
Intermediate	230 (12.9)	313 (12.8)	148 (16.2)	

Meeting Criteria	50 (3.0)	69 (2.8)	38 (4.2)	
Excessive	1156 (84.0)	1523 (84.5)	529 (79.6)	
Empty calories (%)				**0.0001**
Intermediate	1124 (80.2)	1492 (78.9)	510 (72.4)	
Meeting Criteria	204 (13.1)	259 (11.9)	159 (20.9)	
Excessive	108 (6.7)	154 (9.2)	46 (6.5)	

Values are proportions *n* (%) for categorical variables by diabetes status. Statistical differences of categorical variables were assessed using design-based Rao-Scott F adjusted X^2 statistic. Bolded values are significantly different $p < 0.05$.

Notes: Consumption by participants meeting the criteria is equivalent to having the full score; intermediate consumption is equivalent to having a partial score (calculated proportionately); inadequate (i.e., low to none) and excessive consumption are equivalent to having a score of zero. Inadequate consumption was reported for adequacy components; Excessive consumption was reported for the moderation components.

[a]Consumption was calculated as a ratio of the sum of mono- and poly- unsaturated fats to saturated fats.

[b]Sodium consumption was reported using the density-based approach (1000 kcal/d). The 2010 Dietary Guidelines for Americans recommends reducing daily sodium intake to less than 2,300 mg and further reducing intake to 1,500 mg for adults 51 years and older and for those with diabetes and other chronic conditions (i.e., hypertension or chronic kidney disease).

Abbreviations: HEI-2010, Healthy Eating Index 2010.

Table 14. Consumption (in servings) of AHEI-2010 Food and Nutrient groups in servings among U.S. adults (Age ≥ 20 years) by Diabetes Status

Food/Nutrient Group	Consumption *n* (%)			*p* trend
	Nondiabetes (n = 1436)	**Prediabetes** (n = 1905)	**Diabetes** (n = 715)	
[a]**Whole fruit (servings/d)**				0.2274
Inadequate	756 (53.3)	986 (52.8)	367 (51.9)	
Intermediate	519 (36.7)	671 (34.8)	269 (38.6)	
Meeting Criteria	154 (9.9)	242 (12.4)	77 (9.5)	
[b]**Total vegetables (cups/d)**				0.0854
Inadequate	601 (41.2)	758 (38.8)	246 (31.5)	
Intermediate	541 (36.6)	708 (36.6)	311 (44.3)	
Meeting Criteria	287 (22.1)	433 (24.6)	156 (24.2)	
[c]**Whole grains (g/d)**				0.0514
Inadequate	880 (59.5)	1145 (61.1)	380 (53.5)	
Intermediate	324 (24.2)	385 (21.5)	195 (28.6)	
Meeting Criteria	225 (16.3)	369 (17.3)	138 (17.9)	
[d]**Nuts and Legumes (servings/d)**				0.9472
Inadequate	1248 (86.7)	1682 (87.2)	632 (87.7)	
Intermediate	181 (12.9)	217 (12.6)	81 (12.2)	
Meeting Criteria	7 (0.3)	6 (0.2)	2 (0.1)	
Long-chain (ω-3) fats (EPA + DHA) (mg/d)				0.2314
Inadequate	132 (8.2)	189 (9.9)	72 (9.9)	
Intermediate	1167 (80.9)	1499 (78.2)	583 (81.4)	
Meeting Criteria	137 (10.9)	217 (11.9)	60 (8.6)	
[e]**Sugar-sweetened Beverages and fruit juice (servings/d)**				**0.0002**
Intermediate	1040 (73.3)	1342 (68.9)	489 (67.3)	
Meeting Criteria	310 (20.9)	431 (22.5)	202 (28.9)	
Excessive	86 (5.8)	132 (8.5)	24 (3.8)	
[f]**Red and/or Processed Meats (servings/d)**				**0.0122**
Intermediate	561 (37.4)	791 (41.4)	319 (45.4)	
Meeting Criteria	649 (45.2)	783 (39.1)	268 (36.2)	
Excessive	226 (17.4)	331 (19.4)	128 (18.5)	
PUFA (%/d)				0.9000
Inadequate	18 (1.1)	24 (1.2)	7 (0.7)	
Meeting Criteria	1181 (81.0)	1557 (81.1)	575 (79.9)	
Excessive	237 (17.9)	324 (17.7)	133 (19.4)	
Alcohol (# drinks/d)				**<.0001**

Inadequate	1061 (71.5)	1467 (74.2)	614 (85.5)	
Meeting Criteria	256 (20.1)	318 (19.2)	64 (9.3)	
Excessive	112 (8.4)	114 (6.6)	35 (5.2)	
[g]**Sodium (mg)**				**0.0197**
Lowest 10th percentile	148 (8.3)	224 (9.1)	119 (13.1)	
Central	1153 (80.6)	1525 (81.4)	549 (78.7)	
Highest 10th percentile	135 (11.1)	156 (9.6)	47 (8.2)	

Values are proportions *n* (%) for categorical variables by diabetes status. Statistical differences of categorical variables were assessed using design-based Rao-Scott F adjusted X^2 statistic. Bolded values are significantly different $p < 0.05$.

[a]Whole fruit excludes juice. For AHEI-2010, 1 serving is 1 medium piece of fruit or 0.5 cups of berries.

[b]Total vegetables excludes potatoes and juices. Servings were reported as number of cups per day.

[c]Whole grains include brown rice, popcorn, and any grain food with a carbohydrate to fiber ratio no more than 10:1. Servings were reported as number of grams per day.

[d]For nuts and legumes, 1 serving is 1 oz. of dried beans, nuts, tofu, and soy milk.

[e]For sugar-sweetened beverages and fruit juice, 1 serving is 8 oz. of soft drinks and other beverages or 4 oz. of 100% fruit juice.

[f]For red and/or processed meats, 1 serving is 4 oz of unprocessed meat or 1.5 oz of processed meat.

[g]Sodium consumption was based on the actual intake distribution of participants in the sample. The fasting subsample weight was used to obtain representative percentiles for sodium intake in the sample.

Abbreviations: AHEI-2010, Alternate Healthy Eating Index 2010; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acid.

Table 15. HEI-2010 components and total scores of U.S. adults (Age ≥ 20 years) by Diabetes Status

Component	Criteria		Maximum Score Value	Diabetes Status			[a]p-value
	Minimum score	Maximum score		Nondiabetes (n = 1436) LSM ± SE	Prediabetes (n = 1905) LSM ± SE	Diabetes (n = 715) LSM ± SE	
Adequacy							
Total fruit	0	≥0.8 cups/1000 kcal	5	2.1 ± 0.07	2.2 ± 0.08	2.2 ± 0.1	0.6460
Whole fruit	0	≥0.4 cups/1000 kcal	5	0.7 ± 0.04	0.8 ± 0.07	0.8 ± 0.08	0.0554
Total vegetables	0	≥1.1 cups/1000 kcal	5	2.9 ± 0.07	3.0 ± 0.04	3.2 ± 0.07	0.1362
Greens and beans	0	≥0.2 cups/1000 kcal	5	1.3 ± 0.06	1.2 ± 0.07	1.3 ± 0.1	0.5413
Whole grains	0	≥1.5 oz/1000	10	2.5 ± 0.1	2.2 ± 0.1	2.7 ± 0.1	0.0693
Dairy	0	≥1.3 cups/1000 kcal	10	5.4 ± 0.1	5.1 ± 0.09	5.1 ± 0.2	0.1506
Fatty acids	(PUFAs + MUFAs)/ SFAs ≤ 1.2	(PUFAs + MUFAs)/ SFAs ≥ 2.5	10	4.9 ± 0.1	4.9 ± 0.1	5.1 ± 0.2	0.6415
Total protein foods	0	≥2.5 oz/1000 kcal	5	4.2 ± 0.04	4.2 ± 0.04	4.4 ± 0.06	**0.0008**
Seafood and Plant proteins	0	≥0.8 oz/1000 kcal	5	2.2 ± 0.1	2.0 ± 0.08	1.9 ± 0.1	0.1646
Moderation							
Refined grains	≥ 4.3 oz/1000 kcal	≤ 1.8 oz/1000 kcal	10	5.9 ± 0.1	6.3 ± 0.1	5.9 ± 0.2	**0.0122**
Sodium	≥ 2.0 g/1000 kcal	≤ 1.1 g/1000 kcal	10	4.2 ± 0.08	4.4 ± 0.07	3.5 ± 0.2	**0.0006**
[b]Empty calories	≥ 50% of energy	≤ 19% of energy	20	11.1 ± 0.3	10.4 ± 0.3	12.5 ± 0.3	**0.0002**
Total HEI-2010 score			100	47.5 ± 0.6	46.8 ± 0.7	48.8 ± 0.6	0.1110

Values are least square means ± standard error of the mean (SE).
[a]Bonferroni correction (<0.05/12 HEI-2010 components), $P < 0.004$.
[b]Empty Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.
Notes: All scoring criteria were calculated per 1000 kcal/d, except empty calories, which are calculated as % total energy. For adequacy components, higher intake of food/nutrient groups result in higher scores. For moderation components, lower intake of food/nutrient groups result in higher scores.
Abbreviations: HEI-2010, Healthy Eating Index 2010; LSM, least square means; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

Table 16. AHEI-2010 components and total scores of U.S. adults (Age ≥ 20 years) by Diabetes Status

Component	Criteria		Maximum Score value	Diabetes Status			[a]p-value
	Minimum score	Maximum score		Nondiabetes (n = 1436) LSM ± SE	Prediabetes (n = 1905) LSM ± SE	Diabetes (n = 715) LSM ± SE	
Whole fruit	0	≥4 servings/d	10	2.8 ± 0.1	3.0 ± 0.1	2.9 ± 0.2	0.6109
Total vegetables	0	≥2.5 cups/d	10	2.6 ± 0.1	2.8 ± 0.1	2.9 ± 0.2	0.2947
Whole grains	0	Women: 75 g/d Men: 90 g/d	10	2.9 ± 0.1	2.9 ± 0.2	3.3 ± 0.2	0.3386
Sugar-sweetened Beverages and fruit juice	≥8 oz/d	0	10	2.4 ± 0.2	2.5 ± 0.1	3.3 ± 0.2	**0.0011**
Nuts and legumes	0	≥1 oz/d	10	2.5 ± 0.2	2.4 ± 0.1	2.4 ± 0.2	0.8478
Red and/or Processed Meats	≥1.5 servings/d	0	10	6.5 ± 0.2	6.0 ± 0.1	5.9 ± 0.2	**0.0318**
Long-chain (ω-3) fats (EPA + DHA)	0	250 mg/d	10	2.6 ± 0.1	2.8 ± 0.1	2.3 ± 0.2	0.0937
PUFAs	≤2% of energy	≥10% of energy	10	6.9 ± 0.05	6.9 ± 0.05	7.2 ± 0.1	0.0772
[b]Alcohol	Men: ≥3.5 drinks/d Women: ≥2.5 drinks/d	Men: 0.5-2.0 drinks/d Women: 0.5-1.5 drinks/d	10	3.4 ± 0.09	3.3 ± 0.08	2.8 ± 0.07	**<.0001**
[c]Sodium	Highest Decile	Lowest Decile	10	5.2 ± 0.1	5.6 ± 0.1	6.1 ± 0.2	**0.0017**
Total AHEI-2010 score			100	37.9 ± 0.7	38.3 ± 0.5	39.1 ± 0.7	0.4299

Values are least square means ± standard error of the mean (SE).
[a]Bonferroni correction (<0.05/11 AHEI-2010 components), $P < 0.005$.
[b]Alcoholic drinkers were assigned the highest score to moderate, and lowest score to heavy consumers. Nondrinkers received a score of 2.5.
[c]Consumption was based on the actual intake distribution of participants in the sample. The fasting subsample weight was used to obtain representative percentiles for sodium intake in the sample.
Notes: All scoring criteria were calculated based on actual intake of participants rather than absolute standards. Trans fat component was omitted from the AHEI-2010 scoring because it is unavailable in the NHANES dietary files. For sugar-sweetened beverages and fruit juices, red and/or processed meat, and sodium, a higher score corresponds to lower intake.
Abbreviations: AHEI-2010, Alternate Healthy Eating Index-2010; LSM, least square means; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acid.

Table 17. Association between total HEI-2010 score and Health Markers in U.S. adults (Age ≥ 20, N = 4097)

Health Markers	(n)	HEI-2010 Quartiles				*p* trend
		Quartile 1 (n = 982)	**Quartile 2** (n = 1066)	**Quartile 3** (n = 1014)	**Quartile 4** (n = 1035)	
		LSM ± SE	**LSM ± SE**	**LSM ± SE**	**LSM ± SE**	
[a]BMI (kg/m^2)	4097	29.5 ± 0.3	29.5 ± 0.3	28.9 ± 0.2	28.3 ± 0.3	**0.0041***
[a]WC (cm)	4019	101.1 ± 0.5	100.5 ± 0.6	99.3 ± 0.5	97.9 ± 0.6	**0.0014***
[a]Total cholesterol (mg/dl)	4070	201.0 ± 2.1	196.1 ± 1.6	194.7 ± 1.2	196.6 ± 1.5	0.0875*
[b]HDL cholesterol (mg/dl)	4070	51.7 ± 0.7	53.8 ± 0.6	52.4 ± 0.6	54.9 ± 0.5	**0.0014***
[a]LDL cholesterol (mg/dl)	3990	120.7 ± 1.7	116.9 ± 1.5	115.5 ± 0.9	115.4 ± 1.2	0.0987
[a]TG (mg/dl)	4066	150.7 ± 4.9	130.2 ± 3.5	134.8 ± 4.3	129.5 ± 3.1	**0.0001***
[a]TG / HDL choesterol Ratio	4066	3.6 ± 0.2	2.9 ± 0.1	3.1 ± 0.2	2.9 ± 0.1	**0.0002***
[c]CRP (mg/dl)	4086	0.5 ± 0.03	0.4 ± 0.02	0.4 ± 0.02	0.4 ± 0.03	0.1221*
[c]Insulin (uU/mL)	3958	13.8 ± 0.5	13.5 ± 0.4	13.5 ± 0.4	12.6 ± 0.3	0.2315*
[c]Mean SBP (mm Hg)	3928	122.6 ± 0.5	122.2 ± 0.5	122.4 ± 0.6	120.9 ± 0.6	0.1905
[c]Mean DBP (mm Hg)	3928	68.2 ± 0.5	69.0 ± 0.5	68.3 ± 0.5	69.0 ± 0.6	0.4356
[a]Comorbidity Score	4097	2.2 ± 0.1	2.1 ± 0.05	2.0 ± 0.06	1.9 ± 0.07	0.0167

Values are least square means ± standard error of the mean (SE). Bonferroni correction (<0.05/12 health markers), $P < 0.004$.
Adjusted for age, sex, ethnicity, smoking status, PIR, physical activity, and energy intake.
[b]Adjusted for age, sex, ethnicity, smoking status, Poverty-to-Income Ratio, physical activity, energy intake, and BMI.
[c]Adjusted for age, sex, ethnicity, smoking status, Poverty-to-Income Ratio, physical activity, energy intake, BMI and WC.
*Nontransformed LSMs were presented with p-values associated with the variables after log-transformation for normality. Health markers that were log-transformed include BMI, WC, TC, HDL-C, TG, CRP, and Insulin. Bolded values are significantly different $p < 0.01$.
Notes: Highest total HEI-2010 score was compared to the lowest total HEI-2010 (quartile 4 vs. quartile 1) to represent dietary quality. Mean blood pressure (systolic and diastolic) was calculated based on the average of the first three systolic BP readings of the participants while being examined at the MEC. The fourth reading was not included because of missing values. Co-morbidity score was calculated as the sum of self-reported presence of physician-diagnosed comorbidities that tend to co-occur with type 2 diabetes.
Abbreviations: HEI-2010, Healthy Eating Index 2010; LSM, Least-Square Means; BMI, Body Mass Index; WC, Waist Circumference; TC, Total Cholesterol; HDL-C, High density Lipoprotein Cholesterol; LDL-C, Low density Lipoprotein Cholesterol; TG, Triglycerides; CRP, C-reactive protein.

Table 18. Association between total AHEI-2010 score and Health Markers in U.S. adults (Age ≥ 20, N = 4097)

Health Markers	**(n)**	**AHEI-2010 Quartiles**				***p* trend**
		Quartile 1 (n = 990)	**Quartile 2** (n = 1003)	**Quartile 3** (n = 1062)	**Quartile 4** (n = 1042)	
		LSM ± SE	**LSM ± SE**	**LSM ± SE**	**LSM ± SE**	
[a]BMI (kg/m^2)	4097	29.9 ± 0.2	29.2 ± 0.3	29.1 ± 0.2	27.9 ± 0.3	**0.0011***
[a]WC (cm)	4019	101.8 ± 0.5	100.7 ± 0.6	99.4 ± 0.6	96.9 ± 0.7	**0.0003***
[a]Total cholesterol (mg/dl)	4070	199.3 ± 1.8	197.1 ± 1.6	197.8 ± 1.6	194.4 ± 1.4	0.1790*
[b]HDL cholesterol (mg/dl)	4070	51.6 ± 0.7	52.1 ± 0.5	53.8 ± 0.6	55.5 ± 0.6	**<. 0001***
[a]LDL cholesterol (mg/dl)	3990	119.7 ± 1.6	118.6 ± 1.3	116.8 ± 1.3	113.6 ± 1.3	0.0406
[a]TG (mg/dl)	4066	148.0 ± 5.1	134.4 ± 2.7	136.1 ± 3.1	125.9 ± 3.8	**<. 0001***
[a]TG / HDL cholesterol Ratio	4066	3.5 ± 0.2	2.9 ± 0.07	3.1 ± 0.1	2.9 ± 0.2	**<. 0001***
[c]CRP (mg/dl)	4086	0.4 ± 0.03	0.4 ± 0.03	0.4 ± 0.02	0.4 ± 0.02	**0.0054***
[c]Insulin (uU/mL)	3958	13.9 ± 0.3	13.4 ± 0.3	13.2 ± 0.4	12.7 ± 0.2	0.0940*
[c]Mean SBP (mm Hg)	3928	122.7 ± 0.5	122.8 ± 0.6	121.8 ± 0.6	120.6 ± 0.5	0.0109
[c]Mean DBP (mm Hg)	3928	68.1 ± 0.6	68.9 ± 0.5	68.3 ± 0.6	69.2 ± 0.5	0.4184
[a]Comorbidity Score	4097	2.3 ± 0.09	2.1 ± 0.09	2.0 ± 0.09	1.9 ± 0.09	**<.0001**

Values are least square means ± standard error of the mean (SE). Bonferroni correction (<0.05/11 health markers), $P < 0.005$.

[a] Adjusted for age, sex, ethnicity, smoking status, PIR, physical activity, and energy intake.

[b]Adjusted for age, sex, ethnicity, smoking status, Poverty-to-Income Ratio, physical activity, energy intake, and BMI.

[c]Adjusted for age, sex, ethnicity, smoking status, Poverty-to-Income Ratio, physical activity, energy intake, BMI and WC.

*Nontransformed LSMs were presented with p-values associated with the variables after log-transformation for normality. Health markers that were log-transformed include BMI, WC, TC, HDL-C, TG, CRP, and Insulin. P-value is not significant for CRP without log-transformation. Bolded values are significantly different $p < 0.01$.

Notes: Highest total AHEI-2010 score was compared to the lowest total AHEI-2010 (quartile 4 vs. quartile 1) to represent dietary quality. Mean blood pressure (systolic and diastolic) was calculated based on the average of the first three systolic BP readings of the participants while being examined at the MEC. The fourth reading was not included because of missing values. Co-morbidity score was calculated as the sum of self-reported presence of physician-diagnosed comorbidities that tend to co-occur with type 2 diabetes.

Abbreviations: AHEI-2010, Alternate Healthy Eating Index 2010; LSM, Least-Square Means; BMI, Body Mass Index; WC, Waist Circumference; TC, Total Cholesterol; HDL-C, High density Lipoprotein Cholesterol; LDL-C, Low density Lipoprotein Cholesterol; TG, Triglycerides; CRP, C-reactive protein.

Table 19. Association between Diabetes Status and Health Markers in U.S. adults (Age ≥ 20 years)

Health Markers		Diabetes Status			[a]p-value
	(n)	**Nondiabetes** (n = 1436)	**Prediabetes** (n = 1905)	**Diabetes** (n = 715)	
		LSM ± SE	**LSM ± SE**	**LSM ± SE**	
[a]BMI (kg/m^2)	4056	26.7 ± 0.2	29.6 ± 0.2	32.8 ± 0.4	**<.0001***
[a]WC (cm)	3978	93.9 ± 0.6	100.9 ± 0.4	108.8 ± 0.9	**<.0001***
[a]Total cholesterol (mg/dl)	4029	197.6 ± 1.5	201.9 ± 1.0	181.1 ± 2.5	**<.0001***
[b]HDL cholesterol (mg/dl)	4029	55.5 ± 0.5	52.9 ± 0.5	49.3 ± 0.6	**<.0001***
[a]LDL cholesterol (mg/dl)	3952	117.3 ± 1.0	122.1 ± 0.9	101.3 ± 1.8	**<.0001**
[a]TG (mg/dl)	4025	116.9 ± 2.8	139.2 ± 2.7	168.8 ± 8.3	**<.0001***
[a]TG / HDL cholesterol Ratio	4025	2.3 ± 0.08	3.2 ± 0.1	4.5 ± 0.3	**<.0001**
[b]CRP (mg/dl)	4045	0.4 ± 0.01	0.4 ± 0.03	0.4 ± 0.02	0.2205
[c]Insulin (uU/mL)	3918	11.1 ± 0.3	14.1 ± 0.3	15.9 ± 0.7	**<.0001***
[c]Mean SBP (mm Hg)	3888	120.0 ± 0.4	122.4 ± 0.5	124.9 ± 1.1	**<.0001**
[c]Mean DBP (mm Hg)	3888	67.8 ± 0.7	69.4 ± 0.4	68.0 ± 0.7	0.0155
[a]Comorbidity Score	4056	1.7 ± 0.09	2.0 ± 0.09	3.0 ± 0.1	**<.0001**

Values are least square means ± standard error of the mean (SE). Bonferroni correction (<0.05/12 health markers), $P < 0.004$.

[a]Adjusted for age, sex, ethnicity, smoking status, Poverty-to-Income Ratio, physical activity, and energy intake.

[b]Adjusted for age, sex, ethnicity, smoking status, Poverty-to-Income Ratio, physical activity, energy intake, and BMI.

[c]Adjusted for age, sex, ethnicity, smoking status, Poverty-to-Income Ratio, physical activity, energy intake, BMI and WC.

*Nontransformed LSMs were presented with p-values associated with the variables after log-transformation for normality. Health markers that were log-transformed include BMI, WC, TC, HDL-C, TG, CRP, and Insulin. Bolded values are significantly different $p < 0.01$.

Notes: Mean blood pressure (systolic and diastolic) was calculated based on the average of the first three systolic BP readings of the participants while being examined at the MEC. The fourth reading was not included because of missing values. Co-morbidity score was calculated as the sum of self-reported presence of physician-diagnosed comorbidities that tend to co-occur with type 2 diabetes.

Abbreviations: LSM, Least-Square Means; BMI, Body Mass Index; WC, Waist Circumference; TC, Total Cholesterol; HDL-C, High density Lipoprotein Cholesterol; LDL-C, Low density Lipoprotein Cholesterol; TG, Triglycerides; CRP, C-reactive protein.

Table 20. Association between total HEI-2010 score and Diabetes Status in adults (Age ≥ 20, n = 3,632) using Multinomial Logistic Regression (Weighted)

	Prediabetes vs. Non-diabetes	Diabetes vs. Non-diabetes	Analysis of Effects	
Predictors	**OR [95% CI]**	**OR [95% CI]**	**Wald Chi-Sq**	**Pr > Chi-sq**
Age	1.10 [1.01, 1.11]	1.30 [1.20, 1.40]	55.6	<0.0001
Age squared	0.99 [0.99, 1.00]	1.00 [1.00, 1.00]	30.3	<0.0001
Sex			27.3	<0.0001
Male	1.84 [1.43, 2.40]	2.21 [1.50, 3.30]		
Female	—	—	—	—
Ethnicity			28.8	<0.0001
Mexican American	1.40 [0.98, 1.90]	2.51 [1.24, 3.90]		
Non-Hispanic White	—	—		
Non-Hispanic Black	1.30 [0.93, 1.73]	2.40 [1.54, 3.70]		
Other	1.20 [0.80, 1.74]	2.04 [1.20, 3.50]		
Self-reported Health			45.9	<0.0001
Excellent	0.80 [0.60, 1.20]	0.80 [0.50, 1.30]		
Very Good	—	—	—	—
Good	1.30 [1.00, 1.63]	2.00 [1.20, 3.34]		
Fair	1.20 [0.83, 1.74]	3.70 [2.14, 6.30]		
Poor	1.10 [0.54, 2.20]	3.14 [1.40, 7.30]		
Smoking Status			1.95	0.3776
No	—	—	—	—
Yes	1.12 [0.90, 1.50]	0.90 [0.64, 1.30]		
Physical Activity			3.80	0.1522
No	—	—	—	—
Yes	1.20 [0.98, 1.40]	0.95 [0.70, 1.35]		
Poverty-to-Income Ratio	0.92 [0.90, 1.00]	0.92 [0.82, 1.03]	5.30	0.0720
Comorbidity score	1.10 [1.00, 1.13]	1.30 [1.20, 1.40]	35.4	<0.0001
WC (cm)	1.03 [1.02, 1.04]	1.10 [1.04, 1.10]	89.3	<0.0001
Total HEI-2010 score	0.99 [0.98, 1.00]	1.00 [0.98, 1.01]	2.9	0.2390

Baseline outcome category = non-diabetes. Reference categories for categorical predictors are sex (female), ethnicity (non-Hispanic White), self-reported health (very good), smoking status (nonsmoker), physical activity (none).

*P-value for the odds of having diabetes and prediabetes compared to nondiabetes (reference group) < 0.05.

Weighted model: Wald- F (32,1) = 34.97, p = 0.1332; goodness-of-fit chi-squared = 16.846, p = 0.396.

Note: Included a quadratic term for age as a continuous variable to apply polynomial functions and smoothing splines to test the logistic model is truly linear in the logit. This method was suggested by Hosmer and Lemeshow (2000) and Heeringa, West, and Berglund (2010).

Abbreviations: HEI-2010, Healthy Eating Index 2010; SE, standard error; OR, Odds Ratio; CI, Confidence Interval; WC, Waist Circumference.

Table 21. Association between total AHEI-2010 score and Diabetes Status in U.S. adults (Age ≥ 20, n = 3,617) using Multinomial Logistic Regression (Weighted)

	Prediabetes vs. Non-diabetes	**Diabetes vs. Non-diabetes**	**Analysis of Effects**	
Predictors	**OR [95% CI]**	**OR [95% CI]**	**Wald Chi-Sq**	**Pr > Chi-sq**
Age	1.10 [1.01, 1.11]	1.30 [1.21, 1.40]	55.1	<0.0001
Age squared	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	30.7	<0.0001
Sex			25.8	<0.0001
Male	1.80 [1.40, 2.30]	2.40 [1.60, 3.62]		
Female	—		—	—
Race/Ethnicity			28.8	<0.0001
Mexican American	1.40 [1.02, 1.91]	2.70 [1.72, 4.11]		
Non-Hispanic White	—	—	—	—
Non-Hispanic Black	1.30 [0.95, 1.80]	2.34 [1.52, 3.60]		
Other	1.20 [0.82, 1.80]	2.02 [1.20, 3.42]		
Self-reported Health			44.9	<0.0001
Excellent	0.80 [0.60, 1.10]	0.80 [0.50, 1.30]		
Very Good	—	—	—	—
Good	1.30 [1.01, 1.70]	1.97 [1.20, 3.31]		
Fair	1.21 [0.83, 1.80]	3.55 [2.06, 6.10]		
Poor	1.10 [0.55, 2.22]	3.00 [1.31, 6.83]		
Smoking Status			2.50	0.2887
Yes	1.13 [0.90, 1.50]	0.90 [0.62, 1.30]		
No	—	—	—	—
Physical Activity			2.98	0.2251
Yes	1.14 [0.96, 1.40]	0.96 [0.68, 1.40]		
No	—	—	—	—
Poverty-to-Income Ratio	0.92 [0.85, 0.99]	0.93 [0.84, 1.04]	5.98	0.0504
Comorbidity score	1.05 [0.98, 1.14]	1.30 [1.20, 1.40]	33.6	<0.0001
WC (cm)	1.03 [1.02, 1.04]	1.06 [1.05, 1.07]	93.3	<0.0001
Total AHEI-2010 score	1.00 [0.99, 1.01]	1.00 [0.99, 1.01]	0.21	0.9014
Calories (kcal)	1.00 [0.99, 1.00]	1.00 [0.99, 1.00]	6.10	0.0485

Baseline outcome category = non-diabetes. Reference categories for categorical predictors are sex (female), ethnicity (non-Hispanic White), self-reported health (very good), smoking status (nonsmoker), physical activity (none).*P-value for the odds of having diabetes and prediabetes compared to nondiabetes (reference group) < 0.05.

Weighted model: Wald- F (32,1) = 16.73, p = 0.1916; goodness-of-fit chi-squared = 14.119, p = 0.590.

Note: Included a quadratic term for age as a continuous variable to apply polynomial functions and smoothing splines to test the logistic model is truly linear in the logit. This method was suggested by Hosmer and Lemeshow (2000) and Heeringa, West, and Berglund (2010).

Abbreviations: AHEI-2010, Alternate Healthy Eating Index 2010; SE, standard error; OR, Odds Ratio; CI, Confidence Interval; WC, Waist Circumference.

Table 22. Classification of Diabetes Status among U.S. adults (Age ≥ 20 years) using Predicted Probabilities

Models	% correctly classified	% false positive	% false negative
1	65.1	24.2	10.7
2	63.3	7.0	29.6
3	53.9	42.1	4.0
4	54.6	40.5	4.9
5	51.9	48.1	0
6	51.9	47.9	0.1
7	51.9	47.9	0.1
8	63.7	6.2	30.2
9	63.6	6.1	30.3
10	63.7	6.1	30.3
[a]**11**	51.9	47.9	0.2
[b]**12**	52.7	44.8	2.5
[c]**13**	52.9	44.5	2.6
14	63.5	6.3	30.2
15	63.5	6.2	30.3
16	63.6	6.1	30.3

Values are percentages.

Notes: Diabetes status was recoded as a binary outcome. Diabetes and prediabetes were combined as the event and nondiabetes was the nonevent. False negative is when the predicted probability of having diabetes/prediabetes wrongly classifies diabetes/prediabetes as the nonevent. False positive is when the predicted probability of having diabetes/prediabetes wrongly classifies diabetes/prediabetes as the event.

[a]Selected HEI-2010 components that are significantly associated with diabetes status in the bivariate analysis. These include total protein foods, refined grains, sodium, and empty calories.

[b]Selected AHEI-2010 components that are significantly associated with diabetes status in the bivariate analysis. These include sugar-sweetened beverages and fruit juice, red/processed meat, alcohol, and sodium.

[c]Replaced the original scoring of alcohol as 2.5 for nondrinkers with a modified scoring of alcohol as zero for nondrinkers (no alcohol penalty).

Model 1 = Sociodemographics (age, sex, ethnicity, Poverty-to-Income Ratio, self-reported health)
Model 2 = Health Markers (Comorbidity Score, mean systolic BP, WC, LDL-C, HDL-C)
Model 3 = Health Behaviors (total HEI-2010 score + physical activity + smoking status)
Model 4 = Health Behaviors (total AHEI-2010 score + physical activity + smoking status)
Model 5 = Total HEI-2010 score
Model 6 = Total AHEI-2010 score
Model 7 = Modified Total AHEI-2010 score (no alcohol penalty)
Model 8 = Model 1 + Model 2 + Total HEI-2010 score
Model 9 = Model 1 + Model 2 + Total AHEI-2010 score
Model 10 = Model 1 + Model 2 + Modified Total AHEI-2010 score (no alcohol penalty)
Model 11 = HEI-2010 components
Model 12 = AHEI-2010 components
Model 13 = AHEI-2010 components (no alcohol penalty)
Model 14 = Model 1 + Model 2 + HEI-2010 components
Model 15 = Model 1 + Model 2 + AHEI-2010 components
Model 16 = Model 1 + Model 2 + AHEI-2010 components (no alcohol penalty)

Abbreviations: BP, Blood Pressure; WC, Waist Circumference; LDL-C, Low density Lipoprotein Cholesterol; HDL-C, High density Lipoprotein Cholesterol; HEI-2010, Healthy Eating Index 2010; AHEI-2010, Alternate Healthy Eating Index 2010.

4.2 Diabetes Status in Relation to Discrepancy of Perceived and Measured Diet Quality in U.S. Adults

Abstract

Background: Limited studies have evaluated how accurately individuals assess their diet quality. Currently, there are no studies that have examined whether or not there is a discrepancy between perceived diet quality (PDQ) and measured diet quality (MDQ) in U.S. adults with and without T2DM.

Objective: To examine the relationship between diabetes status and discrepancy of PDQ and MDQ using two measures of diet quality: Healthy Eating Index 2010 (HEI-2010) and Alternate Healthy Eating Index 2010 (AHEI-2010).

Methods: This study used a representative sample of U.S. adults 20+ years of age (n = 4097) in the 2007-2010 National Health and Nutrition Examination Survey (NHANES). PDQ was based on a 5-point Likert scale question that assesses self-perceived diet. MDQ was based on total HEI-2010 and AHEI-2010 scores as objective measures of diet quality. Both indices were calculated using data from the first 24-hour dietary recall. Discrepancy scores were calculated separately for HEI-2010 (PDQ-MDQ-HEI2010) and AHEI-2010 (PDQ-MDQ-AHEI2010) to determine the direction of the difference in PDQ and MDQ (discrepancy score = perceived score – measured score). The design-adjusted Rao-Scott Chi-square test was used to examine bivariate associations among the predictors of discrepancy scores. These included diabetes status (nondiabetes, prediabetes, T2DM), sociodemographic and lifestyle characteristics, attitudes, and dietary knowledge. Least Squares Means were computed to determine differences across discrepancy scores (under raters, matchers, over raters) for total and sub-component HEI-2010 and AHEI-2010 scores by

diabetes status. Multinomial logistic regression was used to examine the associations between diabetes status and PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010 while controlling for sociodemographics, perceived health status, and attitudinal factors.

Results: The majority of participants in the sample over rated their diet quality for both PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010 (about 39.4% and 58.3%, respectively). However, diabetics were more likely to under rate their diet (PDQ-MDQ-HEI2010: 29.3%; PDQ-MDQ-AHEI2010: 16.1%). Diabetic under raters had the highest total HEI-2010 scores compared to prediabetics and nondiabetics [57.8 ± 1.0 vs. 55.8 ± 0.8 vs. 55.1 ± 0.8, respectively, $p < 0.001$]. However, prediabetic under raters had the highest total AHEI-2010 scores compared to diabetic and nondiabetics [49.4 ± 1.0 vs. 47.1 ± 1.1 vs. 49.4 ± 1.1, $p < 0.001$]. For the unadjusted models, results showed significant associations between diabetes status and discrepancy scores [PDQ-MDQ-HEI2010: $p = 0.0178$; PDQ-MDQ-AHEI2010: $p = 0.0134$]. However, the associations were not significant after adjusting for perceived health status [PDQ-MDQ-HEI2010: O.R. = 1.2 95% C.I. = 0.9-2.0; PDQ-MDQ-AHEI2010: O.R. = 1.1 95% C.I. = 0.7-1.7]. This suggests that individuals' perceived health has strong predictive power in relation to dietary misperception.

Conclusion: Diabetes status was significantly associated with the direction of the discrepancy between PDQ and MDQ. Discrepancy scores using HEI-2010 and AHEI-2010 were consistent in terms of their relationships with diabetes status and other covariates. Perceived health status was the strongest predictor of discrepancy scores. Nondiabetics were more likely to over rate while diabetics were more likely to under rate their diet quality. Diabetics are possibly benefiting from nutrition education and monitoring and are more aware that they need to improve their diet to improve their health. This may have implications for diabetes prevention. In addition, diabetics reported poorer self-perceived health and self-perceived diet. Interventions should target individuals who have inaccurate perceptions of their health and diet.

Keywords: NHANES, Perceived Diet Quality, Measured Diet Quality, Discrepancy Score, Diabetes Status

Introduction

Type 2 diabetes mellitus (T2DM) remains widespread in the United States. Unhealthful dietary intake is an essential risk factor for T2DM and many other chronic diseases (Wang et al., 2014). The overall nutritional quality of the American diet has not improved much over the last decade. A study by Wang and colleagues examined the trends in dietary quality from 1999 to 2010 using the National Health and Nutrition Examination Survey (NHANES) (Wang et al., 2014). The authors used two measures to assess dietary quality: the Healthy Eating Index-2010 (HEI-2010) and the Alternate Healthy Eating Index-2010 (AHEI-2010). Results showed that the mean total HEI-2010 score increased from 46.6 (needing dietary improvement) in 1999 to 2000 to 49.6 (needing dietary improvement) in 2009 to 2010. Similarly, the mean AHEI-2010 score increased from 39.9 (low adherence) in 1999 to 2000 to 46.8 (intermediate adherence) in 2009 to 2010. The authors concluded that while there was some improvement in diet quality scores over time (using HEI-2010 and AHEI-2010), Americans still fall short of meeting federal dietary recommendations and need further improvement in their dietary pattern (Wang et al., 2014).

In recent years, there has been increased awareness of the relationship between diet and health. In addition, there is greater awareness that an unhealthy diet can increase the risk of adverse health outcomes, including obesity and T2DM. The dietary guidelines and evidence-based recommendations are constantly being updated to help prevent chronic disease. Nevertheless, intake of nutrient-dense foods remains suboptimal among U.S. adults (Powell-Wiley, Miller, Agyemang, Agurs-Collins, & Reedy, 2014). There are several factors that may influence peoples' food choices. People may rank qualities such as taste, variety, and convenience over nutritional value in their food consumption decisions (Bishow, Blaylock, & Variyam, 1998). Currently, there is increasing interest in understanding individuals' perceptions of their own dietary behavior.

Assessment of dietary behavior is multifaceted because it is influenced by various modifiable (i.e., smoking, physical activity) and non-modifiable (i.e., age, sex, ethnicity) factors. A healthful dietary behavior involves the individual choosing to consume from various food groups (i.e., fruits, vegetables, whole grains) along with portion control to prevent excessive caloric intake. In addition, individuals should be aware and change their eating habits from unhealthful (i.e., high sugar and saturated fat intakes) to healthful dietary behaviors. To initiate dietary changes, individuals have to evaluate their own intake relative to the recommended healthful levels, which is often difficult to implement (Bishow et al., 1998). Therefore, it is important to examine how accurately people perceive their dietary intakes as an indicator of how successfully existing dietary guidance and evidence-based recommendations are being used and understood (Bishow et al., 1998).

The development of national dietary recommendations has been aimed at chronic disease prevention, but major discrepancies continue to exist between recommended and actual dietary behavior (Variyam, Shim, & Blaylock, 2001). This can be attributed in part to various environmental or socioeconomic factors (i.e., limited access to health foods) that promote this disconnect between perceived and actual dietary behavior. Moreover, psychosocial barriers (i.e., inadequate social support, perceived self-efficacy, general dietary knowledge) are known to influence peoples' perceptions of their dietary quality (Shaikh, Yaroch, Nebeling, Yeh, & Resnicow, 2008). Earlier studies did not use a measure of overall dietary quality (i.e., an index such as HEI) to assess discrepancy between recommended and actual (objective) dietary intake. Instead, most previous studies examined self-perception of diet in relation to single dietary components (i.e., fat or fruits and vegetables) (Bishow et al., 1998). One of the earliest studies was conducted by Brug and colleagues (1994) in the Netherlands (J. Brug, P.A. Assema, G. Kok, T. Lenderink, 1994). They compared individuals' objectively measured dietary fat intake with self-reported dietary fat intake. The authors specified different categories of awareness: optimistic, realistic, and pessimistic. Overall, more than half of the participants (55%) misperceived their dietary fat intake. About 76% of these individuals underestimated their fat intake (classified as optimistic) (J. Brug, P.A. Assema, G. Kok, T. Lenderink, 1994). Another study by Lechner and colleagues (1997) assessed the prevalence of misperception in fruit and vegetable intakes in the Dutch population (Lechner L, Brug J, 1997). According to the Dutch dietary guidelines, 88% of the respondents who did not consume enough vegetables rated themselves as consuming adequate vegetables, while 65% of the respondents who were too low in fruit intake rated themselves as consuming adequate fruit (Lechner L, Brug J, 1997). These earlier studies looked at only one or two of the recommended dietary components to assess dietary quality (Bishow et al., 1998). However, the overall quality of the diet cannot be assessed by looking at just one or two components.

There is very limited literature that compared individuals perceived diet quality (PDQ) and measured diet quality (MDQ) to determine how well people assess the overall quality of their diets. Variyam and colleagues (2001) was one of the first studies to measure consumers' overall diet quality (using HEI-1995); they compared actual diet quality with self-reported diet quality using the 1989–90 Continuing Survey of Food Intakes by Individuals (CSFII) and the Diet and Health Knowledge Survey (DHKS) (Variyam et al., 2001). The purpose of the study was to assess the degree of misperception regarding one's own diet quality and to identify factors associated with such misperception (Variyam et al., 2001). Similarly, a recent study by Powell-Wiley and colleagues (2014) used 2005-2006 NHANES data to compare perceived diet quality (PDQ) and measured diet quality (MDQ) using a nutrient-based DASH index score (Powell-Wiley et al., 2014). Overall, the authors suggest individuals' self-assessment of diet quality should be taken into account when they are counseled to change their poor dietary habits (Powell-Wiley et al., 2014).

Despite continuous efforts to promote public awareness and knowledge of existing dietary guidelines, major discrepancies continue to exist between the dietary guidelines and individuals' actual (objective) dietary behavior (Variyam et al., 2001). In an effort to understand how people change their dietary habits, it is important to examine how accurately people perceive their diets and how open they are to changing them by improving their food choices. This is important because people cannot be expected to change if they are unaware of the true quality of their diets and the connection between diet and health outcomes. Currently, there are no studies that have examined whether or not there is a discrepancy between PDQ and MDQ among individuals with and without T2DM. Therefore, this study examined the relationship between PDQ and MDQ in U.S. adults across diabetes status (nondiabetes, prediabetes, T2DM). In addition, the present study used the HEI-2010 and AHEI-2010 as two objective measures of diet quality to calculate discrepancy scores for each index (discrepancy score = perceived score – measured score). Findings from this study will have implications for future public health interventions and nutrition education focusing on dietary habits (Powell-Wiley et al., 2014). Moreover, there are no studies that have examined the contribution of knowledge and attitudes as potential factors associated with the discrepancy in dietary quality across diabetes status. Therefore, this study may lead to a better understanding of the factors associated with discrepancy in PDQ and MDQ among individuals with and without T2DM.

The main objectives of this study were four-fold: 1) To determine whether there were relationships between diabetes status (nondiabetes, prediabetes, T2DM) and discrepancy of PDQ and MDQ (for each total HEI-2010 and AHEI-2010 scores); 2) To identify the factors (i.e., sociodemographic, lifestyle, perceived health, attitudes, and knowledge) associated with discrepancies between PDQ and MDQ in U.S. adults with and without T2DM; 3) To determine the strength of the relationships between diabetes status and HEI-2010 and AHEI-2010 discrepancy scores while controlling for sociodemographics, perceived health status, and attitudinal factors; 4) To determine whether HEI-2010 or AHEI-2010 was associated with greater discrepancy in PDQ and MDQ. All analyses were based on data from the 2007-2010 National Health and Nutrition Examination Survey (NHANES).

Participants and Methods

Survey Design

As part of the Centers for Disease Control and Prevention (CDC), the National Health and Nutrition Examination Survey (NHANES) is an ongoing program of the National Center for Health Statistics (NCHS). NHANES is a cross-sectional survey that collects information on the health and nutritional status of adults and children in the United States ("National Health and Nutrition Examination Survey Overview," n.d.). To ensure that the sample is representative of the civilian, non-institutionalized U.S. population, participants in the NHANES surveys are selected using a complex, stratified multistage probability cluster sampling design (Curtin et al., 2010). The survey collects data from health interviews, dietary intake, and laboratory tests, and physical examinations. The CDC website provides details regarding the NHANES study design, contents, procedures, consent document, and survey operation manuals ("National Health and Nutrition Examination Survey Overview," n.d.).

Study Sample

To increase in sample size, the present study combined cycles from 2007-2008 and 2009-2010 NHANES. The analytic sample (n = 4,097) consisted of adults age ≥ 20 years who participated in both the health interview and medical examination, self-reported as non-pregnant at the examination, had complete and reliable 24-hour diet recalls, a Body Mass Index (BMI) ≥ 18.5 kg/m^2, and fasting glucose measures during the morning examination session. NHANES has strict protocols and procedures that ensure confidentiality and protect the identity of participants ("NHANES - NHANES Participants - Eligible Participants," 2017). This study was based on secondary analysis of the NHANES data and did not include personal identifiers. For that reason, a formal institutional review board approval was not required (University of Maryland, n.d.).

Exposure and Outcome Variables

Diabetes Status

T2DM status was the main exposure variable. T2DM could be diagnosed or undiagnosed. Diagnosed diabetics were defined as those who answered "yes" to the question: "Other than during pregnancy, have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?" or who reported taking diabetes medication (i.e., Metformin) during the interview. Undiagnosed diabetics were defined as individuals with a fasting plasma glucose (FPG) ≥ 126 mg/dL, or HbA1c ≥ 6.5% who did not report a previous diabetes diagnosis during the interview. The sum of individuals with diagnosed and undiagnosed diabetes was computed to calculate the total number of adults with T2DM. To minimize the number of respondents with type 1 diabetes (T1DM), individuals diagnosed with diabetes prior to age 30 and continuous users of insulin were excluded from the classification of diabetes status (Jarvandi et al., 2012; Demmer, Zuk, Rosenbaum, & Desvarieux, 2013). Pre-diabetics were defined as those with FPG of 100 – 125 mg/dL, HbA1c 5.7 – 6.4 %, or an answer of "yes" to the question "Have you ever been told by a doctor or other health professional that you have prediabetes?" or an answer of "borderline" to the question "Other than during pregnancy, have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?" Nondiabetics were categorized as those who did not meet the definition for T2DM or pre-diabetes (FPG < 100 mg/dL and HbA1c < 5.7%) (William T. Cefalu, MD et al., 2017).

Perceived Diet Quality

Information about perceived diet quality (PDQ) was obtained from the Diet Behavior and Nutrition questionnaire of NHANES. The survey contains nutrition-related questions about dietary behavior and perception (i.e., self-appraised healthfulness level of one's own diet) ("NHANES 2007-2008: Diet Behavior & Nutrition Questionnaire," n.d.; "NHANES 2009-2010: Diet Behavior & Nutrition Questionnaire," n.d.). PDQ was assessed based on responses to the Question "In general, how healthy is your overall diet?" Responses to these questions were based on a 5-point Likert Scale: Excellent, Very Good, Good, Fair, and Poor.

Measured Diet Quality

The present study used the Healthy Eating Index-2010 (HEI-2010) and the Alternate Eating Index-2010 (AHEI-2010) as measures of diet quality (MDQ). The HEI-2010 and AHEI-2010 were calculated using the dietary intake data available in

NHANES. Dietary intake information was obtained from two 24-hour dietary recall interviews. The first recall was administered in-person at the Medical Examination Center (MEC) by trained interviewers using USDA's Automated Multiple-Pass Method (AMPM). The second recall was administered via telephone interview, approximately 3 to 10 days after attending the MEC (MEC In-Person Dietary Interviewers Procedures Manual, 2008). This study used only data from the in-person recall (day 1) to calculate the HEI-2010 and AHEI-2010 scores for purposes of methodology, interpretation, and comparability with other dietary surveys[2]. Since the two dietary recalls cannot be considered as independent of one another, the use of the first day recall is recommended for most statistical analyses. Otherwise, this would complicate the interpretation of the results because combining them would underestimate the within-person variation. Furthermore, the use of two different methods to collect data (in-person for the first vs. telephone for the second) could affect participants' responses and introduce bias. In addition, the varying length of time between recalls (3 to 10 days) may introduce bias. Therefore, using the in-person (day 1) recall ensures consistency in dietary methodology and yields estimates that are most comparable with other dietary surveys. Additionally, this analysis was limited to dietary recall data reported to be complete and reliable by the National Center for Health Statistics staff (MEC In-Person Dietary Interviewers Procedures Manual, 2008).

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[2] Personal communication with Dr. Joseph Goldman, who is a biostatistician at Food Surveys Research Group, Agricultural Research Service, USDA. 10300 Baltimore Ave. Bldg. 005, Room 102, BARC-West Beltsville, MD 20705.

Healthy Eating Index-2010 (HEI-2010)

The HEI-2010 is a tool developed by the United States Department of Agriculture (USDA) Center for Nutrition Policy and Promotion (CNPP) to measure adherence with the 2010 Dietary Guidelines and monitor the quality of American diets (P. M. Guenther et al., 2014). The HEI-2010 is made up of 12 components: 9 adequacy components (foods that people should consume more of result in higher scores) and 3 moderation components (foods that people should consume less of result in higher scores). The 9 adequacy components are: Total Fruit, Whole Fruit (forms other than juice), Total Vegetables, Greens and Beans (dark-green vegetables and beans and peas), Whole Grains, Dairy (all milk products and soy beverages), Total Protein Foods, Seafood and Plant Proteins, and Fatty Acids (ratio of poly- and monounsaturated fat to saturated fat). The 3 moderation components are: Refined Grains, Sodium, and Empty Calories (all calories from solid fats & added sugars plus calories from alcohol beyond a moderate level) (P. M. Guenther et al., 2014). Seven components were each scored on a 0 to 5 scale and the five other components are each scored on a 0 to 10 scale, with intermediate values scored proportionally. The component scores were summed to obtain total HEI-2010 scores. Higher scores indicate a higher quality diet. Scores above 80 indicate a "good" diet, while scores below 51 indicate a "poor" diet. An HEI score between 51 and 80 is considered as "needing dietary improvement" (Patricia M Guenther et al., 2014). The HEI-2010 scores were calculated using the Food Pattern Equivalents Database (FPED) and the a SAS code downloaded from the USDA CNPP website (United States Department of Agriculture. Center for Nutrition Policy and Promotion., 2013).

Alternate Healthy Eating Index-2010 (AHEI-2010)

The AHEI-2010 is an alternative measure of diet quality to identify future risk of diet-related chronic disease and was developed by the researchers at the Harvard School of Public Health (C. W. Leung et al., 2012; Cindy W. Leung, Epel, Ritchie, Crawford, & Laraia, 2014; Wang et al., 2014). The present study followed the approach from previous studies to calculate the AHEI-2010 scores (C. W. Leung et al., 2012; Cindy W. Leung, Epel, Ritchie, Crawford, & Laraia, 2014; Wang et al., 2014). The AHEI-2010 consists of 11 components: six components for which higher intakes are better [vegetables, fruit, whole grains, nuts and legumes, long chain omega-3 fatty acids (FA) that include docosahexaenoic acid and eicosapentaenoic acid, and Polyunsaturated Fatty Acids (PUFA)], one component for which moderate intake is better [alcohol], and four components that must be limited or avoided [sugar sweetened drinks and fruit juice, red and processed meat, trans fats, and sodium]. Each component was scored on a 0 to 10-point scale. The component scores were summed to obtain the total AHEI-2010 score, which can range from 0 (non-adherence) to 110 (perfect adherence). Higher scores represent healthier diets (A. M. Bernstein, Bloom, Rosner, Franz, & Willett, 2010; Wang et al., 2014; Varraso et al., 2015). However, this study constructed a modified AHEI-2010 score by excluding the trans fat component because trans fat is unavailable in the NHANES dietary files (C. W. Leung et al., 2012). Therefore, the maximum total AHEI-2010 score was rescaled from 110 points to 100 points (excluding trans fat) similar to the approach used in a previous study (C. W. Leung et al., 2012). The NHANES individual foods file was used to estimate servings of food to construct the AHEI-2010 food groups.

The USDA food-coding scheme was used as a reference to categorize each individual food (represented by food codes) into groups (Ahuja et al., 2012). In addition, this study used the supplementary table provided by Wang and colleagues (2014) to identify the foods and beverages that correspond to each AHEI food component (i.e., sugar-sweetened beverages, nuts and legumes, red and/or processed meats) (C. W. Leung et al., 2012; Cindy W. Leung, Epel, Ritchie, Crawford, & Laraia, 2014; Wang et al., 2014). The NHANES total nutrients file was used to estimate the intake of nutrients (i.e., PUFA, long-chain omega-3 fats, sodium) as components of the AHEI. AHEI-2010 scores were calculated using SAS.

Calculation of Discrepancy Score

PDQ was based on the question asked in NHANES, "In general, how healthy is your overall diet?" Possible responses were based on a 5-point scale (1 = 'excellent', 2 = 'very good', 3 = 'good', 4 = 'fair', 5 = 'poor'). MDQ was based on using the total HEI-2010 and AHEI-2010 scores as indices to measure objective (or actual) diet quality. The criterion-referenced method was used to establish cut-offs to convert total HEI-2010 and AHEI-2010 scores to ordinal variables as follows: (80-100 = 'excellent'; 60- <80 = 'very good'; 40- <60 = 'good'; 20- <40 = 'fair'; 0- <20 = 'poor').

Discrepancy scores were calculated as the difference between PDQ and MDQ [discrepancy score = perceived score – objective score]. Positive values indicate that participants under rate and negative values indicate that they over rate their own diet. There were two measures used to estimate MDQ using first total HEI-2010 score and then total AHEI-2010 score: MDQ-HEI2010 and MDQ-AHEI2010. The present study analyzed discrepancy scores using the magnitude (absolute value) and the direction of the difference between PDQ and MDQ. The direction of the difference between PDQ and MDQ was examined by collapsing values into three groups: positive, negative, and zero. This study categorized the direction of discrepancy scores as over raters, under raters, and matchers.

A total of four discrepancy scores were calculated using MDQ-HEI2010 and MDQ-AHEI2010. Two discrepancy scores were calculated for each diet quality index to examine first the magnitude (absolute value), and then the direction: Abs-PDQ-MDQ-HEI2010 (absolute value), Abs-PDQ-MDQ-AHEI2010 (absolute value), PDQ-MDQ-HEI2010 (direction), and PDQ-MDQ-AHEI2010 (direction). After that, the four discrepancy scores were examined in relation to diabetes status (main predictor) and the other predictors. There were no major findings when using magnitude alone. However, the direction of HEI-2010 and AHEI-2010 discrepancy scores yielded more interesting results. For that reason, this study presents the results that represent only the direction of HEI-2010 and AHEI-2010 discrepancy scores. The calculated discrepancy scores (PDQ-MDQ-AHEI2010 and PDQ-MDQ-AHEI2010) were used as the outcome variables in multivariate analyses.

Covariates

Demographic and Health Characteristics

Demographic information was obtained from the household interview component of NHANES. Self-reported sociodemographic characteristics were explored as potential covariates. These included age, sex, ethnicity, education level, smoking status, and adult food security category. Age was used as an ordinal variable in the bivariate analysis and a continuous variable in the multivariate analysis. The remaining covariates were used as categorical variables. Ethnicity was defined as follows: Mexican American, non-Hispanic White, non-Hispanic Black, and other. Education level was categorized as less than high school, high school diploma, some college education, and college graduate and above. Smoking status was categorized as nonsmoker, current smoker, and former smoker. Adult food security category was defined as follows: full, marginal, low, and very low.

Lifestyle and health characteristics were obtained from the health interview and medical examination components of NHANES. These included physical activity, body mass index (BMI) waist circumference (WC), and perceived health status. Physical activity was defined for participants as meeting (≥150 min per week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA guidelines (Powell, 2007). Physical activity level was used as a categorical variable and defined as follows: inactive, insufficient, and sufficient. BMI and WC were used as measures of weight status and abdominal adiposity. BMI was calculated as body weight (in kilograms) divided by height (in meters) squared (Anthropometry Procedures Manual, 2009). In the bivariate analysis, BMI was used as an ordinal variable and defined as follows: normal weight [18.5-24.9 kg/m^2], overweight [25.0-29.9 kg/m^2], and obese [≥ 30 kg/m^2] (National Institutes of Health, 2000). WC was also used as a categorical variable and classified using sex-specific cut-offs: WC >102 for men and WC > 88 for women are considered as abdominally obese (National Institutes of Health, 2000). Perceived health status was obtained from the interview component of NHANES. This variable was assessed based on responses to the Question "Would you say health in general is ....” Responses to these questions were based on a 5-point Likert Scale: Excellent, very good, good, fair, and poor. In the multivariate analysis, perceived health status was reduced to a 3-point Likert scale by combining “excellent” and “very good” into one category and likewise “fair” and “poor” into a category to avoid sparse cells.

Characteristics Related to Attitudes, Knowledge, and Depression

Information about attitude and knowledge were obtained from the Flexible Consumer Behavior Survey follow-up for adults. In NHANES, this survey was designed to collect information on people’s knowledge, attitudes, and beliefs toward nutrition and food choices (“2007-2008 NHANES Consumer Behavior Phone Follow-up Module,” n.d.; “2009-2010 NHANES Consumer Behavior Phone Follow-up Module,” n.d.). Depression status was also evaluated using the Patient Health Questionnaire (PHQ-9) to screen for symptoms (“2007-2008 NHANES Mental Health - Depression Screener,” n.d.; “2009-2010 NHANES Mental Health - Depression Screener,” n.d.). These factors were examined as potential factors that could influence the discrepancy between PDQ and MDQ.

Attitudes about current diet, body weight, and importance of nutrition

The present study examined attitudes based on three questions that are available in NHANES. The questions were related to the following: attitude about change in current diet (no reason to change my diet), fatalistic attitude about body weight (are people born fat/thin), and importance of nutrition while grocery shopping. The first question was related to attitudes about changing diet. Participants were asked about the extent to which they agreed or disagreed with the statement, “There is no reason for me to make changes to the things I eat." The second question was related to fatalistic attitudes about body weight. Participants were asked about the extent to which they agreed or disagreed with the statement, "some people are born to be fat and some thin; there is not much you can do to change this." Responses to these questions were based on a 5-point Likert Scale: Strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, and strongly disagree. In the multivariate analysis, the 5-point Likert scale was reduced to a 3-point Likert scale by combining "Strongly agree" and "Agree" into one category and likewise "Strongly disagree" and "Disagree" into a category. The third question was related to attitudes about importance of nutrition. Participants were asked, "How about "nutrition"? When you buy food from a grocery store or supermarket, how important is "nutrition"? " Responses to these questions are based on a 4-point Likert Scale: Very important, somewhat important, not too important, and not all important.

Knowledge about previous dietary guidelines

Knowledge of dietary guidelines, even if it is not related to the most recent dietary guidelines, can serve as a proxy for general nutrition knowledge. Because the dietary guidelines are updated regularly, the questions in NHANES 2007-2010 primarily reflect the 2005 Dietary Guidelines (e.g. "MyPyramid"). In this study, a knowledge score was created by summing the responses to 7 questions related to having general knowledge about previous dietary guidelines. The seven questions assessed whether participants were able to identify correctly the number of daily servings recommended for each food group based on the MyPyramid guidelines (Britten, Marcoe, Yamini, & Davis, 2006). These food groups include fruits, vegetables, ounces of meat/beans, ounces of grains, ounces of whole grains, and calories needed per day. Since the suggested number of servings for each food group varies depending on the target calorie level (which is determined based on a person's age and physical activity level), a reference level of 2000 calories was used as the cut-off for each suggested food group. For example, participants who answered 3 cups of milk, 2 cups of fruit, 2.5 cups of vegetables, 8 ounces of meats/beans, 6 ounces of grains, and 3 ounces of whole grains (MyPyramid recommends that at least 50% of the grains should be whole grain) and who were able to identify that adults needed about 1,000 – 2,500 calories per day received 1 point for each of these questions. Participants who provided other responses or said they didn't know received 0 points. Total scores ranged from 0 to 7 points.

Depression Status

The PHQ-9 questionnaire is a tool used to screen for depression. The questionnaire asks participants about the frequency of depressive symptoms during the previous 2 weeks. Responses are scored from 0 to 3 where "0" means not at all and "3" means nearly every day. Responses were summed to create a total depression score. Total score ranged from 0-27 and are used to assess the severity of depression. The following cut off points are used to classify the severity of depression: PHQ-9 score 5-9 is classified as mild depression, PHQ-9 score 10-14 as moderate depression, PHQ-9 score 15-19 as moderately severe, and PHQ-9 score ≥ 20 as severe depressive symptoms (Loprinzi, 2015).

Statistical Analysis

Data were analyzed using SAS 9.3 (SAS Institute Inc, Cary, NC) and STATA 14.1 (StataCorp, College Station, TX) to adjust the variances for the complex sample design of NHANES. To account for the complex multistage design, the 4-year fasting sample weight was used throughout the analysis in order to include participants who are already diagnosed with diabetes and taking insulin or oral medications. This study followed the recommendations in the NHANES analytic guidelines when constructing the 4-year fasting weight in the dataset (2007-2008 and 2009-2010) (National Center for Health Statistics (U.S.), 2013a).

SAS (release 9.3) was the primary tool used in data preparation, cleaning, and analysis. The design-adjusted Rao-Scott chi-square test (PROC SURVEYFREQ) was used to compare participants' characteristics related to sociodemographics, lifestyle and health, depression, attitude, and knowledge across discrepancy score. In addition, the design-adjusted Rao-Scott chi-square test (PROC SURVEYFREQ) was used to examine the bivariate associations among the predictors of discrepancy score. Multivariate linear regression (PROC SURVEYREG) was used to determine differences in sub-component and total HEI-2010 and AHEI-2010 scores across discrepancy score (under raters, matchers, over raters) by calculating the Least-square means (LSMs). The models were adjusted for age, sex, ethnicity, education, and poverty-to-income ratio. Least-square means (and the standard errors of the LSMs) were also used determine differences in sub-component and total HEI-2010 and AHEI-2010 scores across discrepancy score and stratified by diabetes status (nondiabetic, prediabetic, diabetic). The models (PROC SURVEYREG) were adjusted for age, sex, ethnicity, education, poverty-to-income ratio, and BMI. Bonferroni correction for multiple comparisons (0.05/number of variables) was applied to obtain the effective p-values for the models. All analyses had statistical significance set at $p < 0.05$.

STATA (release 14.1) software was used to perform multinomial logistic regression (svy: mlogit) to examine the association between diabetes status and discrepancy score [discrepancy score = perceived score – measured score (calculated for each total HEI-2010 and AHEI-2010 scores)]. Discrepancy score was used as a nominal outcome variable with three levels: under raters, matchers, and over raters. This categorization of discrepancy score was specified in order to determine the direction of the difference between PDQ and MDQ across diabetes status. The STATA command (mlogitgof) was executed after fitting the final model (Model 4) to assess the goodness-of-fit for multinomial logit modeling (Fagerland & Hosmer, 2013).

Multivariate Models

This study attempted to produce a final model (Model 4) that explains the relationships between diabetes status and discrepancy scores (HEI-2010 and AHEI-2010). Covariates were similar to those used in a previous study that identified factors associated with consumer misperception of diet quality (Variyam, Shim, & Blaylock, 2001). The present study examined the following factors as potential covariates: age, sex, ethnicity, smoking status, adult food security, perceived health status, depression status, attitude about change in current diet (no reason to change diet), fatalistic attitude about weight (are people born fat/thin), importance of nutrition, and DGA knowledge score. Bivariate associations of these factors were examined with diabetes status and discrepancy scores (PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010). In addition, bivariate associations were examined between the factors to determine what to include in a multivariate model.

Multivariate hierarchical models were constructed using diabetes status as the main predictor variable and discrepancy score [discrepancy score = perceived score – measured score (calculated for each total HEI-2010 and AHEI-2010 scores)] as the outcome variable. The models were run separately for each PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010. The first model did not include any adjustment for covariates (unadjusted model). The second model was adjusted only for sociodemographics including age, sex, ethnicity, and education. The third model was adjusted for sociodemographics in addition to the attitudinal variables, which include attitude about change in current diet (no reason to change my diet) and fatalistic attitude about body weight (are people born fat/thin). Attitudes about importance of nutrition was not included in the model because it was neither significant with diabetes status nor discrepancy score (HEI-2010 and AHEI-2010). The final model was adjusted for sociodemographics, attitudes, and perceived health status as covariates.

Results

Baseline Characteristics of the participants

Table 23 shows the baseline characteristics of the participants using 2007-2010 NHANES. The analytic sample included 4097 individuals ≥ 20 years of age. PDQ was assessed using a 5-point Likert scale in which responses ranged from "excellent" to "poor." The majority of participants in the sample perceived their diet quality as “good” (about 42.9%) followed by “very good” (about 23.7%). In this study, MDQ was assessed using the HEI-2010 and AHEI-2010. The criterion-referenced method was used to estimate the cut-offs for total HEI-2010 and AHEI-2010 scores to approximate PDQ (rated 1 to 5). For each index, the following cut-offs were used to divide the total scores into groups: (80-100 = excellent; 60- <80 = very good; 40- <60 = good; 20- <40 = fair; 0- <20 = poor). For the criterion-referenced HEI-2010 score, about 48.2% of participants fall between 40 and 60 (comparable to PDQ as “good”) and about 31.6% fall between 20 and 40 (comparable to PDQ as “fair”). For the criterion-referenced AHEI-2010 score, the majority of participants (about 49.6%) fall between 20 and 40 (comparable to PDQ as “fair”) and about 34.7% fall between 40 and 60 (comparable to PDQ as “good”). In terms of diabetes status, about 46.1% of the participants in the sample were classified as “prediabetic” and 12.5% are “diabetic”.

Descriptive Analysis of HEI-2010 and AHEI-2010 Discrepancy Scores

As previously mentioned, the present study calculated discrepancy scores (PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010) based on assessing the magnitude (absolute value) and direction of the difference between PDQ and MDQ scores. This analysis was performed to address the fourth objective of this study. **Table 24** presents the univariate analysis of four discrepancy scores (two for each HEI-2010 and AHEI-2010). For the magnitude of discrepancy, results indicate that more than one-third of participants had a discrepancy score of zero, which means that their actual (objective) rating of diet quality is equivalent to their perceived score (about 37.4% and 29.5% for PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010, respectively). However, for the majority of participants, the absolute value of the difference was one point (about 47.9% and 48.2% for PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010, respectively). Furthermore, there was a difference in the magnitude of the discrepancy (mean absolute value) for HEI-2010 and AHEI-2010 in the sample. The mean absolute value PDQ-MDQ-AHEI2010 was greater than the mean absolute value PDQ-MDQ-HEI2010 (mean absolute value: 0.97 ± 0.01 vs. 0.7 ± 0.01, respectively) **(Supplemental Table 10)**.

For analyses incorporating the direction of the discrepancy, results indicate that the majority of participants either over rated or rated their diet quality accurately. For PDQ-MDQ-HEI2010, the majority of participants in the sample over rated their diet quality (about 39.4%) while over a third of the participants match rated their diet quality (about 37.4%). For PDQ-MDQ-AHEI2010, the majority of participants in the sample over rated their diet quality (about 58.3%) while about a third of the participants rated their diet quality accurately (about 29.5%) **(Table 24)**.

To address the first objective, this study examined bivariate associations between diabetes status and PDQ-MDQ-HEI-2010 and PDQ-MDQ-AHEI-2010 (**Table 25**). Results show that the discrepancy scores based on the absolute value of the difference were not significantly associated with diabetes status (PDQ-MDQ-HEI2010: p = 0.7175 and PDQ-MDQ-AHEI2010: p = 0.3401, respectively). However, the HEI-2010 and AHEI-2010 discrepancy scores based on magnitude and direction were significantly associated with diabetes status (p = 0.0125 and p = 0.0313, respectively). Results indicate that the majority of nondiabetics were over raters compared to matchers and under raters [(PDQ-MDQ-HEI2010: 42.0% vs.

37.0% vs. 20.9%, respectively); (PDQ-MDQ-AHEI2010: 61.7% vs. 27.2% vs. 11.0%, respectively)]. Similarity, the majority of diabetics were over raters compared to matchers and under raters [(PDQ-MDQ-HEI2010: 35.7% vs. 34.9% vs. 29.3%, respectively); [(PDQ-MDQ-AHEI2010: 53.9% vs. 30.0% vs. 16.1%, respectively)]. Interestingly, the proportion of under raters was highest among diabetics compared to prediabetics and nondiabetics [(PDQ-MDQ-HEI2010: 29.3% vs. 23.5% vs. 20.9%, respectively); [(PDQ-MDQ-AHEI2010: 16.1% vs. 12.3% vs. 11.0%, respectively)]. Therefore, additional results will be based on the magnitude and direction of the difference between PDQ and MDQ using the HEI-2010 and AHEI-2010 discrepancy scores.

Sociodemographic characteristics by HEI-2010 and AHEI-2010 Discrepancy scores

To address the second objective, this study examined bivariate associations between the potential factors associated with discrepancy scores. These include sociodemographic, lifestyle and health, depression, attitudes, and dietary knowledge **(Tables 26, 27, & 28)**. **Table 26** shows the association between sociodemographic characteristics PDQ-MDQ-HEI-2010 and PDQ-MDQ-AHEI-2010. Results indicate that the majority of sociodemographic characteristics were significantly associated with PDQ-MDQ-HEI-2010 and PDQ-MDQ-AHEI-2010 ($p < 0.001$), except for age and smoking status ($p > 0.05$). In general, the relationships were comparable for both PDQ-MDQ-HEI-2010 and PDQ-MDQ-AHEI-2010. Under raters, were more likely to be female with less than a high school education ($p < 0.001$).

Mexican Americans were more likely to under rate their diet quality compared to non-Hispanic blacks and others [(PDQ-MDQ-HEI-2010: 11.8% vs. 11.8% vs.

13.4%, respectively) (p < .0001); (PDQ-MDQ-AHEI-2010: 14.8% vs. 13.5% vs. 14.9%, respectively)] (p < .0001). Over raters, were more likely to be male and have graduated from college. (p < 0.001). Non-Hispanic blacks were more likely to over rate their diet quality compared to Mexican Americans and others [(PDQ-MDQ-HEI-2010: 10.5% vs. 5.7% vs. 9.9%, respectively) (p < .0001); (PDQ-MDQ-AHEI-2010: 10.2% vs. 5.8% vs. 10.1%, respectively)] (p < .0001). Lastly, the majority of participants were classified as having "full" food security across PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI-2010 (p < 0.001). Over raters had the highest proportion of reporting "full" food security (about 83.3%) compared to matchers (about 82.2%) and under raters (about 75.8%).

Lifestyle and Health characteristics by HEI-2010 and AHEI-2010 Discrepancy scores

Table 27 shows significant associations between lifestyle characteristics and HEI-2010 and AHEI-2010 discrepancy scores (p < 0.001). In general, the relationships were comparable for both PDQ-MDQ-HEI-2010 and PDQ-MDQ-AHEI-2010. Under raters were more likely to be obese (BMI ≥ 30 kg/m^2), abdominally obese (WC >102 for men and WC > 88 for women), and physically inactive (p < .0001). Over raters, were more likely to be overweight (BMI = 18-24.9 kg/m^2) and to report engaging in sufficient physical activity (p < .0001). However, the HEI-2010 and AHEI-2010 discrepancy scores were different in relation to WC among over raters. For PDQ-MDQ-HEI2010, over raters were more likely to be classified as "not abdominally obese" than "abdominally obese" (about 52.9% vs. 47.1%, respectively) (p < .0001). For PDQ-MDQ-AHEI2010, over raters were more likely to be abdominally obese (WC >102 for men and WC > 88 for women) than not abdominally obese (about 50.5% vs. 49.5%, respectively) ($p < .0001$). Perceived health was also significantly associated with HEI-2010 and AHEI-2010 discrepancy scores ($p < 0.01$). In general, the relationships were comparable for both PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010. Over raters were more likely to self-rate their health as "excellent" or "very good" than matchers and under raters ($p < .0001$). However, under raters were more likely to self-rate their health as "fair" and "poor" than matchers and over raters ($p < .0001$).

Characteristics related to depression, attitude, and knowledge by HEI-2010 and AHEI-2010 Discrepancy scores

Table 28 shows significant associations between depression status, attitude about change in current diet, and attitude about importance of nutrition with PDQ-MDQ-HEI-2010 and PDQ-MDQ-AHEI-2010 ($p < 0.05$). In general, the relationships were comparable for both HEI-2010 and AHEI-2010 discrepancy scores. For depression status, individuals with none to minimal depression scores were more likely to be over raters than matchers and under raters [(PDQ-MDQ-HEI-2010: 83.2% vs. 77.9% vs. 70.1%, respectively) ($p < .0001$); [(PDQ-MDQ-AHEI-2010: 81.3% vs. 77.1% vs. 65.6%, respectively)] ($p < .0001$).

For attitude about change in current diet, individuals who reported "disagree" were more likely to be over raters than matchers and under raters [(PDQ-MDQ-HEI-2010: 34.8% vs. 32.8% vs. 27.6%, respectively) ($p < .0001$); [(PDQ-MDQ-AHEI-2010: 34.8% vs. 31.4% vs. 23.5%, respectively)] ($p < .0001$). However, individuals who reported "strongly disagree" were more likely to be under raters than matchers and over raters [(PDQ-MDQ-HEI-2010: 47.2% vs. 39.5% vs. 32.6%, respectively) ($p < .0001$); [(PDQ-MDQ-AHEI-2010: 49.6% vs. 44.2% vs. 33.4%, respectively)] ($p <$

.0001). For attitude about importance of nutrition, individuals who reported "very important" were more likely to be over raters than matchers and under raters [(PDQ-MDQ-HEI-2010: 65.7% vs. 58.0% vs. 58.3%, respectively) (p = 0.0305); [(PDQ-MDQ-AHEI-2010: 63.6% vs. 57.1% vs. 58.9%, respectively)] (p = 0.0057) (**Table 28)**. However, fatalistic attitude about body weight (are people born fat/thin) and DGA knowledge score were not significant with neither HEI-2010 discrepancy score nor AHEI-2010 discrepancy score ($p > 0.05$).

Anthropometric, attitude, and knowledge factors by diabetes status in U.S. adults

Results indicate significant associations between anthropometric characteristics, attitudes, and knowledge about previous dietary guidelines (DGA 2005) with diabetes status ($p < 0.001$). Individuals with prediabetes and diabetes were more likely to be obese (BMI ≥ 30 kg/m^2) and abdominally obese (WC >102 for men and WC > 88 for women) ($p < 0.001$). About 38.6% of prediabetics and 63.5% of diabetics were classified as obese (BMI ≥ 30 kg/m^2). Additionally, about 60.3% of prediabetics and 82.4% of diabetics were classified as abdominally obese (WC >102 for men and WC > 88 for women). Depression status was significantly associated with diabetes status ($p < 0.001$). The majority of participants were found to have none to minimal depression status regardless of diabetes status. However, nondiabetics were more likely to have none to minimal depression (about 79.9%).

Diabetics were more likely to have mild to moderate depression. Among diabetics, about 16.4% reported having mild depression and 7.6% reported having moderate depression. In terms of attitude, a fatalistic attitude about body weight (are people born fat/thin) was significantly associated with diabetes status ($p < 0.001$).

About 25.5% of prediabetics and 30.1% of diabetics reported “agree” that people are born fat/thin. However, attitude about change in current diet (no reason for me to change my diet) was not significant across diabetes status ($p > 0.05$). For general nutrition knowledge, questions related to the nutritional guidelines were significantly associated with diabetes status ($p < 0.05$). About half of the participants have heard about previous dietary guidelines (i.e., Food Pyramid, MyPyramid) across diabetes status. However, the majority of participants reported either “no” or “don’t know” about searching for MyPyramid on Internet or tried MyPyramid Plan. However, diabetics were more likely to respond “Yes” and report having tried MyPyramid Plan. About 35.1% of diabetics report having tried MyPyramid Plan. Nevertheless, the calculated DGA knowledge score (DGA 2005) was not significantly associated with diabetes status ($p > 0.05$) **(Supplemental Table 13)**.

HEI-2010 and AHEI-2010 total and component scores across categories of Discrepancy score

This study explored the sub-component HEI-2010 and AHEI-2010 scores in relation to PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI-2010 after adjusting for age, sex, ethnicity, smoking status, and poverty-to-income ratio **(Tables 29 & 30)**. **Table 29** shows significant differences in mean sub-component and total HEI-2010 scores across categories of PDQ-MDQ-HEI2010 ($p < 0.05$). The total HEI-2010 score was the highest among individuals who under rated their diet quality (mean score = 55.4 ± 0.5, $p < .0001$). Similarly, under raters had the highest adequacy component scores (corresponding to higher intake), with the exception of dairy. These include total fruit, whole fruit, total vegetables, greens and beans, whole grains, fatty acids, total protein foods, and seafood and plant proteins ($p < 0.001$). Under raters also had the highest moderation component scores (corresponding to lower intake). These include refined grains, sodium, and empty calories ($p < 0.001$).

Similarly, under raters had the highest score for all of the AHEI-2010 sub-components ($p < 0.001$). For the sub-component scores that correspond to higher intake, under raters had the highest scores for whole fruit, total vegetables, whole grains, nuts and legumes, omega-3 fats, PUFAs, and alcohol ($p < 0.001$). For the sub-component scores that correspond to lower intake (reverse-scored), under raters had the highest scores for sugar-sweetened beverages and fruit juice, red and/or processed meats, and sodium ($p < 0.001$).

HEI-2010 and AHEI-2010 total and component scores across categories of discrepancy score by diabetes status

This study further examined the sub-component HEI-2010 and AHEI-2010 scores in relation to PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010 by diabetes status after adjusting for age, sex, ethnicity, smoking status, poverty-to-income ratio, and BMI **(Tables 31 & 32)**. The analysis is an extension of the first research objective to better understand the relationship between diabetes status and discrepancy of PDQ and MDQ. **Table 31** shows significant differences in mean sub-component and total HEI-2010 scores ($p < 0.05$) across PDQ-MDQ-HEI2010 groups by diabetes status. Individuals who under rated their diet quality had the highest sub-component and total HEI-2010 across diabetes status. Among nondiabetics, under raters had the highest total HEI-2010 score (mean score = 55.1 ± 0.8, $p < 0.001$) as well as for all the sub-component scores ($p < 0.001$). Similarly, prediabetic under raters had the highest total HEI-2010 score (mean score = 55.8 ± 0.8, $p < 0.001$) as well as for all the sub-component scores ($p < 0.001$). Among diabetics, under raters had the highest total HEI-2010 score (mean score = 57.8 ± 1.0, $p < 0.001$) as well as for the majority of the sub-component scores ($p < 0.001$), except total protein foods ($p > 0.05$). When comparing across diabetes status, diabetic under raters had the highest total HEI-2010 (mean score = 57.8 ± 1.0) scores compared to prediabetics and nondiabetics.

Table 32 shows significant differences in mean sub-component and total AHEI-2010 scores ($p < 0.05$) across PDQ-MDQ-AHEI2010 groups by diabetes status. Individuals who under rated their diet quality had the highest sub-component and total AHEI-2010 across diabetes status. Among nondiabetics, under raters had the highest total AHEI-2010 score (mean score = 46.9 ± 0.9, $p < 0.001$) as well as for all the sub-component scores ($p < 0.001$). Similarly, prediabetic under raters had the highest total AHEI-2010 score (mean score = 49.4 ± 1.0, $p < 0.001$) as well as for all the sub-component scores. Among diabetics, under raters had higher scores for the total AHEI-2010 score (mean score = 47.1 ± 1.1, $p < 0.001$) as well as for the majority of the sub-component scores ($p < 0.001$), except total vegetables, nuts and legumes, and alcohol ($p > 0.05$). When comparing across diabetes status, prediabetic under raters had the highest total AHEI-2010 scores compared to diabetic and nondiabetics (mean score = 49.4 ± 1.0).

Bivariate associations between predictors of HEI-2010 and AHEI-2010 discrepancy scores

Table 33 presents the bivariate associations between the predictors of discrepancy score and each other. These predictors were selected as potential covariates to be included in the multivariate models. As the main predictor variable, diabetes status was strongly associated with age (Rao-Scott Chi-square: 484.6, $p <$ .0001) and perceived health status (Rao-Scott Chi-square: 236.5, $p <$ .0001). In addition, there were significant associations among the other predictors (covariates). For example, perceived health status was strongly associated with education, ethnicity, adult food security category, depression status, and fatalistic attitude about body weight (are people born fat/thin) ($p < 0.001$). For the predictors related to attitude, fatalistic attitude about body weight (are people born fat/thin) was strongly associated with attitude toward change in current diet (no reason to change diet) (Rao-Scott Chi-square: 215.4, $p <$ .0001). Overall, the large Chi-square and significant p-values indicate strong associations between the predictors and each other, which means that they are highly interrelated.

Association between diabetes status and HEI-2010 and AHEI-2010 discrepancy score

To address the third objective, multinomial logistic regression analysis was used to determine the strength of the relationships between diabetes status and PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010. Results from the goodness-of-fit indicate that the data fits the model well with p-value > 0.05 (HEI-2010 model: p = 0.2805; AHEI-2010 model: p = 0.1651) **(Tables 34 & 35)**. **Table 34** shows the association between diabetes status and PDQ-MDQ-HEI2010 before and after controlling for covariates. For the unadjusted model (Model 1), diabetes status was significantly associated with PDQ-MDQ-HEI2010 (p = 0.0178). The association between diabetes status and PDQ-MDQ-HEI2010 remained significant even after controlling for sociodemographics (Model 2: p = 0.0093) and attitudes about change in current diet and being fat/thin (Model 3: p = 0.0199). However, the association between diabetes status and PDQ-MDQ-HEI2010 was not significant after further controlling for perceived health status (Model 4: p = 0.1921).

The results for diabetics were significant using the PDQ-MDQ-HEI2010. In Model 1, diabetics had significantly higher odds of being under raters compared to matchers [O.R. = 1.5, 95% C.I. = 1.1-2.0]. The odds ratio for diabetic under raters slightly increased and remained significant in Models 2 and 3. Diabetics had 1.6 times the odds (16% increase) of being under raters than matchers, holding all other predictor variables constant. However, the odds ratio for diabetic under raters was attenuated and became not significant in Model 4 [O.R. = 1.3, 95% C.I. = 0.9-2.0] (**Table 34**).

Table 35 shows the association between diabetes status and PDQ-MDQ-AHEI2010 before and after controlling for covariates. For the unadjusted model (Model 1), diabetes status was significantly associated with PDQ-MDQ-AHEI2010 (p = 0.0134). The association between diabetes status and PDQ-MDQ-AHEI2010 remained significant even after controlling for sociodemographics (Model 2: p = 0.0293) and attitudes about change in current diet and being fat/thin (Model 3: p = 0.0365). However, the association between diabetes status and PDQ-MDQ-

AHEI2010 was not significant after further controlling for perceived health status (Model 4: $p = 0.2921$).

The results for diabetics using PDQ-MDQ-AHEI2010 were similar to PDQ-MDQ-HEI2010. In model 1, diabetics had higher odds of being under raters compared to matchers [O.R. = 1.3, 95% C.I. = 0.9-1.9]. The odds ratio for diabetic under raters slightly decreased in Model 2 and 3. Diabetics had 1.2 times the odds (12% increase) of being under raters than matchers, holding all other predictors constant. Also, the odds ratio for diabetic under raters was further attenuated in Model 4 [O.R. = 1.1, 95% C.I. = 0.7-1.7] (**Table 35)**. The odds ratios for diabetic under raters in the models (Model 1-4) were not significant using PDQ-MDQ-AHEI2010.

The results for prediabetics were significant using PDQ-MDQ-AHEI2010. In Model 1, prediabetics had significantly lower odds of being over raters compared to matchers raters [O.R. = 0.8, 95% C.I. = 0.6-0.9]. The odds ratio for prediabetic over raters did not change but remained significant in Model 2 and 3. Prediabetics had 0.8 times the odds (20% decrease) of being over raters than matchers raters, holding all other predictors constant. However, the odds ratio for prediabetic over raters became not significant in Model 4 [O.R. = 0.8, 95% C.I. = 0.7-1.0] (**Table 35)**.

Discussion

There have been few studies that have examined dietary misperception in relation to diet quality. The present study was one of the few that examined dietary misperception by calculating discrepancy scores that represent the difference between PDQ and MDQ. However, there are no studies that have examined the relationship between diabetes status and dietary misperception (using discrepancy scores). In addition, this study was the first to use the HEI-2010 and AHEI-2010 as two measures of dietary quality to represent MDQ. Discrepancy scores were evaluated based on three aspects: 1) the magnitude of the difference (absolute value) only, 2) the magnitude and direction of the difference, and 3) the direction only. This study reports the results of analyses based solely on the direction of the difference to evaluate dietary misperception because it provided the most meaningful results. There are different ways to classify dietary misperception. Individuals who self-rated their diet as better than their actual (objective) diet were classified as over raters or "optimists." Individuals who self-rated score matches their objective score were classified as matchers or "realists." Individuals who self-rated their diet as worse than their actual (objective) diet were classified as under raters or "pessimists." Similar to previous studies (J. Brug, P.A. Assema, G. Kok, T. Lenderink, 1994; Variyam et al., 2001), this study classified individuals as under raters, matchers, and over raters based on their discrepancy scores.

The literature on dietary misperception is very limited. There were two studies that examined the discrepancy between PDQ and MDQ among healthy U.S. adults (Variyam et al., 2001; Powell-Wiley et al., 2014). The first was a cross-sectional study by Variyam and colleagues (2001) that compared consumers' overall diet quality (using HEI-1995) and self-reported diet quality using the 1989-1990 CSFII-DHKS. Results showed that about 40% of household meal planners or preparers perceived their diets to be of higher quality than they actually were. These participants were classified as "optimists." Another 40% of the respondents were "realists," which means that they accurately assessed the quality of their diets. The remaining 20% were "pessimists," which means that they perceived their diets to be worse than they actually were. The main finding was that a large proportion of U.S. adults were "optimists" (over raters) about their diet quality. The authors concluded that nutritionists and healthcare professionals need to be aware of this misperception (Variyam et al., 2001). In this study, about 39.4% of participants in the sample over rated their diet quality (using HEI-2010), which is similar to the percentage of optimists in the Variyam study.

As previously mentioned, the present study calculated discrepancy scores using two different measures of diet quality: the Healthy Eating Index (PDQ-MDQ-HEI2010), and the Alternative Health Eating Index (PDQ-MDQ-AHEI2010). In each case, MDQ was subtracted from PDQ to yield a difference score; aggregated positive scores indicated over rating, and aggregated negative scores indicated under rating. The majority of participants in the sample over rated their diet quality for both PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010 **(Table 24)**. However, the percentage of over raters was higher with PDQ-MDQ-AHEI2010 compared to PDQ-MDQ-HEI2010 (58.3% vs. 39.4%, respectively). This indicates that the AHEI-2010 may be more rigorous and difficult to achieve than the HEI-2010. In addition, the percentage of matchers for PDQ-MDQ-HEI2010 was higher than PDQ-MDQ-AHEI2010 (37.4% vs. 29.5%, respectively), which suggests that participants were more likely to meet the dietary recommendations represented by HEI-2010 rather than AHEI-2010.

A possible reason for the large difference in the proportion of over raters is the difference in how each index was constructed. One of the major differences between the HEI-2010 and AHEI-2010 is the treatment of alcohol consumption. The HEI-2010 counts alcohol intake as part of empty calories (threshold exceeds moderate level more than 13 grams/1,000 kcal). However, the AHEI-2010 counts alcohol intake as a separate category where moderate drinking is part of a healthful dietary pattern. The AHEI-2010 scoring methodology as reported by Wang and colleagues (2014) is non-linear and assigns higher scores to moderate alcohol drinkers than to nondrinkers (Wang et al., 2014). Moderate alcohol drinkers (Male: 0.5-2.0 drinks/day; Female: 0.5-1.5 drinks/day) received the maximum score of 10 points, while nondrinkers received 2.5 points. This method of scoring severely penalizes nondrinkers and makes analysis more difficult, because a score of 2.5 could mean either a non-drinker, or a moderately heavy drinker. The methodology used to construct alcohol intake for AHEI-2010 took into account the type of alcohol consumed (i.e., assigned full-weight for beer, wine, and distilled liquors and half-weight for cocktails) but the total alcohol score is the sum of these scores (Wang et al., 2014). This study did not further analyze alcohol consumption by type. Since few diabetics in this study consumed any alcohol (about 1.0%), the sample size does not permit sub-analyses by the type of alcohol on the relative benefits of other types of alcohol.

To better understand the reason for the higher percentage of over raters when using AHEI-2010 as the basis for MDQ, this study explored another approach to scoring alcohol intake to see if it would produce clear results or results more similar to HEI-2010. In this alternative analysis, alcohol consumption was scored linearly. Non-drinkers received the maximum score of 10 points. As alcohol consumption increased, score decreased, reaching 0 for those who exceeded 2.0 drinks per day for males, and 1.5 drinks per day for females. Interpretation of the results is clearer because each score is associated with one specific level of alcohol consumption. The resulting modified AHEI-2010 score (no alcohol penalty) was used to calculate a modified PDQ-MDQ-AHEI2010. There were differences in the percentages of over raters and matchers between the original and modified AHEI-2010 scores. The percentage for over raters was lower in the modified compared to the original AHEI-2010 score (47.7% and 58.3%, respectively). However, the percentage of matchers was higher for the modified compared to the original AHEI-2010 score (34.6% vs. 29.5%, respectively). This suggests that the higher percentage of over raters for AHEI-2010 compared to HEI-2010 is attributable to the difference in alcohol scoring.

The HEI-2010 and AHEI-2010 are different tools to assess dietary quality. For AHEI-2010, the maximum score was rescaled from 110 points to 100 points using a modified form that does not take into account trans fat. For both indices, a maximum score of 100 points were calculated to represent the best possible diet quality. The USDA published cutoffs that can be used to interpret HEI-2010 scores. Scores above 80 indicate a "good" diet, while scores below 51 indicate a "poor" diet. An HEI-2010 score between 51 and 80 is considered as "needing dietary improvement" (P. M. Guenther et al., 2014). Using HEI-2010, about 36.6% of participants in the sample were classified as "needing dietary improvement." If the same numerical cut-offs were applied to the AHEI-2010, about 17.4% of participants would be classified as "needing dietary improvement." However, the proportion of participants having a "poor" diet is higher for AHEI-2010 compared to HEI-2010 (82.5% vs. 61.9%, respectively). Again, this illustrates the differences in scoring between the HEI-2010 and AHEI-2010. Nevertheless, both indices suggest that Americans need to improve the quality of their diets.

In general, results of the present study indicate that under raters (or pessimists) were likely to have higher overall diet quality scores. In this sample, under raters had higher mean PDQ-MDQ-HEI2010 scores than matchers and over raters (55.4 vs. 48.9 vs. 41.3, respectively) **(Table 29)**. Under raters also had higher mean PDQ-MDQ-AHEI2010 scores than matchers and over raters (47.8 vs. 42.1 vs. 34.5, respectively) **(Table 30)**. Variyam and colleagues (2001) found similar results using HEI-1995. They found that pessimists had higher mean HEI-1995 scores than realists and optimists (68.6 vs. 66.2 vs. 60.6, respectively) (Variyam et al., 2001). This suggests that under raters are more aware of the shortcomings of their diets and are willing to improve their health through eating a healthy diet.

The present study further assessed the differences in discrepancy scores (PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010) across diabetes status categories and found that the relationship was highly significant. Diabetics had the highest percentage of being under raters compared to prediabetics and nondiabetics **(Table 25)**. A possible explanation is that diabetics are receiving more nutrition education as a result of greater exposure to healthcare. In this sample, diabetics were more likely to have health insurance compared to prediabetics and nondiabetics (88.1% vs. 82.1% vs. 80.1%, respectively). Diabetics were also more likely to report having a routine place to go for healthcare compared to prediabetics and nondiabetics (93.4% vs. 86.5% vs. 83.8%, respectively). In addition, diabetics were likely to have received a greater number of healthcare visits during the preceding 12-month period. About 39.5% of diabetics received 4-9 healthcare visits compared to 24. 8% of prediabetics and 19.6% of nondiabetics. This analysis supports the idea that diabetics rate their health and their diets more realistically (i.e., poorly) than prediabetics and nondiabetics because they have greater exposure to regular healthcare and diabetic education.

Diabetics appear to have a better sense of what constitutes a healthy versus an unhealthy diet based on the nutrition care and education they are receiving. This study found that diabetic under raters had higher mean scores than nondiabetics for the majority of HEI-2010 and AHEI-2010 sub-components, which suggests that they are doing something to improve their diets. This was also reflected in the individual component scores. Diabetic under raters had higher mean scores for the majority of adequacy components (corresponding to higher intakes). These components include total vegetables, greens and beans, whole grains, and dairy ($p < 0.001$). For the moderation components (where lower consumption leads to a higher score), diabetic under raters had higher scores for refined grains ($p < 0.001$) **(Table 31)**. For AHEI-2010 sub-components, diabetic under raters had higher mean scores (corresponding to higher intakes) for whole fruit and total vegetables and lower mean scores for alcohol ($p < 0.001$). For the reverse-scored components (corresponding to lower intakes), diabetic under raters had higher scores for (i.e., consumed less) sugar-sweetened beverages and sodium ($p < 0.001$) **(Table 32)**. The differences in diet quality (using HEI-2010 and AHEI-2010) across diabetes status (nondiabetes, prediabetes, T2DM) suggest a need to improve the healthcare system in the U.S. through greater provision of nutrition education in healthcare settings. The fact that diabetics receive nutrition counseling and do better on measures of diet quality than nondiabetics and prediabetics suggests that nutrition counseling can be effective in getting people to change their diets. Current trends in diabetes incidence and prevalence suggests that there should be greater emphasis on nutrition education in medical curricula and should not be just limited to diabetics. Reversing the current trend will likely require greater coverage for nutrition counseling for individuals who are at risk for diabetes but who have not yet been diagnosed.

Results from the multinomial logistic regression models suggest that diabetics had greater odds of being under raters than matchers. The odds ratio for diabetic under raters was significant for PDQ-MDQ-HEI2010 but not for PDQ-MDQ-AHEI2010. There are two possible reasons: 1) HEI-2010 and AHEI-2010 are made up of different sub-components and 2) Different approaches were used to construct each index. The AHEI-2010 reflects a critique of the HEI-2010 and incorporates distinct features. For example, the AHEI-2010 pays more attention to fat quality (i.e., omega-3 fats, PUFAs), promotes intake of nuts and legumes, penalizes greater intakes of red meat, sugar-sweetened beverages and fruit juice (added sugars), and considers moderate alcohol intake as beneficial to health regardless of type and disease status (i.e., diabetes). However, the HEI-2010 is reflective of the 2010 Dietary Guidelines for Americans, which represents a consensus of the opinions of many experts, whereas the AHEI-2010 reflects a critique of the Dietary Guidelines by an academic research group at Harvard University. Diabetic education within the healthcare system is more likely to reflect the influence of the HEI rather than the AHEI. The results of this study suggest that the HEI-2010 more closely reflects the current American diet than the AHEI-2010.

The covariates used in these models were similar to those used in an earlier study that analyzed factors associated with consumer misperception of diet quality (using HEI-1995) (Variyam et al., 2001). As a preliminary step, this study evaluated the bivariate relationships among the covariates in order to help build a final parsimonious model. Perceived health status was found to be associated with most other predictors: diabetes status, education, food security, depression, and fatalistic attitude about body weight (are people born fat/thin) **(Table 33)**. This indicates that perceived health status has strong predictive power in relation to discrepancy scores.

The present study constructed hierarchical multivariate models using diabetes status as the main predictor and PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010 as the outcomes. In the simple model (without covariates), diabetes status was significantly associated with PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010. The relationships remained significant even after adjusting for sociodemographic and attitudinal factors. However, diabetes status became insignificant as a predictor of PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010 when perceived health status was added as a covariate into the model. This makes sense because perceived health status was strongly associated with both diabetes status (Rao-Scott Chi-square: 236.5, $p < .0001$) and discrepancy score.

The power of perceived health status to predict discrepancy score was consistent with the results of Variyam and colleagues (2001). They performed binary logistic regression and included several predictors (i.e., age, sex, education, household size) in relation to dietary misperception (0 = realists/pessimists, 1 = optimists) and found that self-perceived health had the largest odds ratio among all predictor variables. Individuals who reported their health as "excellent" had nearly three times the odds of being optimistic about their actual (objective) diet compared to those who self-rated their health to be "other than excellent" (OR = 3.740, p = 0.00) (Variyam et al., 2001). This study found that individuals who perceived their health as "excellent" had about two times the odds of being over raters compared to those who perceived their health as "good" (PDQ-MDQ-HEI2010: OR = 1.9, p = 0.000; PDQ-MDQ-AHEI2010: OR = 2.1, p = 0.000). This supports the finding that perceived health status has strong predictive power in relation to dietary misperception.

Perceived or self-rated health has been shown to be a valid and reliable measure of individuals' overall health (Benyamini, Leventhal, & Leventhal, 1999; Jylhä, 2009; Schnittker & Bacak, 2014). Several studies have shown that self-rated health is a good predictor of morbidity and mortality, especially among individuals diagnosed with chronic disease (i.e., diabetes in older people) (Benyamini et al., 1999; Jylhä, 2009; Schnittker & Bacak, 2014). Since self-rated health reflects the state of mind, it also has potential effect on the human body. Currently, a new line of research is investigating the relationship of self-rated health to biochemical processes and physiological dysregulations (Jylhä, 2009). Studies have found associations between negative self-rated health and higher levels of inflammatory markers (i.e., cytokines), which are known to play a role in the development of diabetes and other chronic diseases (i.e., CVD, cancer) (Jylhä, 2009).

A question about self-rated health has frequently been included in population studies because it is a simple and informative measure of health status (Schnittker & Bacak, 2014). Individuals may perceive things about their health that cannot be measured by a survey instrument or obtained during routine clinical examination (Schnittker & Bacak, 2014). Furthermore, individuals' exposure to health-related information can improve the predictive validity of self-rated health. Currently, U.S. adults are more informed about medical health and can access various sources of health-related information (Schnittker & Bacak, 2014). The results are consistent with the idea that diabetics have poorer health, and are more aware of the limitations of their health and the need for improvement. Future research is needed to examine the association between other chronic diseases and dietary misperception.

Perceived or self-rated health is strongly related to self-rated diet. Self-rated diet does not have the same validity and reliability as self-rated health, but it can be a useful measure of individuals' perception of their own diet. However, there are critical ways in which it is different from self-rated health. People living with diabetes and other chronic conditions may have emotional and physical symptoms that they associate with being in better or worse health. For example, they might experience sickness, pain, or low energy level as a physical response. They may also experience anxiety and/or depressed mood as an emotional response. However, an individual's perception of diet quality is not likely to be based on an immediate physical or emotional response to food consumption. Consumption of a poor diet does not necessarily result in immediate physical or emotional symptoms. The effects of a poor diet may take months or years to manifest themselves, and the relationship of symptoms to diet may not be evident. If a person is aware of the fact that they have a poor diet, it's likely to be because of externally imparted information (i.e., doctor, dietitian) rather than any realization of the relationship between diet and health. Self-assessment of diet is more likely to be based on individuals' prior knowledge of what constitutes a healthy or unhealthy diet rather than the presence or absence of symptoms. In this sample, diabetics had poorer perception of their general health and diet. They were more likely to under rate their diet because their disease has provided them greater exposure to nutrition education as a source of external knowledge.

The single-item question on self-rated diet has been less studied in terms of its validity and reliability. Loftfield and colleagues (2015) conducted secondary analysis of a cross-sectional sample of urban-dwelling adults (n = 1,644) to evaluate the construct validity of self-rated diet with self-reported dietary intake, biomarkers, and diet-related health outcomes (Loftfield, Yi, Immerwahr, & Eisenhower, 2015). The authors found significant associations between self-rated diet and dietary intake, biomarkers and health-related outcomes. Individuals who self-rated their diets as "poor" had decreased intakes of fruits and vegetables (# servings/day) and increased intakes of sugar-sweetened beverages and frequent consumption of fast-food ($P < .001$) compared to those who rated their diets as "excellent". In terms of biomarkers, individuals who self-rated their diet as "poor" had higher mean sodium to potassium ratios than those who rated their diet as "good" or "excellent" (2.0 ± 0.1 vs. 1.8 ± 0.1 vs. 1.3 ± 0.1, respectively, P for trend $< .001$). For health-related outcomes, individuals who self-rated their diet as "poor" also had higher mean systolic and diastolic blood pressure ($P = 0.010$) and BMI ($P < .001$) than those who rated their diets as “excellent”. The authors concluded that self-rated diet quality as a single-item question can be a useful proxy for actual dietary intake, biomarkers, and diet-related clinical measures (Loftfield et al., 2015).

Self-perception can positively or negatively affect individuals’ attitudes. The present study examined three attitudinal variables: a fatalistic attitude about body weight (people born fat/thin), reasons to change in current diet (no reason for me to change my diet), and the importance of nutrition in grocery shopping decisions. In the bivariate analysis, a fatalistic attitude about body weight was significantly associated with diabetes status but not with discrepancy scores (PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010) **(Supplemental table 13)**. Attitude about change in current diet was significantly associated with discrepancy scores but not with diabetes status **(Table 28)**. However, attitude about importance of nutrition was not significantly related to diabetes status or discrepancy scores, and was not included in the multivariate models.

There could be other things that people consider important when buying food from the grocery store. In NHANES, the Flexible Consumer Behavior Survey consists of a series of five questions related to how people choose the foods they buy from grocery stores and supermarkets. These include the importance of price, taste, nutrition, ease of food preparation, and how well the food keeps. In this sample, respondents were asked about the importance of each of these attributes in their food buying decisions. Taste was most important (about 75.9%) followed by nutrition (about 61.1%) when buying food from the grocery store. The question about the importance of nutrition seems to be a leading question. Although the questions don’t necessarily have a right and a wrong answer, people have probably heard many times that nutrition is important, and so may select it as “the right answer” due to social desirability. Attitudinal questions do not necessarily have a right or wrong answer but they are related to individuals’ perception and can affect their willingness to change. Therefore, dietary interventions should take into account change in having more positive attitudes to improve health.

Assessment of general nutrition knowledge was limited in this study. Previous studies have shown that nutrition education helps increase knowledge and subsequently improve dietary intake (Spronk, Kullen, Burdon, & O’Connor, 2014). This study evaluated nutrition knowledge based on knowledge of the 2005 dietary guidelines. The DGA 2005 was used as proxy for general nutrition knowledge because the questions on DGA 2010 are not available in 2007-2010 NHANES. Ideally, assessment of nutrition knowledge would capture individuals’ understanding on importance of nutrients and food groups and their relationship with health outcomes. This study mainly focused on individuals’ ability to determine the recommended consumption of each food group based on the DGA 2005 rather than assessing their knowledge of the relationship between nutrition and health. In addition, knowledge about the dietary guidelines does not measure individuals’ recognition that their own diet needs to change. Knowledge about the dietary guidelines is not enough to determine whether or not individuals have nutrition knowledge. More research is needed on nutrition literacy for individuals to obtain, process, and understand nutrition information and skills needed in order to make appropriate nutrition decisions (Spronk et al., 2014). Interestingly, more than half of diabetics (about 51.6%) reported "no" or "don't know" on whether they heard about MyPyramid. The MyPyramid is based on educating the general population. However, MyPyramid also has practical use for individuals with prediabetes (at high risk of developing diabetes) or with diagnosed diabetes (T2DM) (Clark, Kovarik, Voigt, & Hayes, 2006). The MyPyramid website has some educational tools for individuals with diabetes by providing more specifics about the individual food groups and what food groups are in each (Clark et al., 2006). However, information about which foods contain carbohydrates is not included (Clark et al., 2006). It is possible that diabetics are more familiar with other guidelines (i.e., American Diabetes Association) and receive nutrition education primarily on "carbohydrate counting" for diabetes management.

Strengths and Limitations

Strengths of this study include the use of a large, nationally representative sample of U.S. adults with standardized methods of data collections and quality control. Therefore, the findings are generalizable and have implications for the development of targeted dietary interventions and effective policies to improve health and/or disease outcomes. The present study was the first to examine the relationship between diabetes status and discrepancy score using both HEI-2010 and AHEI-2010 as objective measures of diet quality. In addition, this study included a comprehensive assessment of factors associated with dietary misperception in U.S. adults with and without T2DM.

However, this study also has some limitations: First, NHANES is a cross-sectional study and therefore, the results cannot support causal inferences about the relationships between diabetes status and dietary misperception. Second, self-perceived diet was assessed based on a single-item question available in NHANES. However, a recent study has shown that PDQ is a valid and reliable single-item question to measure of self-rated diet. Findings of the study suggested that self-rated diet could be used as a proxy for self-reported dietary intake and a predictor of diet-related health outcomes (Loftfield et al., 2015). Public health programs could use self-rated diet to monitor the diet healthfulness of population subgroups and evaluate intervention programs that focus on improving overall dietary patterns (Loftfield et al., 2015). Third, this study used a single 24-hour dietary recall to calculate the HEI-2010 and AHEI-2010 scores, which may not reflect individuals' habitual or usual intake. In addition, the 24-hour recall may be subject to measurement error because it relies on participants' ability to recall and accurately self-report dietary intake, which may lead to under- or over- reporting. Lastly, this study was not able to evaluate the relationships of other potential factors such as dietary self-efficacy, barriers to healthy eating, and nutrition literacy, since this information is not available in NHANES. More research is needed to develop a conceptual framework that takes into account the determinants of dietary misperception and how they are related to health and/or disease outcomes.

Conclusion

In conclusion, the present study found significant relationships between diabetes status and discrepancy scores (using PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010). This study also found significant associations of modifiable factors (i.e., lifestyle, attitudes, and self-perceived health) and non-modifiable factors (i.e., sociodemographics) with discrepancy scores. Diabetes status was strongly associated with PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010 before and after controlling for sociodemographic and attitudinal factors. However, perceived health status was found to have the strongest predictive power in relation to PDQ-MDQ-HEI2010 and PDQ-MDQ-AHEI2010. The relationship between diabetes status and discrepancy scores was consistent using the HEI-2010 and AHEI-2010. Neither HEI-2010 nor AHEI-2010 showed clear superiority in terms of their associations with diabetes status and other covariates. However, this study found that the AHEI-2010 was associated with greater discrepancy in PDQ and MDQ than the HEI-2010.

This study was the first to examine the relationship between diabetes status and discrepancy of PDQ and MDQ using HEI-2010 and AHEI-2010. Findings of this study have implications for public health policy and dietary interventions aimed at diabetes prevention. For both HEI-2010 and AHEI-2010, nondiabetics were more likely to over rate while diabetics were likely to be under rate their diet quality. Diabetic under raters had significantly higher total sub-component HEI-2010 and AHEI-2010 scores than prediabetics and non-diabetics, suggesting that these individuals were more aware of the shortcomings in their diets, and that they were making efforts to improve the quality of their diets. The Standards of Medical Care in Diabetes emphasize the importance of medical nutrition therapy on self-management (William T. Cefalu, MD et al., 2017). It is possible that nutrition education is helping diabetics make better food choices. Both HEI-2010 and AHEI-2010 scores indicate that Americans on average are not meeting the recommendations and need to improve the quality of their diets. Providing nutrition education to a broader, but targeted, population of individuals at risk for diabetes may mitigate the increasing trend in diabetes prevalence and help control healthcare costs.

This study found that perceived health status was a powerful predictor of discrepancy scores. One possible reason is that self-perceived health is strongly related to self-perceived diet. Individuals who had poorer perceptions of their health were more likely to have poorer perceptions of their diet. In addition, both self-perceived health and self-perceived diet were strongly associated with diabetes status. This study found that diabetics had poorer perceptions of their health and diet, suggesting that they are aware of the need to improve their diets and their health. These findings suggest that diabetic health care (possibly nutrition education) may be an important factor in diabetics' perceptions of their diets and the need to improve. The fact that diabetics were more likely than nondiabetics and prediabetics to report having a regular place for care (about 93.4%), and also had a higher average number of health care visits during the preceding year provides some support for this conclusion. The measurable differences in diet quality among diabetes status groups also suggests that the care diabetics receive is effective in getting them to change their behavior. In terms of care, diabetes self-management education is the component that focuses most closely on healthful eating pattern (diet quality) and hence, regular monitoring is probably responsible for the differences observed in this study. Elsewhere, diabetes self-management education has been shown to be effective in promoting regular physical activity, self-efficacy and empowerment, increased healthy coping, and decreased depression and other diabetes-related distress (Powers et al., 2016). This suggests that providing targeted diabetes self-management education to individuals who have not been diagnosed with diabetes, but who are at risk of diabetes, may help to improve diet quality and reduce future healthcare costs.

Lastly, this study found a greater discrepancy between PDQ and MDQ using the AHEI-2010 compared to the HEI-2010. The direction of the discrepancy indicates a higher percentage of over raters in the AHEI-2010 than the HEI-2010 (58.3% vs. 39.4%, respectively). This suggests that the AHEI-2010 represents a greater departure from current eating patterns of Americans than the HEI-2010 and may receive less emphasis in public health education. The two indices are similar in some respects (i.e., both capture consumption of fruits, vegetables, whole grains, and sodium) but differ in the method used to score alcohol intake. For AHEI-2010, the alcohol component score was constructed based on an aggregate of types of alcohol. However, the analysis did not differentiate the relative benefits of different types of alcohol. The AHEI-2010 considers moderate alcohol intake as part of a healthful dietary pattern and assigns the highest scores (10 out of 10 possible points) to those who consume alcohol up to the defined limits of moderation. Nondrinkers are assigned a score of 2.5 points out 10, the same score that might be assigned to an individual who consumes excessive alcohol. This method of scoring is not linear, and appears to be heavily biased against nondrinkers of alcohol. This approach to scoring might be appropriate for a healthy population. However, it’s not clear that it reflects a consensus view of the safety of alcohol, and may run counter to some of the key principles of diabetes self-management (Peele, 2009; CDC, 2017). In this study, most of the diabetics were nondrinkers and were thus penalized in their AHEI-2010 scores. As part of their self-management, diabetics are more likely to be advised to limit or not consume alcohol to prevent hypoglycemia and other adverse effects (William T. Cefalu, MD et al., 2017). Therefore, it might not be appropriate to recommend moderate alcohol intake for diabetics to achieve higher AHEI-2010 scores.

Table 23. Baseline characteristics of U.S. adults using 2007-2010 NHANES (Age ≥ 20, N = 4097)

Characteristic	(n)	*n* (%)
[a]Perceived Diet Quality	4096	
Excellent		332 (8.3)
Very Good		879 (23.7)
Good		1743 (42.9)
Fair		936 (20.8)
Poor		206 (4.4)
[b]Criterion-Referenced HEI-2010 Total Score	4097	
(80 – 100)		55 (1.5)
(60 – < 80)		728 (17.7)
(40 – < 60)		2015 (48.2)
(20 – < 40)		1252 (31.6)
(0 - < 20)		47 (1.0)
[b]Criterion-Referenced AHEI-2010 Total Score	4097	
(80 – 100)		3 (0.1)
(60 – < 80)		288 (7.3)
(40 – < 60)		1514 (34.7)
(20 – < 40)		1979 (49.6)
(0 - < 20)		313 (8.3)
[c]Diabetes Status	4056	
Nondiabetic		1436 (41.4)
Prediabetic		1905 (46.1)
Diabetic		715 (12.5)

Data source: Adults 20+ years of age participated in 2007-2010 NHANES.
Notes: Analyses adjusted for complex survey design and applied fasting subsample weights.
[a]Perceived diet quality represents the answer to the question 'In general, how healthy is your overall diet?' on a 5-point Likert scale with possible answers ranging from 'excellent' to 'poor'.
[b]Measured diet quality was based on estimated cut-offs for total HEI-2010 and AHEI-2010 scores using the criterion-referenced method. The following cut-offs were used to divide the total HEI-2010 and AHEI-2010 scores into groups: (80-100 = excellent; 60- <80 = very good; 40- <60 = good; 20- <40 = fair; 0- <20 = poor).
[c]Diabetes status was defined from self-report of participants in the diabetes questionnaire and from the laboratory biomarkers using the cut-offs based on the 2017 Standards of Medical Care from the American Diabetes Association [ADA] for diabetes diagnosis.
Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010.

Table 24. Univariate Analysis of HEI-2010 and AHEI-2010 Discrepancy Scores using 2007-2010 NHANES (N = 4097)

Discrepancy Score	(n)	(*n*) %
[a]**HEI-2010 (absolute value)**	4096	
0		1507 (37.4)
1		1941 (47.9)
2		557 (12.6)
3		91 (2.0)
[a]**AHEI-2010 (absolute value)**	4096	
0		1269 (29.5)
1		1933 (48.2)
2		719 (17.9)
3		715 (4.3)
[b]**HEI-2010 (direction)**	4096	
Under Raters		1070 (23.2)
Matchers		1507 (37.4)
Over Raters		1519 (39.4)
[b]**AHEI-2010 (direction)**	4096	
Under Raters		605 (12.2)
Matchers		1269 (29.5)
Over Raters		2222 (58.3)

[a]Discrepancy scores (absolute value) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality [abs(discrepancy score = perceived score – objective total HEI-2010 or AHEI-2010 score)] regardless of the direction of the difference. For example, an individual who rated his/her diet as "Very Good" but had an objective rating of "Excellent" would have the same discrepancy score as an individual who rated his/her diet as "Excellent" and had and objective rating of "Very Good."
[b]Discrepancy scores (direction) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score – objective total HEI-2010 or AHEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.
Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010.

Table 25. Bivariate associations between HEI-2010 and AHEI-2010 Discrepancy scores and Diabetes Status in U.S. adults (Age ≥ 20 years)

Discrepancy Score	Diabetes Status n (%)			
[a]**Absolute Value**	**Nondiabetes**	**Prediabetes**	**Diabetes (T2DM)**	***p* trend**
HEI-2010				0.7175
0	527 (37.0)	707 (38.5)	259 (34.9)	
1	691 (48.8)	899 (47.1)	329 (48.0)	
2	187 (12.2)	259 (12.4)	107 (14.4)	
3	31 (1.9)	40 (1.9)	20 (2.6)	
AHEI-2010				0.3401
0	414 (27.2)	617 (31.3)	225 (30.0)	
1	691 (48.9)	883 (47.2)	342 (50.1)	
2	265 (18.9)	327 (17.6)	119 (15.9)	
3	66 (4.9)	78 (3.9)	29 (3.9)	
[b]**Direction**	**Nondiabetes**	**Prediabetes**	**Diabetes (T2DM)**	***p* trend**
HEI-2010				0.0125
Under Raters	348 (20.9)	493 (23.5)	219 (29.3)	
Matchers	527 (37.0)	707 (38.5)	259 (34.9)	
Over Raters	561 (42.0)	705 (38.0)	237 (35.7)	
AHEI-2010				0.0313
Under Raters	191 (11.0)	274 (12.3)	135 (16.1)	
Matchers	414 (27.2)	617 (31.3)	225 (30.0)	
Over Raters	831 (61.7)	1014 (56.4)	355 (53.9)	

[a]Discrepancy scores (absolute value) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality [abs(discrepancy score = perceived score – objective total HEI-2010 or AHEI-2010 score)] regardless of the direction of the difference. For example, an individual who rated his/her diet as “Very Good” but had an objective rating of “Excellent” would have the same discrepancy score as an individual who rated his/her diet as “Excellent” and had and objective rating of “Very Good.”

[b]Discrepancy scores (direction) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score – objective total HEI-2010 or AHEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.

Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010.

Table 26. Sociodemographic characteristics of U.S. adults (Age ≥ 20 years) across HEI-2010 and AHEI-2010 Discrepancy scores

Predictors	HEI-2010 Discrepancy Score			*p* trend	AHEI-2010 Discrepancy Score			*p* trend
	Under Raters (n = 1070)	**Matchers** (n = 1507)	**Over Raters** (n = 1519)		**Under Raters** (n = 605)	**Matchers** (n = 1269)	**Over Raters** (n = 2222)	
Age (in years)				0.5111				0.8308
20-39	322 (37.1)	463 (34.4)	445 (34.6)		163 (32.3)	387 (35.2)	680 (35.7)	
40-59	383 (38.2)	514 (40.7)	498 (38.2)		242 (42.6)	426 (39.1)	727 (38.4)	
60-79	312 (20.6)	441 (21.0)	458 (22.2)		169 (20.7)	375 (21.1)	667 (21.7)	
80+	53 (4.1)	89 (3.9)	118 (5.0)		31 (4.4)	81 (4.6)	148 (4.3)	
Sex				0.0003				0.0005
Male	434 (43.3)	708 (46.5)	803 (53.6)		261 (44.7)	570 (45.2)	1114 (51.1)	
Female	636 (56.7)	799 (53.5)	716 (46.4)		344 (55.3)	699 (54.8)	1108 (48.9)	
Race/Ethnicity				**<. 0001**				**<. 0001**
Mexican American	261 (11.8)	274 (7.9)	203 (5.7)		176 (14.8)	268 (9.6)	294 (5.8)	
Non-Hispanic White	441 (62.9)	759 (72.6)	827 (73.8)		225 (56.7)	602 (70.5)	1200 (73.9)	
Non-Hispanic Black	174 (11.8)	245 (9.9)	280 (10.5)		101 (13.5)	201 (10.3)	397 (10.2)	
Other	194 (13.4)	229 (9.5)	209 (9.9)		103 (14.9)	198 (9.6)	331 (10.1)	
Education Level				0.0002				0.0007
Less than high school	365 (22.4)	387 (16.5)	366 (15.4)		217 (24.1)	374 (19.4)	527 (15.0)	
High School diploma	249 (23.6)	374 (25.3)	342 (21.8)		140 (22.8)	284 (21.9)	541 (24.5)	
Some College education	280 (29.5)	402 (28.2)	431 (28.9)		152 (29.7)	346 (28.7)	615 (28.7)	
College Graduate or Above	174 (24.5)	341 (29.9)	379 (33.8)		96 (23.4)	263 (29.9)	535 (31.8)	
Smoking Status				0.9742				0.7192
Nonsmoker	601 (56.2)	845 (55.3)	813 (55.9)		325 (53.0)	701 (55.4)	1233 (56.4)	
Current smoker	192 (18.2)	280 (18.2)	301 (18.8)		118 (21.1)	235 (17.9)	420 (18.1)	
Former smoker	277 (25.6)	382 (26.5)	405 (25.4)		162 (25.9)	333 (26.7)	569 (25.5)	
Adult Food Security Category				0.0002				**<. 0001**
Full	708 (75.8)	1123 (82.2)	1153 (83.3)		384 (73.0)	913 (80.3)	1687 (83.3)	
Marginal	124 (9.2)	151 (7.7)	144 (6.5)		77 (10.3)	121 (7.4)	221 (7.1)	
Low	123 (8.1)	139 (6.3)	140 (7.2)		70 (8.6)	131 (7.4)	201 (6.6)	
Very Low	101 (6.9)	88 (3.7)	70 (3.1)		68 (8.1)	94 (4.9)	97 (3.0)	

Values are presented as column percents *n* (%) across categories of discrepancy scores for HEI-2010 and AHEI-2010.
Notes: Discrepancy scores (direction) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score– objective total HEI-2010 or AHEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.
Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010.

Table 27. Lifestyle and Health characteristics of U.S. adults (Age ≥ 20 years) across HEI-2010 and AHEI-2010 Discrepancy scores

Predictors	**HEI-2010 Discrepancy Score**			***p* trend**	**AHEI-2010 Discrepancy Score**			***p* trend**
	Under Raters (n = 1070)	**Matchers** (n = 1507)	**Over Raters** (n = 1519)		**Under Raters** (n = 1070)	**Matchers** (n = 1507)	**Over Raters** (n = 1519)	
[a]**Physical Activity**				**<. 0001**				**<. 0001**
Inactive	644 (53.9)	789 (44.9)	759 (41.9)		382 (57.0)	702 (48.9)	1108 (41.9)	
Insufficient	150 (14.8)	262 (20.3)	208 (15.9)		88 (16.6)	191 (16.4)	341(17.9)	
Sufficient	276 (31.3)	456 (34.7)	552 (42.0)		135 (26.4)	376 (34.7)	773 (40.1)	
BMI				**<. 0001**				**<. 0001**
Normal (18.5-24.9 kg/m^2)	216 (23.1)	400 (30.3)	471 (34.4)		129 (26.1)	293 (26.4)	665 (33.1)	
Overweight (25-29.9 kg/m^2)	361 (32.3)	507 (32.8)	566 (37.1)		183 (28.9)	464 (34.6)	787 (35.4)	
Obese (≥ 30 kg/m^2)	493 (44.6)	600 (36.9)	482 (28.4)		293 (44.9)	512 (38.9)	770 (31.5)	
[b]**WC**				**<.0001**				**<. 0001**
Not Abdominally Obese	339 (34.9)	591 (43.1)	718 (52.9)		189 (35.3)	470 (40.5)	989 (49.5)	
Abdominally Obese	705 (65.1)	894 (56.9)	771 (47.1)		402 (64.6)	773 (59.5)	1195 (50.5)	
Perceived Health Status				**<.0001**				**<.0001**
Excellent	63 (8.2)	172 (14.4)	304 (24.3)		37 (8.0)	93 (9.8)	409 (22.3)	
Very Good	192 (23.9)	397 (31.1)	505 (37.5)		87 (19.6)	312 (30.2)	695 (35.5)	
Good	416 (41.6)	573 (36.2)	464 (26.9)		216 (39.8)	516 (39.8)	721 (29.5)	
Fair	311 (20.6)	303 (15.4)	199 (9.4)		198 (24.1)	290 (17.4)	325 (10.6)	
Poor	88 (5.6)	62 (2.9)	46 (1.9)		67 (8.6)	58 (2.9)	71 (2.2)	

Values are presented as column percents *n* (%) across categories of discrepancy scores for HEI-2010 and AHEI-2010.

Notes: Discrepancy scores (direction) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score– objective total HEI-2010 or AHEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.

[a]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. [b]WC values were used to screen participants for abdominal obesity using sex-specific cut-offs: WC >102 for men and WC > 88 for women are classified as abdominally obese based on the National, Heart, Lung, and Blood Institute standards [NHLBI]. [c]Diabetes status was defined from self-report of participants in the diabetes questionnaire and from the laboratory biomarkers using the cut-offs based on the 2017 Standards of Medical Care from the American Diabetes Association (ADA) for diabetes diagnosis.

Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010; BMI, Body Mass Index; WC, Waist Circumference.

Table 28. Characteristics related to depression, attitudes, and knowledge of U.S. adults (Age ≥ 20 years) across HEI-2010 and AHEI-2010 Discrepancy scores

Predictors	**HEI-2010 Discrepancy Score**			***p* trend**	**AHEI-2010 Discrepancy Score**			***p* trend**
	Under Raters (n = 1070)	**Matchers** (n = 1507)	**Over Raters** (n = 1519)		**Under Raters** (n = 1070)	**Matchers** (n = 1507)	**Over Raters** (n = 1519)	
Depression Score				**<.0001**				**<.0001**
None/minimal	684 (70.1)	1110 (77.9)	1162 (83.2)		364 (65.6)	909 (77.1)	1683 (81.3)	
Mild	180 (18.3)	213 (15.9)	170 (11.2)		109 (20.1)	166 (14.5)	288 (13.6)	
Moderate	88 (7.3)	64 (3.6)	68 (3.9)		56 (8.1)	74 (5.1)	90 (3.7)	
Moderately Severe	42 (3.3)	32 (2.1)	22 (1.3)		29 (4.6)	37 (2.8)	30 (1.2)	
Severe	12 (0.9)	9 (0.4)	8 (0.4)		9 (1.5)	11 (0.5)	9 (0.3)	
No reason to change diet				**<. 0001**				**<. 0001**
Strongly Agree	129 (7.9)	168 (8.3)	170 (9.1)		86 (10.8)	145 (7.2)	236 (8.7)	
Agree	158 (12.8)	218 (12.9)	253 (17.3)		80 (12.0)	193 (13.1)	356 (15.9)	
Neither Agree nor Disagree	40 (4.5)	76 (6.4)	76 (6.2)		25 (4.1)	43 (4.2)	124 (7.1)	
Disagree	234 (27.6)	375 (32.8)	425 (34.8)		122 (23.5)	303 (31.4)	609 (34.8)	
Strongly Disagree	440 (47.2)	543 (39.5)	464 (32.6)		257 (49.6)	485 (44.2)	705 (33.4)	
Are people born fat/thin				0.0933				0.1028
Strongly Agree	93 (6.3)	101 (4.1)	114 (5.7)		57 (7.9)	94 (4.5)	157 (4.5)	
Agree	261 (25.4)	353 (24.2)	336 (23.3)		146 (25.8)	306 (23.4)	498 (24.1)	
Neither Agree nor Disagree	68 (6.9)	118 (8.6)	100 (7.5)		31 (5.1)	88 (8.3)	167 (8.0)	
Disagree	231 (28.4)	346 (28.2)	326 (25.2)		141 (28.5)	279 (28.7)	483 (25.9)	
Strongly Disagree	348 (33.1)	468 (34.9)	520 (38.4)		196 (32.6)	403 (35.1)	737 (36.9)	
Importance of Nutrition				0.0305				0.0057
Very Important	675 (58.3)	909 (58.0)	982 (65.7)		377 (58.9)	770 (57.1)	1419 (63.6)	
Somewhat Important	291 (37.8)	431 (36.8)	362 (30.3)		167 (35.9)	370 (39.4)	547 (31.7)	
Not too Important	34 (3.6)	44 (4.3)	43 (3.2)		26 (4.7)	31 (3.2)	64 (3.7)	
Not at all Important	5 (0.3)	12 (0.9)	14 (0.7)		4 (0.4)	5 (0.3)	22 (0.9)	
DGA Knowledge Score				0.2108				0.1262
0	167 (21.6)	214 (17.4)	210 (19.6)		104 (27.3)	198 (19.7)	289 (17.3)	
1	249 (34.4)	415 (41.1)	402 (37.6)		142 (35.9)	321 (38.0)	603 (38.8)	
2	198 (30.3)	283 (27.8)	298 (30.6)		107 (25.0)	225 (29.4)	447 (30.4)	
3	80 (12.5)	112 (11.7)	91 (10.0)		37 (10.2)	87 (10.9)	159 (11.6)	
4	9 (1.1)	15 (2.0)	19 (2.3)		3 (1.6)	16 (1.9)	24 (1.9)	

Values are presented as column percents *n* (%) for categorical variables across categories of discrepancy scores for HEI-2010 and AHEI-2010. *Notes*: Discrepancy scores (direction) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score – objective total HEI-2010 or AHEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.
DGA Knowledge score was created by summing the responses to seven questions to assess whether participants were able to identify the correct number of servings recommended for each food group based on the MyPyramid guidelines (DGA 2005) in order to serve as a proxy for general nutrition knowledge.
Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010; DGA, Dietary Guidelines for Americans.

Table 29. HEI-2010 total and component of U.S. adults (Age ≥ 20) across categories of Discrepancy Score

Component	**Criteria**		**Maximum Score Value**	**HEI-2010 Discrepancy Score**			**[a]p-value**
	Minimum score	**Maximum score**		**Under Raters** (n = 1070)	**Matchers** (n = 1507)	**Over Raters** (n = 1519)	
				LSM ± SE	**LSM ± SE**	**LSM ± SE**	
Adequacy							
Total fruit	0	≥0.8 cups/1000 kcal	5	2.6 ± 0.1	2.2 ± 0.07	1.8 ± 0.05	**<.0001**
Whole fruit	0	≥0.4 cups/1000 kcal	5	1.1 ± 0.09	0.8 ± 0.06	0.6 ± 0.05	**<.0001**
Total vegetables	0	≥1.1 cups/1000 kcal	5	3.3 ± 0.06	3.1 ± 0.04	2.8 ± 0.06	**<.0001**
Greens and beans	0	≥0.2 cups/1000 kcal	5	1.5 ± 0.08	1.3 ± 0.06	1.0 ± 0.07	**<.0001**
Whole grains	0	≥1.5 oz/1000	10	3.2 ± 0.1	2.7 ± 0.1	1.7 ± 0.09	**<.0001**
Dairy	0	≥1.3 cups/1000 kcal	10	5.4 ± 0.1	5.2 ± 0.09	5.1 ± 0.1	0.1902
Fatty acids	(PUFAs + MUFAs)/ SFAs ≤ 1.2	(PUFAs + MUFAs)/ SFAs ≥ 2.5	10	6.1 ± 0.1	5.2 ± 0.1	4.1 ± 0.1	**<.0001**
Total protein foods	0	≥2.5 oz/1000 kcal	5	4.4 ± 0.05	4.3 ± 0.04	4.1 ± 0.04	**<.0001**
Seafood and Plant proteins	0	≥0.8 oz/1000 kcal	5	2.5 ± 0.1	2.2 ± 0.1	1.7 ± 0.08	**<.0001**
Moderation							
Refined grains	≥ 4.3 oz/1000 kcal	≤ 1.8 oz/1000 kcal	10	6.9 ± 0.1	6.2 ± 0.2	5.4 ± 0.1	**<.0001**
Sodium	≥ 2.0 g/1000 kcal	≤ 1.1 g/1000 kcal	10	4.9 ± 0.1	4.2 ± 0.1	3.9 ± 0.09	**<.0001**
[b]Empty calories	≥ 50% of energy	≤ 19% of energy	20	13.6 ± 0.2	11.7 ± 0.3	8.9 ± 0.2	**<.0001**
Total HEI-2010 score			100	55.4 ± 0.5	48.9 ± 0.6	41.3 ± 0.4	**<.0001**

Values are least square means ± standard error of the mean (SE).
Adjusted for age, sex, ethnicity, education, and poverty-to-income ratio.
[a]Bonferroni correction (<0.05/12 HEI-2010 components), $P < 0.004$.
[b]Empty Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.
Notes: All scoring criteria were calculated per 1000 kcal/d, except empty calories, which were calculated as % total energy. For adequacy components, higher intake of food/nutrient groups result in higher scores. For moderation components, lower intake of food/nutrient groups result in higher scores.
Discrepancy scores (direction) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score – objective total HEI-2010 or AHEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.
Abbreviations: LSM, least square means; HEI-2010, Healthy Eating Index-2010; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

Table 30. AHEI-2010 total and component scores of U.S. adults (Age ≥ 20) across categories of Discrepancy Score

Component	**Criteria**		**Maximum Score value**	**AHEI-2010 Discrepancy Score**			[a]**p-value**
	Minimum score	**Maximum score**		**Under Raters** (n = 605)	**Matchers** (n = 1269)	**Over Raters** (n = 2222)	
				LSM ± SE	**LSM ± SE**	**LSM ± SE**	
Whole fruit	0	≥4 servings/d	10	3.9 ± 0.2	3.3 ± 0.1	2.5 ± 0.1	**<.0001**
Total vegetables	0	≥2.5 cups/d	10	3.0 ± 0.1	2.9 ± 0.1	2.5 ± 0.1	0.0065
Whole grains	0	Women: 75 g/d Men: 90 g/d	10	3.8 ± 0.2	3.7 ± 0.2	2.4 ± 0.1	**<.0001**
Sugar-sweetened Beverages and fruit juice	≥8 oz/d	0	10	4.2 ± 0.2	2.9 ± 0.1	2.2 ± 0.09	**<.0001**
Nuts and legumes	0	≥1 oz/d	10	3.4 ± 0.2	2.9 ± 0.1	1.9 ± 0.09	**<.0001**
Red and/or Processed Meats	≥1.5 servings/d	0	10	7.9 ± 0.2	6.9 ± 0.1	5.4 ± 0.1	**<.0001**
Long-chain (ω-3) fats (EPA + DHA)	0	250 mg/d	10	3.6 ± 0.2	2.7 ± 0.1	2.2 ± 0.07	**<.0001**
PUFAs	≤2% of energy	≥10% of energy	10	7.7 ± 0.09	7.3 ± 0.06	6.6 ± 0.04	**<.0001**
[b]Alcohol	Men: ≥3.5 drinks/d Women: ≥2.5 drinks/d	Men: 0.5-2.0 drinks/d Women: 0.5-1.5 drinks/d	10	3.6 ± 0.2	3.3 ± 0.1	3.1 ± 0.06	0.0129
[c]Sodium	Highest Decile	Lowest Decile	10	6.4 ± 0.2	5.9 ± 0.1	5.5 ± 0.07	**<.0001**
Total AHEI-2010 score			100	47.8 ± 0.7	42.1 ± 0.5	34.5 ± 0.4	**<.0001**

Values are least square means ± standard error of the mean (SE).
Adjusted for age, sex, ethnicity, education, and poverty-to-income ratio.
[a]Bonferroni correction (<0.05/11 AHEI-2010 components), $P < 0.005$.
[b]Alcoholic drinkers was assigned the highest score to moderate, and lowest score to heavy consumers. Nondrinkers received a score of 2.5.
[c]Sodium consumption was based on the actual intake distribution of participants in the sample. The fasting subsample weight was used to obtain representative percentiles for sodium intake in the sample.
Notes: All scoring criteria were calculated based on actual intake of participants rather than absolute standards. Trans fat component was omitted from the AHEI-2010 scoring because it is unavailable in the NHANES dietary files. For sugar-sweetened beverages and fruit juices, red and/or processed meat, and sodium, a higher score corresponds to lower intake.
Discrepancy scores (direction) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score – objective total HEI-2010 or AHEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.
Abbreviations: LSM, least square means; AHEI-2010, Alternate Healthy Eating Index-2010; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acid.

Table 31. HEI-2010 total and component scores across categories of Discrepancy Score by Diabetes Status

Discrepancy Score	Nondiabetic (n = 1436)			[a]p-value	Prediabetic (n = 1905)			[a]p-value	Diabetic (n = 715)			[a]p-value
	Under Raters	Matchers	Over Raters		Under Raters	Matchers	Over Raters		Under Raters	Matchers	Over Raters	
HEI-2010 components	**LSM ± SE**	**LSM ± SE**	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	**LSM ± SE**	
Total fruit	2.7 ± 0.1	2.1 ± 0.1	1.8 ± 0.07	**<.0001**	2.8 ± 0.1	2.2 ± 0.07	1.9 ± 0.1	**<.0001**	2.8 ± 0.2	2.4 ± 0.1	1.6 ± 0.2	**<.0001**
Whole fruit	0.9 ± 0.1	0.6 ± 0.07	0.5 ± 0.05	0.0002	1.2 ± 0.1	0.8 ± 0.07	0.6 ± 0.07	**<.0001**	1.2 ± 0.1	0.9 ± 0.09	0.4 ± 0.1	**<.0001**
Total vegetables	3.2 ± 0.1	3.1 ± 0.08	2.7 ± 0.09	**<.0001**	3.3 ± 0.09	3.1 ± 0.07	2.8 ± 0.08	**<.0001**	3.6 ± 0.1	2.9 ± 0.1	3.1 ± 0.1	0.0001
Greens and beans	1.3 ± 0.1	1.4 ± 0.1	1.1 ± 0.09	0.0006	1.6 ± 0.1	1.1 ± 0.07	0.9 ± 0.09	0.0005	1.7 ± .02	1.1 ± 0.2	1.1 ± 0.2	0.0213
Whole grains	3.0 ± 0.2	3.0 ± 0.2	1.7 ± 0.1	**<.0001**	3.3 ± 0.2	2.4 ± 0.2	1.6 ± 0.1	**<.0001**	3.6 ± 0.3	2.7 ± 0.2	1.9 ± 0.2	**<.0001**
Dairy	5.5 ± 0.2	5.2 ± 0.2	5.3 ± 0.2	0.0034	5.1 ± 0.2	5.2 ± 0.2	4.9 ± 0.2	0.0019	5.9 ± 0.4	5.0 ± 0.2	4.5 ± 0.3	**<.0001**
Fatty acids	6.2 ± 0.2	5.4 ± 0.2	4.0 ± 0.2	**<.0001**	6.2 ± 0.2	5.1 ± 0.2	4.0 ± 0.2	**<.0001**	5.9 ± 0.3	5.0 ± 0.3	4.4 ± 0.3	0.0036
Total protein foods	4.3 ± 0.07	4.2 ± 0.07	4.1 ± 0.06	0.0001	4.5 ± 0.07	4.3 ± 0.06	3.9 ± 0.07	**<.0001**	4.4 ± 0.1	4.5 ± 0.09	4.3 ± 0.1	0.2059
Seafood and plant proteins	2.5 ± 0.2	2.4 ± 0.2	1.8 ± 0.1	**<.0001**	2.6 ± 0.2	2.1 ± 0.1	1.4 ± 0.09	**<.0001**	2.4 ± 0.2	1.9 ± 0.1	1.6 ± 0.2	**<.0001**
Refined grains	7.0 ± 0.2	6.0 ± 0.2	5.3 ± 0.2	**<.0001**	6.9 ± 0.2	6.5 ± 0.2	5.5 ± 0.1	**<.0001**	6.9 ± 0.3	5.6 ± 0.3	5.3 ± 0.3	0.0373
Sodium	5.3 ± 0.2	4.3 ± 0.2	3.8 ± 0.2	**<.0001**	4.9 ± 0.2	4.4 ± 0.2	4.1 ± 0.2	0.0001	4.2 ± 0.3	3.4 ± 0.2	3.3 ± 0.2	0.0095
[b]Empty calories	13.3 ± 0.3	12.0 ± 0.4	9.1 ± 0.3	**<.0001**	13.5 ± 0.4	10.9 ± 0.4	8.3 ± 0.2	**<.0001**	15.2 ± 0.5	13.3 ± 0.4	9.9 ± 0.4	**<.0001**
Total HEI-2010 score	55.1 ± 0.8	49.8 ± 0.9	41.3 ± 0.5	**<.0001**	55.8 ± 0.8	48.1 ± 0.7	40.2 ± 0.5	**<.0001**	57.8 ± 1.0	48.7 ± 0.7	41.4 ± 0.7	**<.0001**

Values are least square means ± standard error of the mean (SE). Adjusted for age, sex, ethnicity, education, poverty-to-income ratio and BMI.
[a]Bonferroni correction (<0.05/12 HEI-2010 components), $P < 0.004$.
[b]Empty Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.
Notes: All scoring criteria were calculated per 1000 kcal/d, except empty calories, which are calculated as % total energy. For adequacy components, higher intake of food/nutrient groups result in higher scores. For moderation components, lower intake of food/nutrient groups result in higher scores.
Discrepancy scores (direction) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score – objective total HEI-2010 or AHEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.
Diabetes status was defined from self-report of participants in the diabetes questionnaire and from the laboratory biomarkers using the cut-offs based on the 2017 Standards of Medical Care from the American Diabetes Association (ADA) for diabetes diagnosis.
Abbreviations: LSM, least square means; HEI-2010, Healthy Eating Index-2010.

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Table 32. AHEI-2010 total and component scores across categories of Discrepancy Score by Diabetes Status

Discrepancy Score	Nondiabetic (n = 1436)			ap-value	Prediabetic (n = 1905)			ap-value	Diabetic (n = 715)			ap-value
	Under Raters	Matchers	Over Raters		Under Raters	Matchers	Over Raters		Under Raters	Matchers	Over Raters	
AHEI-2010 components	**LSM ± SE**	**LSM ± SE**	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	**LSM ± SE**	
Whole fruit	3.7 ± 0.2	3.1 ± 0.2	2.4 ± 0.2	**<.0001**	4.3 ± 0.2	3.4 ± 0.2	2.5 ± 0.1	**<.0001**	3.8 ± 0.4	3.3 ± 0.3	2.4 ± 0.2	0.0030
Total vegetables	2.7 ± 0.3	2.6 ± 0.2	2.4 ± 0.1	**<.0001**	3.1 ± 0.3	2.9 ± 0.2	2.6 ± 0.2	0.0003	3.6 ± 0.4	3.1 ± 0.3	2.5 ± 0.2	0.2465
Whole grains	3.5 ± 0.3	3.6 ± 0.3	2.4 ± 0.1	**<.0001**	3.9 ± 0.3	3.7 ± 0.3	2.3 ± 0.2	**<.0001**	4.3 ± 0.4	3.9 ± 0.4	2.7 ± 0.2	0.0019
Sugar-sweetened beverages & fruit juice	4.3 ± 0.4	2.6 ± 0.2	2.0 ± 0.2	**<.0001**	4.3 ± 0.4	3.0 ± 0.3	2.1 ± 0.1	**<.0001**	4.4 ± 0.4	3.8 ± 0.4	2.9 ± 0.3	0.0005
Nuts and legumes	3.1 ± 0.3	2.9 ± 0.3	2.1 ± 0.2	**<.0001**	3.8 ± 0.3	3.1 ± 0.2	1.6 ± 0.2	**<.0001**	3.3 ± 0.3	2.6 ± 0.3	1.9 ± 0.2	0.0628
Red and/or processed meats	8.4 ± 0.1	7.6 ± 0.2	5.6 ± 0.2	**<.0001**	7.8 ± 0.3	6.7 ± 0.2	5.3 ± 0.2	**<.0001**	7.5 ± 0.3	6.7 ± 0.4	5.1 ± 0.3	**<.0001**
Long-chain (ω-3) fats (EPA + DHA)	3.5 ± 0.3	2.7 ± 0.2	2.4 ± 0.1	0.0011	3.8 ± 0.3	2.9 ± 0.2	2.2 ± 0.1	**<.0001**	3.0 ± 0.4	2.8 ± 0.3	1.6 ± 0.2	**<.0001**
PUFAs	7.8 ± 0.2	7.3 ± 0.08	6.6 ± 0.08	**<.0001**	7.7 ± 0.2	7.3 ± 0.09	6.5 ± 0.09	**<.0001**	7.6 ± 0.3	7.2 ± 0.2	6.8 ± 0.1	**<.0001**
bAlcohol	3.6 ± 0.2	3.6 ± 0.2	3.3 ± 0.09	0.0011	4.0 ± 0.3	3.3 ± 0.1	3.1 ± 0.09	0.0011	2.6 ± 0.1	2.9 ± 0.2	2.8 ± 0.09	0.0605
cSodium	6.2 ± 0.3	5.8 ± 0.2	5.1 ± 0.1	**<.0001**	6.5 ± 0.2	5.8 ± 0.2	5.6 ± 0.1	**<.0001**	6.9 ± 0.2	6.3 ± 0.2	6.1 ± 0.2	**<.0001**
Total AHEI-2010 score	46.9 ± 0.9	41.8 ± 0.7	34.3 ± 0.7	**<.0001**	49.4 ± 1.0	42.4 ± 0.8	33.9 ± 0.5	**<.0001**	47.1 ± 1.1	42.6 ± 0.9	34.8 ± 0.7	**<.0001**

Values are least square means ± standard error of the mean (SE). Adjusted for age, sex, ethnicity, education, poverty-to-income ratio and BMI. [a]Bonferroni correction (<0.05/11 AHEI-2010 components), $P < 0.005$.[b]Alcoholic drinkers were assigned the highest score to moderate, and lowest score to heavy consumers. Nondrinkers received a score of 2.5. [c]Sodium consumption was based on the actual intake distribution of participants in the sample. The fasting subsample weight was used to obtain representative percentiles for sodium intake in the sample.

Notes: All scoring criteria were calculated based on actual intake of participants rather than absolute standards. Trans fat component was omitted from the AHEI-2010 scoring because it is unavailable in the NHANES dietary files. For sugar-sweetened beverages and fruit juices, red and/or processed meat, and sodium, a higher score corresponds to lower intake.

Discrepancy scores (direction) for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score – objective total HEI-2010 or AHEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.

Diabetes status was defined from self-report of participants in the diabetes questionnaire and from the laboratory biomarkers using the cut-offs based on the 2017 Standards of Medical Care from the American Diabetes Association (ADA) for diabetes diagnosis.

Abbreviations: LSM, least square means; AHEI-2010, Alternate Healthy Eating Index-2010; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acid

Table 33. Bivariate associations between predictors of HEI-2010 and AHEI-2010 Discrepancy Scores

Predictors	Diabetes Status	Age	Sex	Ethnicity	Education	Smoking status	Food Security	Perceived Health	Depression Status	Change diet	born fat/thin	Importance of nutrition	Knowledge score
Diabetes Status	-	484.6 **<.0001**	61.1 **<.0001**	19.9 0.0029	63.9 **<.0001**	38.9 **<.0001**	7.4 0.2894	236.5 **<.0001**	22.6 0.0039	12.3 0.1382	35.9 **<.0001**	10.2 0.1159	3.3 0.7671
Age	484.6 **<.0001**	-	25.4 **<.0001**	174.5 **<.0001**	48.4 **<.0001**	192.5 **<.0001**	95.9 **<.0001**	80.6 **<.0001**	26.4 0.0017	116.3 **<.0001**	30.7 0.0022	22.0 0.0088	6.3 0.7117
Sex	61.1 **<.0001**	25.4 **<.0001**	-	13.2 0.0043	3.4 0.3347	25.5 **<.0001**	2.6 0.4507	2.9 0.5678	40.0 **<.0001**	47.8 **<.0001**	8.4 0.0769	55.6 **<.0001**	6.3 0.0986
Race/Ethnicity	19.9 0.0029	174.5 **<.0001**	13.2 0.0043	-	213.7 **<.0001**	80.8 **<.0001**	112.2 **<.0001**	134.4 **<.0001**	16.7 0.0534	137.3 **<.0001**	110.7 **<.0001**	96.1 **<.0001**	49.1 **<.0001**
Education	63.9 **<.0001**	48.4 **<.0001**	3.4 0.3347	213.7 **<.0001**	-	123.3 **<.0001**	212.9 **<.0001**	412.3 **<.0001**	57.9 **<.0001**	140.9 **<.0001**	121.8 **<.0001**	51.3 **<.0001**	25.9 0.0022
Smoking status	38.9 **<.0001**	192.5 **<.0001**	25.5 **<.0001**	80.8 **<.0001**	123.3 **<.0001**	-	107.7 **<.0001**	78.5 **<.0001**	60.7 **<.0001**	9.8 0.2759	14.9 0.0596	26.4 0.0009	24.9 0.0016
Adult Food Security	7.4 0.2894	95.9 **<.0001**	2.6 0.4507	112.2 **<.0001**	212.9 **<.0001**	107.7 **<.0001**	-	198.9 **<.0001**	99.0 **<.0001**	31.2 0.002	61.4 **<.0001**	21.2 0.0116	27.3 0.0012
Perceived Health Status	236.5 **<.0001**	80.6 **<.0001**	2.9 0.5678	134.4 **<.0001**	412.3 **<.0001**	78.5 **<.0001**	198.9 **<.0001**	-	237.4 **<.0001**	87.5 **<.0001**	119.1 **<.0001**	27.3 0.0070	12.3 0.4257
Depression status	22.6 0.0039	26.4 0.0017	40.0 **<.0001**	16.7 0.0534	57.9 **<.0001**	60.7 **<.0001**	99.0 **<.0001**	237.4 **<.0001**	-	48.6 **<.0001**	37.3 0.0002	5.6 0.4744	9.1 0.4289
No reason to change diet	12.3 0.1382	116.3 **<.0001**	47.8 **<.0001**	137.3 **<.0001**	140.9 **<.0001**	9.8 0.2759	31.2 0.002	87.5 **<.0001**	48.6 **<.0001**	-	215.4 **<.0001**	75.4 **<.0001**	17.5 0.1304
Are people born fat/thin	35.9 **<.0001**	30.7 0.0022	8.4 0.0769	110.7 **<.0001**	121.8 **<.0001**	14.9 0.0596	61.4 **<.0001**	119.1 **<.0001**	37.3 0.0002	215.4 **<.0001**	-	80.3 **<.0001**	11.1 0.5235
Importance of nutrition	10.2 0.1159	22.0 0.0088	55.6 **<.0001**	96.1 **<.0001**	51.3 **<.0001**	26.4 0.0009	21.2 0.0116	27.3 0.0070	5.6 0.4744	75.4 **<.0001**	80.3 **<.0001**		11.3 0.2574
DGA knowledge score	3.3 0.7671	6.3 0.7117	6.3 0.0986	49.1 **<.0001**	25.9 0.0022	24.9 0.0016	27.3 0.0012	12.3 0.4257	9.1 0.4289	17.5 0.1304	11.1 0.5235	11.3 0.2574	-

Values are Rao-Scott (design-adjusted) Chi-square and p-values. *Notes*: Age and depression were re-classified as categorical variables to examine bivariate associations with other predictors. DGA Knowledge score was created by summing the responses to seven questions to assess whether participants were able to identify the correct number of servings recommended for each food group based on the MyPyramid guidelines (DGA 2005) in order to serve as a proxy for general nutrition knowledge.

Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010; BMI, Body Mass Index; WC, Waist Circumference; DGA, Dietary Guidelines for Americans.

Table 34. Association between Diabetes Status and HEI-2010 Discrepancy Scores in U.S. adults (Age ≥ 20 years) using Multinomial Logistic Regression

Weighted Estimates							
Model	(n)	Prediabetic		Diabetic		Analysis of Effects	
		Under raters	Over raters	Under raters	Over raters	Wald Chi-Sq	Pr > Chi-Sq
		OR [95% C.I.]	OR [95% C.I.]	OR [95% C.I.]	OR [95% C.I.]		
1	4056	1.1 [0.9, 1.3]	0.9 [0.7,1.1]	1.5 [1.1,2.0]	0.9 [0.7,1.1]	11.9	0.0178
2	4050	1.1 [0.9,1.4]	0.8 [0.7,1.0]	1.6 [1.1, 2.4]	0.8 [0.6,1.2]	13.5	0.0093
3	3712	1.1 [0.9,1.4]	0.8 [0.6,1.0]	1.6 [1.1,2.4]	0.9 [0.6,1.2]	11.7	0.0199
4	3712	1.0 [0.8,1.3]	0.9 [0.7,1.1]	1.3 [0.9,2.0]	1.2 [0.8,1.7]	6.1	0.1921
Unweighted Estimates							
Model	(n)	Prediabetic		Diabetic		Analysis of Effects	
		Under raters	Over raters	Under raters	Over raters	Wald Chi-Sq	Pr > Chi-Sq
		OR [95% C.I.]	OR [95% C.I.]	OR [95% C.I.]	OR [95% C.I.]		
1	4056	1.1 [0.9,1.3]	0.9 [0.8,1.1]	1.3 [1.0,1.6]	0.9 [0.7,1.1]	12.1	0.0163
2	4050	1.1 [0.9,1.3]	0.9 [0.7,1.0]	1.3 [0.9,1.7]	0.8 [0.6,0.9]	14.9	0.0048
3	3712	1.1 [0.9,1.2]	0.9 [0.8,0.9]	1.4 [1.2,1.7]	0.8 [0.7,0.9]	15.2	0.0043
4	3712	1.0 [0.8,1.3]	0.9 [0.8,1.1]	1.1 [0.8,1.4]	0.9 [0.7,1.2]	2.3	0.6764

Values are odds ratios [confidence intervals] for diabetes status before and after adjusting for covariates. Wald Chi-square and associated p-values are also presented for diabetes status.
Model 1 = Diabetes Status (no adjustment)
Model 2 = Model 1 + sociodemographics (age, sex, race/ethnicity, education)
Model 3 = Model 2 + attitude (no reason to change diet, people born fat/thin)
Model 4 = Model 3 + perceived health status
*P-value for the odds of being an under rater and over rater compared to matchers (reference group) < 0.05.
Weighted (Model 4): Wald-F (32,1) = 7.62, p = 0.2805; goodness-of-fit chi-squared = 17.9, p = 0.325. Unweighted (Model 4): Pseudo R^2 = 0.0453, p < 0.0001; goodness-of-fit chi-squared = 14.885, p = 0.533.
Note: Discrepancy scores (direction) for HEI-2010 represents the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score – objective total HEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.
Abbreviations: SE = standard error; OR = Odds Ratio; CI= Confidence Interval; HEI-2010 = Healthy Eating Index 2010.

Table 35. Association between Diabetes Status and AHEI-2010 Discrepancy Scores in U.S. adults (Age ≥ 20 years) using Multinomial Logistic Regression

Weighted Estimates							
Model	(n)	Prediabetic		Diabetic		Analysis of Effects	
		Under raters	Over raters	Under raters	Over raters		
		OR [95% C.I.]	OR [95% C.I.]	OR [95% C.I.]	OR [95% C.I.]	Wald Chi-Sq	Pr > Chi-Sq
1	4056	0.9 [0.7,1.3]	0.8 [0.6,0.9]	1.3 [0.9,1.9]	0.8 [0.6,1.1]	12.6	0.0134
2	4050	0.9 [0.7,1.3]	0.8 [0.6,0.9]	1.2 [0.7,1.8]	0.8 [0.5,1.1]	10.8	0.0293
3	3712	0.9 [0.6,1.2]	0.8 [0.6,0.9]	1.2 [0.7,1.9]	0.8 [0.6,1.3]	10.2	0.0365
4	3712	0.8 [0.6,1.1]	0.8 [0.7,1.0]	1.0 [0.6,1.6]	1.1 [0.7,1.7]	4.9	0.2921
Unweighted Estimates							
Model	(n)	Prediabetic		Diabetic		Analysis of Effects	
		Under raters	Over raters	Under raters	Over raters		
		OR [95% C.I.]	OR [95% C.I.]	OR [95% C.I.]	OR [95% C.I.]	Wald Chi-Sq	Pr > Chi-Sq
1	4056	0.9 [0.8,1.2]	0.8 [0.7,0.9]	1.3 [0.9,1.7]	0.8 [0.6,0.9]	20.4	0.0004
2	4050	0.9 [0.8,1.2]	0.8 [0.7,0.9]	1.2 [0.9,1.7]	0.8 [0.6,0.9]	15.9	0.0031
3	3712	0.9 [0.7,1.1]	0.8 [0.7,0.9]	1.3 [0.9,1.7]	0.8 [0.6,1.0]	16.5	0.0024
4	3712	0.8 [0.7,1.1]	0.8 [0.7,0.9]	1.0 [0.7,1.4]	0.9 [0.8,1.3]	6.7	0.1511

Values are odds ratios [confidence intervals] for diabetes status before and after adjusting for covariates. Wald Chi-square and associated p-values are also presented for diabetes status.
Model 1 = Diabetes Status (no adjustment)
Model 2 = Model 1 + sociodemographics (age, sex, race/race/ethnicity, education)
Model 3 = Model 2 + attitude (no reason to change diet, people born fat/thin)
Model 4 = Model 3 + perceived health status
*P-value for the odds of being an under rater and over rater compared to matchers (reference group) < 0.05.
Weighted (Model 4): Wald-F (32, 1) = 22.66, p = 0.1651; goodness-of-fit chi-squared = 21.318, p = 0.167. Unweighted (Model 4): Pseudo R^2 = 0.0489, p < 0.0001; goodness-of-fit chi-squared = 10.621, p = 0.832.
Note: Discrepancy scores (direction) for AHEI-2010 represents the distance between perceived and measured (objective) diet quality (discrepancy score = perceived score – objective total AHEI-2010 score). Positive discrepancy scores indicated under raters and negative discrepancy scores indicated over raters.
Abbreviations: SE = standard error; OR = Odds Ratio; CI= Confidence Interval; AHEI-2010 = Alternate Healthy Eating Index 2010.

4.3 Lifestyle Behaviors in Relation to Dietary Quality by Diabetes Status in U.S. Adults

Abstract

Background: Dietary quality is complex and is interrelated with many different factors (i.e., sociodemographics, health behaviors), including lifestyle choices, which can lead to the development of type 2 diabetes (T2DM). Limited studies have examined the contribution of lifestyle behaviors to dietary quality among individuals with and without T2DM.

Objective: To examine the relationship between selected lifestyle behaviors independently, and in combination with other lifestyle behaviors, and dietary quality (using total HEI-2010 and AHEI-2010 scores) overall and by diabetes status while controlling for sociodemographic and health characteristics.

Methods: This study used a representative sample of U.S. adults 20+ years of age (n = 4097) in the 2007-2010 National Health and Nutrition Examination Survey (NHANES). Lifestyle behaviors were examined as the main exposure variables. Six individual lifestyle behaviors were selected: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Each of these variables was dichotomized to whether or not individuals reported practicing a positive or negative lifestyle behavior. In addition, a combined Lifestyle Behaviors score was created as the sum of individual lifestyle behaviors. Dietary quality was examined as the outcome variable. Total HEI-2010 and the AHEI-2010 were used as measures of dietary quality and were calculated using data from the first 24-hour dietary recall. Design-adjusted Rao-Scott chi-square tests were used to

examine bivariate associations between lifestyle behaviors and diabetes status groups (nondiabetes, prediabetes, T2DM). Least Squares Means were computed to estimate differences in total HEI-2010 and AHEI-2010 scores by lifestyle behaviors. Multivariable Linear Regression was used to examine relationships among lifestyle behaviors independently, and in combination with total HEI-2010 and AHEI-2010 scores, after adjusting for demographic and health characteristics.

Results: The relationships between individual lifestyle behaviors and diabetes status groups (nondiabetes, prediabetes, T2DM) were significant ($p < 0.05$). Diabetics were more likely to report being on a special diet, taking dietary supplements, and not drinking alcohol. However, diabetics were also less likely to report getting adequate sleep and meeting physical activity guidelines. There were significant differences in mean total HEI-2010 and AHEI-2010 scores by individual and combined lifestyle behaviors ($p < 0.01$). The mean total HEI-2010 and AHEI-2010 scores were higher among individuals who reported getting adequate sleep, being on a special diet, taking dietary supplements, meeting physical activity guidelines, not smoking, and who had higher Lifestyle Behaviors scores. In addition, results suggest significant associations between individual lifestyle behaviors and total HEI-2010 and AHEI-2010 scores by diabetes status ($p < 0.05$). For nondiabetics, being on a special diet and meeting physical activity guidelines had the highest coefficient in relation to dietary quality [total HEI-2010 score: $\beta = 4.44$, $p = 0.0015$ for on a special diet; total AHEI-2010 score: $\beta = 2.02$, $p = 0.0031$ for physical activity]. For prediabetics, meeting physical activity guidelines and being on a special diet had the highest coefficient in relation to dietary quality [total HEI-2010 score: $\beta = 3.61$, $p = 0.0003$

for physical activity; total AHEI-2010 score: β = 2.65, p = 0.0449 for on a special diet]. For diabetics, being on a special diet and taking dietary supplements had the highest coefficient in relation to dietary quality [total HEI-2010 score: β = 5.08, p = 0.0011 for on a special diet, total AHEI-2010 score: β = 3.89, p = 0.0019 for supplement intake]. Moreover, the aggregate Lifestyle Behaviors score was a significant predictor of total HEI-2010 and AHEI-2010 scores ($p < 0.0001$). Results indicate that for a one-unit change in Lifestyle Behaviors score, the total HEI-2010 score increased by 1.92 points, and the AHEI-2010 score increased by 1.26 points, while controlling for demographic and health characteristics. In addition, the coefficient of Lifestyle Behaviors score in the HEI-2010 and AHEI-2010 models was comparable by diabetes status. The coefficient of Lifestyle Behaviors score in relation to dietary quality was lowest for nondiabetics [HEI-2010: β = 1.76, $p < 0.0001$; AHEI-2010: β = 0.84, p = 0.0142] and were fairly similar for prediabetics [(HEI-2010: β = 1.96, p = 0.0003; AHEI-2010: β = 1.50, p = 0.0005] and diabetics [HEI-2010: β = 1.96, $p < 0.0001$; AHEI-2010: β = 1.45, p = 0.0004].

Conclusion: Selected lifestyle behaviors independently, and in combination, were significantly associated with total HEI-2010 and AHEI-2010 scores by diabetes status. The results were similar for each HEI-2010 and AHEI-2010 in terms of their association with lifestyle behaviors. The significant relationships between 1) lifestyle behaviors and diabetes status and 2) dietary quality and lifestyle behaviors suggest that lifestyle behaviors can influence individuals' dietary choices and diabetes status can influence whether or not individuals' make changes in their lifestyle behaviors. Diabetics did better on several of the lifestyle indicators and had higher HEI-2010

and AHEI-2010 scores, suggesting that diabetic education and nutrition counseling may have influence on their behavior. However, diabetics need more healthcare advice on getting adequate sleep as part of their lifestyle behaviors.

Keywords: NHANES, Lifestyle Behaviors, HEI-2010, AHEI-2010, Diabetes Status

Introduction

Type 2 diabetes mellitus (T2DM) remains as one of the most prevalent chronic diseases in the United States. T2DM is largely preventable through positive lifestyle changes. Prospective studies have shown that positive changes in lifestyle behaviors, such as adopting a healthy diet (Ley et al., 2016), engaging in greater physical activity (Consortium, 2012), abstaining from smoking (Willi, Bodenmann, Ghali, Faris, & Cornuz, 2007), or a combination of these factors, were associated with decreased risk of diabetes incidence (Hu, Frank B., J., Stampfer Meir, Colditz Graham, Liu Simin, & Willett, 2001; Simmons et al., 2006; Long et al., 2015). In addition, intervention studies had similar findings on the effect of positive changes in lifestyle behaviors and T2DM. Results from the Diabetes Prevention Program (DPP) and the Finnish Diabetes Prevention Study (DPS), which are two large randomized clinical trials, have shown that lifestyle intervention (i.e., dietary modification, physical activity, weight loss) decreased the incidence of T2DM by 58% among high-risk group individuals with impaired glucose tolerance (Knowler et al., 2002; Lindstrom et al., 2003). Both observational and intervention studies have confirmed that modification of lifestyle behaviors can reduce the incidence of T2DM, which can reduce the burden of treating diabetes-related complications.

Epidemiological studies have examined the relationships between several lifestyle behaviors and T2DM. Unhealthful lifestyle behaviors such as poor diet quality (Schwingshackl & Hoffmann, 2015; Ley et al., 2016), lack of exercise (Consortium, 2012), and smoking (Willi et al., 2007; Services, 2015) are recognized as factors that increase T2DM risk and lead to other adverse health outcomes. However, the relationships between some lifestyle behaviors (i.e., alcohol consumption, dietary supplement intake) and T2DM have shown mixed results. For example, the benefit of moderate alcohol consumption remains controversial, especially among individuals with chronic disease (i.e., diabetes). Moderate alcohol consumption is found to be associated with cardiovascular benefits for individuals with T2DM (Solomon et al., 2000). However, some studies have shown that moderate alcohol consumption has behavioral consequences and is a potential barrier to diabetes self-care (Ahmed A.T., Karter A. J., 2008; Engler Patricia A., Ramsey Susan E., 2013). In addition, there are mixed findings on the relationship between dietary supplementation and T2DM. Some studies indicate that dietary supplements including antioxidant nutrients (i.e., vitamin C and E) and vitamin D are beneficial and may prevent T2DM (Garcia-Bailo et al., 2011), while other studies suggest the need for more clinical controlled trials to better understand the role of dietary supplementation (i.e., vitamin C and D) in diabetes prevention (Christie-David, Girgis, & Gunton, 2015). Sleep quality is also an important factor and considered part of individuals' lifestyle behaviors. Recent research has examined the role of sleep quality (i.e., duration, timing) in relation to T2DM and other health outcomes (Cappuccio, D'Elia, Strazzullo, & Miller, 2010; Grandner, Perlis, & Gehrman, 2011;

Liu, Hay, & Faught, 2013; M. P. St-Onge et al., 2016; Lee, Ng, & Chin, 2017). There is growing evidence that inadequate sleep could be a potential risk factor for T2DM (Chao et al., 2011). These studies were not conclusive, suggesting the need to further examine the interrelationships of several lifestyle behaviors with one another in order to better understand their roles on health and/or disease outcomes (i.e., obesity, diabetes, cardiovascular disease).

Diet is multifaceted and is strongly interrelated to various health-related behaviors. Epidemiological studies have examined the relationships between several lifestyle behaviors and dietary quality. Alcohol consumption is a risk factor for poor dietary quality. Breslow and colleagues used 1999-2006 NHANES to examine the association between alcoholic beverage consumption and dietary quality (measured by HEI-2005 scores) among U.S. adults. They found that increased alcohol consumption was associated with decline in total HEI-2005 scores, apparently due to higher energy intake from alcohol and the propensity of drinkers to make less healthy food choices (Breslow, Rosalind A. Guenther Patricia M. Juan Wenyen, 2010). In addition, sleep duration is another potential risk factor for poor dietary quality. Xiao and colleagues used 2005-2012 NHANES to examine the association of dietary quality (measured by HEI-2010 scores) with sleep duration among U.S. women within 5 years of childbirth. Overall, the authors found that longer sleep duration (≥ 9 hours) was associated with lower diet quality, lower consumption of total fruit, whole fruit, and total protein and higher consumption of empty calories (Xiao, 2016). Moreover, smoking is a risk factor and associated with poor dietary quality. Alkerwi and colleagues examined the association between smoking intensity (i.e., tobacco consumption) and dietary quality (measured by eight indices). Overall, there was an inverse relationship between the intensity of tobacco consumption and overall dietary quality. The authors found that moderate and heavy smokers had significantly lower diet quality scores compared to never smokers (*p-value*s all models <0.01) (Alkerwi et al., 2017). These studies suggest that there are independent associations between lifestyle behaviors (i.e., alcohol consumption, sleep quality, smoking) and dietary quality. The association between each of these factors and dietary quality suggest the need to explore several behaviors related to individuals' lifestyle and examine their relationship to diabetes (T2DM).

Lifestyle behavior modification involves altering long-term habits and maintaining new behavior(s). Lifestyle management is a fundamental aspect of diabetes care and includes diabetes self-management education (DSME), diabetes self-management support (DSMS), nutrition therapy, physical activity, smoking cessation counseling, and psychosocial care (William T. Cefalu, MD et al., 2017). Along with medical treatment, changes in diet and physical activity habits are the main lifestyle behaviors modification recommended for diabetes self-management. In addition, individuals with T2DM are often advised to abstain from smoking and reduce or minimize alcohol consumption (William T. Cefalu, MD et al., 2017). However, it is not common in clinical practice to counsel individuals with T2DM to improve their sleep quality. Therefore, it is important to understand different behavioral aspects of an individual's lifestyle that can potentially impact health and/or disease outcomes.

Diet is complex and is influenced by numerous factors, which in turn can have an impact on disease development (i.e., T2DM). Several studies have examined the association between lifestyle behaviors (including diet) and T2DM (Schwingshackl & Hoffmann, 2015; Ley et al., 2016; Consortium, 2012; Willi et al., 2007; Services, 2015; Garcia-Bailo et al., 2011; Christie-David et al., 2015; Chao et al., 2011). In addition, most studies have only examined the independent associations between individual lifestyle behaviors and dietary quality (Breslow, Rosalind A. Guenther Patricia M. Juan Wenyen, 2010; Xiao, 2016; Alkerwi et al., 2017). However, no studies have examined the contribution of lifestyle behaviors independently, and in combination, to dietary quality among individuals with and without T2DM. A better understanding of the behaviors that can influence dietary choices may lead to the development of more effective strategies to improve compliance to dietary recommendations leading to better health outcomes and disease prevention.

The main objectives of this study are three-fold: 1) To examine the independent association between selected individual lifestyle behaviors and dietary quality (using HEI-2010 and AHEI-2010 scores) and determine whether the associations are different by diabetes status groups (nondiabetes, prediabetes, T2DM); 2) To examine the association between combined Lifestyle Behaviors score and dietary quality (using HEI-2010 and AHEI-2010 scores) and determine whether the association differs by diabetes status groups (nondiabetes, prediabetes, T2DM); 3) To determine the strength of the relationships between selected individual lifestyle behaviors and Lifestyle Behaviors score with dietary quality (using HEI-2010 and AHEI-2010 scores) while controlling for demographic and health characteristics. All analyses were based on data from the 2007-2010 National Health and Nutrition Examination Survey (NHANES).

Participants and Methods

Survey Design

The National Health and Nutrition Examination Survey (NHANES) is an ongoing program of the National Center for Health Statistics (NCHS), which is a part of the Centers for Disease Control and Prevention (CDC). NHANES is a cross-sectional survey that collects information on the health and nutritional status of the U.S. population ("National Health and Nutrition Examination Survey Overview," n.d.). Participants in the NHANES surveys are selected using a complex, stratified multistage probability cluster sampling design to ensure that the sample is representative of the civilian, non-institutionalized U.S. population (Curtin et al., 2010). Details regarding the NHANES study design, implementation, analytical considerations, consent document, and survey operation manuals are published and available on the CDC website ("National Health and Nutrition Examination Survey Overview," n.d.).

Study Sample

The present study combined data from NHANES 2007-2008 and 2009-2010 to increase sample size. The analytic sample (n = 4,097) consisted of adults age ≥ 20 years who participated in both the health interview and medical examination, self-reported as non-pregnant at the examination, had complete and reliable 24-hour diet recalls, a Body Mass Index (BMI) ≥ 18.5 kg/m^2, and fasting glucose measures during the morning examination session. In compliance with federal law, NHANES has stringent protocols and procedures that ensure confidentiality and protect participants' identity ("NHANES - NHANES Participants - Eligible Participants," 2017). This study was based on secondary analysis of the NHANES data and did not include personal identifiers, so it did not require a formal institutional review board approval (University of Maryland, n.d.).

Exposure and Outcome Variables

Lifestyle Behaviors

The present study utilized several lifestyle behaviors as the main exposure variables in relation to dietary quality (using total HEI-2010 and AHEI-2010 scores). Lifestyle behaviors were assessed using two approaches: 1) selected individual lifestyle behaviors and 2) created a Lifestyle Behaviors score that is made up of aggregate individual lifestyle behaviors. The associations of lifestyle behaviors were examined independently, and in combination with dietary quality using two indices: HEI-2010 and AHEI-2010 scores.

Individual Lifestyle Behaviors

This study selected six lifestyle behaviors that are available in NHANES. These include self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Some of the individual lifestyle behaviors were initially examined as continuous variables. For instance, physical activity was measured in number of minutes, alcohol consumption was based on average number of drinks, and sleep adequacy was based on number of hours of sleep. The distributions of these variables were highly skewed. Therefore, the variables were categorized to resolve the issue of non-normality.

Alcohol Consumption

The present study examined self-reported alcohol consumption from the Alcohol Use Questionnaire of NHANES. Self-reported alcohol consumption was based on the average alcoholic drinks reported per day in the past 12 months. In NHANES, participants were asked "In the past 12 months, on those days that you drank alcoholic beverages, on the average, how many drinks did you have?" Individuals who reported zero drinks were defined as nondrinkers. Individuals were defined as drinkers if they reported consuming any amount of alcohol, including moderate (Female: 1 drink; Male: 1-3 drinks) or heavy (Female: > 1 drink; Male: > 3 drinks). Self-reported alcohol consumption was dichotomized to "yes" for drinkers (including moderate or heavy) or "no" for nondrinkers in the analysis.

Sleep Adequacy

This study used the Sleep Disorders questionnaire of NHANES to evaluate sleep adequacy based on participants' sleep duration (number of hours of sleep at night). Participants were asked "How much sleep do you usually get at night on weekdays or workdays?" The responses ranged from 1 to 11 hours. Participants who reported sleeping 12 or more hours were coded together as a category. Previous studies have defined adequate sleep as participants reporting 7-8 hours of sleep at night (Grandner, Jackson, Gerstner, & Knutson, 2013; Beydoun et al., 2014). The present study defined adequate sleep by assigning a "1" to individuals who slept at least 7 hours at night and "0" to those who did not (< 7 hours).

On a special diet

As part of the dietary interview in NHANES, participants were asked: "Are you currently on any kind of diet, either to lose weight or for some other health-related reason?" Responses were coded as "yes" or "no." Participants who responded "yes" were further asked to specify the type of diet that they followed. However, this study only used the general question related to being on a special diet as an indicator of participants' intent to change their diets.

Supplement Intake

In the Dietary Supplements component of NHANES, participants were asked to participants to report any dietary supplements taken in the preceding month. Participants were asked: "Have you used or taken any vitamins, minerals or other dietary supplements in the past month? Include those products prescribed by a health professional such as a doctor or dentist, and those that do not require a prescription." Participants' responses to the question were coded as "yes" or "no."

Smoking Status

The smoking Questionnaire of NHANES was used to categorize smoking status based on the responses of two questions. Participants who said "no" to having smoked 100 cigarettes during their lifetimes were classified as nonsmokers. Participants who said "yes" to having smoked at least 100 cigarettes in their lives and who reported now smoking either "everyday" or "some days" were classified as smokers. Those who said "yes" to having smoked at least 100 cigarettes in their lives and reported "not at all" to current smoking were classified as former smokers. Smoking status was further dichotomized to "yes" and "no" in the analysis. Current and former smokers were aggregated into "yes" as a category and were contrasted with nonsmokers as "no" in a separate category.

Physical Activity

The NHANES Physical Activity questionnaire was used to evaluate the frequency, duration, and intensity of recreational physical activity based on the 2008 Physical Activity Guidelines for Americans (Leavitt, n.d.). The Guidelines call for 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity per week or some combination of the two (Leavitt, n.d.). In the analysis, physical activity was dichotomized to "yes" for participants as meeting ≥150 min per week of moderate-to-vigorous physical activity [MVPA], and "no" for not meeting MVPA guidelines (Paul D. Loprinzi, Ellen Smit, Sara Mahoney, 2014).

Lifestyle Behaviors score

As previously mentioned, this study created a total Lifestyle Behaviors score to examine the effect of a combination of individual lifestyle behaviors in relation to dietary quality (using HEI-2010 and AHEI-2010 scores). A total Lifestyle Behaviors score variable was constructed using participants' responses to six selected individual lifestyle behaviors: 1) self-reported alcohol consumption, 2) sleep adequacy, 3) on a special diet, 4) supplement intake, 5) smoking status, and 6) physical activity adequacy. Individuals received 1 point for each positive lifestyle behavior: sleep adequacy, on a special diet, supplement intake, and physical activity. Smoking and alcohol consumption were reverse-scored. Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status. The total Lifestyle

Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors (Maximum score = 6 points). The Lifestyle Behaviors score was used as a discrete variable in the multivariate analysis.

Estimation of Diet Quality

This study utilized the Healthy Eating Index-2010 (HEI-2010) and the Alternate Eating Index-2010 (AHEI-2010) as the main outcome variables to measure dietary quality in U.S. adults. The HEI-2010 and AHEI-2010 were calculated using the dietary intake data available in NHANES. Dietary intake information includes two 24-hour dietary recall interviews. The first recall was administered in-person at the Medical Examination Center (MEC) by trained interviewers using USDA's Automated Multiple-Pass Method (AMPM). The second recall was administered via telephone interview, approximately 3 to 10 days after attending the MEC (MEC In-Person Dietary Interviewers Procedures Manual, 2008). This study used only data from the in-person recall (day 1) to calculate the HEI-2010 and AHEI-2010 scores for reasons of methodology, interpretation, and comparability with other dietary surveys[3]. The use of the first day recall is recommended for most statistical analyses because the two dietary recalls should not be assumed to be independent of one another. The within-person variation would be underestimated when combining the two recalls and complicate the interpretation of the results. Furthermore, the use of two different methods to collect data (in-person for the first vs. telephone for the second) could

[3] Personal communication with Dr. Joseph Goldman, who is a biostatistician at Food Surveys Research Group, Agricultural Research Service, USDA. 10300 Baltimore Ave. Bldg. 005, Room 102, BARC-West Beltsville, MD 20705.

introduce bias from participants' responses. In addition, the varying length of time between recalls (3 to 10 days) may introduce bias. Therefore, using the in-person (day 1) recall ensures consistency in dietary methodology and yields estimates that are most comparable with other dietary surveys. This analysis was limited to dietary recall data reported to be complete and reliable by the National Center for Health Statistics staff (Centers for Disease Control and Prevention, 2008).

Healthy Eating Index-2010 (HEI-2010)

The HEI-2010 was developed by the United States Department of Agriculture (USDA) Center for Nutrition Policy and Promotion (CNPP) as a tool that assess adherence to the 2010 Dietary Guidelines for Americans. The HEI-2010 is made up of a total of 12 components: 9 adequacy and 3 moderation components. The 9 adequacy components (foods that people should consume more of) are: Total Fruit, Whole Fruit (forms other than juice), Total Vegetables, Greens and Beans (dark-green vegetables and beans and peas), Whole Grains, Dairy (all milk products and soy beverages), Total Protein Foods, Seafood and Plant Proteins, and Fatty Acids (ratio of poly- and monounsaturated fat to saturated fat). The 3 moderation components (foods that people should consume less of) are: Refined Grains, Sodium, and Empty Calories (all calories from solid fats & added sugars plus calories from alcohol beyond a moderate level) (P. M. Guenther et al., 2014). Seven components were each scored on a 0 to 5 scale and the five other components are each scored on a 0 to 10 scale, with intermediate values scored proportionally. The component scores were summed to obtain total HEI-2010 scores. The Food Pattern Equivalents Database (FPED) and a SAS code downloaded from the USDA CNPP website were used to calculate the HEI-2010 scores (United States Department of Agriculture. Center for Nutrition Policy and Promotion., 2013).

Alternate Healthy Eating Index-2010 (AHEI-2010)

The AHEI-2010 was originally developed on the basis of the Food Frequency Questionnaire (FFQ) to identify future risk of diet-related chronic disease (C. W. Leung et al., 2012; Cindy W. Leung, Epel, Ritchie, Crawford, & Laraia, 2014; Wang et al., 2014). However, the present study applied the methodology from previous studies to calculate the AHEI-2010 scores using 24-hour recalls from NHANES (C. W. Leung et al., 2012; Cindy W. Leung, Epel, Ritchie, Crawford, & Laraia, 2014; Wang et al., 2014). The AHEI-2010 consists of 11 components: six components for which higher intakes are better [vegetables, fruit, whole grains, nuts and legumes, long chain omega-3 fatty acids (FA) that include docosahexaenoic acid and eicosapentaenoic acid, and Polyunsaturated Fatty Acids (PUFA)], one component for which moderate intake is better (alcohol), and four components that must be limited or avoided [sugar sweetened drinks and fruit juice, red and processed meat, trans fats, and sodium]. Each component was scored on a 0 to 10 point scale. The component scores were summed to obtain the total AHEI-2010 score, which can range from 0 (non-adherence) to 110 (perfect adherence). Higher scores represent healthier diets (A. M. Bernstein, Bloom, Rosner, Franz, & Willett, 2010; Wang et al., 2014; Varraso et al., 2015). However, this study constructed a modified AHEI-2010 score by excluding the trans fat component because trans fat is unavailable in the NHANES dietary files (C. W. Leung et al., 2012). Therefore, the maximum total AHEI-2010 score was rescaled from 110 points to 100 points (excluding trans fat) similar to the approach used in a previous study (C. W. Leung et al., 2012). The NHANES individual foods file was used to estimate servings of food to construct the AHEI-2010 food groups. The USDA food-coding scheme was used as a reference to categorize each individual food (represented by food codes) into groups (Ahuja et al., 2012). In addition, this study used the supplementary table provided by Wang and colleagues (2014) to identify the foods and beverages that correspond to each AHEI food component (i.e., sugar-sweetened beverages, nuts and legumes, red and/or processed meats) (C. W. Leung et al., 2012; Cindy W. Leung, Epel, Ritchie, Crawford, & Laraia, 2014; Wang et al., 2014). The NHANES total nutrients file was used to estimate the intake of nutrients (i.e., PUFA, long-chain omega-3 fats, sodium) as components of the AHEI. SAS was used to construct and calculate the AHEI-2010 scores.

Covariates

Diabetes Status

The association between lifestyle behaviors and dietary quality was examined by diabetes status groups in the bivariate and multivariate analyses. T2DM could be diagnosed or undiagnosed. Diagnosed diabetics were defined as those who answered "yes" to the question: "Other than during pregnancy, have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?" or those who reported taking diabetes medication (i.e., Metformin) during the interview. Undiagnosed diabetics were defined as individuals with a fasting plasma glucose (FPG) $\geq$ 126 mg/dL, or HbA1c $\geq$ 6.5% who did not report a previous diabetes diagnosis during the interview. The total number of adults with T2DM was computed as the sum of individuals with diagnosed and undiagnosed diabetes. Individuals diagnosed with diabetes prior to age 30 and continuous users of insulin were excluded to minimize the number of respondents with type 1 diabetes (T1DM) (Jarvandi et al., 2012; Demmer, Zuk, Rosenbaum, & Desvarieux, 2013). Pre-diabetics were defined as those with FPG of 100 – 125 mg/dL, HbA1c 5.7 – 6.4 %, or an answer of "yes" to the question "Have you ever been told by a doctor or other health professional that you have prediabetes?" or an answer of "borderline" to the question "Other than during pregnancy, have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?" Nondiabetics were categorized as participants who did not meet the definition for T2DM or pre-diabetes (FPG < 100 mg/dL and HbA1c < 5.7%) (William T. Cefalu, MD et al., 2017).

Demographic and Health Characteristics

Demographic information was obtained from the household interview component of NHANES. Self-reported sociodemographic characteristics were explored as potential covariates. These included age, sex, race/ethnicity, education level, poverty-to-income ratio, and perceived health status. Age and poverty-to-income ratio were used as ordinal variables in the bivariate analysis and as continuous variables in the multivariate analysis. Poverty-to-income ratio was used as a measure of socioeconomic status (SES) that takes into account both family size and income (range 0 to 5). In the bivariate analysis, poverty-to-income ratio was used as a categorical variable. Individuals with a poverty-to-income ratio less than 1.30 were considered as low SES, poverty-to-income ratio between 1.30 and 3.49 were considered as medium SES, and poverty-to-income ratio of at least 3.5 were considered as high SES.

The remaining covariates were used as categorical variables. Ethnicity was defined as follows: Mexican American, non-Hispanic White, non-Hispanic Black, and other. Education level was categorized as less than high school, high school diploma, some college education, and college graduate and above. Perceived health status was obtained from the interview component of NHANES. This variable was assessed based on responses to the Question “Would you say health in general is ....” Responses to these questions were based on a 5-point Likert Scale: Excellent, very good, good, fair, and poor. In the multivariate analysis, perceived health status was reduced to a 3-point Likert scale by combining “excellent” and “very good” into one category and likewise “fair” and “poor” into a category to avoid sparse cells.

Body Mass Index (BMI) and waist circumference (WC) were used as measures of weight status and abdominal adiposity and were evaluated as potential covariates. Measurements of height, weight, and WC were obtained in the MEC according to the NHANES protocols (MEC Interviewers Procedures Manual, 2009). BMI was calculated as body weight (in kilograms) divided by height (in meters) squared (Anthropometry Procedures Manual, 2009). In the bivariate analysis, BMI was used as an ordinal variable and defined as follows: normal weight [18.5-24.9 kg/m^2], overweight [25.0-29.9 kg/m^2], and obese [$\geq$ 30 kg/m^2] (National Institutes of Health, 2000). WC was also used as a categorical variable and classified using sex-specific cut-offs: WC >102 for men and WC > 88 for women are considered as abdominally obese (National Institutes of Health, 2000).

Statistical Analysis

Data was analyzed using SAS 9.4 (SAS Institute Inc, Cary, NC) to adjust the variances for the complex sample design of NHANES. The 4-year fasting sample weight was used to account for the complex survey design and include participants who are already diagnosed with diabetes and taking insulin or oral medications. As recommended in the NHANES analytic guidelines, the fasting subsample weights (WTSAF2YR) for both cycles (2007-2008 and 2009-2010) were used to construct a 4-year fasting weight and used throughout the analysis (National Center for Health Statistics (U.S.), 2013a).

SAS (release 9.4) was the primary tool used in data preparation, cleaning, and analysis. Univariate analysis (PROC SURVEYFREQ) was used for descriptive statistics (i.e., numbers and percentages) on selected individual lifestyle behaviors and Lifestyle Behaviors score. The design-adjusted Rao-Scott chi-square test (PROC SURVEYFREQ) was used to examine bivariate associations between lifestyle behaviors and diabetes status groups, and to compare participants' demographic characteristics across Lifestyle Behaviors score.

Linear regression (PROC SURVEYREG) was used to examine differences in total HEI-2010 and AHEI-2010 scores across individual lifestyle behaviors (categorized as "yes" and "no") and Lifestyle Behaviors score (categorized as low and high) by calculating the Least-squares means (LSMs). Least-squares means (and the standard errors of the LSMs) were also calculated to determine differences in total and sub-component HEI-2010 and AHEI-2010 scores across Lifestyle Behaviors score (categorized as low, medium, and high). The Bonferroni correction for multiple comparisons (0.05/number of variables) was applied to obtain the effective p-values for the models.

Multivariate Models

Multivariable Linear Regression (PROC SURVEYREG) was used to examine the association between lifestyle behaviors and dietary quality (using total HEI-2010 and AHEI-2010 scores) after adjusting for demographic and health characteristics. In addition, the regression analyses were performed within diabetes status groups (nondiabetes, prediabetes, T2DM) as a class variable using the Domain statement in SAS. Separate models were performed for individual lifestyle behaviors and Lifestyle Behaviors score. The first model examined the association between the selected individual lifestyle behaviors (predictors) and total HEI-2010 and AHEI-2010 scores (outcomes). The second model examined the association between Lifestyle Behaviors score (predictor) and total HEI-2010 and AHEI-2010 scores (outcomes). All analyses had statistical significance set at $p < 0.05$.

Theoretical models of Lifestyle Behaviors and Dietary Quality

This study attempted to produce a model that explains the relationship between lifestyle behaviors and dietary quality (using total HEI-2010 and AHEI-2010 scores). Covariates were selected based on previous studies of the associations between healthy lifestyle characteristics (i.e., physical activity, healthy diet, smoking status) and health outcomes (i.e., CVD markers, depression) (Loprinzi & Mahoney, 2014; Loprinzi, Branscum, Hanks, & Smit, 2016), associations between sleep quality and health outcomes (i.e., obesity, diabetes) (Liu et al., 2013), and the association between sleep quality and dietary intake (Grandner et al., 2013). The present study examined the following predictors as potential covariates: age, sex, race/ethnicity, education level, poverty-to-income ratio, presence of comorbidities, perceived health status, and BMI. Poverty-to-income ratio and presence of comorbidities were excluded from later models because they were not statistically significant ($p > 0.05$). Therefore, the multivariable linear regression models were adjusted for age, sex, race/ethnicity, education, perceived health status, and BMI. BMI was log-transformed for normality. Energy intake was included as a covariate for the AHEI-2010 because it is based on absolute amount of intake whereas the HEI-2010 already adjusts for energy intake using the density-based approach (amounts consumed per 1,000 calories).

Results

Univariate Analysis of selected Lifestyle Behaviors

Table 36 presents the univariate analysis of selected lifestyle behaviors using 2007-2010 NHANES. The present study selected six individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, being on a special diet, supplement intake, smoking status, and physical activity. The majority of participants in the sample reported consuming alcoholic drinks (about 69.6%) and the majority reported getting adequate sleep (≥ 7 hours) at night (about 64.4%). In addition, more than half of the participants (about 54.1%) reported engaging in physical activity and being nonsmokers (about 55.7%). The majority of participants in the sample reported that they were not on a special diet (about 86.5%). However, about half of the participants reported taking dietary supplements (about 52.3%). This study also evaluated the combination of lifestyle behaviors by calculating a Lifestyle Behaviors score, which was based on the sum of six selected individual lifestyle behaviors (Total = 6 points). The mean Lifestyle Behaviors score in the sample was 2.70 ± 0.04. About one-third (about 30.9%) of participants reported doing at least three out of the six selected individual lifestyle behaviors.

Bivariate relationships between Lifestyle Behaviors and Diabetes Status

Table 37 shows bivariate associations between lifestyle behaviors and diabetes status. Results indicate significant associations between individual lifestyle behaviors and diabetes status ($p < 0.05$). About half of diabetics reported consuming alcohol drinks within the past year. However, diabetics were less likely to report alcohol consumption compared to prediabetics and nondiabetics (51.9% vs. 69.7% vs. 74.8%, respectively). More than half of diabetics reported getting adequate sleep (≥ 7 hours). However, diabetics were less likely to report getting adequate sleep compared to prediabetics and nondiabetics (54.7% vs. 63.4% vs. 68.3%, respectively). The majority of diabetics reported not engaging in any physical activity (about 63.9%). In addition, diabetics were less likely to report engaging in any physical activity compared to prediabetics and nondiabetics (50.5% vs. 47.1% vs. 39.1%, respectively). The majority of diabetics reported not being on a special diet (about 72.6%). However, diabetics were more likely to report being on a special diet compared to prediabetics and nondiabetics (27.4% vs. 11.7% vs. 10.6%, respectively). More than half of diabetics reported taking dietary supplements (about 55.6%). In addition, diabetics were more likely to report taking dietary supplements compared to prediabetics and nondiabetics (55.6% vs. 54.2% vs. 49.2%, respectively). About half of diabetics reported having ever smoked (whether current or former smokers). In addition, diabetics were more likely to report that they have smoked compared to prediabetics and nondiabetics (50.5% vs. 47.1% vs. 39.1%, respectively). The association between Lifestyle Behaviors score and diabetes status was not significant (p = 0.0666). The mean Lifestyle Behaviors score across diabetes status was 2.75 ± 0.05 for nondiabetics, 2.65 ± 0.05 for prediabetics, and 2.71 ± 0.09 for diabetics. Although not statistically significant, it appears that prediabetics had a slightly lower Lifestyle Behaviors score and were less likely to practice several lifestyle behaviors compared to diabetics and nondiabetics.

Demographic Characteristics of U.S. adults (Age ≥ 20) by Lifestyle Behaviors score

Table 38 shows that the majority of the demographic characteristics were significantly associated with Lifestyle Behaviors score ($p < 0.01$), with the exception of BMI and WC ($p > 0.05$). Lifestyle Behaviors score was categorized as "low" (0-1 point), "medium" (2-3 points), and "high" (4-6 points). In general, older individuals were more likely to have higher Lifestyle Behavior scores (20-39 years: mean score = 2.62 ± 0.05; 40-59 years: mean score = 2.65 ± 0.05; 60-79 years: mean score = 2.85 ± 0.05; 80+ years: mean score = 3.13 ± 0.06). In addition, individuals with "high" (4-6 points) Lifestyle Behaviors score were more likely to be female (about 61.3%) and to report having a college education or more ($p < 0.01$). Also, about 47.9% of individuals with poverty-to-income ratio ≥ 3.50 were more likely to have "high" (4-6 points) Lifestyle Behaviors score (p < 0.0001). For self-reported health, individuals who positively rated their health had higher Lifestyle behaviors scores ("excellent," mean score = 3.03 ± 0.09; "very good," mean score = 2.98 ± 0.06; "good," mean score = 2.71 ± 0.05; "fair," mean score = 2.39 ± 0.06; "poor," mean score = 2.05 ±

0.14). However, individuals with "low" (0-1 point) Lifestyle Behaviors scores were more likely to be male (about 58.6%) and to report having a high school education ($p < 0.01$). Among ethnic groups (except non-Hispanic White), non-Hispanic blacks were more likely to have "low" (0-1 point) Lifestyle Behaviors scores (about 13.9%) than Mexican Americans and Other (p = 0.0115).

Bivariate Relationships between Lifestyle Behaviors and Total HEI-2010 Scores

Table 39 presents the bivariate associations between lifestyle behaviors and total HEI-2010 scores in U.S. adults. Results indicate significant differences in mean total HEI-2010 scores by individual lifestyle behaviors ($p < 0.05$), except for self-reported alcohol consumption (p = 0.0688). The mean total HEI-2010 score was higher among individuals who reported getting adequate sleep (mean = 48.2 ± 0.5, p < 0.0001), being on a special diet (mean = 51.8 ± 0.7, p < 0.0001), taking supplements (mean = 49.8 ± 0.6, p < 0.0001), and meeting physical activity guidelines (mean = 49.0 ± 0.6, p < 0.0001). In addition, the mean total HEI-2010 score was higher among individuals who reported being nonsmokers (mean = 48.6 ± 0.5, p < 0.0001). Lifestyle Behaviors score was dichotomized as "low" (0-2 points) and "high" (3-6 points). Results indicate significant differences in mean total HEI-2010 scores by Lifestyle Behaviors score. The mean total HEI-2010 score was greater among individuals with "high" (3-6 points) Lifestyle Behaviors score (mean = 49.7 ± 0.5, p < 0.0001). Moreover, the associations between lifestyle behaviors and total HEI-2010 score were also examined by diabetes status. The relationships were the same for nondiabetics, prediabetics, and diabetics.

Bivariate Relationships between Lifestyle Behaviors and Total AHEI-2010 Scores

Table 40 presents the bivariate associations between lifestyle behaviors and total AHEI-2010 score in U.S. adults. Results indicate significant differences in mean total AHEI-2010 scores by individual lifestyle behaviors ($p < 0.05$), except for self-reported alcohol consumption (p = 0.7297). The mean total AHEI-2010 score was higher among individuals who reported getting adequate sleep (mean = 38.9 ± 0.4, p = 0.0037), being on a special diet (mean = 40.8 ± 0.7, p < 0.0001), supplement intake (mean = 40.8 ± 0.5, p < 0.0001), and meeting physical activity guidelines (mean = 39.6 ± 0.6, p < 0.0001). In addition, the mean total AHEI-2010 score was higher among individuals who reported being nonsmokers (mean = 39.2 ± 0.5, p < 0.0040). Lifestyle Behaviors score was dichotomized as “low” (0-2 points) and “high” (3-6 points). Results indicate significant differences in mean total AHEI-2010 scores by Lifestyle Behaviors score. The mean total AHEI-2010 score was greater among individuals with “high” (3-6 points) Lifestyle Behaviors scores (mean = 40.2 ± 0.5, p < 0.0001). Moreover, the associations between lifestyle behaviors and total AHEI-2010 score were also examined by diabetes status. The relationships were the same for nondiabetics, prediabetics, and diabetics.

HEI-2010 and AHEI-2010 component scores by Lifestyle Behaviors score

Results show significant differences in the mean HEI-2010 and AHEI-2010 component scores by Lifestyle Behaviors score ($p < 0.05$) (**Supplemental Tables 17 and 18**). In this bivariate analysis, Lifestyle Behaviors score was categorized as “low” (0-1 points), “medium” (2-3 points), and “high” (4-6 points). For HEI-2010 component scores, the mean scores for the adequacy components (a higher score corresponds to higher intake) were greater among individuals with higher Lifestyle Behaviors score. The mean scores for total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, and seafood and plant proteins were the greatest among individuals with "high" (4-6) Lifestyle Behaviors score ($p < 0.01$). In addition, the mean scores for the moderation components (a higher score corresponds to lower intake) were greater among individuals with higher Lifestyle Behaviors score. The mean scores for sodium and empty calories were greatest among individuals with "high" (4-6) Lifestyle Behaviors score ($p < 0.05$) (**Supplemental Table 17**). For AHEI-2010 component scores, the mean component scores for whole fruit, total vegetables, whole grains, nuts and legumes, and red and/or processed meats (higher score corresponds to lower intake) were the greatest among individuals with "high" (4-6) Lifestyle Behaviors score ($p < 0.01$).

Association between Lifestyle Behaviors and Total HEI-2010 and AHEI-2010 scores

Multiple linear regression analysis was used to determine the associations between lifestyle behaviors and total HEI-2010 and AHEI-2010 scores (**Tables 41 and 42**). **Table 41** shows separate multivariate linear regression models for selected individual lifestyle behaviors (Model 1) and Lifestyle Behaviors score (Model 2) in relation to total HEI-2010 score after adjusting for age, sex, race/ethnicity, education, and BMI. Results indicate significant associations between individual lifestyle behaviors and total HEI-2010 score ($p < 0.05$), except for alcohol consumption ($p = 0.4728$) (Model 1). For Model 1, being on a special diet had the highest predictive power in relation to total HEI-2010 score ($\beta = 4.28$, $p < 0.0001$), followed by physical activity ($\beta = 2.98$, $p < 0.0001$), and smoking status ($\beta = -1.86$, $p = 0.0028$). For Model

2, Lifestyle Behaviors score had moderate predictive power and was significantly associated with total HEI-2010 score (β = 1.92, $p < 0.0001$). In other words, for one-unit change in Lifestyle Behaviors score, the total HEI-2010 score increases by 1.92 points, while controlling for the other predictors in the model. The R-square value was comparable for Model 1 ($R^2 = 0.1565$) and Model 2 ($R^2 = 0.1486$), which suggest that both models (Model 1 and Model 2) perform about the same in explaining the percent of variability in total HEI-2010 score.

Table 42 shows separate multivariate linear regression models for selected individual lifestyle behaviors (Model 1) and Lifestyle Behaviors score (Model 2) in relation to total AHEI-2010 score after adjusting for age, sex, race/ethnicity, education, BMI, and energy intake. Results indicate significant associations between individual lifestyle behaviors and total AHEI-2010 score ($p < 0.05$), except for sleep adequacy (p = 0.1610) (Model 1). For Model 1, physical activity had the highest predictive power in relation to total AHEI-2010 score (β = 2.35, $p < 0.0001$), followed by supplement intake (β = 2.18, $p < 0.0001$), and being on a special diet (β = 2.02, p = 0.0020). For Model 2, Lifestyle Behaviors score was significantly associated with total AHEI-2010 score (β = 1.26, $p < 0.0001$). In other words, for one-unit change in Lifestyle Behaviors score, the total AHEI-2010 score increases by 1.26 points, while controlling for the other predictors in the model. The R-square value was comparable for Model 1 ($R^2 = 0.1805$) and Model 2 ($R^2 = 0.1693$), which suggest that both models (Model 1 and Model 2) perform about the same in explaining the percent of variability in total AHEI-2010 score. Overall, R-square values suggest that a large proportion of the variability in total HEI-2010 and AHEI-2010 scores is unexplained.

Association between individual Lifestyle Behaviors and Total HEI-2010 score by Diabetes Status

Multiple linear regression analysis was used to examine the associations between selected individual lifestyle behaviors and total HEI-2010 and AHEI-2010 scores by diabetes status (**Tables 43 and 44**). **Table 43** shows multivariate linear regression models for individual lifestyle behaviors in relation to total HEI-2010 score by diabetes status (nondiabetes, prediabetes, T2DM) after adjusting for age, sex, race/ethnicity, education, and BMI. For nondiabetics, being on a special diet had the highest predictive power in relation to total HEI-2010 score ($\beta = 4.44$, $p = 0.0015$) followed by physical activity ($\beta = 2.80$, $p = 0.0058$). For prediabetics, physical activity had the highest predictive power in relation to total HEI-2010 score ($\beta = 3.61$, $p = 0.0003$), followed by being on a special diet ($\beta = 3.48$, $p = 0.0275$), and smoking status ($\beta = -2.45$, $p = 0.0068$). For diabetics, being on a special diet had the highest predictive power in relation to total HEI-2010 score ($\beta = 5.08$, $p = 0.0011$), followed by supplement intake ($\beta = 4.25$, $p = 0.0030$), and alcohol consumption ($\beta = -2.27$, $p = 0.0142$). The magnitude of the R-square for the models was comparable by diabetes status (**Table 43**). The R-square was the highest for nondiabetics ($R^2 = 0.1708$) followed by prediabetics ($R^2 = 0.1629$) and diabetics ($R^2 = 0.1423$).

Association between individual Lifestyle Behaviors and Total AHEI-2010 score by Diabetes Status

Table 44 shows multivariate linear regression models for individual lifestyle behaviors in relation to total AHEI-2010 score by diabetes status after adjusting for age, sex, race/ethnicity, education, BMI, and energy intake. For nondiabetics, physical activity was the only predictor significantly associated with total AHEI-2010 score and had the highest predictive power (β = 2.02, p = 0.0031). For prediabetics, being on a special diet had the highest predictive power in relation to total AHEI-2010 score (β = 2.65, p = 0.0449), followed by smoking status (β = -2.55, p = 0.0043), supplement intake (β = 2.13, p = 0.0039), and physical activity (β = 2.02, p = 0.0031). For diabetics, supplement intake had the highest predictive power in relation to total AHEI-2010 score (β = 3.89, p = 0.0019), followed by being on a special diet (β = 3.31, p = 0.0090), and physical activity (β = 1.61, p = 0.1728). The magnitude of the R-square for the models was comparable by diabetes status (**Table 44)**. The R-square was the highest for prediabetics (R^2 = 0.1976) followed by nondiabetics (R^2 = 0.1902) and diabetics (R^2 = 0.1749). Overall, the R-square in the models for HEI-2010 and AHEI-2010 were comparable. The R-square values suggest that a large proportion of the variability in total HEI-2010 and AHEI-2010 scores by diabetes status is unexplained.

Association between Lifestyle Behaviors score and Total HEI-2010 and AHEI-2010 scores by Diabetes Status

Multiple linear regression analysis was used to examine the association between Lifestyle Behaviors score and total HEI-2010 and AHEI-2010 scores by diabetes status (**Tables 45 and 46**). **Table 45** shows multivariate linear regression models for Lifestyle Behaviors score in relation to total HEI-2010 score by diabetes status after adjusting for age, sex, race/ethnicity, education, and BMI. Results indicate that Lifestyle Behaviors score was a significant predictor in relation to total HEI-2010 score by diabetes status ($p < 0.0001$). The predictive power of Lifestyle Behaviors score in relation to total HEI-2010 score was the same for prediabetics (β = 1.96, p = 0.0003) and diabetics (β = 1.96, $p < 0.0001$) and greater than nondiabetics (β = 1.76, $p < 0.0001$). The magnitude of the R-square for the models was comparable by diabetes status (**Table 45**). The R-square was highest for nondiabetics ($R^2 = 0.1636$) followed by prediabetics ($R^2 = 0.1521$) and diabetics ($R^2 = 0.1082$). **Table 45** shows multivariate linear regression models for Lifestyle Behaviors score as a predictor of total AHEI-2010 score by diabetes status after adjusting for age, sex, race/ethnicity, education, BMI, and energy intake. Results indicate that Lifestyle Behaviors score was a significant predictor of total AHEI-2010 score by diabetes status ($p < 0.0001$). The predictive power of Lifestyle Behaviors score in relation to total AHEI-2010 score was comparable for prediabetics (β = 1.50, p = 0.0005) and diabetics (β = 1.45, p = 0.0004). However, the predictive power of Lifestyle Behaviors score was lowest for nondiabetics (β = 0.84, p = 0.0142). Overall, the magnitude of the R-square for the models was comparable by diabetes status (**Table 46**). The R-square was highest for prediabetics ($R^2 = 0.1825$) followed by nondiabetics ($R^2 = 0.1790$) and diabetics ($R^2 = 0.1520$). Again, the R-square value suggests that a large proportion of the variability in total HEI-2010 and AHEI-2010 scores by diabetes status is unexplained.

Discussion

The present study was the first that examined the association of selected lifestyle behaviors independently, and in combination with dietary quality in U.S. adults with and without T2DM. In addition, this study was one of the few that used HEI-2010 and AHEI-2010 as two measures of dietary quality. The main result of this study was that associations among lifestyle behaviors were generally comparable regardless of which index of dietary quality (HEI-2010 or AHEI-2010) was used. The AHEI-2010 did not perform better than the HEI-2010 in terms of being influenced by lifestyle behaviors within diabetes status groups.

This study selected several individual lifestyle behaviors as predictors of dietary quality. These included self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Overall, there were meaningful bivariate relationships among the predictors. For example, there were positive associations among positive behaviors such as supplement intake, sleep adequacy, physical activity, and being on a special diet. In addition, there was a positive association between two negative behaviors: smoking and alcohol consumption. However, alcohol consumption was negatively associated with being on a special diet. In addition, supplement intake was negatively associated with alcohol consumption and smoking. Overall, these relationships suggest that individuals practice several lifestyle behaviors together that can either positively or negatively affect their health. The mean lifestyle behavior score was 2.70, indicating that individuals typically practice more than one lifestyle behavior.

Similar to a previous study (Breslow, Rosalind A. Guenther Patricia M. Juan Wenyen, 2010), the present study examined self-reported alcohol consumption (# drinks per day – last 12 months) as part of individuals' lifestyle behaviors. In NHANES, the average daily consumption of alcoholic beverages was estimated using two instruments: the 24-hour recall and the Alcohol Use questionnaire. The 24-hour dietary recalls provide a detailed record of the types and amounts of alcoholic beverages consumed at a specific point in time (Patricia M Guenther, Bowman, &

Goldman, 2010). However, the Alcohol Use questionnaire asks about current and lifetime use of alcohol, and does not collect specific information on the type of alcohol consumed. Responses to the Alcohol Use questionnaire are more likely to reflect usual alcohol consumption. The present study examined usual behavior of alcohol consumption based participants' self-report on the average alcoholic drinks per day in the past 12 months (not specific to type of alcoholic drink) (Patricia M Guenther et al., 2010).

The present study was interested in determining whether or not the relationships between lifestyle behaviors and dietary quality (using HEI-2010 and AHEI-2010) differ by diabetes status. Diabetes status was included as a three-level class variable in the multivariate linear regression models. This analysis would allow to determine differences on the relationship between lifestyle behaviors and dietary quality within diabetes status groups (nondiabetes, prediabetes, T2DM).

Results from the multivariate linear regression models indicate significant associations between individual lifestyle behaviors and total HEI-2010 and AHEI-2010 scores (**Tables 41 and 42**). In the sample, being on a special diet had the largest effect size (greatest coefficient) in relation to total HEI-2010 score, followed by physical activity and smoking status **(Table 41)**. In addition, physical activity had the largest effect size (greatest coefficient) in relation to AHEI-2010 score, followed by supplement intake and being on a special diet **(Table 42)**. The coefficients for AHEI-2010 were generally lower in the models than HEI-2010. This can be due to the lower total AHEI-2010 score on average than total HEI-2010 score in the sample (mean total HEI-2010 score = 47.3 ± 0.4; mean total AHEI-2010 score = 38.2 ± 0.4).

Moreover, there were significant associations between individual lifestyle behaviors and total HEI-2010 and AHEI-2010 scores by diabetes status (**Tables 43 and 44**). The effect size of individual lifestyle behaviors in relation to total HEI-2010 score within diabetes status groups had some similarities and differences **(Table 43)**. For nondiabetics, being on a special diet had the largest estimated effect (greatest coefficient) on HEI-2010, followed by physical activity and smoking status. For prediabetics, physical activity had the largest estimated effect (greatest coefficient) on the HEI-2010 model, followed by being on a special diet and smoking status. For diabetics, being on a special diet had the largest estimated effect (greatest coefficient) on the HEI-2010 model, followed by supplement intake and self-reported alcohol consumption **(Table 43)**. Likewise, there were some similarities and differences on the effect size of individual lifestyle behaviors in relation to total AHEI-2010 score within diabetes status groups **(Table 44)**. For nondiabetics, physical activity had the largest estimated effect (greatest coefficient) on the AHEI-2010 model, followed by supplement intake and alcohol consumption. For prediabetics, being on a special diet had the largest estimated effect (greatest coefficient) on the AHEI-2010 model, followed by smoking status, supplement intake, and physical activity. For diabetics, supplement intake had the largest estimated effect (greatest coefficient) on the AHEI-2010 model, followed by being on a special diet and physical activity **(Table 44)**.

There are some possible explanations for the magnitude of effect size of individual lifestyle behaviors in relation to dietary quality. Among nondiabetics, being on a special diet had the largest estimated effect on the HEI-2010 model (**Table 43**) and physical activity on the AHEI-2010 model (**Table 44**) might be due to the influence by the media promoting changes in individual lifestyle behaviors, including nutrition and physical activity. It might be possible that nondiabetics are being on a special diet and engaging in physical activity because they are dissatisfied with their weight or physical appearance. Among prediabetics, physical activity had the largest estimated effect on the HEI-2010 model (**Table 43**) and being on a special diet on the AHEI-2010 model (**Table 44**) could be related to prediabetics beginning to receive medical advice from healthcare professionals targeting change in their lifestyle behaviors, mainly diet and physical activity. In addition, being on a special diet, smoking status, supplement intake, and physical activity were similar in magnitude in the AHEI-2010 model for prediabetics (**Table 45**). This suggests that modifying any of these lifestyle behaviors are associated with better dietary quality (as measured by AHEI-2010) and prevent prediabetics from advancing to become diabetics. Among diabetics, being on a special diet had the largest estimated effect on the HEI-2010 model (**Table 43**) and supplement intake on the AHEI-2010 model (**Table 44**) are consistent with diabetics being more likely to receive nutrition education to manage their diet. In this sample, diabetics had better dietary quality than prediabetics and nondiabetics (mean total HEI-2010 score = 48.8 ± 0.6; mean total AHEI-2010 score = 38.2 ± 0.4). However, the effect of physical activity in the HEI-2010 and AHEI-2010 models was not significant among diabetics (**Tables 43 and 44**). It may be that diabetics are relying on the healthcare services provided, which primarily focus on medication and change in their diet. Diabetics are held more accountable to manage their diet than engage in physical activity. In addition, compliance with dietary advice can directly be measured through blood tests (i.e., blood sugar, lipid profile) whereas compliance with physical activity guidelines is more difficult to measure. Nevertheless, a healthy diet and increased physical activity are equally important for diabetes self-management.

Diabetics reported had the highest percentages for being on a special diet (about 27.4%) and taking dietary supplements (about 55.6%) than prediabetics and nondiabetics (**Table 37**). In addition, being on a special diet and taking dietary supplements had the largest effect size on total HEI-2010 and AHEI-2010 scores for diabetics (**Tables 43 and 44**). A possible explanation for these differences is that diabetics receive more health care, which is likely to include nutrition education and diet monitoring. Data on access to health care support this interpretation. From information in the Hospital Utilization and Access to Care Questionnaire, diabetics were more likely to report having a routine place to go for healthcare compared to prediabetics and nondiabetics (93.4% vs. 86.5% vs. 83.8%, respectively). In addition, diabetics were likely to have received a greater number of healthcare visits during the preceding 12-month period. About 39.5% of diabetics received 4-9 healthcare visits compared to 24.8% of prediabetics and 19.6% of nondiabetics. Moreover, those on a special diet and taking dietary supplements were likely to have greater exposure to healthcare. About 20.0% of individuals being on a special diet received 4-9 healthcare visits, compared with 79.9% of those not on a special diet. About 59.4% of individuals taking dietary supplements received 4-9 healthcare visits, compared with 40.6% of those not taking dietary supplements. Since diabetics are more likely to have a routine place to go to healthcare and receive greater number of healthcare visits, they are more likely to receive nutrition counseling. The fact that diabetics receive nutrition counseling and do better on measures of dietary quality than nondiabetics and prediabetics suggests that nutrition counseling can be effective in getting people to change their diets and make positive changes in their lifestyle behaviors.

Moreover, the regression coefficients for self-reported alcohol consumption were found to be different in magnitude in the HEI-2010 and AHEI-2010 models (**Tables 40 and 41**). This could be due to the difference in scoring methodology between HEI-2010 and AHEI-2010. The HEI-2010 counts alcohol intake as part of empty calories (alcohol threshold exceeds intake level more than 13 grams/1,000 kcal). However, the AHEI-2010 counts alcohol intake as a separate category and assumes that moderate drinking is part of a healthful dietary pattern. The AHEI-2010 scoring methodology as reported by Wang and colleagues (2014) is non-linear and assigns higher scores to moderate alcohol drinkers than to nondrinkers (Wang et al., 2014). For AHEI-2010, moderate alcohol drinkers (Male: 0.5-2.0 drinks/day; Female: 0.5-1.5 drinks/day) received the maximum score of 10 points, while nondrinkers received 2.5 points; a person who consumed about 2-3 drinks of alcohol (for example, males having 3.12 drinks and females having 2.25 drinks) would also receive a score of 2.5. This method of scoring severely penalizes nondrinkers and makes interpretation of the results more difficult, because a score of 2.5 could mean either a non-drinker, or a moderately heavy drinker. The present study explored another approach to scoring alcohol intake to see if it would produce results more similar to HEI-2010. In this alternative analysis, alcohol consumption was scored linearly. Non-drinkers received the maximum score of 10 points. As alcohol consumption increased, score decreased, reaching 0 for those who exceeded 2.0 drinks per day for males, and 1.5 drinks per day for females. The interpretation is clearer using this method because each score is associated with one specific level of alcohol consumption. The resulting modified total AHEI-2010 score (no alcohol penalty) was used as the outcome in the multivariate linear regression models. With the modified AHEI-2010 model, the regression coefficient for self-reported alcohol consumption had the same magnitude as in the HEI-2010 model but it was different from the original AHEI-2010 model (β = -0.99 vs. β = -0.39 vs. β = 1.37, respectively). Similarly, the regression coefficient for Lifestyle Behaviors score with the modified AHEI-2010 model was closer to the HEI-2010 model and was higher than the original AHEI-2010 model (β = 1.70 vs. β = 1.92 vs. β = 1.26, respectively). This suggests that the differences in the regression coefficients in the HEI-2010 and AHEI-2010 models were attributable to the difference in alcohol scoring.

The logical conclusion of the AHEI method of alcohol scoring is that nondrinkers can significantly improve their diets by becoming moderate drinkers. The AHEI-2010 assigns the highest scores (10 out of 10 possible points) to those who consume alcohol up to the defined limits of moderation. It is appropriate to advise individuals who drink alcohol heavily to consume less. But it is questionable to encourage nondrinkers of alcohol to become drinkers, especially if they are diabetic. Currently, there is no consensus view of the safety of alcohol, which is consistent with some of the key principles of diabetes self-management (Peele, 2009; CDC, 2017). As part of diabetes self-management, the American Diabetes Association (ADA) recommends that individuals with diabetes (both type 1 and type 2) reduce or minimize alcohol consumption (William T. Cefalu, MD et al., 2017), because alcohol intake (especially on an empty stomach) can lower blood glucose and cause hypoglycemia. In addition, many alcoholic beverages contain added sugars, which can lead to excess calories and elevated triglycerides, increasing the risk of heart disease (William T. Cefalu, MD et al., 2017). The treatment of alcohol consumption in the AHEI-2010 is based on an assumption of safety of alcohol intake that has not been scientifically validated. A recent article was published in the New York Times that questioned the safety of moderate alcohol consumption. There was a concern that the alcohol industry was having too much influence on research studies. The safety of alcohol intake remains an open question. The article highlights the difficulty of designing a definitive clinical trial that is objective and free from bias from the alcohol industry ("Federal Agency Courted Alcohol Industry to Fund Study on Benefits of Moderate Drinking," 2018). Moreover, a new article published in the Lancet questioned the recommended limits for alcohol consumption from different national guidelines (including the U.S. dietary guidelines). In addition, the study questioned findings from previous epidemiological studies that moderate alcohol consumption is associated with lower cardiovascular disease risk (Wood et al., 2018). The authors conducted a combined analysis of individual-participant data sources in 19 high-income countries (the Emerging Risk Factors Collaboration, EPIC-CVD, and the UK Biobank) (Wood et al., 2018). The study included 599 912 current drinkers from 83 prospective studies and examined alcohol consumption in relation to all-cause mortality, total cardiovascular disease, and cardiovascular disease subtypes. Results did show that moderate alcohol intake was associated with lower myocardial infarction. However, results also indicated that moderate alcohol intake was linearly associated with higher risk of stroke, aortic aneurysm, fatal hypertensive disease, and heart failure (Wood et al., 2018). Moreover, the authors found a dose-response association of higher alcohol consumption and lower life expectancy. For example, compared to individuals reported drinking >0-≤ 100 g per week, those who reported drinking >100-≤ 200 g per week had lower life expectancy of approximately 6 months (at age 40 years) (Wood et al., 2018). Overall, the authors suggest revising the current guidelines (including the U.S. dietary guidelines) for alcohol consumption to lower limits (Wood et al., 2018).

Although the AHEI-2010 measures some different components, it is relatively consistent with the HEI-2010. The indices are similar in some respects (i.e., both require consumption of fruits, vegetables, whole grains, healthy fats) but differ in the method used to score alcohol intake. In this sample, diabetics seemed to minimize alcohol or not drink it at all, which is consistent with diabetes self-management. The HEI-2010 does not penalize nondrinkers for not consuming alcohol like the AHEI-2010. For that reason, the HEI-2010 may be a better tool for assessing dietary quality than the AHEI-2010 for individuals with T2DM. The HEI-2010 is more reflective of the 2010 Dietary Guidelines for Americans, which represents a consensus of the opinions of many experts, whereas the AHEI-2010 reflects a critique of the Dietary Guidelines by an academic research group at Harvard University. Diabetic education within the healthcare system is more likely to reflect the underlying assumptions of the HEI rather than the AHEI. The results of this study suggest that the HEI-2010 more closely reflects the current American diet than the AHEI-2010.

Current research suggests that inadequate sleep duration (i.e., less than 6 hours of sleep at night) is associated with increased food consumption. There is emerging evidence that short sleep duration is considered a risk factor for poor dietary intake (Chaput, 2014; Dashti, Scheer, Jacques, Lamon-Fava, & Ordovas, 2015). In addition, current research is investigating the interaction of the circadian rhythm (biological clock) with dietary intake, energy metabolism, and health outcomes (i.e., weight gain and obesity) (Tahara & Shibata, 2013). The relationship between short sleep duration and dietary intake has extensively been investigated in experimental and epidemiological studies (Chaput, 2014; Dashti et al., 2015; St-Onge et al., 2016). Some of the proposed mechanisms that explain the association between short sleep duration and dietary intake include: 1) changes in appetite hormones (i.e., leptin and ghrelin), 2) hedonic pathways (i.e., increased sensitivity to food reward), 3) decreased dietary restraint, 4) extended hours for intake (i.e., snacking, more meals) 5) altered time of intake, 6) psychological distress, and 7) more energy needed to sustain extended wakefulness (Chaput, 2014; Dashti et al., 2015). Consequently, inadequate sleep duration has implications for eating behaviors and dietary quality.

Short sleep duration may be a potential factor for poor dietary quality (Stern et al., 2014). The present study examined the association of sleep adequacy (using self-reported sleep duration) as one of the selected individual lifestyle behaviors with dietary quality (using HEI-2010 and AHEI-2010) in U.S. adults with and without T2DM. The Sleep Disorders Questionnaire of NHANES captures information about sleeping habits. The number of hours each individual usually slept was captured as a number between 1 and 12 hours. Individuals who reported 7 or more hours/night were coded as getting adequate sleep. Anything less was considered inadequate. About 64.4% of participants in the sample were getting adequate sleep, and 35.6% were not getting adequate sleep (**Table 36**). In addition, results indicate that individuals who reported inadequate sleep had significantly lower total HEI-2010 and AHEI-2010 scores than those who reported adequate sleep at night (**Tables 39 and 40**). This finding was consistent with another cross-sectional study by Haghighatdoost and colleagues (2012) that examined the association between self-reported sleep duration and HEI-1995 among female youths (age 18-28 years, n = 410). They found that short sleep duration of less than 6 hours was significantly associated with lower total HEI-1995 score (p = 0.002) (Haghighatdoost, Karimi, Esmaillzadeh, & Azadbakht, 2012). The findings of the previous study with the present study were consistent with only the HEI (HEI-1995 vs. HEI-2010). Haghighatdoost and colleagues (2012) also examined the relationships between self-reported sleep duration with other diet quality indices (i.e., dietary diversity score, dietary energy density) but did not use the AHEI in their analysis (Haghighatdoost et al., 2012). In addition, the findings of the previous study and the present study were based on bivariate relationships between self-reported sleep duration and dietary quality.

Moreover, this study found a significant association between self-reported sleep duration and total AHEI-2010 score in the bivariate but not in the multivariate analysis (**Tables 40 and 42**). This is in contrast with the results by Stern and colleagues (2014) that examined the relationship between self-reported sleep duration and dietary quality using AHEI-2005 using the Women's Health Initiative prospective Observational Study (WHI-OS). They found that women sleeping ≤ 6 hours had lower AHEI-2005 scores than women sleeping 7 hours at night even after adjusting for covariates (β = -1.634, p = 0.017) (Stern et al., 2014). Possible inconsistencies between the previous and present study include differences in the study design, study population, and sample size. The analysis of the previous study was based on a sample of postmenopausal women (n = 769) (Stern et al., 2014). However, the analysis of the present study was based on a representative sample of U.S. adult men and women aged 20 years and older (n = 4097). In addition, this study used the total AHEI score based on the 2010 evidence-based recommendations rather than the 2005 recommendations.

Results from the multivariate linear regression models indicate that sleep adequacy was not a significant predictor of total HEI-2010 and AHEI-2010 scores after adjusting for covariates (**Tables 41-44**). There are two possible reasons: 1) presence of interrelationships among the covariates, and 2) assessment of sleep adequacy was based on a subjective measure of sleep duration. In the crude models, sleep adequacy was a significant predictor of total HEI-2010 and AHEI-2010 scores. Sleep adequacy remained significant even after including the individual lifestyle behaviors as predictors in the models. However, sleep adequacy was no longer significant when demographics (i.e., race/ethnicity, education, self-rated health) were included as covariates in the models. It seems that that sleep adequacy is strongly associated with demographic and health characteristics.

To further understand the interrelationships between the predictors, this study examined the bivariate relationships between sleep adequacy and demographics and health characteristics. In this sample, individuals who reported getting inadequate sleep were more likely to be male (about 52.3%), non-Hispanic blacks (about 15.9%), and with BMI ≥ 30 kg/m^2 (about 39.9%). However, individuals who reported getting adequate sleep were likely to be more educated (more likely to be college graduates or above (about 33.1%) and to rate their health as excellent/very good (about 53.3%). It is possible that individuals with higher education and positive self-rated health have better access to healthcare. Interestingly, this study found that individuals who had more healthcare visits during the year were more likely to get adequate sleep (2-3 visits: about 31.3%; 4-9 visits about 23.9%). However, about 16.4% of those who don't receive any healthcare visit reported inadequate sleep. This suggests that better access to healthcare has potential benefits for overall health and well-being.

The present study evaluated sleep adequacy based on the self-reported number of hours participants usually get at night on weekdays or workdays. An interesting finding from this study was significance of sleep adequacy in the bivariate but not in the multivariate analysis. There is more to sleep quality than just the number of hours slept, but self-reported sleep duration was the only sleep variable available in this dataset. Sleep duration is only one aspect of sleep quality. Therefore, other aspects of sleep (for example, timing of sleep, REM sleep) would further need to be examined to better determine individuals' sleep quality. Moreover, self-reported sleep duration is a self-reported measure and could be subject to error and bias. Therefore, more objective measures of sleep (i.e., using actigraphy) are needed to evaluate sleep quality and better understand the effect of sleep on diet. Short sleep duration is an area of increasing public health concern (Dashti et al., 2015). This study found that about 35.6% of U.S. adults reported sleeping 6 hours or less, whereas only 57.7%

reported sleeping 7-8 hours (**Table 36**). In addition, about 34% of U.S. adults who have routine access to healthcare reported inadequate sleep. More attention to sleep quality may be needed, and healthcare professionals would need to discuss sleep with their patients for overall health.

There is growing evidence that inadequate sleep could be a risk factor for diabetes (T2DM) (C.-Y. Chao et al., 2011). A plausible biological mechanism would be that sleep deprivation causes a decrease in glucose tolerance and compromises insulin sensitivity (Spiegel, Knutson, Leproult, Tasali, & Cauter, 2005; Gangwisch, 2007). Although the mechanisms involved in the relationship between short sleep duration and diabetes risk are not fully understood, it has been suggested that habitually short sleep duration could lead to insulin resistance by increasing sympathetic nervous system activity, raising evening cortisol levels, and decreasing cerebral glucose utilization (Spiegel et al., 2005; Gangwisch, 2007). Over time, the increased burden on the pancreas from insulin resistance can compromise β-cell function and lead to T2DM (Gangwisch, 2007; Grandner et al., 2013). Epidemiological studies have shown that short sleep duration has adverse effects on T2DM and other health outcomes (i.e., obesity, hypertension, CVD) (Gangwisch, 2007; C.-Y. Chao et al., 2011; Liu et al., 2013; Dashti et al., 2015; St-Onge et al., 2016). The present study found that sleep adequacy was significantly associated with diabetes status ($p = 0.0003$). Diabetics were less likely to report adequate sleep than prediabetics and nondiabetics (**Table 37**). In this sample, almost half of diabetics (about 54.3%) reported getting inadequate sleep (≤ 6 hours) at night. In addition, diabetics were more likely to tell a doctor or other health professional that they had trouble sleeping than prediabetics and nondiabetics (31.5% vs. 26.7% vs. 22.1%, respectively, p = 0.0005). Diabetics were also more likely to have been told by a doctor or other health professionals that they had a sleep disorder than prediabetics and nondiabetics (12.3% vs. 7.4% vs. 5.2%, respectively, $p < 0.0001$). Results from a previous study suggest that the impact of having trouble sleeping and sleep disorders among diabetics may be explained by the individual's obesity status (Liu et al., 2013). In this sample, about 63.5% of participants were classified as obese (BMI ≥ 30 kg/m^2). About 40.1% of obese individuals reported getting inadequate sleep (≤ 6 hours) at night. This study also found that about 28.1% of obese (BMI ≥ 30 kg/m^2) individuals told a doctor or other health professional that they had trouble sleeping. In addition, obese individuals (BMI ≥ 30 kg/m^2) were more likely to have been told by a doctor or other health professionals that they had a sleep disorder than those who were overweight (BMI = 25-29.9 kg/m^2) and normal weight (BMI = 18.5 – 24.9 kg/m^2) individuals (28.1% vs. 24.1% vs. 23.7%, respectively, $p < 0.001$). Taken together, these findings suggest that prolonged short sleep duration may lead to weight gain and obesity over time, probably because short sleep duration is strongly related to increased food intake. Subsequently, weight gain and obesity can lead to the development of T2DM and other chronic disease.

The American Diabetes Association (ADA) currently does not include sleep quality as part of Standards of Medical Care for Diabetes. Lifestyle management, including Nutrition Therapy, Physical Activity, Smoking Cessation (i.e., Tobacco and e-Cigarettes), and Psychosocial Issues, are the main focus of the standards of care (William T. Cefalu, MD et al., 2017). Diabetics may have an unmet need for sleep-related care. Doctors at a minimum should discuss with their patients about having adequate sleep, especially among diabetics since they are more likely to report not having adequate sleep. Due to the deleterious impact of short sleep on glucose metabolism and appetite regulation, habitual sleep patterns and sleep disorders should be routinely assessed in clinical practice (Morselli l, Leproult R, 2010). In addition, sleep quality should be assessed particularly among diabetics. Measures of sleep duration and quality should be obtained on the night before diabetes screening (Morselli l, Leproult R, 2010). Individuals on weight loss programs should also be monitored for adequate sleep duration (Morselli l, Leproult R, 2010) to prevent weight gain from consuming a poor quality diet. As a beginning, screening habitual sleep patterns can have a positive impact on overall health and better management of T2DM and other chronic disease.

Strengths and Limitations

Strengths of this study include the use of a large, nationally representative sample of U.S. adults with findings that are generalizable and have implications to develop effective dietary interventions and policies to improve health and/or disease outcomes. The present study was the first to examine the relationship between selected lifestyle behaviors and HEI-2010 and AHEI-2010 scores as two measures of dietary quality in U.S. adults with and without T2DM. In addition, this study assessed lifestyle behaviors using two approaches: 1) examining the effects of selected individual lifestyle behaviors individually and 2) using a Lifestyle Behaviors score to examine the effect of a combined individual lifestyle behavior score with HEI-2010 and AHEI-2010, overall and by diabetes status group (nondiabetes, prediabetes, T2DM).

However, this study also has some limitations: First, NHANES is a cross-sectional study and therefore, the results cannot support causal inferences about the relationships between lifestyle behaviors and dietary quality. Second, this study used a single 24-hour dietary recall to calculate the HEI-2010 and AHEI-2010 scores, which may not reflect individuals' habitual or usual intake. In addition, the 24-hour recall may be subject to measurement error because it relies on participants' ability to recall and accurately self-report dietary intake, which may lead to under- or over-reporting. Third, sleep adequacy was only examined based on a self-reported measure of sleep duration, which may be inaccurate or biased. In addition, diabetics were more likely to report inadequate sleep. However, this study did not examine the association between diabetes status and types of sleep disorders (i.e., sleep apnea). Lastly, the NHANES survey contains limited variables related to lifestyle behaviors. For example, this study was not able to examine stress as part of individuals' lifestyle behaviors since the questions about stress-related behaviors are currently not available in NHANES. However, this study selected several lifestyle behaviors variables and examined their relationships independently, and in combination with dietary quality by diabetes status groups. Further work is needed to develop validated questionnaire(s) that evaluates a composite of individuals' habitual lifestyle behaviors. In addition, more research is needed to examine the impact of stress and other lifestyle behaviors on diet and health and/or disease outcomes.

Conclusion

In conclusion, the present study found significant associations between selected lifestyle behaviors independently, and in combination, and dietary quality (using total HEI-2010 and AHEI-2010 scores) overall and by diabetes status. The associations between lifestyle behaviors and dietary quality were similar regardless of the diet assessment tool used whether total HEI-2010 or AHEI-2010 score. In addition, this study found significant bivariate relationships between 1) lifestyle behaviors and diabetes status and 2) dietary quality and lifestyle behaviors. Diabetics were more likely to practice positive individual lifestyle behaviors (i.e., being on a special diet, taking dietary supplements, not drinking alcohol) and had higher total HEI-2010 and AHEI-2010 scores. This suggests that nutrition education may be effective in getting individuals to change their behavior, as diabetics typically receive counseling to monitor their diet and make better food choices. However, this study found that diabetics were less likely to meet physical activity guidelines. This suggests that the content of diabetes education may focus more on dietary advice than on physical activity. In addition, diabetics were less likely to report getting adequate sleep (7-8 hours at night). This study did not conduct an in-depth analysis of sleep quality but these findings regarding sleep duration suggest that diabetics may have an unmet need for sleep. Diabetes self-management education focuses mainly on nutrition therapy, physical activity, smoking cessation counseling, and psychosocial care (William T. Cefalu, MD et al., 2017). However, the Standards of Medical Care for Diabetes currently does not include recommendations for improving sleep quality. Healthcare providers should consider exploring the reasons for not getting enough sleep with their diabetic patients, to determine whether there is a need for counseling or other treatments to improve sleep adequacy. Adequate sleep should be included as part of changes in lifestyle behaviors particularly among diabetics.

The present study found that neither HEI-2010 nor AHEI-2010 showed clear superiority in terms of their associations with lifestyle behaviors by diabetes status. The HEI-2010 and AHEI-2010 performed about equally because they are similar in some aspects, (i.e., both capture consumption of fruits, vegetables, whole grains, sodium, and healthy fats). However, the biggest difference between the indices is in the method used to score alcohol intake. The AHEI-2010 assumes that moderate alcohol intake as part of a healthful dietary pattern and severely penalizes nondrinkers (AHEI assigns moderate drinkers 10 points out of 10 while non-drinkers receive 2.5 points out of 10). However, this assumption remains controversial. There is no scientific consensus at the present on the safety or healthfulness of moderate alcohol consumption (regardless of type) for individuals who drink alcohol, and there is certainly no consensus that alcohol consumption should be advised for nondrinkers, especially if they are diabetic. This makes the application of the AHEI somewhat problematic particularly among diabetics because 1) alcohol intake (especially on an empty stomach) lowers blood glucose and causes hypoglycemia (William T. Cefalu, MD et al., 2017), 2) many alcoholic drinks contain added sugars and empty calories leading to increased risk of heart disease (William T. Cefalu, MD et al., 2017), and 3) exposes alcoholic drinkers to potential behavioral risks and addiction. In this study, diabetics who are compliant in their diet seemed to be more in line with HEI and not AHEI. This is because nutrition education within the U.S. healthcare system is more likely to reflect the influence of the HEI rather than the AHEI. In addition, diabetics seemed to minimize or not drink alcohol at all as part of their self-management. Both the dietary guidelines and recommendations for diabetes self-management do not encourage alcohol consumption at any level as part of a healthful dietary pattern (Dietary Guidelines 2015-2020, 2015; William T. Cefalu, MD et al., 2017). This suggests that the HEI-2010 may be a better tool for assessing dietary quality than the AHEI-2010 for individuals with T2DM.

Table 36. Univariate Analysis of selected Lifestyle Behaviors using 2007-2010 NHANES (Age ≥ 20, N = 4097)

Lifestyle Behaviors	(n)	*n* (%)
[a]Alcohol Consumption	4093	
No		1490 (30.4)
Yes		2603 (69.6)
[b]Sleep Adequacy	4095	
No		1580 (35.6)
Yes		2515 (64.4)
[c]On a special Diet	4096	
No		3523 (86.5)
Yes		573 (13.5)
[d]Supplement Intake	4096	
No		2046 (47.7)
Yes		2050 (52.3)
[f]Smoking Status	4097	
No		2259 (55.7)
Yes		1838 (44.3)
[e]Physical Activity	4097	
No		2193 (45.9)
Yes		1904 (54.1)
[g]Lifestyle Behaviors Score	4097	
0		162 (3.8)
1		600 (13.3)
2		1091 (25.2)
3		1221 (30.9)
4		794 (20.8)
5		204 (5.4)
6		25 (0.7)

Values are proportions *n* (%) for categorical variables.

Data source: Adults 20+ years of age participating in 2007-2010 NHANES. Analyses adjusted for complex survey design and using fasting subsample weights.

[a]Alcohol consumption was dischotomized to "Yes" to reporting any amount of alcoholic drinks consumed (including moderate and heavy drinking) and "No" to reporting zero alcohol intake.

[b]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays and was dichotomized to "Yes" to reporting sleep 7 or more hours at night, and "No" to reporting sleep less than 7 hours at night.

[c]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).

[d]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).

[e]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category.

[f]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity.

[g]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points).

Table 37. Bivariate Associations between Lifestyle Behaviors and Diabetes Status

Lifestyle Behaviors	(n)	[a]Diabetes Status *n* (%)			*p* trend
		Nondiabetes (n = 1436)	Prediabetes (n = 1905)	Diabetes (n = 715)	
[b]Alcohol Consumption	4052				**<0.0001**
No		428 (25.2)	670 (30.3)	375 (48.1)	
Yes		1008 (74.8)	1232 (69.7)	339 (51.9)	
[c]Sleep Adequacy	4054				0.0003
No		513 (31.7)	746 (36.6)	307 (45.3)	
Yes		923 (68.3)	1158 (63.4)	407 (54.7)	
[d]On a special Diet	4055				**<0.0001**
No		1290 (89.4)	1686 (88.3)	524 (72.6)	
Yes		146 (10.6)	219 (11.7)	190 (27.4)	
[e]Supplement Intake	4055				0.0482
No		762 (50.8)	920 (45.8)	344 (44.4)	
Yes		673 (49.2)	985 (54.2)	371 (55.6)	
[f]Smoking Status	4056				0.0004
No		876 (60.6)	1008 (52.9)	353 (49.5)	
Yes		560 (39.4)	897 (47.1)	362 (50.5)	
[g]Physical Activity	4056				**<0.0001**
No		654 (38.6)	1020 (47.2)	489 (63.9)	
Yes		782 (61.4)	885 (52.8)	226 (36.1)	
[h]Lifestyle Behaviors Score	4056				0.0666
0		50 (3.0)	85 (4.4)	24 (3.9)	
1		194 (11.8)	295 (13.9)	108 (16.2)	
2		374 (24.7)	510 (25.8)	196 (24.6)	
3		458 (33.8)	564 (29.8)	191 (27.1)	
4		294 (21.6)	348 (20.4)	139 (18.3)	
5		60 (4.7)	92 (5.0)	49 (8.3)	
6		6 (0.5)	11 (0.6)	8 (1.6)	

Values are proportions *n* (%) for categorical variables by diabetes status. Statistical differences were assessed using design-based Rao-Scott F adjusted X^2 statistic. Bolded values are significantly different $p < 0.01$.

[a]Diabetes status was defined from self-report of participants in the diabetes questionnaire and from the laboratory biomarkers using the cut-offs based on the 2017 Standards of Medical Care from the American Diabetes Association (ADA) for diabetes diagnosis.[b]Alcohol consumption was dischotomized to "Yes" to reporting any amount of alcoholic drinks consumed (including moderate and heavy drinking) and "No" to reporting zero alcohol intake.[c]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays and was dichotomized to "Yes" to reporting sleep 7 or more hours at night, and "No" to reporting sleep less than 7 hours at night. [d]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).[e]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).[f]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category. [g]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity. [h]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points).

Table 38. Demographic Characteristics of U.S. Adults (Age ≥ 20 years) by Lifestyle Behaviors Score

Characteristic	**(n)**	**[a]Lifestyle Behaviors Score**						
		Low (n = 762)		**Medium** (n = 2312)		**High** (n = 1023)		***p* trend**
		n	%	*n*	%	*n*	%	
Age	4097							**<.0001**
20 - 39		241	36.8	721	36.8	269	30.6	
40 – 59		311	43.9	757	37.4	327	39.6	
60 – 79		183	16.9	965	21.8	333	23.3	
80+		27	2.3	139	4.0	94	6.5	
Sex	4097							**<.0001**
Male		442	58.6	1134	50.3	370	38.7	
Female		320	41.4	1178	49.7	653	61.3	
Race/Ethnicity	4097							0.0115
Mexican American		130	8.4	444	8.6	165	6.4	
Non-Hispanic White		363	67.7	1122	70.9	542	72.7	
Non-Hispanic Black		157	13.9	393	10.6	149	8.6	
Other		112	10.1	353	9.9	167	12.3	
Education Level	4091							**<.0001**
Less than high school		281	26.7	637	17.7	201	11.0	
High School diploma		213	29.5	553	24.1	199	18.5	
Some College education		177	26.6	635	29.3	301	29.1	
College Graduate or Above		89	17.2	485	28.8	320	41.4	
Poverty-to-Income Ratio	4097							**<.0001**
<1.30		366	36.7	817	23.6	295	18.9	
1.30-3.49		255	34.5	834	35.4	370	33.1	
≥3.50		141	28.8	661	41.0	358	47.9	
Perceived Health Status	4096							**<.0001**
Excellent		51	6.2	167	7.1	114	12.3	
Very Good		94	12.0	521	25.0	264	28.4	
Good		307	43.9	984	42.7	452	42.4	
Fair		239	28.5	528	21.3	169	14.8	
Poor		71	9.3	111	3.9	24	2.1	
BMI	4097							0.1130
Normal (18.5-24.9 kg/m^2)		186	25.8	600	29.9	301	33.9	
Overweight (25-29.9 kg/m^2)		282	36.9	819	34.9	333	31.7	
Obese (≥ 30 kg/m^2)		294	37.3	893	35.2	389	34.5	
[b]WC	4019							0.8944
Not Abdominally Obese		321	44.0	918	45.2	409	45.4	
Abdominally Obese		433	55.9	1344	54.8	594	54.6	

Values are proportions *n* (%) for categorical variables by Lifestyle Behaviors Score. Statistical differences were assessed using design-based Rao-Scott F adjusted X^2 statistic. Bolded values are significantly different $p < 0.01$.
[a]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity (Maximum score = 6 points). Lifestyle behaviors score was categorized as low (0-1 pt), medium (2-3 pts), and high (4-6 pts).
[b]WC values were used to screen participants for abdominal obesity using sex-specific cut-offs: WC >102 for men and WC > 88 for women are classified as abdominally obese based on the National, Heart, Lung, and Blood Institute standards [NHLBI].
Abbreviations: BMI, Body Mass Index; WC, Waist Circumference.

Table 39. Bivariate Associations between Lifestyle Behaviors and Total HEI-2010 scores in U.S. adults (Age ≥ 20 years)

Total HEI-2010 score		**[a]p-value**
[b]Alcohol Consumption (n = 4093)		0.0688
No	Yes	
LSM ± SE	**LSM ± SE**	
48.2 ± 0.5	46.9 ± 0.5	
[c]Sleep Adequacy (n = 4095)		0.0007
No	Yes	
LSM ± SE	**LSM ± SE**	
45.8 ± 0.5	48.2 ± 0.5	
[d]On a special Diet (n = 4096)		**<0.0001**
No	Yes	
LSM ± SE	**LSM ± SE**	
46.6 ± 0.5	51.8 ± 0.7	
[e]Supplement Intake (n = 4096)		**<0.0001**
No	Yes	
LSM ± SE	**LSM ± SE**	
44.7 ± 0.3	49.8 ± 0.6	
[f]Smoking status (n = 4097)		**<0.0001**
No	Yes	
LSM ± SE	**LSM ± SE**	
48.6 ± 0.5	45.7 ± 0.6	
[g]Physical Activity (n = 4097)		**<0.0001**
No	Yes	
LSM ± SE	**LSM ± SE**	
45.3 ± 0.4	49.0 ± 0.6	
[h]Lifestyle Behaviors Score (n = 4097)		**<0.0001**
Low	High	
LSM ± SE	**LSM ± SE**	
44.1 ± 0.5	49.7 ± 0.5	

Values are least square means ± standard error of the mean. [a]Bonferroni correction (<0.05/6 lifestyle behaviors), $P < 0.008$. [b]Alcohol consumption was dischotomized to "Yes" to reporting any amount of alcoholic drinks consumed (including moderate and heavy drinking) and "No" to reporting zero alcohol intake.[c]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays and was dichotomized to "Yes" to reporting sleep 7 or more hours at night, and "No" to reporting sleep less than 7 hours at night. [d]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).[e]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).[f]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category. [g]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity. [h]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points). Non-alcohol consumers and nonsmokers each receive 1 point. Lifestyle behaviors score was dichotomized as "low" (0-2 pts) and "high" (3-6 pts).
Abbreviations: LSM, least square means; SE, Standard Error; HEI-2010, Healthy Eating Index-2010.

Table 40. Bivariate Associations between Lifestyle Behaviors and Total AHEI-2010 scores in U.S. adults (Age ≥ 20 years)

Total AHEI-2010 score		[a]p-value
[b]Alcohol Consumption (n = 4078)		0.7297
No	Yes	
LSM ± SE	**LSM ± SE**	
38.1 ± 0.5	38.3 ± 0.5	
[c]Sleep Adequacy (n = 4080)		0.0037
No	Yes	
LSM ± SE	**LSM ± SE**	
37.0 ± 0.5	38.9 ± 0.4	
[d]On a special Diet (n = 4081)		**<0.0001**
No	Yes	
LSM ± SE	**LSM ± SE**	
37.8 ± 0.4	40.8 ± 0.7	
[e]Supplement Intake (n = 4081)		**<0.0001**
No	Yes	
LSM ± SE	**LSM ± SE**	
35.5 ± 0.4	40.8 ± 0.5	
[f]Smoking status (n = 4082)		0.0040
No	Yes	
LSM ± SE	**LSM ± SE**	
39.2 ± 0.5	37.0 ± 0.6	
[g]Physical Activity (n = 4082)		**<0.0001**
No	Yes	
LSM ± SE	**LSM ± SE**	
36.6 ± 0.4	39.6 ± 0.6	
[h]Lifestyle Behaviors Score (n = 4082)		**<0.0001**
Low	High	
LSM ± SE	**LSM ± SE**	
35.6 ± 0.5	40.2 ± 0.5	

Values are least square means ± standard error of the mean. [a]Bonferroni correction (<0.05/6 lifestyle behaviors), $P < 0.008$. [b]Alcohol consumption was dischotomized to "Yes" to reporting any amount of alcoholic drinks consumed (including moderate and heavy drinking) and "No" to reporting zero alcohol intake. [c]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays and was dichotomized to "Yes" to reporting sleep 7 or more hours at night, and "No" to reporting sleep less than 7 hours at night.[d]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).[e]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).[f]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category. [g]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity. [h]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points). Non-alcohol consumers and nonsmokers each receive 1 point. Lifestyle behaviors score was dichotomized as "low" (0-2 pts) and "high" (3-6 pts).
Abbreviations: LSM, least square means; SE, Standard Error; AHEI-2010, Alternate Healthy Eating Index-2010.

Table 41. Association between Lifestyle Behaviors and Total HEI-2010 score in U.S. adults (Age ≥ 20 years) using Multiple Linear Regression (Weighted)

Total Sample (n = 4083)						
	R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
Model 1	0.1565					**<0.0001**
		[a]Alcohol Consumption	-0.39	0.55	[-1.51, 0.72]	0.4728
		[b]Sleep Adequacy	1.27	0.61	[0.02, 2.52]	0.0461
		[c]On a Special Diet	4.28	0.60	[3.05, 5.51]	**<0.0001**
		[d]Supplement Intake	1.56	0.64	[0.25, 2.87]	0.0209
		[e]Smoking Status	-1.86	0.57	[-3.03, -0.69]	0.0028
		[f]Physical Activity	2.98	0.59	[1.77 , 4.20]	**<0.0001**
Total Sample (n = 4090)						
	R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**P-value**
Model 2	0.1486					**<0.0001**
		[g]Lifestyle Behaviors Score	1.92	0.25	[1.42, 2.42]	**<0.0001**

Separate multivariable linear regression models were computed for individual lifestyle behaviors and Lifestyle Behaviors score in the sample. Each model was adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor) and BMI (continuous). Ethnicity was included as a nominal class variable. BMI was log-transformed for normality.

[a]Alcohol consumption was dischotomized to "Yes" to reporting any amount of alcoholic drinks consumed (including moderate and heavy drinking) and "No" to reporting zero alcohol intake.

[b]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays and was dichotomized to "Yes" to reporting sleep 7 or more hours at night, and "No" to reporting sleep less than 7 hours at night.

[c]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).

[d]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).

[e]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category.

[f]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity.

[g]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points).

Abbreviations: HEI-2010, Healthy Eating Index-2010; BMI, Body Mass Index; SE, Standard Error; C.I., Confidence Interval.

Table 42. Association between Lifestyle Behaviors and Total AHEI-2010 score in U.S. adults (Age ≥ 20 years) using Multiple Linear Regression (Weighted)

Total Sample (n = 4068)						
	R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
Model 1	0.1805					**<0.0001**
		[a]Alcohol Consumption	1.37	0.47	[0.41, 2.32]	0.0065
		[b]Sleep Adequacy	0.88	0.61	[-0.37, 2.12]	0.1610
		[c]On a Special Diet	2.02	0.60	[0.79, 3.25]	0.0020
		[d]Supplement Intake	2.18	0.42	[1.33, 3.02]	**<0.0001**
		[e]Smoking Status	-1.40	0.66	[-2.68, -0.08]	0.0420
		[f]Physical Activity	2.35	0.53	[1.28, 3.42]	**<0.0001**
Total Sample (n = 4075)						
	R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**P-value**
Model 2	0.1693					**<0.0001**
		Lifestyle Behaviors Score	1.26	0.23	[0.79, 1.73]	**<0.0001**

Separate multivariable linear regression models were computed for individual lifestyle behaviors and Lifestyle Behaviors score in the sample. Each model was adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor), BMI (continuous) and energy intake (continuous). Race/ethnicity was included as a nominal class variable. BMI and energy intake were log-transformed for normality.

[a]Alcohol consumption was dischotomized to "Yes" to reporting any amount of alcoholic drinks consumed (including moderate and heavy drinking) and "No" to reporting zero alcohol intake.

[b]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays and was dichotomized to "Yes" to reporting sleep 7 or more hours at night, and "No" to reporting sleep less than 7 hours at night.

[c]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).

[d]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).

[e]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category.

[f]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity.

[g]Lifestyle Behaviors score was calculated as the sum of self-reported individual lifestyle behaviors: alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals reported "Yes" receive 1 point to each lifestyle behavior (Total Points = 6).

[g]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points).

Abbreviations: AHEI-2010, Alternate Healthy Eating Index-2010; SE, Standard Error; C.I., Confidence Interval.

Table 43. Association between Individual Lifestyle Behaviors and Total HEI-2010 score by Diabetes Status using Multiple Linear Regression (Weighted)

Nondiabetic (n = 1435)					
R^2	Main Predictors	β - Coefficient	SE	95% C.I.	p-value
0.1708					**<0.0001**
	[a]Alcohol Consumption	-0.48	0.81	[-2.13, 1.17]	0.5603
	[b]Sleep Adequacy	0.92	0.92	[-0.95, 2.79]	0.3244
	[c]On a Special Diet	4.44	1.27	[1.85, 7.04]	0.0015
	[d]Supplement Intake	0.96	1.06	[-1.19, 3.12]	0.3686
	[e]Smoking Status	-2.12	1.15	[-4.45, 0.21]	0.0737
	[f]Physical Activity	2.80	0.94	[0.87, 4.72]	0.0058
Prediabetic (n = 1897)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1629					**<0.0001**
	[a]Alcohol Consumption	0.39	0.99	[-1.64, 2.42]	0.7004
	[b]Sleep Adequacy	1.68	0.95	[-0.25, 3.61]	0.0854
	[c]On a Special Diet	3.48	1.51	[0.41, 6.55]	0.0275
	[d]Supplement Intake	1.39	0.85	[-0.33, 3.12]	0.1091
	[e]Smoking Status	-2.45	0.85	[-4.18, -0.73]	0.0068
	[f]Physical Activity	3.61	0.88	[1.82, 5.40]	0.0003
Diabetic (n = 710)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1423					**<0.0001**
	[a]Alcohol Consumption	-2.27	0.88	[-4.06, -0.49]	0.0142
	[b]Sleep Adequacy	0.93	0.96	[-1.04, 2.89]	0.3427
	[c]On a Special Diet	5.08	1.42	[2.18, 7.98]	0.0011
	[d]Supplement Intake	4.25	1.32	[1.55, 6.94]	0.0030
	[e]Smoking Status	1.71	1.16	[-0.65, 4.07]	0.1489
	[f]Physical Activity	0.99	1.60	[-2.28, 4.26]	0.5425

Multivariable linear regression model was computed for individual lifestyle behaviors and stratified by diabetes status. Adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor) and BMI (continuous). Race/ethnicity was included as a nominal class variable. BMI was log-transformed for normality.

[a]Alcohol consumption was dischotomized to "Yes" to reporting any amount of alcoholic drinks consumed (including moderate and heavy drinking) and "No" to reporting zero alcohol intake.

[b]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays and was dichotomized to "Yes" to reporting sleep 7 or more hours at night, and "No" to reporting sleep less than 7 hours at night.

[c]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).

[d]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).

[e]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category.

[f]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity.

Abbreviations: HEI-2010, Healthy Eating Index-2010; SE, Standard Error; C.I., Confidence Interval

Table 44. Association between Individual Lifestyle Behaviors and Total AHEI-2010 score by Diabetes Status using Multiple Linear Regression (Weighted)

Nondiabetic (n = 1428)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1902					**<0.0001**
	[a]Alcohol Consumption	1.28	1.04	[-0.83, 3.39]	0.2269
	[b]Sleep Adequacy	-0.06	0.98	[-2.05, 1.93]	0.9527
	[c]On a Special Diet	0.57	0.98	[-1.43, 2.57]	0.5661
	[d]Supplement Intake	1.73	0.96	[-0.22, 3.69]	0.0807
	[e]Smoking Status	-0.42	1.01	[-2.66, 1.82]	0.7051
	[f]Physical Activity	2.83	0.90	[0.99, 4.67]	0.0036
Prediabetic (n = 1981)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1976					**<0.0001**
	[a]Alcohol Consumption	1.95	0.75	[0.42, 3.47]	0.0140
	[b]Sleep Adequacy	1.63	0.91	[-0.23, 3.49]	0.0837
	[c]On a Special Diet	2.65	1.27	[0.06, 5.24]	0.0449
	[d]Supplement Intake	2.13	0.68	[0.74, 3.52]	0.0039
	[e]Smoking Status	-2.55	0.83	[-4.23, -0.86]	0.0043
	[f]Physical Activity	2.02	0.63	[0.73, 3.30]	0.0031
Diabetic (n = 708)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1749					**<0.0001**
	[a]Alcohol Consumption	0.07	1.14	[-2.24, 2.38]	0.9526
	[b]Sleep Adequacy	0.66	0.87	[-1.11, 2.42]	0.4552
	[c]On a Special Diet	3.31	1.20	[0.88, 5.73]	0.0090
	[d]Supplement Intake	3.89	1.15	[1.54, 6.24]	0.0019
	[e]Smoking Status	0.29	0.95	[-1.64, 2.22]	0.7594
	[f]Physical Activity	1.61	1.15	[-0.74, 3.96]	0.1728

Multivariable linear regression model was computed for individual lifestyle behaviors and stratified by diabetes status. Adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor), BMI (continuous), and energy intake (continuous). Race/ethnicity was included as a nominal class variable. BMI and energy intake were log-transformed for normality.

[a]Alcohol consumption was dischotomized to "Yes" to reporting any amount of alcoholic drinks consumed (including moderate and heavy drinking) and "No" to reporting zero alcohol intake. [b]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays and was dichotomized to "Yes" to reporting sleep 7 or more hours at night, and "No" to reporting sleep less than 7 hours at night.[c]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).[d]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).[e]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category. [f]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity.

Abbreviations: AHEI-2010, Alternate Healthy Eating Index-2010; SE, Standard Error; C.I., Confidence Interval.

Table 45. Association between Lifestyle Behaviors score and Total HEI-2010 score by Diabetes Status using Multiple Linear Regression (Weighted)

Nondiabetic (n = 1436)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1636					**<0.0001**
	Lifestyle Behaviors Score	1.76	0.30	[1.14, 2.37]	**<0.0001**
Prediabetic (n = 1900)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1521					**<0.0001**
	Lifestyle Behaviors Score	1.96	0.49	[0.97, 2.96]	0.0003
Diabetic (n = 713)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1082					**<0.0001**
	Lifestyle Behaviors Score	1.96	0.40	[1.16, 2.77]	**<0.0001**

Multivariable linear regression model was computed for Lifestyle Behaviors score and stratified by diabetes status. Adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor) and BMI (continuous). Race/ethnicity was included as a nominal class variable. BMI was log-transformed for normality.

Note: Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points).

Abbreviations: HEI-2010, Healthy Eating Index-2010; SE, Standard Error; C.I., Confidence Interval.

Table 46. Association between Lifestyle Behaviors score and Total AHEI-2010 score by Diabetes Status using Multiple Linear Regression (Weighted)

Nondiabetic (n = 1429)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1790					**<0.0001**
	Lifestyle Behaviors Score	0.84	0.32	[0.18, 1.49]	0.0142
Prediabetic (n = 1894)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1825					**<0.0001**
	Lifestyle Behaviors Score	1.50	0.38	[0.72, 2.28]	0.0005
Diabetic (n = 711)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.1520					**<0.0001**
	Lifestyle Behaviors Score	1.45	0.36	[0.71, 2.19]	0.0004

Multivariable linear regression model was computed for Lifestyle Behaviors score and stratified by diabetes status. Adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor), BMI (continuous), and energy intake (continuous). Race/ethnicity was included as a nominal class variable. BMI and energy intake were log-transformed for normality.

Note: Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points).

Abbreviations: AHEI-2010, Alternate Healthy Eating Index-2010; SE, Standard Error; C.I., Confidence Interval.

Chapter 5: Strengths and Limitations

5.1 Strengths

This research study has several strengths: First, NHANES is a population-based survey that is nationally representative of civilian non-instutionalized U.S. adults from various ethnic backgrounds. Therefore, the findings will allow the development of policy implications that are generalizable to the U.S. adult population. In addition, by combining several sets of NHANES data releases (2007-2008 and 2009-2010 cycles), a large sample size is obtained and thus, there is greater power to detect differences. Second, the survey can be used to assess the health and nutritional status (i.e., measuring dietary quality) of the U.S. population and its association with various factors that may contribute to prevalent chronic diseases such as diabetes (T2DM). The NHANES survey has multiple components, including a physical examination, laboratory tests, and in-person interviews questionnaires that enable evaluation of the association between dietary quality and the development of T2DM, and numerous other factors (i.e., demographics, anthropometrics, biomarkers, perceptions, knowledge, lifestyle behaviors) in relation to dietary quality and diabetes. Therefore, since there are a wide array of variables available in the NHANES survey, many of them can be used to control for potential confounders in the analysis. Third, NHANES is the only national survey that currently provides complete nutrient intake from foods, beverages, and dietary supplements at the national level for individuals of all ages (including adults) (Ahluwalia et al., 2016). Therefore, computing the HEI-2010 and AHEI-2010 scores through using this dataset was representative of U.S. adults. Moreover, this research was one of the few studies to use both the HEI-2010 and the AHEI-2010 scores to measure adherence to a healthy dietary pattern in a representative sample of U.S. adults with and without T2DM. Lastly, this research will further contribute to the literature on the role of perception and lifestyle behaviors to dietary quality in adults with and without T2DM.

5.2 Limitations

Despite high standards for data collection, examination data and laboratory data in NHANES, the survey is cross-sectional and causal relationships cannot be inferred. For that reason, there are several limitations that arise from this study: 1) Dietary assessment does not represent habitual intake (single 24-hour recall), which leads to some concerns regarding the quality of NHANES data; 2) Possible misclassification of diabetes status (i.e., diagnosed vs. undiagnosed prediabetes); 3) A single-item question was used to assess self-perceived diet (PDQ); 4) Sleep disorders (i.e., sleep apnea) were not examined in relation to diabetes status; 5) Lack of distinction among alcoholic nondrinkers group (i.e., ex-drinkers or never drinkers).

To begin with, study used a single 24-hour recall to calculate HEI-2010 and AHEI-2010 scores. The 24-hour dietary recalls relies on participant self-report of dietary intakes, which is subject to memory limitations and possible bias. Therefore, data limitations may attenuate associations. Also, since day-to-day intake varies, and the dietary intake data based on a single 24-hour dietary recall (day 1) it may not represent usual intake. The choice of dietary method is based on the purpose for which it is intended. For example, this proposed research intends to estimate population means of dietary intake rather than examining distributions to assess usual intake; for that a single 24-hour recall is appropriate to use as the suggested by the literature (Willett, 2012; Ahluwalia, Dwyer, Terry, Moshfegh, & Johnson, 2016; Krebs-Smith, Guenther, Subar, Kirkpatrick, & Dodd, 2010). For foods, beverages, nutrients, and bioactives that are episodically consumed, even with using two-days 24-hour dietary recalls may not be sufficiently precise to satisfactorily model the usual intake estimates due to high intra- and inter-individual variation in dietary intake (Ahluwalia, Dwyer, Terry, Moshfegh, & Johnson, 2016). Therefore, there is no single perfect method for assessing dietary intake so far. Moreover, the Healthy Eating Index (HEI-2010) is more likely to be valid for the U.S. population than for populations from other countries. In addition, the Alternate Healthy Index (AHEI-2010), developed using cohorts of mostly white well-educated health professionals, may not be representative of the dietary quality in the United States (Chiuve et al., 2012).

Second, this study defined diabetes (T2DM) using NHANES based on calculating the sum of diagnosed and undiagnosed diabetes. Diagnosed diabetes was based on self-report but was not verified by medical records (Menke et al., 2015). Undiagnosed diabetes was based on a single FPG or HbA1c measurement. The ADA recommends more than a single measurement of FPG, HbA1c or 2-hour OGTT in order to have T2DM positive test result (Menke et al., 2015). Therefore, it is possible that some participants without T2DM may have been misclassified as having T2DM. Similarly, prediabetes was classified based on the combination of self-report and laboratory markers. This study was not able to distinguish between diagnosed and undiagnosed prediabetics, which can lead to misclassification of prediabetes and nondiabetes. Furthermore, NHANES does not explicitly collect information on the type of diabetes, such as type 1 diabetes (T1DM) and gestational diabetes. Misclassification of type 1 diabetes (T1DM) precluded the identification of maturity-onset diabetes of the young (MODY), which is characterized by youth-onset diabetes that is inherited in an autosomal dominant (monogenic) pattern (Winter, 2000; Demmer et al., 2013). Therefore, this may lead to misclassification on case definition of diabetes (T2DM), which may influence the association between diabetes status (T2DM, prediabetes, nondiabetes) and other parameter estimates in our study. However, the effect of misclassified T1DM in our proposed case definition of diabetes (T2DM) was minimal since T2DM accounts for the majority (at least 90%) of all diabetes cases (Maxwell & Wood, 2011). In addition, information regarding age at diabetes diagnosis and current use of insulin is used to exclude individuals who may have T1DM.

Third, this study used only a single-item question to assess perceived diet quality (PDQ) and is a part of the Diet and Behavior Questionnaire in NHANES. Therefore, response bias may lead to misclassification errors. However, a recent study examined the reliability and validity of the single-item question to measure PDQ and found that it can be used as proxy for actual dietary intake (Loftfield et al., 2015). More studies are needed to confirm these findings. In addition, previous studies have used the single-item question since it is the only available question so far to evaluate PDQ (Powell-Wiley et al., 2014; Variyam et al., 2001).

Another limitation is the assessment of sleep quality. This study evaluated sleep adequacy based on self-reported sleep duration (number of hours per night), which may be inaccuate and subject to bias. In addition, this study did not examine the relationship between presence of sleep disorders and diabetes status. It is possible that diabetics were more likely to report inadequate sleep because they have sleep apnea. Studies have shown that sleep apnea is strongly associated with obesity and T2DM (Barone & Menna-Barreto, 2011; Doumit & Prasad, 2016). Diabetics in our study were more likely to be overweight and/or obese. People with weight gain and/or obesity are at risk of having both T2DM and sleep apnea, which has shown to have impact on glucose metabolism and other physiological changes (i.e., sympathatic nervous system, hormone regulation) (Barone & Menna-Barreto, 2011). Furthermore, the NHANES survey does not contain many variables to evaluate day-to-day or habitual lifestyle behaviors. For example, questions about stress and stress-related behaviors were not assessed. This study attempted to select several variables (i.e., sleep duration, on a special diet, supplement intake) that are available in the NHANES survey to assess lifestyle behaviors and their relationship with dietary quality and diabetes.

Lastly, alcohol consumption was assessed based on self-report. This study was not able to distinguish between nondrinkers (i.e., never drinkers and ex-drinkers) of alcohol since participants in NHANES reported drinking status at a given point of time. It is possible that individuals reported as current nondrinkers have stopped consuming alcohol because they developed health problems, which indicates that they were previously alcoholic drinkers (i.e., heavy drinking). Therefore, misclassification can be a potential source of error. It is widely accepted that alcohol consumption follows a J-shaped curve in relation to chronic disease (i.e., CHD, HTN, diabetes) and all-cause mortality (O'Keefe, Bybee, & Lavie, 2007). However, the J-shaped curve does not distinguish between the nondrinkers group. Prospective studies have shown that dividing the nondrinkers group into never-drinkers and ex-drinkers result in differences in health risks (i.e., annual mortality rate) as well as differences among participants reporting lifetime abstinence of alcohol (Doll, 2004; Caldwell, Rodgers, Power, Clark, & Stansfeld, 2006; Connor, 2006). Self-reported alcohol consumption is commonly under-reported among participants (Connor, 2006; Guenther et al., 2010). For that reason, participants' self-report on drinking status, including nondrinkers, needs to be interpreted with caution.

Chapter 6: Summary/Conclusions

6.1 Summary/Conclusions

This study was the first to use the HEI-2010 and AHEI-2010 to assess dietary quality in relation to diabetes status using a representative sample of U.S. adults. In addition, this research examined the association of dietary quality with factors such as health markers (including biomarkers), perceptions of dietary quality (self-rated diet), and selected lifestyle behaviors among nondiabetics, prediabetics, and diabetics. The initial hypothesis was that AHEI-2010 would be more strongly associated with diabetes status than HEI-2010. However, findings from this research suggest that the two indices generally performed equally in terms of their associations with diabetes status, discrepancy between self-rated and measured diet, and selected lifestyle behaviors.

This research had several interesting findings: 1) Neither total HEI-2010 nor AHEI-2010 score was significantly associated with diabetes status after controlling for health markers, sociodemographic and lifestyle factors (OR = 1.00, $p > 0.05$). Contrary to the results from previous prospective studies (McCullough et al., 2002; Stephanie E Chiuve et al., 2012; Jacobs et al., 2015; Täger, Peltner, & Thiele, 2016), the results from the present study suggest that neither index was clearly superior to the other in terms of its predictive ability in relation to T2DM. In addition, sociodemographic characteristics alone classified the largest percentage of the sample correctly with respect to diabetes status (about 65.1% correct classification), and adding an index of dietary quality (i.e., HEI-2010 and AHEI-2010) does not significantly increase classification of diabetes status to the models. This could point to unmeasured genetic differences; 2) Diabetes status was significantly associated with discrepancies between perceived and actual diet (as measured by HEI-2010 and AHEI-2010 scores) both alone and after controlling for sociodemographic and attitudinal factors. However, the association was no longer significant when controlling for perceived health status [HEI2010-based discrepancy scores: O.R. = 1.2, p = 0.1921; AHEI-2010-based discrepancy scores: O.R. = 1.1, p = 0.2921]. This suggests that individuals' perceived health has strong predictive power in relation to dietary misperception (measured by discrepancy scores). Although both HEI-2010 and AHEI-2010 discrepancy scores performed equally in terms of their associations with diabetes status and other covariates, this study found that the AHEI-2010 was associated with greater discrepancy in PDQ and MDQ than the HEI-2010; 3) Selected lifestyle behaviors were significantly associated with dietary quality in the sample and by diabetes status both individually and collectively. The associations between lifestyle behaviors and dietary quality were similar regardless of whether using total HEI-2010 or AHEI-2010 score.

The HEI-2010 and AHEI-2010 are useful tools to measure adherence to dietary guidelines and evidence-based recommendations. The HEI-2010 and AHEI-2010 have similarities and differences in their food and/or nutrient components. For example, HEI-2010 and AHEI-2010 are similar in how they capture consumption of fruits, vegetables, whole grains, sodium, and fats. However, the AHEI-2010 incorporates distinct components that have been shown to be associated with chronic disease, including T2DM (McCullough et al., 2002; Chiuve et al., 2012). For example, the AHEI-2010 pays more attention to fat quality (i.e., intakes of omega-3 fats and polyunsaturated fats), promotes intake of nuts and legumes, recommends limiting intake of red meat and processed meats and avoiding added sugars (i.e., sugar-sweetened beverages and fruit juice), and considers moderate alcohol intake (Male: 0.5-2.0 drinks/day; Female: 0.5-1.5 drinks/day) as beneficial to health regardless of disease status (i.e., diabetes).

Some of the food and/or nutrient components in the AHEI-2010 are constructed differently than the HEI-2010. One of the major differences between the HEI-2010 and AHEI-2010 is in the treatment of alcohol consumption. The HEI-2010 counts alcohol intake as part of empty calories (threshold exceeds moderate level more than 13 grams/1,000 kcal). However, the AHEI-2010 assumes that moderate alcohol intake as part of a healthful dietary pattern and severely penalizes nondrinkers. The treatment of alcohol consumption in the AHEI-2010 is based on an assumption of safety of alcohol intake that has not been scientifically validated. Currently, there is no scientific consensus on the safety or healthfulness of moderate alcohol consumption (regardless of type) for individuals who drink alcohol, and there is certainly no consensus that alcohol consumption should be advised for nondrinkers, especially if they are diabetic. This makes the application of the AHEI somewhat problematic particularly among diabetics because 1) alcohol intake (especially on an empty stomach) lowers blood glucose and causes hypoglycemia (William T. Cefalu, MD et al., 2017), 2) many alcoholic drinks contain added sugars and empty calories leading to increased risk of heart disease (William T. Cefalu, MD et al., 2017), and 3) exposes alcoholic drinkers to potential behavioral risks and addiction. In this sample, diabetics seemed to minimize alcohol or not drink it at all (only 20% reporting drinking at all), which is consistent with effective diabetes self-management.

This research found that diabetics who were compliant in their diet seemed to be more in line with HEI and not AHEI. Neither the Dietary Guidelines for Americans nor the American Diabetes Association recommend alcohol consumption at any level as part of a healthful dietary pattern (Dietary Guidelines 2015-2020, 2015; William T. Cefalu, MD et al., 2017). The HEI-2010 does not penalize nondrinkers for not consuming alcohol like the AHEI-2010. For that reason, the HEI-2010 may be a better tool for assessing dietary quality than the AHEI-2010 for individuals with T2DM. In addition, the HEI-2010 is more reflective of the 2010 Dietary Guidelines for Americans, which represents a consensus of the opinions of many experts, whereas the AHEI-2010 reflects a critique of the Dietary Guidelines by an academic research group at Harvard University. Diabetic education within the healthcare system is more likely to reflect the underlying assumptions of the HEI rather than the AHEI. The results of this research suggest that the HEI-2010 more closely reflects the current American diet than the AHEI-2010, and that HEI-2010 is a better tool for assessing dietary quality in diabetics and prediabetics.

Although total HEI-2010 and AHEI-2010 scores were not significantly associated with diabetes status as expected, the role of diet should not be dismissed as a potential factor in the development of T2DM. The significant relationships between 1) some of the sub-component HEI-2010 and AHEI-2010 scores and diabetes status, 2) diabetes status and health markers and 3) between HEI-2010 and AHEI-2010 scores and health markers (i.e., BMI, WC, systolic BP) suggest that diet has some influence on T2DM. Moreover, diabetes status was significantly associated with the direction of the discrepancy between perceived and measured diet quality (using HEI-2010 and AHEI-2010 scores). In this sample, diabetics were more likely to under rate their diet quality than prediabetics and nondiabetics. In addition, diabetic under raters had significantly higher total sub-component HEI-2010 and AHEI-2010 scores than prediabetics and non-diabetics, suggesting that these individuals were more aware of the shortcomings in their diets, and that they were making efforts to improve the quality of their diets. Lastly, diabetics were more likely to practice positive lifestyle behaviors, which include being on a special diet, taking dietary supplements, and not drinking alcohol. Diabetics did better on lifestyle indicators that primarily focus on changes in diet, which is consistent with their higher HEI-2010 and AHEI-2010 scores. This suggests that diabetic education and nutrition counseling may have an influence on their behavior.

Chapter 7: Implications and Future Work

7.1 Implications

There are some methodological concerns regarding the quality of NHANES data. NHANES has been strongly criticized on the measurement errors related to self-reported dietary data. Dietary assessment (i.e., 24-hour recall) is prone to measurement error (including random and systematic), which has implications on examining the influence of diet and nutrition on health and/or disease outcomes (i.e., T2DM). Archer and colleagues used 1971-2010 NHANES to evaluate the validity of energy intake data with calculated basal metabolic rate and reported that the results were not physiologically plausible (Archer, Hand, & Blair, 2013). The authors concluded that the NHANES data are extremely limited for public policy on diet-health relationships (Archer et al., 2013). Menachemi and colleagues also concluded that observational studies related to nutrition or obesity should not be the primary source for nutrition and public health policy (Menachemi et al., 2013). Although there is no perfect method to assess dietary intake, NHANES continues to improve and refine their dietary methodology, including dietary data collection (i.e., AMPM) and measurement protocols to mitigate the effect of self-report errors (i.e., multiple days of 24-hour recall, account for day-to-day variation, omission of foods) (Satija, Yu, Willett, & Hu, 2015; Hébert et al., 2014). So far, NHANES is the only available national survey that provides dietary intake data that are reasonably valid and reliable (Satija et al., 2015; Hébert et al., 2014).

There is strong evidence that diabetes (T2DM) can be prevented through adherence to a healthy dietary pattern and modify poor lifestyle behaviors. Despite strong efforts in continuously updating dietary recommendations aimed at preventing chronic disease risk, American adults still fall short of meeting these guidelines. Assessing dietary quality and improving compliance with nutritional recommendations may help reduce the burden of diabetes in the U.S. population. For that reason, this research has implications in several areas: clinical practice, primary care, counseling, and public policy. Although not feasible in clinical settings, the HEI-2010 and the AHEI-2010 can be used as screening tools that measure the degree of patients' compliance to dietary guidelines and evidence-based recommendations. In terms of counseling, understanding patients' awareness on food choices and self-rated misperceptions will help target interventions to improve diet quality in U.S. adults. Moreover, identifying clusters of lifestyle behaviors that could lead to poor diet quality and diabetes may suggest a broader approach to nutrition counseling (i.e., improve sleep quality) with specific recommendations rather than providing patients with general advice on dietary changes. For primary care practice, this supports that prevention of diabetes is key to a good quality of life. In addition, early detection of prediabetes (and T2DM) is warranted. Interventions need to be tailored for individuals diagnosed and undiagnosed with prediabetes. People diagnosed with prediabetes would need to receive interventions that are more aggressive to prevent them from becoming diabetic. With improving clinical practice and primary care, this study may improve the effectiveness of strategies and nutrition interventions aimed at preventing progression of prediabetes and T2DM and their associated costs in the U.S. Therefore, it may be important to develop novel methods of increasing adherence with recommended dietary guidelines in addition to targeting food policy. Moreover, there is a need to incorporate other lifestyle modifications to address behaviors that tend to co-occur with poor diet quality and improve the coordination of efforts to reduce unhealthy behaviors such as smoking, number of alcoholic drinks consumed per day, increase minutes of physical activity per day, and improve sleep behaviors. Public health strategies that target unhealthful environment are critical. Translating clinical and epidemiologic findings into practice requires fundamental shifts in public policies and health systems. To control the diabetes epidemic, primary prevention through the promotion of a healthy diet and lifestyle should be a global public policy priority.

6.2 Future Work

The findings of this cross-sectional study suggest associations of dietary quality with several factors including health markers, perceptions (self-rated health and diet), and lifestyle behaviors, all of which can contribute to the development of T2DM. Future research is needed to re-examine these associations with prospective data using assessment methods that represent habitual or usual dietary intake (i.e., FFQ or multiple 24-hour recalls) to have a better understanding on causal relationships. In addition, this study used the HEI-2010 and AHEI-2010 as tools to assess dietary quality. However, these tools were not specifically designed for individuals with T2DM. Future research is needed to develop an evidence-based diet quality index containing food and/or nutrient components that contribute to the development of T2DM. In addition, there are implications for alcohol research and public policy (Caldwell et al., 2006). The J-shaped curve on alcohol intake does not make distinction among the nondrinkers group, which leads to misclassification of drinking status and inaccurate assessment of alcohol intake. Future research is needed to better assess the nondrinkers group over time (i.e., distinguish between lifetime abstainers and ex-drinkers). Moreover, this study found association between diabetes status and dietary misperception. Future research is needed to determine the validity and reliability of self-rated diet and its relationship with health and/or disease outcomes. Furthermore, this study found associations between selected lifestyle behaviors and dietary quality and differences in the relationships by diabetes status. However, NHANES provides limited variables related to individuals' daily lifestyle behaviors. Future work is needed to develop validated questionnaire(s) that contain more variables (i.e., stress-related behaviors) related to individuals' day-to-day lifestyle behaviors and examine these variables in relation to health and/or disease outcomes. In addition, more objective measures (i.e., Accelerometer, Actigraph) are needed to be available to have a better assessment of habitual lifestyle behaviors.

Appendices

Appendix 1. Classification of the Alternate Healthy Eating Index-2010 Food Groups

Food Group	Full weight	Half weight	Exclusion	Serving Size
Vegetables	Dark-green vegetables, deep yellow vegetables, tomatoes (raw & cooked), and other vegetables (raw & cooked)	Tomato mixtures, Tomato sandwiches, vegetables with sauces, vegetable soups, and baby foods	Potatoes and Starchy vegetables, tomato juices, tomato sauces, olives, pickles, and relishes	65 g (0.5 cup)
Fruit	Citrus, dried fruits, other fruits, berries, and fruit mixtures	Mixtures with non-fruits and baby food mixtures	Juices, fruit desserts and fruit-flavored puddings	65 g (0.5 cup)
Whole grains	Brown rice, popcorn, and any grain food with a carbohydrate-to-fiber ratio ≤ 10:1	NA	NA	40 g (1 cup) of cereal 75 g (0.5 cup) of pasta 30 g (1 slice) of bread
Sugar-sweetened beverages and fruit juice				
Sugar sweetened beverages	Soft drinks, fruitades, *beverage concentrates*, *nonalcoholic beers/wines/cocktails*, *sweetened coffee*, Frappuccino, *Cappuccino, latte*, *mocha*, *sweetened tea*, fruit drinks, sweetened water, and smoothie drinks	Reduced sugar sodas *Sugar-free drinks*	NA	226.8 g (8 oz)
100% juice	Citrus fruit juice, other fruit juice, nectars	Baby food fruit juice mixtures	NA	113.4 g (4 oz)
Nuts and legumes				
Nuts/Legumes/Seeds	Dried beans, dried bean mixtures, dried peas, lentils, and bean mixtures; nuts, nut mixtures, and seeds	Frozen plate meals, soups, and legumes baby food	Soybean derived products, meat substitutes, nut butters, coconut beverages, and carob products	50 g
Nut Butters	Almond, cashew, and peanut butters	Peanut butter and jelly and nut butter sandwiches	Nut gravy and peanut sauce	32 g
Tofu	Soybean curd, soybeans, and soy nuts	Soy yogurt, soy dessert, tofu soup, *frozen plate meals with legumes*, and tofu mixed dishes	NA	50 g
Soy milk	NA	Regular and low-fat soy milk	NA	50 g
Red/processed meat				
Beef	Beef steak, ribs, roasts, ground beef, patties, and meatballs	Beef baby food, beef with gravy or sauce, beef with starch item,	Beef bacon *Miscellaneous meats with starch item unless specified*	100 g (3.5 oz)

		beef with starch item and vegetables, beef with vegetables, sandwiches, frozen meals, soups, broths, and extracts	*"beef"*	
Pork	Pork chops, steaks, cutlets, ham, roasts, and spareribs	Pork baby food, Pork with gravy or sauce, pork with starch item, pork with starch item and vegetables, pork with vegetables, sandwiches, frozen meals, soups, broths, and extracts	Canadian bacon, bacon/salt pork, pork skin, and *miscellaneous meats with starch item unless specified "pork"*	100 g (3.5 oz)
Processed meat	Canadian bacon, bacon, salt pork, Frankfurters, sausages, lunchmeats, meat spreads, and pork skin	Sandwiches with frankfurters, luncheon meat, and potted meat sandwiches	*Chicken and turkey frankfurters and sausages*	100 g (3.5 oz)
Alcohol	Beer, wine and distilled liquors	Cocktails	NA	141.75 g of wine 340.2 g of beer 42.53 g of liquor *225 g of cocktails**

Source: Wang et al. (2014) Trends in Dietary Quality Among Adults in the United States, 1999 Through 2010. *JAMA Internal Medicine*, *174*(10), 1587. Available Online: http://doi.org/10.1001/jamainternmed.2014.3422.
Note: Modified based on supplementary table provided by Wang et al. (2014). Font in Italic indicates additional foods and beverages included and excluded.
*Intake for cocktails are estimated using a standardized serving size from the USDA Agriculture Research Service Food Survey Research Group " What's in the food you eat Search Tool." Available online: https://reedir.arsnet.usda.gov/codesearchwebapp/(S(lb2ewe2gmpfunvztzy1tha1u))/CodeSearch.aspx.

Appendix 2. USDA Food Coding Scheme and AHEI-2010 Food Groups

Food code	Food Item	AHEI Food Group	Assigned Weights	Notes
21	**Beef**	**Red/processed meat**		
210	Beef, NFS	Beef	Full-weight	
211	Beef Steak	Beef	Full-weight	
213	Beef oxtails, neckbones, short ribs, head	Beef	Full-weight	
214	Beef roasts, stew meat, corned beef, beef brisket, sandwich steaks	Beef	Full-weight	
215	Ground beef, beef patties, beef meatballs	Beef	Full-weight	
216	Other beef items (beef bacon; dried beef; pastrami)	Beef		
217	Beef baby food	Beef	Half-weight	
22	**Pork**	**Red/processed meat**		
220	Pork, NS; ground, dehydrated	Pork	Full-weight	
221	Pork Chops	Pork	Full-weight	
222	Pork steaks, cutlets	Pork	Full-weight	
223	Ham	Pork	Full-weight	
224	Pork roasts	Pork	Full-weight	
225	Canadian bacon	Processed meat	Full-weight	
226	Bacon, salt pork	Processed meat	Full-weight	
227	Other pork items (spareribs; cracklings; skin; miscellaneous parts)	Pork	Full-weight	
228	Pork baby food	Pork	Half-weight	
25	**Organ meats, sausages and lunchmeats, and meat spreads**			
252	***Franfurters, sausages, lunchmeats, meat spreads***	**Red/processed meat**		
2521	Frankfurters	Processed meat	Full-weight	Excluded chicken and turkey frankfurters
2522	Sausages	Processed meat	Full-weight	
2523	Luncheon meats (loaf)	Processed meat	Half-weight	
2524	Potted meat, spreads	Processed meat	Half-weight Full weight	Potted meat counted as Half-weight Spreads counted as Full-weight
27	**Meat, poultry, fish with nonmeat items**			
271	***Meat, poultry, fish in gravy or sauce or creamed***	**Red/processed meat**		
2711	Beef in gravy sauce (tomato-based sauce;gravy; cream,white, or soup-based sauce; soy-based sauce; other cause; Peurto Rican)	Beef	Half-weight	
2712	Pork with gravy or sauce	Pork	Half-weight	
272	***Meat, poultry, fish with starch item (include white potatoes)***	**Red/processed meat**		
2721	Beef with starch item (potatoes; noodles; rice; bread; Puerto Rican)	Beef	Half-weight	
2722	Pork with starch item	Pork	Half-weight	
2726	Miscellaneous meats with starch			Counted half-weight

Food code	Food Item	AHEI Food Group	Assigned Weights	Notes
	item			only for items that specify "beef" and/or "pork," otherwise excluded
273	***Meat, poultry, fish with starch item and vegetables***	**Red/processed meat**		
2731	Beef with starch and vegetable (potatoes; noodles; rice; bread; Puerto Rican)	Beef	Half-weight	
2732	Pork with starch and vegetable	Pork	Half-weight	
274	***Meat, poultry, fish with vegetables (excluding white potatoes)***	**Red/processed meat**		
2741	Beef with vegetable, no potatoes	Beef	Half-weight	
2742	Pork with vegetable, no potatoes	Pork	Half-weight	
275	***Sandwiches with meat, poultry, fish***	**Red/processed meat**		
2751	Beef sandwiches	Beef	Half-weight	
2752	Pork sandwiches	Pork	Half-weight	
2756	Frankfurters, luncheon meat, potted meat sandwiches	Processed meat	Half-weight	
276	***Meat, poultry, fish with nonmeat items baby food***	**Red/processed meat**		
2761	Beef mixtures baby food	Beef	Half-weight	
28	**Frozen and shelf-stable plate meals, soups, and gravies with meat, poultry, fish base; gelatin and gelatin-based drinks**			
281	***Frozen or shelf-stable plate meals with meat, poultry, fish as major ingredient***	**Red/processed meat**		
2811	Beef frozen or shelf-stable meals	Beef	Half-weight	
2812	Pork or ham frozen or shelf-stable meals	Pork	Half-weight	
283	***Soups, broths, extracts from meat, poulry, fish base***	**Red/processed meat**		
2831	Beef soups	Beef	Half-weight	
2832	Pork soups	Pork	Half-weight	
41	**Legumes**	**Nuts and Legumes**		
411	Dried Beans	Nuts/Legumes/Seeds	Full-weight	
412	Dried Beans mixtures	Nuts/Legumes/Seeds	Full-weight	
413	Dried peas, lentils, and mixtures	Nuts/Legumes/Seeds	Full-weight	
414	Soybean derived products (excluding milks)			Excluded as part of nuts/legumes/seeds. Some included as part of tofu
415	Frozen plate meals with legumes as major ingredient	Nuts/Legumes/Seeds	Half-weight	
416	Soups with legumes as major ingredient	Nuts/Legumes/Seeds	Half-weight	
418	Meat substitutes, mainly legume protein			Excluded as part of nuts/legumes/seeds
419	Meat substitute sandwiches			Excluded as part of nuts/legumes/seeds

Food code	Food Item	AHEI Food Group	Assigned Weights	Notes
42	**Nuts, nut butters, and nut mixtures**	**Nuts and Legumes**		
421	Nuts	Nuts/Legumes/Seeds	Full-weight	
422	Nut butters	Nut butters	Full-weight	
423	Nut butter sandwiches	Nut butters	Half-weight	
424	Coconut beverages			Excluded as part of nuts/legumes/seeds
425	Nut mixtures	Nuts/Legumes/Seeds	Full-weight	
43	**Seeds and seed mixtures**			
431	Seeds	Nuts/Legumes/Seeds	Full-weight	
44	**Carob products**			
441	Carob powder, flour			Excluded as part of nuts/legumes/seeds
442	Carob chips, syrup			Excluded as part of nuts/legumes/seeds
50	**Flour and dry mixes**	**Whole Grains**		
500	Flour and dry mixes			Excluded unless specified as “whole wheat” counted as Full-weight
51	**Yeast breads, rolls**	**Whole Grains**		
512	Whole wheat breads, rolls		Full-weight	
513	Wheat, cracked wheat breads, rolls		Full-weight	
514	Rye breads, rolls		Full-weight	
515	Oat breads		Full-weight	
518	Other breads			Excluded unless carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
52	**Quick breads**	**Whole Grains**		
521	Biscuits			Excluded unless carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
522	Cornbread, corn muffins, tortillas			Excluded unless carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
523	Other muffins, popovers			Excluded unless carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
524	Other quick breads			Excluded unless carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
54	**Crackers and salty snacks from grain products**	**Whole Grains**		
542	Low sodium crackers			Excluded unless specified as “whole wheat” counted as Full-weight
543	Nonsweet crackers			Excluded unless specified as “whole wheat” counted as Full-weight

Food code	Food Item	AHEI Food Group	Assigned Weights	Notes
544	Salty snacks from grain products			Included "popcorn" and items specified as "whole wheat" counted as Full-weight
55	**Pancakes, waffles, French toast, other grain products**	**Whole Grains**		
551	Pancakes			Excluded unless specified as "whole wheat" or carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
552	Waffles			Excluded unless specified as "whole wheat" or carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
56	**Pastas, cooked cereals, rice**	**Whole Grains**		
561	Pastas			Excluded unless specified as "whole wheat" or carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
562	Cooked cereals, rice			Excluded unless specified as "whole wheat," "oatmeal," "brown rice," or "bulgur" or carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
57	**Cereals, not cooked or NS as to cooked**	**Whole Grains**		
570	Cereal, NS as to cooked			Excluded unless carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
572	Ready-to-eat cereals			Excluded unless carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
573	Ready-to-eat cereals			Excluded unless specified as "whole wheat" or carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
574	Ready-to-eat cereals			Excluded unless specified as "whole wheat" or carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
576	Cereal grains, not cooked			Excluded unless specified as "whole wheat" or carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
578	Cereals baby food			Excluded unless specified as "whole wheat" or carbohydrate-

Food code	Food Item	AHEI Food Group	Assigned Weights	Notes
				to-fiber ratio ≤ 10:1 counted as Full-weight
58	**Grain mixtures, frozen plate meals, soups**	**Whole Grains**		
581	Mixtures, mainly grain, pasta, or bread			Excluded unless specified as “whole wheat” or “brown rice” or carbohydrate-to-fiber ratio ≤ 10:1 counted as Full-weight
61	**Citrus fruits, juices**	**Fruit**		
611	Citrus fruits		Full-weight	Excluded canned or cooked in light or heavy syrup (fruit desserts)
62	**Dried Fruits**	**Fruit**		
621	Dried fruits		Full-weight	Excluded cooked with sugar (fruit desserts)
63	**Other fruits**	**Fruit**		
631	Fruits, excluding berries		Full-weight	Excluded stewed or baked with sugar; cooked or canned with syrup or juice pack; pie filling (other fruit desserts)
632	Berries		Full-weight	Excluded raw or frozen with sugar; cooked or canned with syrup or juice pack; pie filling (other fruit desserts)
633	Mixtures of two or more fruits		Half-weight	Excluded cooked or canned in syrup or juice pack (other fruit desserts)
634	Mixtures of fruits and nonfruit items		Half-weight	Excluded fruit whip (other fruit desserts)
67	**Fruits and juices baby food**	**Fruit**		
671	Fruits and fruit mixtures baby food		Half-weight	
673	Fruits with cereal baby food		Half-weight	
674	Fruit desserts and fruit-flavored puddings and yogurt desserts baby food			Excluded from fruit
675	Fruits with meat or poultry baby food		Half-weight	
676	Fruits and vegetables mixtures baby food		Half-weight	
72	**Dark-green vegetables**	**Vegetables**		
721	Dark-green leafy vegetables		Full-weight	
722	Dark-green nonleafy vegetables		Full-weight	
723	Dark-green vegetable soups		Half-weight	
73	**Deep-yellow vegetables**	**Vegetables**		
731	Carrots		Full-weight	
732	Pumpkin		Full-weight	
733	Squash, winter		Full-weight	

Food code	Food Item	AHEI Food Group	Assigned Weights	Notes
734	Sweet potatoes		Full-weight	
735	Deep-yellow vegetable soups		Half-weight	
74	**Tomatoes and tomato mixtures**	**Vegetables**		
741	Tomatoes, raw		Full-weight	
742	Tomatoes, cooked		Full-weight	
743	Tomato juices			Excluded from vegetables
744	Tomato sauces			Excluded from vegetables
745	Tomato mixtures		Half-weight	
746	Tomato soups		Half-weight	
747	Tomato sandwiches		Half-weight	
75	**Other vegetables**	**Vegetables**		
751	Other vegetables, raw		Full-weight	
752	Other vegetables, cooked		Full-weight	Excluded yeast and yeast extract spread from vegetables
753	Other vegetable mixtures, cooked		Full-weight	
754	Other cooked vegetables, cooked with sauces, batters, casseroles		Half-weight	
755	Olives, pickles, relishes (excluding tomatoes)			Excluded from vegetables
756	Vegetable soups		Half-weight	
76	**Vegetables and mixtures mostly vegetables baby food**	**Vegetables**		
761	Dark-green vegetables baby food		Half-weight	
762	Deep-yellow vegetables baby food		Half-weight	
764	Vegetables other than dark-green, deep-yellow, and tomato baby food		Half-weight	
765	Vegetables with grain baby food		Half-weight	
766	Vegetables with meat baby food		Half-weight	
77	**Vegetables with meat, poultry, fish**	**Vegetables**		
771	White potato with meat, poultry, fish (mixtures)		Half-weight	
772	Puerto Rican starchy vegetable (viandas) mixtures		Half-weight	
773	Other vegetable mixtures		Half-weight	
775	Puerto Rican stews or soups with starchy vegetables (viandas)		Half-weight	
61	**Citrus fruits, juices**	**Sugar-sweetened beverages and fruit juice**		
612	Citrus fruit juices	100% juice	Full-weight	Excluded canned or cooked in light or heavy syrup (fruit desserts)
64	**Fruit juices and nectars**	**Sugar-sweetened beverages and fruit juice**		Excluding citrus
641	Fruit juices, excluding citrus	100% juice	Full-weight	
642	Nectars	100% juice	Full-weight	
67	**Fruit and juices baby food**	**Sugar-sweetened beverages and fruit**		

Food code	Food Item	AHEI Food Group	Assigned Weights	Notes
		juice		
672	Fruit juice and fruit juice mixtures baby food	100% juice	Half-weight	
78	**Mixtures mostly vegetables without meat, poultry, fish**	**Sugar-sweetened beverages and fruit juice**		
781	Vegetable and fruit juice blends, 100% juice	100% juice	Full-weight	
92	**Nonalcoholic beverages**	**Sugar-sweetened beverages and fruit juice**		
921	Coffee	Sugar-sweetened beverages		Excluded except specified as "sweetened", "pre-sweetened," and "pre-sweetened or sweetened with sugar" counted as Full-weight
923	Tea	Sugar-sweetened beverages		Excluded except specified as "sweetened", "pre-sweetened," and "pre-sweetened or sweetened with sugar" counted as Full-weight
924	Soft drinks, carbonated	Sugar-sweetened beverages	"Reduced sugar sodas" or "sugar free" counted as Half-weight. Otherwise Full-weight	
925	Fruit drinks	Sugar-sweetened beverages	Half-weight for "reduced sugar" or "low sugar." Otherwise Full-weight	
9251	Fruit juice drinks and fruit-flavored drinks	Sugar-sweetened beverages	Full-weight	
9253	Fruit juice drinks and fruit flavored drinks with high vitamin C		Half-weight for "reduced sugar." Otherwise Full-weight	
9254	Fruit flavored drinks, made from powdered mix	Sugar-sweetened beverages	Full-weight	
9255	Fruit juice drinks and fruit flavored drinks, low calorie		Half-weight for "reduced sugar" or "low sugar." Otherwise Full-weight	
9256	Sports drinks and thirst quencher beverages	Sugar-sweetened beverages	Full-weight	
9257	Beverages, fluid replacement	Sugar-sweetened beverages	Full-weight	
9258	Fruit juice drinks and fruit flavored drinks, fortified with calcium	Sugar-sweetened beverages	Half-weight for "reduced sugar." Otherwise Full-weight	

Food code	Food Item	AHEI Food Group	Assigned Weights	Notes
926	Beverages, nonfruit		Full-weight	
9265	Beverages, nonfruit, fortified (include energy drinks)		Full-weight	
928	Nonalcoholic beers, wines, cocktails	Sugar-sweetened beverages	Full-weight	
929	Beverage concentrates, dry, not reconstituted	Sugar-sweetened beverages	Full-weight	
93	**Alcoholic beverages**	**Alcohol**		
931	Beer and ales		Full-weight	
932	Cordials and liqueurs		Full-weight	Considered as distilled liquors and assigned Full-weight
933	Cocktails		Half-weight	
934	Wines		Full-weight	
935	Distilled liquors		Full-weight	

Note: This table summarizes the USDA food groups that are included (and excluded) to classify the AHEI-2010 food groups based on the supplementary table provided by Wang et al. (2014). The USDA food-coding scheme provides an outline of the major food groups and subgroups identified by the first three or four digits of the 8-digit code.

Supplemental Table 1. Consumption (in servings) of HEI-2010 Food and Nutrient groups among U.S. adults (Age ≥ 20, N = 4097)

Food/Nutrient Group	Consumption (in servings)					
	Mean ± SE	Median	*n* (%)			
Adequacy			Inadequate	Intermediate	Meeting Criteria	Excessive
Total fruit	1.0 ± 0.03	0.5	1159 (27.9)	1196 (30.2)	1742 (41.9)	—
Whole fruit	0.2 ± 0.01	0	3028 (75.5)	478 (12.6)	591 (14.7)	—
Total vegetables	1.6 ± 0.04	1.4	192 (4.1)	1515 (36.0)	2390 (59.9)	—
Greens and beans	0.2 ± 0.01	0	2710 (67.4)	334 (7.9)	1053 (24.7)	—
Whole grains	0.8 ± 0.04	0.3	1972 (45.6)	1443 (36.1)	682 (18.2)	—
Dairy	1.7 ± 0.04	1.3	210 (4.3)	2042 (45.7)	1845 (49.9)	—
Fatty acids	1.9 ± 0.02	1.8	454 (11.5)	2813 (69.5)	830 (19.0)	—
Total protein foods	6.5 ± 0.1	5.5	53 (1.3)	668 (14.5)	3376 (84.2)	—
Seafood and Plant proteins	1.6 ± 0.07	0.3	1779 (41.0)	747 (17.9)	1571 (41.0)	—
Moderation						
Refined grains	5.6 ± 0.09	5.1	—	1267 (30.6)	463 (10.9)	2367 (58.5)
[a]Sodium	3605.6 ± 37.6	3268.6	—	695 (13.2)	158 (3.1)	3244 (83.8)
[b]Empty calories	32.7 ± 0.4	32.6	—	3158 (78.6)	628 (13.6)	311 (7.8)

Values are presented as means ± SE and medians for continuous variables and proportions *n* (%) for categorical variables.
Notes: Inadequate consumption was reported by participants not consuming any amount of food/nutrient groups except for fatty acids, which was reported as having very low consumption. Intermediate consumption was reported by participants consuming some amount of food/nutrient groups but less than the recommended criteria. Consumption by participants meeting the criteria is equivalent to having the full score; intermediate consumption is equivalent to having a partial score (calculated proportionately); inadequate consumption (i.e., low to none) and excessive consumption is equivalent to having a score of zero. Adequacy components are food/nutrient groups that are recommended for higher consumption. Moderation components are food/nutrient groups that are recommended for lower consumption.
[a]Sodium consumption was reported using the density-based approach (1000 kcal/d). The 2010 Dietary Guidelines for Americans recommends reducing daily sodium intake to less than 2,300 mg and further reducing intake to 1,500 mg for adults 51 years and older and for those with diabetes and other chronic conditions (i.e., hypertension or chronic kidney disease).
[b]Empty Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.
Abbreviations: HEI-2010, Healthy Eating Index 2010; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

Supplemental Table 2. Consumption (in servings) of AHEI-2010 Food and Nutrient groups among U.S. adults (Age ≥ 20, N = 4097)

Food/Nutrient Group	Consumption (in servings)					
	Mean ± SE	Median	*n* (%)			
			Inadequate	Intermediate	Meeting Criteria	Excessive
[a]Whole Fruit	1.4 ± 0.06	0	2133 (52.9)	1474 (36.0)	475 (11.0)	—
[b]Total Vegetables	1.5 ± 0.06	0.7	1621 (38.8)	1577 (37.7)	884 (23.5)	—
[c]Whole Grains	43.1 ± 2.2	0	2428 (59.5)	913 (23.5)	741 (16.9)	—
[e]Nuts and legumes	0.6 ± 0.03	0	3598 (87.0)	484 (12.8)	15 (0.2)	—
Long-chain (ω-3) fats (EPA + DHA)	129.6 ± 7.9	31.4	400 (9.3)	3278 (79.7)	419 (11.1)	—
[d]Sugar-sweetened Beverages and fruit juice	2.9 ± 0.08	2.1	—	2906 (70.7)	949 (22.5)	242 (6.8)
[f]Red and/or Processed Meats	0.8 ± 0.03	0.3	—	1689 (40.2)	1714 (41.2)	694 (18.6)
PUFA	7.8 ± 0.05	7.0	49 (1.1)	—	3344 (80.9)	704 (18.1)
Alcohol	0.7 ± 0.05	0	3175 (74.5)	—	644 (18.3)	263 (7.2)
			Lowest 10th percentile	**Central**	**Highest 10th percentile**	
[g]Sodium	3605.6 ± 37.6	3268.6	495 (9.2)	3261 (80.7)	341 (10.0)	

Values are presented as means ± SE and medians for continuous variables and proportions *n* (%) for categorical variables.

Notes: Inadequate consumption were reported by participants not consuming any amount of food/nutrient groups except for fatty acids, which was reported as having very low consumption. Intermediate consumption were reported by participants consuming some amount of food/nutrient groups but less than the recommended criteria. Consumption by participants meeting the criteria is equivalent to having the full score; intermediate consumption is equivalent to having a partial score (calculated proportionately); inadequate consumption (i.e., low to none) and excessive consumption is equivalent to having a score of zero. Scores were calculated based on actual intakes of participants rather than absolute standards. Trans fat component was omitted from the AHEI-2010 scoring because it is unavailable in the NHANES dietary files.

[a]Whole fruit excludes juice. For AHEI-2010, 1 serving is 1 medium piece of fruit or 0.5 cups of berries.

[b]Total vegetables excludes potatoes and juices. Servings were reported as number of cups per day.

[c]Whole grains include brown rice, popcorn, and any grain food with a carbohydrate to fiber ratio no more than 10:1. Servings were reported as number of grams per day.

[d]For sugar-sweetened beverages and fruit juice, 1 serving is 8 oz. of soft drinks and other beverages or 4 oz. of 100% fruit juice.

[e]For nuts and legumes, 1 serving is 1 oz. of dried beans, nuts, tofu, and soy milk.

[f]For red and/or processed meats, 1 serving is 4 oz of unprocessed meat or 1.5 oz of processed meat.

[g]Sodium consumption was based on the actual intake distribution of participants in the sample. The fasting subsample weight was used to obtain representative percentiles for sodium intake in the sample.

Abbreviations: AHEI-2010, Alternate Healthy Eating Index 2010; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acid.

Supplemental Table 3. Consumption (in servings) of HEI-2010 Food and Nutrient groups among U.S. adults (Age ≥ 20 years) by Diabetes Status

Food/Nutrient Group	**Consumption (in servings)**					
	Nondiabetes (n = 1436)		**Prediabetes** (n = 1905)		**Diabetes** (n = 715)	
	Mean ± SE	**Median**	**Mean ± SE**	**Median**	**Mean ± SE**	**Median**
Adequacy						
Total fruit	0.9 ± 0.05	0.5	1.1 ± 0.05	0.6	0.9 ± 0.06	0.4
Whole fruit	0.2 ± 0.01	0	0.2 ± 0.02	0	0.2 ± 0.03	0
Total vegetables	1.6 ± 0.06	1.3	1.7 ± 0.05	1.4	1.6 ± 0.05	1.4
Greens and beans	0.2 ± 0.02	0	0.2 ± 0.01	0	0.2 ± 0.02	0
Whole grains	0.9 ± 0.06	0.4	0.7 ± 0.05	0.1	0.8 ± 0.06	0.4
Dairy	1.7 ± 0.06	1.4	1.6 ± 0.06	1.2	1.4 ± 0.09	1.0
[a]Fatty acids	1.9 ± 0.02	1.8	1.9 ± 0.03	1.8	1.9 ± 0.04	1.8
Total protein foods	6.4 ± 0.2	5.4	6.6 ± 0.2	5.6	6.2 ± 0.2	5.4
Seafood and Plant proteins	1.6 ± 0.1	0.4	1.6 ± 0.1	0.3	1.4 ± 0.2	0.1
Moderation						
Refined grains	6.0 ± 0.1	5.3	5.8 ± 0.1	5.0	5.2 ± 0.2	4.3
[b]Sodium	3632.3 ± 63.3	3246.4	3629.6 ± 59.7	3298.8	3386.9 ± 88.8	2995.7
[c]Empty calories	32.4 ± 0.5	32.2	33.8 ± 0.5	33.9	29.9 ± 0.7	29.3

Values are means ± SE and median consumption in servings.
[a]Consumption was calculated as a ratio of the sum of mono- and poly- unsaturated fats to saturated fats.
[b]Sodium consumption was reported using the density-based approach (1000 kcal/d). The 2010 Dietary Guidelines for Americans recommends reducing daily sodium intake to less than 2,300 mg and further reducing intake to 1,500 mg for adults 51 years and older and for those with diabetes and other chronic conditions (i.e., hypertension or chronic kidney disease).
[c]Empty Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.
Abbreviations: HEI-2010, Healthy Eating Index 2010; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid

Supplemental Table 4. Consumption (in servings) of AHEI-2010 Food and Nutrient groups among U.S. adults (Age ≥ 20 years) by Diabetes Status

Food/Nutrient Group	**Consumption (in servings)**					
	Nondiabetes (n = 1436)		**Prediabetes** (n = 1905)		**Diabetes** (n = 715)	
	Mean ± SE	**Median**	**Mean ± SE**	**Median**	**Mean ± SE**	**Median**
Whole fruit	1.3 ± 0.07	0	1.6 ± 0.1	0	1.4 ± 0.09	0
Total vegetables	1.4 ± 0.09	0.5	1.6 ± 0.1	0.7	1.5 ± 0.09	0.9
Whole grains	41.8 ± 2.4	0	42.9 ± 3.5	0	48.6 ± 3.7	0
[a]Sugar-sweetened Beverages and fruit juice	2.9 ± 0.1	2.2	3.1 ± 0.1	2.2	2.1 ± 0.1	1.4
Nuts and legumes	0.6 ± 0.05	0	0.6 ± 0.04	0	0.6 ± 0.06	0
[a]Red and/or Processed Meats	0.7 ± 0.04	0.2	0.8 ± 0.03	0.4	0.8 ± 0.05	0.5
Long-chain (ω-3) fats (EPA + DHA)	127.3 ± 8.4	31.3	137.9 ± 12.1	31.9	109.3 ± 18.8	25.6
PUFAs	7.4 ± 0.07	7.0	7.4 ± 0.07	6.9	7.7 ± 0.1	7.3
[b]Alcohol	0.8 ± 0.07	0	0.7 ± 0.06	0	0.5 ± 0.07	0
[a]Sodium	3632.3 ± 63.3	3246.4	3629.6 ± 59.7	3298.8	3386.9 ± 88.8	2995.7

Values are means ± SE and median consumption in servings.
[a]Whole fruit excludes juice. For AHEI-2010, 1 serving is 1 medium piece of fruit or 0.5 cups of berries.
[b]Total vegetables excludes potatoes and juices. Servings were reported as number of cups per day.
[c]Whole grains include brown rice, popcorn, and any grain food with a carbohydrate to fiber ratio no more than 10:1. Servings were reported as number of grams per day.
[d]For sugar-sweetened beverages and fruit juice, 1 serving is 8 oz. of soft drinks and other beverages or 4 oz. of 100% fruit juice.
[e]For nuts and legumes, 1 serving is 1 oz. of dried beans, nuts, tofu, and soy milk.
[f]For red and/or processed meats, 1 serving is 4 oz of unprocessed meat or 1.5 oz of processed meat.
Abbreviations: AHEI-2010, Alternate Healthy Eating Index 2010; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acid.

Supplemental Table 5. HEI-2010 components and total scores of U.S. adults (Age ≥ 20, N = 4097)

Component	Criteria		Maximum Score Value	(n)	Mean ± SE	Median
	Minimum score	Maximum score				
Adequacy						
Total fruit	0	≥0.8 cups/1000 kcal	5	4097	2.1 ± 0.05	1.5
Whole fruit	0	≥0.4 cups/1000 kcal	5	4097	0.8 ± 0.05	0
Total vegetables	0	≥1.1 cups/1000 kcal	5	4097	3.0 ± 0.03	3.1
Greens and beans	0	≥0.2 cups/1000 kcal	5	4097	1.2 ± 0.04	0
Whole grains	0	≥1.5 oz/1000	10	4097	2.4 ± 0.07	0.8
Dairy	0	≥1.3 cups/1000 kcal	10	4097	5.2 ± 0.07	5.1
Fatty acids	(PUFAs + MUFAs)/ SFAs ≤ 1.2	(PUFAs + MUFAs)/ SFAs ≥ 2.5	10	4097	4.9 ± 0.08	4.5
Total protein foods	0	≥2.5 oz/1000 kcal	5	4097	4.2 ± 0.03	5.0
Seafood and Plant proteins	0	≥0.8 oz/1000 kcal	5	4097	2.1 ± 0.06	1.0
Moderation				4097		
Refined grains	≥ 4.3 oz/1000 kcal	≤ 1.8 oz/1000 kcal	10	4097	6.1 ± 0.09	6.7
Sodium	≥ 2.0 g/1000 kcal	≤ 1.1 g/1000 kcal	10	4097	4.2 ± 0.06	3.9
[a]Empty calories	≥ 50% of energy	≤ 19% of energy	20	4097	10.9 ± 0.2	11.2
Total			100	4097	47.3 ± 0.4	46.3

Values are means ± standard error (SE) and medians.

Notes: HEI-2010 scores were calculated from 24-hour dietary recall (day 1) of participants attending in-person at the MEC and conducted by trained interviewers using the USDA's Automated Multiple-Pass Method (AMPM). All scoring criteria were calculated per 1000 kcal/d, except empty calories, which were calculated as % total energy. For adequacy components, higher intake of food/nutrient groups result in higher scores. For moderation components, lower intake of food/nutrient groups result in higher scores.

[a]Empty Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.

Abbreviations: HEI-2010, Healthy Eating Index 2010; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

Supplemental Table 6. AHEI-2010 components and total scores of U.S. adults (Age ≥ 20, N = 4097)

Component	Criteria		Maximum Score value	(n)	Mean ± SE	Median
	Minimum score	Maximum score				
Whole fruit	0	≥4 servings/d	10	4082	2.9 ± 0.09	0
Total vegetables	0	≥2.5 cups/d	10	4082	2.7 ± 0.07	1.4
Whole grains	0	Women: 75 g/d Men: 90 g/d	10	4082	2.9 ± 0.1	0
Sugar-sweetened Beverages and fruit juice	≥8 oz/d	0	10	4082	2.6 ± 0.09	0
Nuts and legumes	0	≥1 oz/d	10	4082	2.5 ± 0.09	0
Red and/or Processed Meats	≥1.5 servings/d	0	10	4082	6.2 ± 0.1	7.8
Long-chain (ω-3) fats (EPA + DHA)	0	250 mg/d	10	4082	2.7± 0.07	1.3
PUFAs	≤2% of energy	≥10% of energy	10	4082	6.9 ± 0.03	7.0
[a]Alcohol	Men: ≥3.5 drinks/d Women: ≥2.5 drinks/d	Men: 0.5-2.0 drinks/d Women: 0.5-1.5 drinks/d	10	4082	3.3 ± 0.04	2.5
[b]Sodium	Highest Decile	Lowest Decile	10	4082	5.4 ± 0.06	5.9
Total			100	4082	38.2 ± 0.4	37.4

Values are means ± standard error (SE) and medians.

Notes: AHEI-2010 scores were calculated from 24-hour dietary recall (day 1) of participants attending in-person at the MEC and conducted by trained interviewers using the USDA's Automated Multiple-Pass Method (AMPM). All scoring criteria were calculated based on actual intake of participants rather than absolute standards. Trans fat component was omitted from the AHEI-2010 scoring because it is unavailable in the NHANES dietary files.

For sugar-sweetened beverages and fruit juices, red and/or processed meat, and sodium, a higher score corresponds to lower intake.

[a]Alcoholic drinkers were assigned the highest score to moderate, and lowest score to heavy consumers. Nondrinkers received a score of 2.5.

[b]Sodium consumption was based on the actual intake distribution of participants in the sample. The fasting subsample weight was used to obtain representative percentiles for sodium intake in the sample.

Abbreviations: AHEI-2010, Alternate Healthy Eating Index 2010; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acid.

Supplemental Table 7. Association between total HEI-2010 score and Diabetes Status in adults (Age ≥ 20, n = 3,632) using Multinomial Logistic Regression (Unweighted)

	Prediabetes vs. Non-diabetes	**Diabetes vs. Non-diabetes**	**Analysis of Effects**	
Predictors	**OR [95% CI]**	**OR [95% CI]**	**Wald Chi-Sq**	**Pr > Chi-sq**
Age	1.06 [1.03, 1.10]	1.26 [1.20, 1.34]	51.1	<0.0001
Age squared	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	23.1	<0.0001
Sex			55.3	<0.0001
Male	1.80 [1.52, 2.13]	2.2 [1.70, 2.80]		
Female	—	—	—	—
Race/Ethnicity			43.4	<0.0001
Mexican American	1.40 [1.10, 1.80]	2.42 [1.70, 3.44]		
Non-Hispanic White	—	—	—	—
Non-Hispanic Black	1.35 [1.06, 1.70]	2.60 [1.85, 3.60]		
Other	1.22 [0.96, 1.60]	1.83 [1.30, 2.65]		
Self-Reported Health			72.7	<0.0001
Excellent	0.80 [0.60, 0.98]	0.70 [0.43, 1.15]		
Very Good	—	—	—	—
Good	1.14 [0.93, 1.40]	1.76 [1.27, 2.44]		
Fair	1.10 [0.84, 1.43]	3.20 [2.20, 4.70]		
Poor	0.92 [0.55, 1.54]	2.90 [1.60, 4.23]		
Smoking Status			4.90	0.0877
Yes	1.14 [0.96, 1.35]	0.94 [0.73, 1.20]		
No	—	—	—	—
Physical Activity			3.90	0.1377
Yes	1.12 [0.94, 1.33]	0.92 [0.71, 1.20]		
No	—	—		—
Poverty-to-Income Ratio	0.93 [0.90, 1.00]	0.95 [0.88, 1.03]	6.02	0.0493
Comorbidity Score	1.06 [0.90, 1.10]	1.24 [1.14, 1.34]	34.3	<0.0001
WC (cm)	1.04 [1.02, 1.04]	1.06 [1.05 1.07]	191.2	<0.0001
Total HEI-2010 score	0.99 [0.99, 1.00]	1.00 [0.99, 1.01]	1.63	0.4426

Baseline outcome category = non-diabetes. Reference categories for categorical predictors are sex (female), race/ethnicity (non-Hispanic White), self-reported health (very good), smoking status (nonsmoker), physical activity (none).

[*]P-value for the odds of having diabetes and prediabetes compared to nondiabetes (reference group) < 0.05.

Unweighted model: Pseudo $R^2 = 0.1969$, $p < 0.0001$; goodness-of-fit chi-squared = 22.83, $p = 0.595$.

Note: Included a quadratic term for age as a continuous variable to apply polynomial functions and smoothing splines to test the logistic model is truly linear in the logit. This method was suggested by Hosmer and Lemeshow (2000) and Heeringa, West, and Berglund (2010).

Abbreviations: HEI-2010, Healthy Eating Index 2010; SE, standard error; OR, Odds Ratio; CI, Confidence Interval; WC, Waist Circumference.

Supplemental Table 8. Association between total AHEI-2010 score and Diabetes Status in U.S. adults (Age ≥ 20, n = 3,617) using Multinomial Logistic Regression (Unweighted)

	Prediabetes vs. Non-diabetes	**Diabetes vs. Non-diabetes**	**Analysis of Effects**	
Predictors	**OR (95% CI)**	**OR (95% CI)**	**Wald Chi-Sq**	**Pr > Chi-sq**
Age	1.05 [1.02, 1.10]	1.26 [1.20, 1.31]	49.6	<0.0001
Age squared	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	23.6	<0.0001
Sex			51.9	<0.0001
Male	1.80 [1.50, 2.13]	2.34 [1.61, 2.62]		
Female	—	—	—	—
Race/Ethnicity			42.8	<0.0001
Mexican American	1.42 [1.11, 1.81]	2.51 [1.75, 3.40]		
Non-Hispanic White	—	—	—	—
Non-Hispanic Black	1.40 [1.10, 1.73]	2.51 [1.52, 2.80]		
Other	1.23 [0.96, 1.60]	1.80 [1.30, 2.60]		
Self-reported Health			68.9	<0.0001
Excellent	0.77 [0.60, 0.98]	0.70 [0.43, 1.12]		
Very Good	—	—	—	—
Good	1.20 [0.94, 1.41]	1.75 [1.30, 2.32]		
Fair	1.10 [0.83, 1.44]	3.06 [2.12, 4.32]		
Poor	0.92 [0.55, 1.55]	2.80 [1.44, 4.30]		
Smoking Status			5.75	0.0564
Yes	1.20 [0.98, 1.37]	0.93 [0.80, 1.20]		
No	—	—	—	—
Physical Activity			3.80	0.1501
Yes	1.12 [0.94, 1.33]	0.92 [0.70, 1.14]		
No	—	—	—	—
Poverty-to-Income Ratio	0.93 [0.88, 0.98]	0.96 [0.91, 1.10]	6.70	0.0357
Comorbidity score	1.06 [0.99, 1.13]	1.24 [1.14, 1.31]	33.8	<0.0001
WC (cm)	1.04 [1.03, 1.04]	1.06 [1.05, 1.07]	192.3	<0.0001
Total AHEI-2010 score	1.00 [0.99, 1.01]	0.99 [0.99, 1.01]	0.20	0.9078
Calories (kcal)	1.00 [0.99, 1.00]	1.00 [0.99 1.00]	7.10	0.0295

Baseline outcome category = non-diabetes. Reference categories for categorical predictors are sex (female), race/ethnicity (non-Hispanic White), self-reported health (very good), smoking status (nonsmoker), physical activity (none).*P-value for the odds of having diabetes and prediabetes compared to nondiabetes (reference group) < 0.05.

Unweighted model: Pseudo $R^2 = 0.1980$, $p < 0.0001$; goodness-of-fit chi-squared = 15.50, $p = 0.491$.

Note: Included a quadratic term for age as a continuous variable to apply polynomial functions and smoothing splines to test the logistic model is truly linear in the logit. This method was suggested by Hosmer and Lemeshow (2000) and Heeringa, West, and Berglund (2010). Abbreviations: AHEI-2010, Alternate Healthy Eating Index 2010; SE, standard error; OR, Odds Ratio; CI, Confidence Interval; WC, Waist Circumference.

Supplemental Table 9. AHEI-2010 Alcohol component variation scores by Diabetes Status

Scores	Diabetes Status			p-value
	Nondiabetes	**Prediabetes**	**Diabetes**	
[a]Alcohol score (original)	3.4 ± 0.09	3.3 ± 0.08	2.8 ± 0.07	**<.0001**
AHEI-2010 score	37.9 ± 0.7	38.3 ± 0.5	39.1 ± 0.7	0.4299
[b]Alcohol score (variation 1)	6.7 ± 0.08	6.8 ± 0.07	6.9 ± 0.1	0.2390
AHEI-2010 score	41.2 ± 0.6	41.7 ± 0.5	43.2 ± 0.7	0.1088
[c]Alcohol score (variation 2)	8.1 ± 0.1	8.3 ± 0.1	8.9 ± 0.1	**0.0003**
AHEI-2010 score	42.7 ± 0.6	43.3 ± 0.5	45.2 ± 0.7	**0.0287**

Values are least square means ± standard error of the mean (SE). Bonferroni correction, P < 0.005.
[a]As suggested by Wang and Colleagues, nondrinkers were assigned a score of 2.5. This scoring method severely penalized non-drinkers.
[b]Nondrinkers were assigned a score of 7.5. This method partially penalized these participants.
[c]Nondrinkers were assigned a score of 10. These participants were assigned the full score with no penalty.
Abbreviations: AHEI-2010, Alternate Healthy Eating Index-2010.

Supplemental Table 10. Mean absolute value of HEI-2010 and AHEI-2010 Discrepancy Score in the sample (N = 4097) and by Diabetes Status

Variables	Diabetes Status Mean ± SE			Total Sample
	Nondiabetic (n = 1436)	**Prediabetic** (n = 1905)	**Diabetic** (n = 715)	
Absolute HEI-2010 Discrepancy Score	0.79 ± 0.02	0.8 ± 0.02	0.8 ± 0.04	0.7 ± 0.01
Absolute AHEI-2010 Discrepancy Score	1.0 ± 0.02	0.9 ± 0.02	0.9 ± 0.04	0.97 ± 0.01

Values are means ± standard error (SE).
Notes: Absolute discrepancy scores for HEI-2010 and AHEI-2010 represent the distance between perceived and measured (objective) diet quality [abs(discrepancy score = perceived score – objective score)] regardless of the direction of the difference. For example, an individual who rated his/her diet as "Very Good" but had an objective rating of "Excellent" would have the same discrepancy score as an individual who rated his/her diet as "Excellent" and had and objective rating of "Very Good."
Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010.

Supplemental Table 11. Factors associated with absolute value of HEI-2010 Discrepancy Score

Predictors	Absolute HEI-2010 Discrepancy Score *n* (%)				*p* trend
	0	1	2	3	
Age					0.2822
20-39	463 (36.7)	587 (49.5)	159 (12.1)	21 (1.7)	
40-59	514 (38.9)	674 (47.0)	171 (11.8)	36 (2.2)	
60-79	441 (36.8)	558 (47.1)	181 (13.7)	31 (2.4)	
80+	89 (33.2)	122 (47.1)	46 (18.7)	3 (0.9)	
Sex					0.4083
Male	708 (35.8)	923 (49.2)	267 (12.7)	47 (2.2)	
Female	799 (38.9)	1018 (46.7)	290 (12.5)	44 (1.9)	
Race/Ethnicity					0.1792
Mexican American	274 (37.4)	350 (47.0)	102 (13.7)	12 (1.9)	
Non-Hispanic White	759 (38.4)	954 (47.7)	275 (12.2)	39 (1.7)	
Non-Hispanic Black	245 (35.2)	327 (47.3)	107 (14.7)	20 (2.9)	
Other	229 (33.5)	310 (50.7)	73 (12.4)	20 (3.4)	
Education Level					0.3219
Less than high school	387 (35.4)	542 (47.9)	161 (13.7)	28 (2.9)	
High School diploma	374 (40.2)	453 (47.4)	119 (10.8)	19 (1.5)	
Some College education	402 (36.7)	528 (47.9)	154 (13.1)	29 (2.3)	
College Graduate or Above	341 (37.1)	415 (48.3)	123 (12.9)	15 (1.7)	
Marital Status					0.1156
Current Married	909 (37.2)	1197 (47.7)	346 (12.9)	55 (2.2)	
Former Married	363 (38.9)	418 (46.7)	138 (12.9)	27 (2.5)	
Never Married	235 (37.0)	326 (51.4)	72 (10.7)	9 (0.9)	
Adult Food Security Category					0.3469
Full	1123 (38.1)	1386 (47.0)	411 (12.9)	64 (2.1)	
Marginal	151 (38.3)	206 (50.4)	56 (10.1)	6 (1.1)	
Low	139 (33.7)	200 (51.7)	54 (12.7)	9 (1.9)	
Very Low	88 (33.0)	128 (51.7)	32 (11.7)	11 (3.6)	
[a]**Physical Activity**					**0.0155**
Inactive	789 (36.7)	1033 (48.2)	317 (12.8)	53 (2.4)	
Insufficient	262 (43.9)	273 (43.3)	78 (11.5)	7 (1.3)	
Sufficient	456 (35.3)	635 (49.9)	162 (12.9)	31 (1.9)	
BMI					0.2708
Normal (18.5-24.9 kg/m^2)	400 (37.4)	511 (46.9)	144 (12.7)	32 (2.8)	
Overweight (25-29.9 kg/m^2)	507 (35.7)	684 (48.4)	213 (13.9)	30 (2.0)	
Obese (≥ 30 kg/m^2)	600 (39.1)	746 (48.3)	200 (11.2)	29 (1.4)	
[b]**WC**					0.3739
Not Abdominally Obese	591 (35.9)	792 (49.0)	221 (12.5)	44 (12.5)	
Abdominally Obese	894 (38.9)	1109 (47.1)	320 (12.2)	47 (12.2)	
Perceived Health Status					**0.0002**
Excellent	172 (31.9)	255 (47.2)	90 (16.6)	22 (4.3)	
Very Good	397 (36.5)	522 (49.7)	156 (12.3)	19 (1.5)	
Good	573 (40.1)	686 (47.3)	171 (11.3)	23 (1.3)	
Fair	303 (40.4)	394 (48.3)	98 (9.4)	18 (1.9)	
Poor	62 (34.9)	84 (39.5)	42 (22.5)	8 (3.0)	
Depression Score					0.2951
None/minimal	1110 (37.3)	1409 (48.9)	375 (11.7)	62 (1.9)	
Mild	213 (40.9)	247 (42.9)	90 (14.1)	13 (2.0)	

Moderate	64 (29.4)	110 (54.1)	38 (13.4)	8 (3.1)	
Moderately Severe/Severe	41 (36.1)	61 (47.8)	19 (13.9)	4 (2.1)	
No reason to change diet					**0.0496**
Strongly Agree	168 (36.6)	211 (44.7)	70 (13.4)	18 (5.2)	
Agree	218 (33.2)	312 (51.1)	88 (13.9)	11 (1.7)	
Neither Agree nor Disagree	76 (40.9)	84 (43.7)	23 (12.0)	9 (3.4)	
Disagree	375 (37.9)	503 (48.6)	140 (11.8)	16 (1.7)	
Strongly Disagree	543 (38.4)	682 (47.5)	196 (12.7)	26 (1.4)	
Are people born fat/thin					**0.0022**
Strongly Agree	101 (29.2)	145 (48.3)	48 (17.1)	14 (5.4)	
Agree	353 (37.6)	452 (48.7)	126 (12.2)	19 (1.4)	
Neither Agree nor Disagree	118 (41.5)	126 (46.1)	34 (8.9)	8 (3.5)	
Disagree	346 (38.9)	446 (49.8)	100 (9.9)	11 (1.3)	
Strongly Disagree	468 (36.5)	626 (46.2)	213 (15.3)	29 (2.1)	
[c]**DGA Knowledge Score**					0.3101
0	214 (17.4)	279 (19.9)	85 (21.3)	13 (26.4)	
1	415 (41.1)	489 (36.2)	146 (38.4)	16 (28.1)	
2	283 (27.8)	374 (30.6)	102 (29.2)	20 (36.9)	
3	127 (13.7)	154 (13.3)	41 (11.1)	4 (8.5)	

Values are presented as column percent *n* (%) for categorical variables across absolute HEI-2010 discrepancy score.

Notes: The HEI-2010 discrepancy score represents the distance between perceived and measured (objective) diet quality [abs(discrepancy score = perceived score – objective total HEI-2010 score)] regardless of the direction of the difference. For example, an individual who rated his/her diet as "Very Good" but had an objective rating of "Excellent" would have the same discrepancy score as an individual who rated his/her diet as "Excellent" and had and objective rating of "Very Good."

[a]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans.

[b]WC values were used to screen participants for abdominal obesity using sex-specific cut-offs: WC >102 for men and WC > 88 for women are classified as abdominally obese based on the National, Heart, Lung, and Blood Institute standards [NHLBI].

[c]DGA Knowledge score was created by summing the responses to seven questions to assess whether participants were able to identify the correct number of servings recommended for each food group based on the MyPyramid guidelines (DGA 2005) in order to serve as a proxy for general nutrition knowledge.

Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010; BMI, Body Mass Index; WC, Waist Circumference; DGA, Dietary Guidelines for Americans.

Supplemental Table 12. Factors associated with absolute value of AHEI-2010 Discrepancy Score

Predictors	Absolute AHEI-2010 Discrepancy Score *n* (%)				*p* trend
	0	1	2	3	
Age					0.8581
20-39	387 (29.6)	579 (48.6)	209 (17.1)	55 (4.7)	
40-59	426 (29.5)	686 (49.1)	227 (17.4)	56 (3.9)	
60-79	375 (29.1)	560 (47.2)	225 (19.5)	51 (4.1)	
80+	81 (30.9)	108 (41.2)	58 (22.4)	13 (5.5)	
Sex					**0.0252**
Male	570 (27.5)	896 (48.1)	381 (19.4)	98 (4.9)	
Female	699 (31.5)	1037 (48.2)	338 (16.6)	77 (3.7)	
Race/Ethnicity					0.2214
Mexican American	268 (35.4)	346 (46.6)	106 (15.4)	18 (2.6)	
Non-Hispanic White	602 (29.4)	953 (48.0)	374 (18.2)	98 (4.4)	
Non-Hispanic Black	201 (28.6)	323 (47.4)	139 (18.6)	36 (5.4)	
Other	198 (26.9)	311 (51.1)	100 (17.9)	23 (3.9)	
Education Level					0.1904
Less than high school	374 (32.9)	522 (46.4)	169 (15.3)	53 (5.4)	
High School diploma	284 (27.4)	464 (50.8)	180 (18.4)	37 (3.4)	
Some College education	346 (29.5)	510 (46.9)	210 (19.3)	47 (4.3)	
College Graduate or Above	263 (29.3)	434 (48.3)	159 (17.9)	38 (4.4)	
Marital Status					0.1309
Current Married	751 (28.1)	1204 (49.7)	441 (17.5)	111 (4.6)	
Former Married	299 (31.3)	448 (45.9)	154 (18.1)	45 (4.7)	
Never Married	218 (32.7)	281 (44.8)	124 (19.8)	19 (2.7)	
Adult Food Security Category					0.3012
Full	913 (29.2)	1412 (48.5)	539 (18.2)	120 (4.1)	
Marginal	121 (28.8)	202 (47.5)	72 (18.8)	24 (4.9)	
Low	131 (31.0)	184 (44.5)	67 (18.7)	20 (5.9)	
Very Low	94 (34.7)	123 (50.1)	32 (11.3)	10 (3.9)	
[a]**Physical Activity**					**0.0042**
Inactive	702 (31.5)	1032 (48.2)	361 (15.8)	97 (4.5)	
Insufficient	191 (27.9)	301 (50.3)	115 (19.7)	13 (2.0)	
Sufficient	376 (27.8)	600 (47.1)	243 (19.9)	65 (5.2)	
BMI					**0.0019**
Normal (18.5-24.9 kg/m^2)	293 (25.8)	525 (48.9)	216 (20.3)	53 (5.1)	
Overweight (25-29.9 kg/m^2)	464 (29.7)	637 (45.8)	255 (19.1)	78 (5.3)	
Obese (≥ 30 kg/m^2)	512 (32.6)	771 (49.9)	248 (14.9)	44 (2.7)	
[b]**WC**					**0.0027**
Not Abdominally Obese	470 (26.4)	775 (48.3)	312 (19.7)	91 (5.6)	
Abdominally Obese	773 (31.9)	1130 (48.5)	387 (16.3)	80 (3.3)	
Perceived Health Status					**<.0001**
Excellent	93 (17.1)	243 (45.2)	145 (27.5)	58 (10.2)	
Very Good	312 (27.9)	518 (48.5)	219 (19.8)	45 (3.8)	
Good	516 (34.8)	682 (48.2)	214 (14.3)	41 (2.7)	
Fair	290 (36.2)	396 (49.8)	100 (11.1)	27 (2.9)	
Poor	58 (26.8)	94 (53.4)	41 (18.3)	3 (1.5)	
Depression Score					**0.0191**
None/minimal	909 (29.3)	1369 (46.9)	546 (19.2)	132 (4.5)	
Mild	166 (29.4)	286 (52.9)	88 (13.6)	23 (3.9)	

Moderate	74 (32.8)	102 (45.4)	37 (19.7)	7 (2.1)	
Moderately Severe/Severe	48 (38.3)	55 (48.9)	17 (9.7)	5 (3.0)	
No reason to change diet					**0.0288**
Strongly Agree	145 (24.9)	207 (48.2)	92 (19.5)	23 (7.4)	
Agree	193 (26.3)	297 (49.8)	106 (18.9)	33 (4.9)	
Neither Agree nor Disagree	43 (20.9)	100 (52.2)	39 (22.1)	10 (4.7)	
Disagree	303 (28.6)	508 (49.8)	181 (17.8)	42 (3.8)	
Strongly Disagree	485 (33.8)	674 (45.9)	233 (16.4)	55 (3.9)	
Are people born fat/thin					0.1945
Strongly Agree	94 (25.6)	142 (48.1)	51 (18.3)	21 (7.9)	
Agree	306 (28.5)	443 (50.0)	157 (16.7)	44 (4.7)	
Neither Agree nor Disagree	88 (31.4)	139 (50.6)	51 (15.4)	8 (2.6)	
Disagree	279 (31.2)	444 (47.7)	157 (18.6)	23 (2.5)	
Strongly Disagree	403 (28.8)	628 (47.3)	238 (18.6)	67 (5.3)	
[c]**DGA Knowledge Score**					0.8181
0	198 (19.7)	258 (17.4)	114 (22.6)	21 (22.4)	
1	321 (38.0)	524 (39.1)	182 (36.2)	39 (36.9)	
2	225 (29.4)	389 (30.4)	131 (27.0)	34 (28.9)	
3	103 (12.9)	158 (12.9)	53 (14.2)	12 (11.8)	

Values are presented as column percent *n* (%) for categorical variables across absolute AHEI-2010 discrepancy score.

Notes: The AHEI-2010 discrepancy score represents the distance between perceived and measured (objective) diet quality [abs(discrepancy score = perceived score – objective total HEI-2010 score)] regardless of the direction of the difference. For example, an individual who rated his/her diet as "Very Good" but had an objective rating of "Excellent" would have the same discrepancy score as an individual who rated his/her diet as "Excellent" and had and objective rating of "Very Good."

[a]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans.

[b]WC values were used to screen participants for abdominal obesity using sex-specific cut-offs: WC >102 for men and WC > 88 for women are classified as abdominally obese based on the National, Heart, Lung, and Blood Institute standards [NHLBI].

[c]DGA Knowledge score was created by summing the responses to seven questions to assess whether participants are able to identify the correct number of servings recommended for each food group based on the MyPyramid guidelines (DGA 2005) in order to serve as a proxy for general nutrition knowledge.

Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010; BMI, Body Mass Index; WC, Waist Circumference; DGA, Dietary Guidelines for Americans.

Supplemental Table 13. Anthropometric, Attitude, and Knowledge factors by Diabetes Status in U.S. adults (Age ≥ 20 years)

Variables	Diabetes Status *n* (%)			*p* trend
	Nondiabetic (n = 1436)	**Prediabetic** (n = 1905)	**Diabetic** (n = 715)	
BMI				**<. 0001**
Normal (18.5-24.9 kg/m^2)	577 (43.5)	418 (23.2)	90 (13.5)	
Overweight (25-29.9 kg/m^2)	501 (33.6)	717 (38.1)	203 (23.0)	
Obese (≥ 30 kg/m^2)	358 (22.9)	770 (38.6)	422 (63.5)	
[a]**WC**				**<. 0001**
Not Abdominally Obese	802 (59.5)	707 (39.7)	131 (17.6)	
Abdominally Obese	615 (40.5)	1166 (60.3)	557 (82.4)	
Depression Score				0.0050
None/minimal	1042 (79.9)	1410 (78.6)	483 (72.2)	
Mild	196 (14.5)	247 (14.0)	108 (16.4)	
Moderate	74 (4.1)	89 (4.2)	52 (7.6)	
Moderately Severe	26 (1.2)	42 (2.7)	26 (2.7)	
Severe	6 (0.4)	16 (0.5)	7 (1.1)	
No reason to change diet				0.1444
Strongly Agree	138 (7.0)	229 (9.1)	96 (11.6)	
Agree	213 (14.2)	310 (14.9)	101 (14.8)	
Neither Agree nor Disagree	72 (5.9)	92 (6.1)	27 (5.5)	
Disagree	413 (34.2)	463 (32.2)	151 (27.5)	
Strongly Disagree	512 (38.7)	671 (37.7)	245 (40.5)	
Are people born fat/thin				**<. 0001**
Strongly Agree	72 (3.5)	150 (5.5)	80 (9.9)	
Agree	301 (20.7)	455 (25.5)	181 (30.1)	
Neither Agree nor Disagree	107 (8.2)	126 (7.2)	53 (8.8)	
Disagree	358 (29.8)	412 (25.7)	126 (23.2)	
Strongly Disagree	517 (37.8)	628 (36.1)	180 (28.0)	
Importance of Nutrition				0.1224
Very important	453 (67.4)	888 (61.3)	1198 (59.2)	
Somewhat important	156 (29.8)	417 (34.7)	502 (35.7)	
Not too important	17 (2.4)	42 (3.4)	61 (4.2)	
Not at all important	4 (0.5)	9 (0.6)	18 (0.9)	
Heard of MyPyramid				0.0015
Yes	700 (55.3)	744 (46.8)	272 (48.4)	
No/don't know	656 (44.7)	1037 (53.2)	360 (51.6)	
Heard of Food Pyramid				**<. 0001**
Yes	397 (69.4)	479 (54.1)	143 (46.4)	
No/don't know	264 (30.6)	566 (45.9)	220 (53.6)	
Looked up MyPyramid on Internet				0.0002
Yes	110 (19.3)	82 (10.6)	28 (13.7)	
No/don't know	590 (80.7)	662 (89.4)	244 (86.3)	
Tried MyPyramid Plan				0.0445
Yes	314 (27.2)	352 (27.0)	159 (35.1)	
No/don't know	781 (72.8)	870 (72.9)	255 (64.9)	

[b]**DGA Knowledge Score**				0.8391
0	231 (19.3)	272 (20.1)	85 (15.5)	
1	418 (38.1)	473 (38.3)	167 (39.3)	
2	317 (29.9)	330 (28.2)	117 (30.9)	
3	111 (10.4)	130 (11.9)	40 (11.9)	
4	20 (2.2)	17 (1.5)	6 (2.4)	

Values are presented as column percent *n* (%) for categorical variables by diabetes status.

Notes: Diabetes status was defined from self-report of participants in the diabetes questionnaire and from the laboratory biomarkers using the cut-offs based on the 2017 Standards of Medical Care from the American Diabetes Association (ADA) for diabetes diagnosis.

[a]WC values were used to screen participants for abdominal obesity using sex-specific cut-offs: WC >102 for men and WC > 88 for women are classified as abdominally obese based on the National, Heart, Lung, and Blood Institute standards [NHLBI].

[b]DGA Knowledge score was created by summing the responses to seven questions to assess whether participants were able to identify the correct number of servings recommended for each food group based on the MyPyramid guidelines (DGA 2005) in order to serve as a proxy for general nutrition knowledge.

Abbreviations: HEI-2010, Healthy Eating Index-2010; AHEI-2010, Alternate Healthy Eating Index-2010; BMI, Body Mass Index; WC, Waist Circumference; DGA, Dietary Guidelines for Americans.

Supplemental Table 14. Sociodemographic characteristics of U.S. adults (Age ≥ 20) across categories of perceived diet quality

Characteristics	Perceived Diet Quality category *n* (%)					*p* trend
	Excellent (n = 332)	**Very Good** (n = 879)	**Good** (n =1743)	**Fair** (n = 936)	**Poor** (n = 206)	
Age (years)						**<.0001**
20-39	66 (23.9)	208 (28.8)	512 (34.3)	364 (46.4)	80 (44.7)	
40-59	104 (39.5)	264 (36.6)	614 (41.5)	332 (36.9)	81 (39.9)	
60-79	124 (28.3)	326 (28.8)	513 (20.2)	210 (14.3)	38 (12.9)	
80+	38 (8.3)	81 (5.8)	104 (3.9)	30 (2.4)	7 (2.5)	
Sex						0.4674
Male	171 (49.1)	419 (46.0)	817 (49.2)	452 (50.8)	86 (44.2)	
Female	161 (50.9)	460 (53.9)	926 (50.8)	484 (49.2)	120 (55.8)	
Race/Ethnicity						**<.0001**
Mexican American	39 (5.3)	104 (4.3)	284 (7.3)	268 (14.0)	43 (10.9)	
Non-Hispanic White	197 (77.1)	522 (78.4)	847 (70.3)	361 (62.2)	100 (64.7)	
Non-Hispanic Black	60 (9.7)	130 (7.7)	300 (10.5)	170 (13.2)	39 (16.2)	
Other	36 (7.8)	123 (9.6)	312 (11.8)	137 (10.6)	24 (8.2)	
Education Level						**<.0001**
Less than high school	72 (13.5)	165 (11.2)	461 (16.9)	345 (24.3)	75 (30.5)	
High School diploma	63 (17.7)	176 (18.6)	420 (24.9)	241 (26.3)	65 (33.9)	
Some College education	89 (26.5)	243 (26.9)	508 (30.6)	222 (28.5)	51 (27.4)	
College Graduate or Above	108 (42.3)	294 (43.3)	349 (27.4)	128 (20.8)	15 (8.2)	
Marital Status						**0.0007**
Current Married	220 (72.5)	586 (70.7)	1043 (63.9)	543 (59.9)	115 (57.2)	
Former Married	84 (17.5)	176 (15.4)	419 (18.7)	216 (18.7)	51 (20.9)	
Never Married	28 (9.9)	117 (13.9)	281 (17.5)	176 (21.4)	40 (21.9)	
Smoking Status						**<.0001**
Nonsmoker	194 (60.3)	497 (57.1)	989 (57.9)	489 (51.1)	90 (40.3)	
Current smoker	46 (11.3)	106 (11.5)	337 (19.3)	217 (23.6)	67 (36.1)	
Former smoker	92 (28.3)	276 (31.4)	417 (22.8)	230 (25.4)	49 (23.6)	
PIR						**<.0001**
<1.30	97 (20.6)	248 (19.6)	613 (23.7)	414 (30.4)	105 (40.7)	
1.30-3.49	114 (30.1)	294 (30.4)	645 (36.1)	333 (37.9)	73 (35.4)	
≥3.50	121 (49.3)	337 (49.9)	485 (40.3)	189 (31.6)	28 (23.9)	
Number of people in household						**<.0001**

1-2	186 (55.9)	492 (56.3)	767 (46.6)	340 (41.5)	82 (38.4)	
3-4	96 (31.1)	265 (31.9)	615 (36.7)	339 (37.7)	84 (45.4)	
5-6	37 (10.5)	90 (9.3)	262 (12.9)	174 (16.2)	28 (12.8)	
7+	13 (2.5)	32 (2.4)	99 (3.8)	83 (4.6)	12 (3.4)	
Adult Food Security Category						**<.0001**
Full	264 (88.1)	741 (89.7)	1287 (81.3)	577 (72.0)	115 (62.6)	
Marginal	26 (4.5)	63 (4.5)	172 (7.6)	136 (11.5)	22 (11.6)	
Low	25 (4.9)	50 (4.1)	174 (7.4)	125 (10.0)	28 (9.9)	
Very Low	14 (2.4)	21 (1.6)	98 (3.7)	89 (6.4)	37 (15.9)	
[a]Physical Activity						**<.0001**
Inactive	156 (38.0)	375 (33.8)	931 (46.1)	573 (56.4)	157 (74.1)	
Insufficient	47 (16.9)	136 (17.7)	267 (17.7)	150 (17.8)	20 (9.7)	
Sufficient	129 (45.0)	368 (48.5)	545 (36.2)	213 (25.8)	29 (16.2)	
BMI						**<.0001**
Normal (18.5-24.9 kg/m^2)	129 (46.1)	297 (38.7)	439 (27.4)	184 (22.0)	38 (20.8)	
Overweight (25-29.9 kg/m^2)	123 (32.7)	336 (36.6)	603 (34.8)	329 (34.4)	43 (22.1)	
Obese (≥ 30 kg/m^2)	80 (21.2)	246 (24.7)	701 (37.8)	423 (43.6)	125 (57.0)	
[b]WC						**<.0001**
Not Abdominally Obese	166 (57.6)	421 (53.4)	692 (43.8)	320 (36.9)	49 (27.2)	
Abdominally Obese	157 (42.4)	445 (46.6)	1014 (56.2)	601 (63.1)	153 (72.8)	
[c]Diabetes Status						0.1837
Nondiabetic	124 (46.5)	319 (45.4)	611 (40.0)	311 (38.3)	71 (38.9)	
Prediabetic	151 (42.1)	413 (43.2)	804 (47.4)	448 (48.3)	89 (46.6)	
Diabetic	55 (11.4)	139 (11.4)	310 (12.6)	167 (13.3)	44 (14.4)	

Values are presented as column percent *n* (%) for categorical variables by perceived diet quality category. Statistical differences were assessed using design-based Rao-Scott F adjusted X^2 statistic. Bolded values were significantly different $p < 0.01$.

Notes: Perceived diet quality represents the answer to the question 'In general, how healthy is your overall diet?' on a 5-point Likert scale with possible answers ranging from 'excellent' to 'poor'.

[a]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans.

[b]WC values were used to screen participants for abdominal obesity using sex-specific cut-offs: WC >102 for men and WC > 88 for women are classified as abdominally obese based on the National, Heart, Lung, and Blood Institute standards [NHLBI].

[c]Diabetes status was defined from self-report of participants in the diabetes questionnaire and from the laboratory biomarkers using the cut-offs based on the 2017 Standards of Medical Care from the American Diabetes Association [ADA] for diabetes diagnosis.

Abbreviations: PIR, Poverty-to-Income Ratio; BMI, Body Mass Index; WC, Waist Circumference.

Supplemental Table 15. HEI-2010 total and component scores of U.S. adults (Age ≥ 20) across categories of perceived diet quality

Component	Maximum Score Value	Perceived Diet Quality category					[a]p-value
		Excellent (n = 332)	**Very Good** (n = 879)	**Good** (n =1743)	**Fair** (n = 936)	**Poor** (n = 206)	
		LSM ± SE	**LSM ± SE**	**LSM ± SE**	**LSM ± SE**	**LSM ± SE**	
Adequacy							
Total fruit	5	2.8 ± 0.1	2.5 ± 0.07	2.1 ± 0.07	1.8 ± 0.1	1.1 ± 0.2	**<.0001**
Whole fruit	5	1.4 ± 0.2	0.9 ± 0.09	0.7 ± 0.04	0.6 ± 0.07	0.5 ± 0.1	**<.0001**
Total vegetables	5	3.5 ± 0.1	3.3 ± 0.08	2.9 ± 0.06	2.8 ± 0.07	2.5 ± 0.1	**<.0001**
Greens and beans	5	1.9 ± 0.2	1.6 ± 0.1	1.1 ± 0.05	0.9 ± 0.07	0.6 ± 0.1	**<.0001**
Whole grains	10	3.2 ± 0.2	3.0 ± 0.1	2.3 ± 0.07	1.8 ± 0.09	1.2 ± 0.1	**<.0001**
Dairy	10	5.6 ± 0.3	5.7 ± 0.2	5.1 ± 0.1	4.9 ± 0.1	4.6 ± 0.3	0.0012
Fatty acids	10	5.2 ± 0.2	5.3 ± 0.1	4.8 ± 0.1	4.8 ± 0.2	4.7 ± 0.3	0.0085
Total protein foods	5	4.4 ± 0.07	4.2 ± 0.06	4.3 ± 0.04	4.2 ± 0.05	4.1 ± 0.09	0.0680
Seafood and plant proteins	5	2.6 ± 0.1	2.6 ± 0.09	2.0 ± 0.08	1.7 ± 0.1	1.6 ± 0.2	**<.0001**
Moderation							
Refined grains	10	6.9 ± 0.2	6.5 ± 0.1	5.8 ± 0.1	5.7 ± 0.2	6.0 ± 0.3	0.0006
Sodium	10	4.1 ± 0.2	4.0 ± 0.1	4.2 ± 0.1	4.4 ± 0.1	4.9 ± 0.3	0.0885
[b]Empty calories	20	12.9 ± 0.4	12.4 ± 0.3	10.7 ± 0.2	9.7 ± 0.3	7.4 ± 0.6	**<.0001**
HEI-2010 score	100	54.5 ± 1.0	52.1 ± 0.7	46.0 ± 0.5	43.5 ± 0.5	39.2 ± 0.9	**<.0001**

Values are least square means ± standard error of the mean (SE).
[a]Bonferroni correction (<0.05/12 HEI-2010 components), $P < 0.004$.
[b]Empty Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.
Notes: Perceived diet quality represents the answer to the question 'In general, how healthy is your overall diet?' on a 5-point Likert scale with possible answers ranging from 'excellent' to 'poor'.
For HEI-2010, all scoring criteria were calculated per 1000 kcal/d, except empty calories, which were calculated as % total energy. For adequacy components, higher intake of food/nutrient groups result in higher scores. For moderation components, lower intake of food/nutrient groups result in higher scores.
Abbreviations: LSM, least square means; HEI-2010, Healthy Eating Index-2010.

Supplemental Table 16. AHEI-2010 total and component scores of U.S. adults (Age ≥ 20) across categories of perceived diet quality

Component	Maximum Score value	Perceived Diet Quality category					[a]p-value
		Excellent (n = 332)	**Very Good** (n = 879)	**Good** (n =1743)	**Fair** (n = 936)	**Poor** (n = 206)	
		LSM ± SE	**LSM ± SE**	**LSM ± SE**	**LSM ± SE**	**LSM ± SE**	
Whole fruit	10	4.3 ± 0.3	3.5 ± 0.1	2.7 ± 0.1	2.3 ± 0.2	1.6 ± 0.3	**<.0001**
Total vegetables	10	4.1 ± 0.2	3.3 ± 0.1	2.5 ± 0.1	2.0 ± 0.1	1.4 ± 0.2	**<.0001**
Whole grains	10	3.8 ± 0.3	3.6 ± 0.2	2.9 ± 0.1	2.4 ± 0.2	1.3 ± 0.2	**<.0001**
Sugar-sweetened beverages & fruit juice	10	3.7 ± 0.5	3.4 ± 0.1	2.2 ± 0.1	2.2 ± 0.1	1.4 ± 0.2	**<.0001**
Nuts and legumes	10	3.5 ± 0.3	3.2 ± 0.2	2.3 ± 0.1	1.8 ± 0.1	1.4 ± 0.3	**<.0001**
Red and/or processed meats	10	6.4 ± 0.3	6.6 ± 0.2	6.0 ± 0.2	5.9 ± 0.1	6.5 ± 0.3	0.0449
Long-chain (ω-3) fats (EPA + DHA)	10	2.9 ± 0.3	2.9 ± 0.1	2.6 ± 0.1	2.3 ± 0.1	2.5 ± 0.3	0.0168
[b]Alcohol	10	3.8 ± 0.2	3.7 ± 0.1	3.2 ± 0.08	2.9 ± 0.1	3.1 ± 0.3	0.0010
PUFAs	10	6.9 ± 0.1	7.2 ± 0.09	6.9 ± 0.05	6.9 ± 0.1	6.9 ± 0.2	0.0733
[c]Sodium	10	5.5 ± 0.2	5.4 ± 0.1	5.5 ± 0.09	5.6 ± 0.3	5.7 ± 0.3	0.8923
AHEI-2010 score	100	44.9 ± 0.9	42.9 ± 0.7	36.9 ± 0.4	34.3 ± 0.5	31.7 ± 0.9	**<.0001**

Values are least square means ± standard error of the mean (SE).
[a]Bonferroni correction (<0.05/11 AHEI-2010 components), $P < 0.005$.
[b]Alcoholic drinkers were assigned the highest score to moderate, and lowest score to heavy consumers. Nondrinkers received a score of 2.5.
[c]Consumption was based on the actual intake distribution of participants in the sample. The fasting subsample weight was used to obtain representative percentiles for sodium intake in the sample.
Notes: Perceived diet quality represents the answer to the question 'In general, how healthy is your overall diet?' on a 5-point Likert scale with possible answers ranging from 'excellent' to 'poor'.
For AHEI-2010, all scoring criteria were calculated based on actual intake of participants rather than absolute standards. Trans fat component was omitted from the AHEI-2010 scoring because it is unavailable in the NHANES dietary files. For sugar-sweetened beverages and fruit juices, red and/or processed meat, and sodium, a higher score corresponds to lower intake.
Abbreviations: LSM, least square means; AHEI-2010, Alternate Healthy Eating Index-2010; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acid.

Supplemental Table 17. HEI-2010 components and total scores of U.S. adults (Age ≥ 20 years) by Lifestyle Behaviors score

Component	Criteria		Maximum Score Value	[a]Lifestyle Behaviors Score			[a]p-value
	Minimum score	Maximum score		Low (n = 762)	Medium (n = 2312)	High (n =1023)	
				LSM ± SE	LSM ± SE	LSM ± SE	
Adequacy							
Total fruit	0	≥0.8 cups/1000 kcal	5	1.4 ± 0.1	2.1 ± 0.05	2.6 ± 0.08	**<.0001**
Whole fruit	0	≥0.4 cups/1000 kcal	5	0.4 ± 0.08	0.8 ± 0.05	0.9 ± 0.08	0.0010
Total vegetables	0	≥1.1 cups/1000 kcal	5	2.7 ± 0.06	3.0 ± 0.05	3.2 ± 0.06	**<.0001**
Greens and beans	0	≥0.2 cups/1000 kcal	5	0.9 ± 0.08	1.2 ± 0.06	1.5 ± 0.08	0.0015
Whole grains	0	≥1.5 oz/1000	10	1.4 ± 0.1	2.3 ± 0.08	3.2 ± 0.2	**<.0001**
Dairy	0	≥1.3 cups/1000 kcal	10	4.8 ± 0.2	5.1 ± 0.09	5.7 ± 0.1	**<.0001**
Fatty acids	(PUFAs + MUFAs)/ SFAs ≤ 1.2	(PUFAs + MUFAs)/ SFAs ≥ 2.5	10	4.8 ± 0.2	4.9 ± 0.1	5.2 ± 0.1	0.0980
Total protein foods	0	≥2.5 oz/1000 kcal	5	4.2 ± 0.07	4.2 ± 0.03	4.3 ± 0.05	0.4956
Seafood and Plant proteins	0	≥0.8 oz/1000 kcal	5	1.6 ± 0.09	2.1 ± 0.06	2.5 ± 0.09	**<.0001**
Moderation							
Refined grains	≥ 4.3 oz/1000 kcal	≤ 1.8 oz/1000 kcal	10	5.9 ± 0.2	6.1 ± 0.1	6.1 ± 0.2	0.7494
Sodium	≥ 2.0 g/1000 kcal	≤ 1.1 g/1000 kcal	10	4.4 ± 0.2	4.3 ± 0.07	3.9 ± 0.1	0.0332
[b]Empty calories	≥ 50% of energy	≤ 19% of energy	20	8.8 ± 0.4	10.7 ± 0.2	12.9 ± 0.3	**<.0001**
Total HEI-2010 score			100	41.5 ± 0.6	46.9 ± 0.5	51.9 ± 0.7	**<.0001**

Values are least square means ± standard error of the mean (SE). Bonferroni correction (<0.05/12 HEI-2010 components), $P < 0.004$.

Notes: All scoring criteria were calculated per 1000 kcal/d, except empty calories, which are calculated as % total energy. For adequacy components, higher intake of food/nutrient groups result in higher scores. For moderation components, lower intake of food/nutrient groups result in higher scores.

[a]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity (Maximum score = 6 points). Lifestyle behaviors score was categorized as low (0-1 pt), medium (2-3 pts), and high (4-6 pts).

[b]Empty. Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.

Abbreviations: LSM, least square means; HEI-2010, Healthy Eating Index-2010; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

Supplemental Table 18. AHEI-2010 components and total scores of U.S. adults (Age ≥ 20) by Lifestyle Behaviors Score

Component	Criteria		Maximum Score value	[a]Lifestyle Behaviors Score			[a]p-value
	Minimum score	Maximum score		Low (n = 762) LSM ± SE	Medium (n = 2312) LSM ± SE	High (n = 1023) LSM ± SE	
Whole fruit	0	≥4 servings/d	10	1.8 ± 0.2	2.9 ± 0.09	3.6 ± 0.2	**<.0001**
Total vegetables	0	≥2.5 cups/d	10	2.1 ± 0.2	2.7 ± 0.1	3.1 ± 0.1	**<.0001**
Whole grains	0	Women: 75 g/d Men: 90 g/d	10	1.9 ± 0.2	2.9 ± 0.1	3.7 ± 0.2	**<.0001**
Sugar-sweetened Beverages and fruit juice	≥8 oz/d	0	10	2.2 ± 0.2	2.6 ± 0.1	2.8 ± 0.2	0.0708
Nuts and legumes	0	≥1 oz/d	10	1.9 ± 0.2	2.5 ± 0.1	2.8 ± 0.1	0.0002
Red and/or Processed Meats	≥1.5 servings/d	0	10	5.5 ± 0.2	6.1 ± 0.1	6.7 ± 0.2	0.0011
Long-chain (ω-3) fats (EPA + DHA)	0	250 mg/d	10	2.4 ± 0.2	2.6 ± 0.07	2.9 ± 0.1	0.1125
PUFAs	≤2% of energy	≥10% of energy	10	6.7 ± 0.1	7.0 ± 0.06	7.1 ± 0.09	0.0477
[b]Alcohol	Men: ≥3.5 drinks/d Women: ≥2.5 drinks/d	Men: 0.5-2.0 drinks/d Women: 0.5-1.5 drinks/d	10	3.3 ± 0.1	3.3 ± 0.08	3.3 ± 0.09	0.9461
[c]Sodium	Highest Decile	Lowest Decile	10	5.5 ± 0.1	5.5 ± 0.09	5.4 ± 0.1	0.6751
Total AHEI-2010 score			100	33.4 ± 0.6	38.2 ± 0.5	41.4 ± 0.5	**<.0001**

Values are least square means ± standard error of the mean (SE). Bonferroni correction (<0.05/11 AHEI-2010 components), $P < 0.005$.
Notes: All scoring criteria were calculated based on actual intake of participants rather than absolute standards. Trans fat component was omitted from the AHEI-2010 scoring because it is unavailable in the NHANES dietary files. For sugar-sweetened beverages and fruit juices, red and/or processed meat, and sodium, a higher score corresponds to lower intake.
[a]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity (Maximum score = 6 points). Lifestyle behaviors score was categorized as low (0-1 pt), medium (2-3 pts), and high (4-6 pts).
[b]Alcoholic drinkers were assigned the highest score to moderate, and lowest score to heavy consumers. Nondrinkers received a score of 2.5.
[c]Consumption was based on the actual intake distribution of participants in the sample. The fasting subsample weight was used to obtain representative percentiles for sodium intake in the sample.
Abbreviations: LSM, least square means; AHEI-2010, Alternate Healthy Eating Index-2010; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acid.

Supplemental Table 19. Association between Lifestyle Behaviors and Total HEI-2010 score in U.S. adults (Age ≥ 20 years) using Multiple Linear Regression (Unweighted)

Total Sample (n = 4083)						
	R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
Model 1	0.141792					**<0.0001**
		[a]Alcohol Consumption	-0.36	0.45	[-1.25, 0.52]	0.4221
		[b]Sleep Adequacy	1.05	0.42	[0.22, 1.88]	0.0135
		[c]On a Special Diet	3.84	0.60	[2.67, 5.02]	**<0.0001**
		[d]Supplement Intake	2.24	0.44	[1.38, 3.09]	**<0.0001**
		[e]Smoking Status	-2.13	0.43	[-2.97, -1.28]	**<0.0001**
		[f]Physical Activity	2.61	0.48	[1.73, 3.49]	**<0.0001**
Total Sample (n = 4090)						
	R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
Model 2	0.138701					**<0.0001**
		[g]Lifestyle Behaviors score	1.91	0.17	[1.57, 2.25]	**<0.0001**

Separate multivariable linear regression models were computed for individual lifestyle behaviors and Lifestyle Behaviors score in the sample. Each model was adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, Non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor) and BMI (continuous). Race/ethnicity was included as a nominal class variable. BMI was log-transformed for normality.

[a]Alcohol consumption was based on self-reported number of alcoholic drinks/day in the past year. Individuals were categorized "Yes" to reporting any amount of alcoholic drinks consumed, including moderate (Female: 1 drink; Male 1-3 drinks) or heavy (Female: >1 drink; Male: >3 drinks) intakes. Individuals were classified "No" to reporting zero intake.

[b]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays. Individuals were categorized "Yes" to report sleeping more than 7 hours at night.

[c]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).

[d]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).

[e]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category.

[f]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity.

[g]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points).

Abbreviations: HEI-2010, Healthy Eating Index-2010; BMI, Body Mass Index; SE, Standard Error; C.I., Confidence Interval.

Supplemental Table 20. Association between Lifestyle Behaviors and Total AHEI-2010 score in U.S. adults (Age ≥ 20 years) using Multiple Linear Regression (Unweighted)

Total Sample (n = 4068)						
	R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
Model 1	0.169239					**<0.0001**
		[a]Alcohol Consumption	1.06	0.43	[0.23, 1.89]	0.0128
		[b]Sleep Adequacy	0.14	0.39	[-0.64, 0.93]	0.7195
		[c]On a Special Diet	2.23	0.57	[1.21, 3.34]	**<0.0001**
		[d]Supplement Intake	2.48	0.41	[1.67, 3.28]	**<0.0001**
		[e]Smoking Status	-1.38	0.41	[-2.18, -0.59]	0.0007
		[f]Physical Activity	2.18	0.42	[1.35, 3.00]	**<0.0001**
Total Sample (n = 4075)						
	R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
Model 2	0.153514					**<0.0001**
		[g]Lifestyle Behaviors score	1.20	0.16	[0.88, 1.53]	**<0.0001**

Separate multivariable linear regression models were computed for individual lifestyle behaviors and Lifestyle Behaviors score in the sample. Each model was adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, Non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor), BMI (continuous), and energy intake (continuous). Race/ethnicity was included as a nominal class variable. BMI and energy intake were log-transformed for normality.

[a]Alcohol consumption was based on self-reported number of alcoholic drinks/day in the past year. Individuals were categorized "Yes" to reporting any amount of alcoholic drinks consumed, including moderate (Female: 1 drink; Male 1-3 drinks) or heavy (Female: >1 drink; Male: >3 drinks) intakes. Individuals were classified "No" to reporting zero intake.

[b]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays. Individuals were categorized "Yes" to report sleeping more than 7 hours at night.

[c]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).

[d]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).

[e]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category.

[f]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity.

[g]Lifestyle Behaviors score was calculated as the sum of self-reported individual lifestyle behaviors: alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals reported "Yes" receive 1 point to each lifestyle behavior (Total Points = 6).

[g]Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points).

Abbreviations: AHEI-2010, Alternate Healthy Eating Index-2010; SE, Standard Error; C.I., Confidence Interval.

Supplemental Table 21. Association between Individual Lifestyle Behaviors and Total HEI-2010 score by Diabetes Status (Unweighted)

Nondiabetic (n = 1435)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.153496					**<0.0001**
	[a]Alcohol Consumption	-1.09	0.80	[-2.67, 0.49]	0.1760
	[b]Sleep Adequacy	1.07	0.74	[-0.39, 2.53]	0.1513
	[c]On a Special Diet	4.90	1.18	[2.54, 7.16]	**<0.0001**
	[d]Supplement Intake	2.31	0.76	[0.83, 3.79]	0.0023
	[e]Smoking Status	-2.43	0.76	[-3.92, -0.95]	0.0013
	[f]Physical Activity	1.92	0.77	[0.41, 3.42]	0.0126
Prediabetic (n = 1897)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.162696					**<0.0001**
	[a]Alcohol Consumption	0.75	0.65	[-0.52, 2.01]	0.2493
	[b]Sleep Adequacy	1.30	0.61	[0.09, 2.50]	0.0340
	[c]On a Special Diet	2.96	0.95	[1.11, 4.82]	0.0018
	[d]Supplement Intake	2.00	0.64	[0.74, 3.25]	0.0018
	[e]Smoking Status	-2.90	0.62	[-4.12, -1.68]	**<0.0001**
	[f]Physical Activity	3.29	0.64	[2.05, 4.54]	**<0.0001**
Diabetic (n = 710)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.111423					**<0.0001**
	[a]Alcohol Consumption	-1.92	1.06	[-3.99, 0.16]	0.0699
	[b]Sleep Adequacy	0.54	1.01	[-1.45, 2.52]	0.5949
	[c]On a Special Diet	4.23	1.13	[2.01, 6.46]	0.0002
	[d]Supplement Intake	3.01	1.04	[1.04, 5.11]	0.0030
	[e]Smoking Status	0.64	1.03	[-1.39, 2.67]	0.5360
	[f]Physical Activity	1.88	1.14	[-0.37, 4.11]	0.1009

Multivariable linear regression model was computed for individual lifestyle behaviors and stratified by diabetes status. Adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, Non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor) and BMI (continuous). Race/ethnicity was included as a nominal class variable. BMI was log-transformed for normality.

[a]Alcohol consumption was based on self-reported number of alcoholic drinks/day in the past year. Individuals were categorized "Yes" to reporting any amount of alcoholic drinks consumed, including moderate (Female: 1 drink; Male 1-3 drinks) or heavy (Female: >1 drink; Male: >3 drinks) intakes. Individuals were classified "No" to reporting zero intake.[b]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays. Individuals were categorized "Yes" to report sleeping more than 7 hours at night. [c]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).[d]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).[e]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category.

[f]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity.

Abbreviations: HEI-2010, Healthy Eating Index-2010; SE, Standard Error; C.I., Confidence Interval.

Supplemental Table 22. Association between Individual Lifestyle Behaviors and Total AHEI-2010 score by Diabetes Status (Unweighted)

Nondiabetic (n = 1428)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.169382					**<0.0001**
	[a]Alcohol Consumption	0.76	0.76	[-0.72, 2.25]	0.3125
	[b]Sleep Adequacy	0.21	0.69	[-1.16, 1.58]	0.7586
	[c]On a Special Diet	0.88	1.11	[-1.29, 3.05]	0.4259
	[d]Supplement Intake	2.31	0.71	[0.92, 3.70]	0.0012
	[e]Smoking Status	-0.76	0.71	[-2.16, 0.63]	0.2818
	[f]Physical Activity	2.16	0.72	[0.75, 3.57]	0.0027
Prediabetic (n = 1891)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.186103					**<0.0001**
	[a]Alcohol Consumption	1.41	0.62	[0.20, 2.62]	0.0227
	[b]Sleep Adequacy	0.17	0.58	[-0.97, 1.32]	0.7682
	[c]On a Special Diet	2.42	0.91	[0.64, 4.20]	0.0077
	[d]Supplement Intake	2.25	0.61	[1.06, 3.45]	0.0002
	[e]Smoking Status	-2.24	0.59	[-3.41, -1.08]	0.0002
	[f]Physical Activity	2.34	0.61	[1.15, 3.53]	0.0001
Diabetic (n = 708)					
R^2	**Main Predictors**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.145273					**<0.0001**
	[a]Alcohol Consumption	0.51	0.96	[-1.37, 2.38]	0.5973
	[b]Sleep Adequacy	-0.19	0.91	[-1.97, 1.59]	0.8352
	[c]On a Special Diet	3.69	1.02	[1.69, 5.70]	0.0003
	[d]Supplement Intake	3.81	0.94	[1.97, 5.66]	**<0.0001**
	[e]Smoking Status	0.04	0.93	[-1.79, 1.86]	0.9681
	[f]Physical Activity	1.60	1.03	[-0.41, 3.62]	0.1186

Multivariable linear regression model was computed for individual lifestyle behaviors and stratified by diabetes status. Adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, Non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor), BMI (continuous) and energy intake (continuous). Race/ethnicity was included as a nominal class variable. BMI and energy intake were log-transformed for normality.

[a]Alcohol consumption was based on self-reported number of alcoholic drinks/day in the past year. Individuals were categorized "Yes" to reporting any amount of alcoholic drinks consumed, including moderate (Female: 1 drink; Male 1-3 drinks) or heavy (Female: >1 drink; Male: >3 drinks) intakes. Individuals were classified "No" to reporting zero intake.

[b]Sleep Adequacy was based on self-reported number of hours of sleep at night on weekdays/workdays. Individuals were categorized "Yes" to report sleeping more than 7 hours at night.

[c]On a special diet was based on self-report to following any type of special diet for health-related reason (i.e., weight loss, Diabetic, low fat, low sodium).

[d]Supplement intake was based on self-reported use of dietary supplements and medications during the past month (30 days).

[e]Smoking status was based on individuals' self-report to whether they had smoked at least 100 cigarettes in their life and whether they now smoke cigarettes. Smoking status was originally categorized as current, former, and nonsmokers. In the analysis, current and former smokers were combined as "Yes" as a category and were contrasted with nonsmokers as "no" in another category.

[f]Physical Activity guidelines were defined for participants meeting (≥150 min/week of moderate-to-vigorous physical activity [MVPA]) or not meeting MVPA based on the 2008 Physical Activity Guidelines for Americans. Response "Yes" included a combination of insufficient and sufficient physical activity. Response "No" included no physical activity.

Abbreviations: AHEI-2010, Alternate Healthy Eating Index-2010; SE, Standard Error; C.I., Confidence Interval.

Supplemental Table 23. Association between Lifestyle Behaviors score and Total HEI-2010 score by Diabetes Status using Multiple Linear Regression (Unweighted)

Nondiabetic (n = 1436)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.150842					**<0.0001**
	Lifestyle Behaviors Score	2.02	0.31	[1.41, 2.63]	**<0.0001**
Prediabetic (n = 1900)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.151964					**<0.0001**
	Lifestyle Behaviors Score	1.90	0.25	[1.41, 2.39]	**<0.0001**
Diabetic (n = 713)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.098836					**<0.0001**
	Lifestyle Behaviors score	1.77	0.40	[0.98, 2.55]	**<0.0001**

Multivariable linear regression model was computed for Lifestyle Behaviors score and stratified by diabetes status. Adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, Non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor) and BMI (continuous). Race/ethnicity was included as a nominal class variable. BMI was log-transformed for normality.

Note: Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points).

Abbreviations: HEI-2010, Healthy Eating Index-2010; SE, Standard Error; C.I., Confidence Interval.

Supplemental Table 24. Association between Lifestyle Behaviors score and Total AHEI-2010 score by Diabetes Status using Multiple Linear Regression (Unweighted)

Nondiabetic (n = 1429)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.160970					**<0.0001**
	Lifestyle Behaviors Score	1.01	0.29	[0.43, 1.58]	0.0006
Prediabetic (n = 1894)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.171229					**<0.0001**
	Lifestyle Behaviors Score	1.32	0.24	[0.85, 1.78]	**<0.0001**
Diabetic (n = 711)					
R^2	**Main Predictor**	**β - Coefficient**	**SE**	**95% C.I.**	**p-value**
0.117545					**<0.0001**
	Lifestyle Behaviors score	1.40	0.36	[0.64, 2.07]	0.0002

Multivariable linear regression model was computed for Lifestyle Behaviors score and stratified by diabetes status. Adjusted for age (continuous), sex (men/women), race/ethnicity (Mexican American, non-Hispanic White, Non-Hispanic black, other), education (less than high school, high school, some college education, college graduate or above), self-reported health (excellent/very good, good, fair/poor), BMI (continuous), and energy intake (continuous). Race/ethnicity was included as a nominal class variable. BMI and energy intake were log-transformed for normality.

Note: Lifestyle Behaviors score was calculated as the sum of participants' responses to the six selected individual lifestyle behaviors: self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. Individuals received 1 point for being categorized as "yes" for each positive lifestyle behavior, except for smoking and alcohol consumption (reverse-scored). Individuals received 1 point for being categorized as "no" for alcohol consumption and smoking status (Maximum score = 6 points).

Abbreviations: AHEI-2010, Alternate Healthy Eating Index-2010; SE, Standard Error; C.I., Confidence Interval

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