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ORIGINAL ARTICLE

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

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Abstract

Background: Limited studies have examined the contribution of lifestyle behaviors to dietary quality among individuals with and without type 2 diabetes.

Objective: To examine the relationship between selected lifestyle behaviors independently, and in combination with other lifestyle behaviors, and dietary quality by diabetes status.

Methods: This study used a representative sample of U.S. adults 20+ years of age (n = 4097) using NHANES 2007-2010. Six individual lifestyle behaviors were selected as main exposure variables: Self-reported alcohol consumption, sleep adequacy, on a special diet, supplement intake, smoking status, and physical activity. 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. 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: Selected lifestyle behaviors independently, and in combination, were significantly associated with total HEI-2010 and AHEI-2010 scores by diabetes status ($p < 0.05$). Diabetics were more likely to report being on a special diet, taking dietary supplements, and not drinking alcohol but were less likely to report getting adequate sleep and meeting physical activity guidelines. Results indicate that being on a special diet and taking dietary supplements had the highest coefficient in relation to dietary quality for diabetics [total HEI-2010 score: $\beta = 5.08$, $p = 0.0011$ for on a special diet, total AHEI-2010 score: $\beta = 3.89$, $p = 0.0019$ for supplement intake]. However, the coefficients of the combined Lifestyle Behaviors score in relation to dietary quality were fairly similar for diabetics and prediabetics ($p < 0.001$).

Conclusion: 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.

Keywords

NHANES, Lifestyle behaviors, HEI-2010, AHEI-2010, Diabetes status

Abbreviations

T2DM: Type 2 Diabetes; HEI-2010: Healthy Eating Index-2010; AHEI-2010: Alternate Healthy Eating Index-2010; NHANES: National Health and Nutrition Examination Survey

Introduction

Type 2 diabetes mellitus (T2DM) is largely preventable through positive lifestyle changes, including a good quality diet. Few epidemiological studies have examined the relationships between individual lifestyle behaviors and dietary quality. For instance, short sleep duration has been found to be a potential risk factor for poor dietary quality. Xiao and colleagues 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 among U.S. women within 5 years of childbirth [1]. In addition, smoking is a risk factor and associated with poor dietary quality. Alkerwi and colleagues found moderate and heavy smokers had significantly lower diet quality scores compared to never smokers (P values all models < 0.01) [2]. These studies suggest that there are independent associations between lifestyle behaviors (i.e., 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).

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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 [3-10]. In addition, most studies have only examined the independent associations between individual lifestyle behaviors and dietary quality [1,2,11]. 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 and determine whether the associations are different by diabetes status groups (nondiabetes, prediabetes, diabetes); 2) To examine the association between combined Lifestyle Behaviors score and dietary quality and determine whether the association differs by diabetes status groups (nondiabetes, prediabetes, diabetes); 3) To determine the strength of the relationships between selected individual lifestyle behaviors and Lifestyle Behaviors score with dietary quality while controlling for demographic and health characteristics. All analyses were based on data from the 2007-2010 National Health and Nutrition Examination Survey.

Participants and Methods

Survey design

The National Health and Nutrition Examination Survey (NHANES) is an ongoing program of the National Center for Health Statistics, which is a part of the Centers for Disease Control and Prevention of the U.S. Department of Health and Human Services. NHANES is a cross-sectional survey that collects information on the health and nutritional status of adults and children in the United States [12]. 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 [13]. Details regarding the NHANES study design, contents, procedures, consent document, and survey operation manuals are published and available on the CDC website [12].

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 aged ≥ 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 [14]. 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 [15].

Exposure and outcome variables

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 and the distributions of these variables were highly skewed. 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 Alcohol Use Questionnaire of NHANES was used to examine self-reported alcohol consumption. 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). In the analysis, self-reported alcohol consumption was dichotomized to "yes" for drinkers (including moderate or heavy) or "no" for nondrinkers.

Sleep adequacy: The NHANES Sleep Disorders questionnaire 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 [16,17]. This analysis 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: The dietary interview component 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: Individuals with higher socioeconomic status are more likely to incorporate healthier lifestyle habits such as dietary supplement consumption to improve nutrient intake. For that reason, the present study examined the association between dietary supplement intake (independently and in combination of other lifestyle behaviors) and dietary quality as a holistic approach to better understand the influence of dietary choices. 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. 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. This study used the 2008 Physical Activity Guidelines for Americans as the standard [18]. 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 [18]. 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 [19]. 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 [19].

Lifestyle behaviors score: 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.

Measurement 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. 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 [1]. Using the in-person (day 1) recall ensures consistency in di-

etary 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 [20].

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. 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) [21]. 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. The HEI-2010 scores were calculated using the Food Pattern Equivalents Database (FPED) and the SAS code was downloaded from the USDA Center for Nutrition Policy and Promotion website [22].

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 [23-25]. This study applied the methodology used by Wang and colleagues (2014) to calculate the AHEI-2010 scores. 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 eicosatetraenoic 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 [25-27]. 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 [23]. 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 [23]. 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 [28]. 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) [23-25]. 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.

Diabetes status

The association between lifestyle behaviors and dietary quality was examined by diabetes status groups in the bivariate and multivariate analyses. The cut-offs for the laboratory biomarkers are based on the 2017 Standards of Medical Care from the American Diabetes Association (ADA) for diabetes diagnosis [29]. T2DM could be diagnosed or undiagnosed. Diagnosed diabetes was 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 diabetes was 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 total number of adults with T2DM was calculated 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 [30,31]. Prediabetes was 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 prediabetes (FPG < 100 mg/dL and HbA1c < 5.7%) were categorized as nondiabetes [29].

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. 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 4-year fasting weight was constructed by assigning one-half of

the 2-year weight for each survey cycle (2007-2008 and 2009-2010), as recommended in the NHANES analytic guidelines. The design-adjusted Rao-Scott chi-square test (PROC SURVEYFREQ) was used to examine bivariate associations between lifestyle behaviors and diabetes status groups. Least-squares means (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). 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, diabetes) 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 $p < 0.05$.

Covariates

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) [32,33], associations between sleep quality and health outcomes (i.e., obesity, diabetes) [34], and the association between sleep quality and dietary intake [16]. The multivariable linear regression models were adjusted for age, sex, 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

Table 1: 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				0.066
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 dichotomized 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 2: Bivariate associations between Lifestyle Behaviors and Dietary Quality in U.S. adults (Age ≥ 20).

Lifestyle Behaviors	**Dietary Quality**					
Alcohol Consumption	**Total HEI-2010 score** (n = 4093)		**[a]P-value**	**Total AHEI-2010 score** (n = 4078)		**[a]P-value**
	No	Yes		No	Yes	
	LSM ± SE	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	
	48.2 ± 0.5	46.9 ± 0.5	0.069	38.1 ± 0.5	38.3 ± 0.5	0.73
Sleep Adequacy	**Total HEI-2010 score** (n = 4095)			**Total AHEI-2010 score** (n = 4080)		
	No	Yes		No	Yes	
	LSM ± SE	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	
	45.8 ± 0.5	48.2 ± 0.5	0.0007	37.0 ± 0.5	38.9 ± 0.4	0.0037
On a Special Diet	**Total HEI-2010 score** (n = 4096)			**Total AHEI-2010 score** (n = 4081)		
	No	Yes		No	Yes	
	LSM ± SE	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	
	46.6 ± 0.5	51.8 ± 0.7	< 0.0001	37.8 ± 0.4	40.8 ± 0.7	< 0.0001
Supplement Intake	**Total HEI-2010 score** (n = 4096)			**Total AHEI-2010 score** (n = 4081)		
	No	Yes		No	Yes	
	LSM ± SE	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	
	44.7 ± 0.3	49.8 ± 0.6	< 0.0001	35.5 ± 0.4	40.8 ± 0.5	< 0.0001
Smoking Status	**Total HEI-2010 score** (n = 4097)			**Total AHEI-2010 score** (n = 4082)		
	No	Yes		No	Yes	
	LSM ± SE	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	

	48.6 ± 0.5	45.7 ± 0.6	< 0.0001	39.2 ± 0.5	37.0 ± 0.6	0.0040
Physical Activity	**Total HEI-2010 score** (n = 4097)			**Total AHEI-2010 score** (n = 4082)		
	No	Yes		No	Yes	
	LSM ± SE	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	
	45.3 ± 0.4	49.0 ± 0.6	< 0.0001	36.6 ± 0.4	39.6 ± 0.6	< 0.0001
[b]**Lifestyle Behaviors Score**	**Total HEI-2010 score** (n = 4097)			**Total AHEI-2010 score** (n = 4082)		
	Low	High		Low	High	
	LSM ± SE	**LSM ± SE**		**LSM ± SE**	**LSM ± SE**	
	44.1 ± 0.5	49.7 ± 0.5	< 0.0001	35.6 ± 0.5	40.2 ± 0.5	< 0.0001

Values are least square means ± standard error of the mean.

[a]Bonferroni correction (< 0.05/6 lifestyle behaviors), $P < 0.008$.

[b]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; AHEI-2010: Alternate Healthy Eating Index-2010.

1,000 calories).

Results

Table 1 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). However, the association between Lifestyle Behaviors score and diabetes status was not significant ($p = 0.066$).

Table 2 presents the bivariate associations between lifestyle behaviors and dietary quality (using total HEI-2010 and AHEI-2010 scores) in U.S. adults. Results indicate significant differences in mean total HEI-2010 and AHEI-2010 scores by individual lifestyle behaviors ($p < 0.05$), except for self-reported alcohol consumption ($p > 0.05$). The mean total HEI-2010 and AHEI-2010 scores were higher among individuals who reported getting adequate sleep (HEI-2010: mean = 48.2 ± 0.5, $p < 0.0001$; AHEI-2010: 38.9 ± 0.4, $p = 0.0037$), being on a special diet (HEI-2010: mean = 51.8 ± 0.7, $p < 0.0001$; AHEI-2010: mean = 40.8 ± 0.7, $p < 0.0001$), taking supplements (HEI-2010: mean = 49.8 ± 0.6, $p < 0.0001$; AHEI-2010: mean = 40.8 ± 0.5, $p < 0.0001$), and meeting physical activity guidelines (HEI-2010: mean = 49.0 ± 0.6, $p < 0.0001$; AHEI-2010: mean = 39.6 ± 0.6, $p < 0.0001$). In addition, the mean total HEI-2010 and AHEI-2010 scores were higher among individuals who reported being nonsmokers (HEI-2010: mean = 48.6 ± 0.5, $p < 0.0001$, AHEI-2010: 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 HEI-2010 and AHEI-2010 scores by Lifestyle Behaviors score. The mean total HEI-2010 and AHEI-2010 scores were greater among individuals with "high" (3-6 points) Lifestyle Behaviors score (HEI-2010: mean = 49.7 ± 0.5, $p < 0.0001$; AHEI-2010: mean = 40.2 ± 0.5, $p < 0.0001$).

Table 3 shows multivariate linear regression models for individual lifestyle behaviors in relation to total HEI-2010 score by diabetes status groups after adjusting

Table 3: Association between Individual Lifestyle Behaviors and Total HEI-2010 score by Diabetes Status.

Nondiabetes (n = 1435)					
R^2	**Main Predictors**	**β-Coefficient**	**SE**	**95% C.I.**	**P-value**
0.171					
	Alcohol Consumption	-0.48	0.81	[-2.13, 1.17]	0.56
	Sleep Adequacy	0.92	0.92	[-0.95, 2.79]	0.32
	On a Special Diet	4.44	1.27	[1.85, 7.04]	0.002
	Supplement Intake	0.96	1.06	[-1.19, 3.12]	0.37
	[e]Smoking Status	-2.12	1.15	[-4.45, 0.21]	0.074
	[f]Physical Activity	2.80	0.94	[0.87, 4.72]	0.006
Prediabetes (n = 1897)					
R^2	**Main Predictors**	**β-Coefficient**	**SE**	**95% C.I.**	**P-value**
0.163					
	Alcohol Consumption	0.39	0.99	[-1.64, 2.42]	0.70
	Sleep Adequacy	1.68	0.95	[-0.25, 3.61]	0.08
	On a Special Diet	3.48	1.51	[0.41, 6.55]	0.028
	Supplement Intake	1.39	0.85	[-0.33, 3.12]	0.11
	Smoking Status	-2.45	0.85	[-4.18, -0.73]	0.007
	Physical Activity	3.61	0.88	[1.82, 5.40]	0.0003
Diabetes (n = 710)					
R^2	**Main Predictors**	**β-Coefficient**	**SE**	**95% C.I.**	**P-value**
0.142					
	Alcohol Consumption	-2.27	0.88	[-4.06, -0.49]	0.014
	Sleep Adequacy	0.93	0.96	[-1.04, 2.89]	0.34
	On a Special Diet	5.08	1.42	[2.18, 7.98]	0.001
	Supplement Intake	4.25	1.32	[1.55, 6.94]	0.003
	Smoking Status	1.71	1.16	[-0.65, 4.07]	0.15
	Physical Activity	0.99	1.60	[-2.28, 4.26]	0.54

Multivariable linear regression model was computed for individual lifestyle behaviors and stratified by diabetes status. Adjusted for age (continuous), sex (men/women), 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.

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

Table 4: Association between Individual Lifestyle Behaviors and Total AHEI-2010 score by Diabetes Status.

Nondiabetes (n = 1428)					
R^2	**Main Predictors**	**β-Coefficient**	**SE**	**95% C.I.**	**P-value**
0.190					
	Alcohol Consumption	1.28	1.04	[-0.83, 3.39]	0.227
	Sleep Adequacy	-0.06	0.98	[-2.05, 1.93]	0.953
	On a Special Diet	0.57	0.98	[-1.43, 2.57]	0.566
	Supplement Intake	1.73	0.96	[-0.22, 3.69]	0.081
	Smoking Status	-0.42	1.01	[-2.66, 1.82]	0.71
	Physical Activity	2.83	0.90	[0.99, 4.67]	0.004
Prediabetes (n = 1981)					
R^2	**Main Predictors**	**β-Coefficient**	**SE**	**95% C.I.**	**P-value**
0.198					
	Alcohol Consumption	1.95	0.75	[0.42, 3.47]	0.014
	Sleep Adequacy	1.63	0.91	[-0.23, 3.49]	0.084
	On a Special Diet	2.65	1.27	[0.06, 5.24]	0.045
	Supplement Intake	2.13	0.68	[0.74, 3.52]	0.004

	Smoking Status	-2.55	0.83	[-4.23, -0.86]	0.004
	Physical Activity	2.02	0.63	[0.73, 3.30]	0.003
Diabetes (n = 708)					
R^2	**Main Predictors**	**β-Coefficient**	**SE**	**95% C.I.**	**P-value**
0.175					
	Alcohol Consumption	0.07	1.14	[-2.24, 2.38]	0.95
	Sleep Adequacy	0.66	0.87	[-1.11, 2.42]	0.46
	On a Special Diet	3.31	1.20	[0.88, 5.73]	0.009
	Supplement Intake	3.89	1.15	[1.54, 6.24]	0.002
	Smoking Status	0.29	0.95	[-1.64, 2.22]	0.76
	Physical Activity	1.61	1.15	[-0.74, 3.96]	0.17

Multivariable linear regression model was computed for individual lifestyle behaviors and stratified by diabetes status. Adjusted for age (continuous), sex (men/women), 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). Ethnicity was included as a nominal class variable. BMI and energy intake were log-transformed for normality.

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

for age, sex, ethnicity, education, and BMI. For nondiabetes, being on a special diet had the highest predictive power in relation to total HEI-2010 score (β = 4.44, p = 0.002) followed by physical activity (β = 2.80, p = 0.006). For prediabetes, physical activity had the highest predictive power in relation to total HEI-2010 score (β = 3.61, p = 0.0003), followed by being on a special diet (β = 3.48, p = 0.028), and smoking status (β = -2.45, p = 0.007). For diabetes, being on a special diet had the highest predictive power in relation to total HEI-2010 score (β = 5.08, p = 0.001), followed by supplement intake (β = 4.25, p = 0.003), and alcohol consumption (β = -2.27, p = 0.014).

Table 4 shows multivariate linear regression models for individual lifestyle behaviors in relation to total AHEI-2010 score by diabetes status groups after adjusting for age, sex, ethnicity, education, BMI, and energy intake. For nondiabetes, physical activity was the only predictor significantly associated with total AHEI-2010 score and had the highest predictive power (β = 2.02, p = 0.003). For prediabetes, being on a special diet had the highest predictive power in relation to total AHEI-2010 score (β = 2.65, p = 0.045), followed by smoking status (β = -2.55, p = 0.0043), supplement intake (β = 2.13, p = 0.004), and physical activity (β = 2.02, p = 0.003). For diabetes, supplement intake had the highest predictive power in relation to total AHEI-2010 score (β = 3.89, p = 0.002), followed by being on a special diet (β = 3.31, p = 0.009), and physical activity (β = 1.61, p = 0.17). The magnitude of the R-square for the models was comparable by diabetes status.

Table 5 shows multivariate linear regression models for Lifestyle Behaviors score in relation to dietary quality (using total HEI-2010 and AHEI-2010 scores) by diabetes status after adjusting for age, sex, ethnicity, education, BMI, and energy intake (in the AHEI-2010 Model). Results indicate that Lifestyle Behaviors score was a significant predictor in relation to total HEI-2010 and AHEI-2010 scores by diabetes status (p < 0.0001). The predictive power of Lifestyle Behaviors score in relation to total HEI-2010 and AHEI-2010 scores was similar for prediabetics (HEI-2010 Model: β = 1.96, p = 0.0003; AHEI-2010 Model: β = 1.50, p = 0.0005) and diabetics (HEI-2010 Model: β = 1.96, p < 0.0001; AHEI-2010 Model: β = 1.45, p = 0.0004). However, the predictive power of Lifestyle Behaviors score was lowest for nondiabetics (HEI-2010 Model: HEI-2010 Model: β = 1.76, p < 0.0001; AHEI-2010 Model: β = 0.84, p = 0.014).

Discussion

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) 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.

Results from the multivariate linear regression models indicate the significant associations between individual lifestyle behaviors and total HEI-2010 and AHEI-2010 scores (Tables 3 and Table 4) by diabetes status. The effect size of individual lifestyle behaviors in relation to total HEI-2010 and AHEI-2010 score within diabetes status groups had some similarities and differences. 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 3) and physical activity on the AHEI-2010 model (Table 4) 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

Table 5: Association between Lifestyle Behaviors score and Dietary Quality by Diabetes Status using Multiple Linear Regression.

Diabetes Status	Dietary Quality									
Nondiabetes	**Total HEI-2010 score (n = 1436)**					**Total AHEI-2010 score (n = 1429)**				
	R^2	**β**	**SE**	**95% C.I.**	**P-value**	**R^2**	**β**	**SE**	**95% C.I.**	**P-value**
[a]Lifestyle Behaviors Score	0.164	1.76	0.30	[1.14, 2.37]	< 0.0001	0.18	0.84	0.32	[0.18, 1.49]	0.014
Prediabetes	**Total HEI-2010 score (n = 1900)**					**Total AHEI-2010 score (n = 1894)**				
	R^2	**β**	**SE**	**95% C.I.**	**P-value**	**R^2**	**β**	**SE**	**95% C.I.**	**P-value**
[a]Lifestyle Behaviors Score	0.152	1.96	0.49	[0.97, 2.96]	0.0003	0.183	1.50	0.38	[0.72, 2.28]	0.0005
Diabetes	**Total HEI-2010 score (n = 713)**					**Total AHEI-2010 score (n = 711)**				
	R^2	**β**	**SE**	**95% C.I.**	**P-value**	**R^2**	**β**	**SE**	**95% C.I.**	**P-value**
[a]Lifestyle Behaviors Score	0.108	1.96	0.40	[1.16, 2.77]	< 0.0001	0.152	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. Models for total HEI-2010 and AHEI-2010 scores were adjusted for age (continuous), sex (men/women), 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). The model for total AHEI-2010 score was further adjusted for energy intake (continuous). Ethnicity was included as a nominal class variable. BMI was log-transformed for normality.

[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. 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; AHEI-2010: Alternate Healthy Eating Index-2010; SE: Standard Error; CI: Confidence Interval.

appearance. Among prediabetics, physical activity had the largest estimated effect on the HEI-2010 model and being on a special diet on the AHEI-2010 model 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. 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 and supplement intake on the AHEI-2010 model 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. 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.

The regression coefficient for sleep adequacy was not a significant predictor of total HEI-2010 and AHEI-2010 scores after adjusting for covariates (Tables 3 and Table 4). 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., 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.

The regression coefficients for self-reported alcohol consumption were found to be different in magnitude in the HEI-2010 and AHEI-2010 models (Tables 3 and Table 4). 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 [25]. 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.

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.

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