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Dietary intake of adults with and without diabetes: results from NHANES 2013–2016

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ABSTRACT

Introduction Diet is a critical aspect of the management of adults with diabetes. This paper aims to compare dietary intakes of key macronutrients and micronutrients of US adults with and without diabetes and across the spectrum of diabetes.

Research design and methods We compared absolute and energy-adjusted dietary intake of major macronutrients and micronutrients among those with and without diabetes and across the spectrum of glycemic control using a 24-hour dietary recall from a cross-sectional, nationally representative sample of 9939 US adults, 20+ years old (National Health and Nutrition Examination Survey 2013–2016). Diabetes was defined as an glycohemoglobin A1c (HbA1c)≥6.5%, fasting glucose ≥126 mg/dL, serum glucose at 2 hours following a 75 g glucose load (oral glucose tolerance test) ≥200 mg/dL, any diagnosis of diabetes or use of diabetes medication (self-reported).

Results Percent of calories from macronutrients was similar for those with and without diabetes (p>0.05, energy adjusted and adjusted for age, race, and sex). In both groups, sugar accounted for about 20% of calories. Those with diabetes consumed about 7% more calcium (p=0.033), about 5% more sodium (p=0.026), and had lower diet quality (Healthy Eating Index-2015, p=0.021) than those without diabetes. Among those with diabetes, those with an HbA1c>9.0% consumed about 4% less magnesium (p-analysis of variance=0.007) than those with an HbA1c<6.5%. Results were similar within strata of age, race, and sex. Macronutrient intake did not vary consistently by HbA1c level.

Conclusions In this nationally representative sample, there were no substantial or consistent differences in the dietary intake of macronutrients or micronutrients between US adults with and without diabetes. Improving the diets of those with diabetes will likely require enhanced targeted efforts to improve the dietary intake of persons with diabetes, as well as broad efforts to improve the dietary intake of the general population.

Significance of this study

What is already known about this subject?

- Improved nutrition is critical to preventing and managing type 2 diabetes.
- It has been well established that US adults (regardless of diabetes status) do not meet US dietary guidelines.
- It remains unclear, however, whether dietary intakes differ by diabetes status, and whether there are differences in intake by hemoglobin A1c.

What are the new findings?

- In this nationally representative sample, there were no substantial or consistent differences in the dietary intake of macronutrients or micronutrients between US adults with and without diabetes.
- Those with diabetes had slightly lower diet quality overall based on the Healthy Eating Index-2015.
- Those with diabetes were less likely to have full food security, with fewer than half of those with hemoglobin A1c >9.0% having full food security.

How might these results change the focus of research or clinical practice?

- Improving the diets of those with diabetes will likely require enhanced targeted efforts to improve the dietary intake of persons with diabetes, as well as broad efforts to improve the dietary intake and food security of the general population.

INTRODUCTION

Improved nutrition is critical to preventing and managing type 2 diabetes. The American Diabetes Association (ADA) notes that, while diet alone may not be sufficient to manage type 2 diabetes, it is an 'important component' of care.[1] The current dietary recommendations for those with diabetes are similar to the general population, emphasizing nutrient-dense foods and healthful dietary patterns.[1–3] The 2020 ADA recommendations encourage consuming non-starchy vegetables, minimizing refined grains and added sugars, and consuming whole foods rather than highly processed ones.[3] While there is no ideal target for macronutrient ratios among those with diabetes, reducing total carbohydrate intake may improve glycemia.[3]

It has been well established that US adults (regardless of diabetes status) do not meet US dietary guidelines (including the US Department of Agriculture (USDA) Dietary Guidelines for Americans and the American Heart Association targets).[4 5] It remains unclear, however, whether dietary intakes differ by diabetes status, and whether there are differences in intake by hemoglobin A1c. An analysis of cross-sectional data from China found some small but statistically significant differences in the diets of those with and without type 1 diabetes, but did not examine those with type 2 diabetes.[6] Further understanding of the differences, or lack thereof, in the dietary intake of US adults with and without diabetes could inform dietary recommendations, nutrition interventions, and broader food policies aimed at improving the diet of those with diabetes.

The objective of this paper is to compare dietary intakes of key macronutrients and micronutrients that impact cardiometabolic disease of US adults with and without diabetes and across the spectrum of diabetes.[7] We analyzed both energy-adjusted and absolute intake using data from the National Health and Nutrition Examination Survey (NHANES)-What We Eat in America (NHANES-WWEIA) cycles from 2013 to 2016.

MATERIALS AND METHODS

We used data from two cycles (2013–2014 and 2015–2016) of the NHANES. NHANES is a nationally representative cross-sectional survey of the US population consisting of a dietary intake interview portion (WWEIA), laboratory measurements, physical examinations, and medical and non-medical questionnaires. We included 4299 participants (representing 217 296 304 people) who were 20 years of age or older, not pregnant, had one complete 24-hour dietary interview, and had fasted for at least 8 hours but less than 24 hours at the time of the laboratory examination. Nutrient intake was estimated from a single in-person 24-hour dietary intake interview linked to a nutrient database. Serum fasting glucose, glycohemoglobin A1c (HbA1c), and other variables (cholesterol) were obtained from fasting serum samples taken by venipuncture. Following this fasting specimen collection, participants consumed 75 g of dextrose followed by a second serum sample 2 hours later for the oral glucose tolerance test (OGTT). Blood pressure was measured after a 5 min rest in the seated position. Three consecutive blood pressure measurements were taken. Self-reported history of diabetes diagnosis, insulin use, and other medication use was obtained by a medical history questionnaire administered by trained study personnel.

Diabetes

In the main analysis, we defined diabetes as any of the following: HbA1c≥6.5%, serum glucose at 2 hours following a 75 g glucose load (OGTT) ≥200 mg/dL, fasting glucose ≥126 mg/dL, any self-reported diagnosis of diabetes, or any self-reported use of insulin or other diabetes medication.[8] Time since diabetes diagnosis was calculated by subtracting participants' current age from self-reported age at diagnosis, or zero for those diagnosed during the NHANES examination.

In the secondary analysis, we used the same definition of diabetes, but further categorized by HbA1c level: normal (no diabetes and HbA1c<5.7%), pre-diabetes (no diabetes and HbA1c≥5.7% and <6.5%), diabetes without elevated HbA1c (HbA1c<6.5%), diabetes with elevated HbA1c (HbA1c≥6.5% and <9.0%), diabetes with very elevated HbA1c (HbA1c≥9.0%).

Dietary intake and other covariates

We calculated the dietary intake of macronutrients and micronutrients from single 24-hour recalls. Investigated nutrients affect cardiometabolic health, including macronutrients and micronutrients. The latter include certain micronutrients (eg, potassium, magnesium, calcium and sodium) potentially relevant to diabetes and associated comorbidities, such as hypertension.[2 3 9–11] Diet quality was estimated from 0 (worst) to 100 (best) using the Healthy Eating Index based on the 2010–2015 Dietary Guidelines for Americans (HEI-2015).[12–14] Self-reported food security was categorized as full food security for participants with no affirmative responses on the food security questionnaire.[15] Those with at least one affirmative response were categorized as marginal to very low food security. Self-reported access to healthcare was defined as having at least one place the participant usually goes to when sick or needs health advice.

Serum samples were analyzed for total cholesterol, high-density lipoprotein (HDL) cholesterol, and triglycerides. Low-density lipoprotein (LDL) cholesterol was then calculated using the Friedewald equation.[16] The mean of all available measurements was reported for systolic and diastolic blood pressure. Self-reported education level was categorized as less than or equal to a high school diploma, or greater than a high school diploma. Income was categorized as less than three times the poverty line or greater than or equal to three times the poverty line. The ratio of family income to poverty was calculated using self-reported family income and the yearly Department of Health and Human Services poverty guidelines.

Statistical analysis

Appropriate 4-year survey weights were used to account for NHANES multistage design and the use of two NHANES cycles (2013–2014 and 2015–2016). Four-year mean dietary intakes were reported as absolute and energy adjusted using marginal estimates from linear regression. Models were adjusted for age (continuous), race (non-Hispanic white, non-Hispanic black, Mexican American, and other), and sex. Energy adjustment for macronutrients was performed by calculating the percent of total energy intake from a given nutrient. Total carbohydrate, sugar, and protein were multiplied by 4 kcal/g and total fat, saturated fat, polyunsaturated fat, and monounsaturated fat were multiplied by 9 kcal/g. Energy adjustment

Table 1 Demographic and medical characteristics by diabetes states of non-pregnant adults 20+ years old from NHANES 2013–2016*

	No diabetes	Diabetes	P value
n (unweighted)	3352	947	
Sex			
Male (%)	48.1 (46.4 to 49.8)	51.7 (47.7 to 55.7)	0.113
Female (%)	51.9 (50.2 to 53.6)	48.3 (44.3 to 52.3)	
Age (years)	45.5 (44.6 to 46.4)	59.1 (58.1 to 60.0)	**<0.001**
Race			
Non-Hispanic white (%)	66.4 (60.8 to 71.9)	65.1 (58.6 to 71.5)	**0.025**
Non-Hispanic black (%)	10.7 (7.8 to 13.7)	13.1 (9.8 to 16.4)	
Mexican American (%)	8.4 (5.7 to 11.1)	9.0 (5.6 to 12.5)	
Other (%)	14.5 (12.0 to 16.9)	12.8 (9.6 to 16.1)	
Education†			
≤High school diploma (%)	35.3 (30.3 to 40.3)	42.9 (38 to 47.9)	**0.010**
>High school diploma (%)	64.7 (59.7 to 69.7)	57.1 (52.1 to 62)	
Income‡			
<3 times the poverty rate (%)	50.6 (45.8 to 55.4)	55.2 (48.9 to 61.6)	0.159
≥3 times the poverty rate (%)	49.4 (44.6 to 54.2)	44.8 (38.4 to 51.1)	
Food security§			
Full food security (%)	74.5 (71.8 to 77.3)	68.8 (63.2 to 74.5)	**0.046**
Marginal to very low food security (%)	25.5 (22.7 to 28.2)	31.2 (25.5 to 36.8)	
Routine place to go for healthcare (%)	81.5 (79.6 to 83.4)	92.1 (89.8 to 94.3)	**<0.001**
Diabetes			
Self-reported diabetes (%)		64.6 (60.5 to 68.8)	
Time since diagnosis (years)		7.1 (6.5 to 7.7)	
Medication use			
Insulin use (%)		34.0 (29.4 to 38.7)	
Any diabetes medication (%)		61.8 (57.3 to 66.2)	
Blood pressure			
Systolic blood pressure (mm Hg)	120.5 (119.8 to 121.2)	130.5 (128.9 to 132.2)	**<0.001**
Diastolic blood pressure (mm Hg)	68.9 (68.2 to 69.6)	69.5 (68.4 to 70.7)	0.269
Hypertensive (%)	29.9 (27.5 to 32.3)	68.2 (63.1 to 73.2)	**<0.001**
Cholesterol			
HDL (mg/dL)	55.8 (54.9 to 56.6)	49.8 (48.3 to 51.3)	**<0.001**
LDL (mg/dL)	113.4 (111.9 to 114.8)	105.9 (102.8 to 108.9)	**<0.001**
Total cholesterol (mg/dL)	190.9 (189.2 to 192.6)	185.3 (181.1 to 189.5)	**0.012**
Triglycerides (mg/dL)	109.7 (106.6 to 112.9)	152.6 (138.2 to 167.0)	**<0.001**

Bold text indicates statistical significance at the $P < 0.05$ level.
*Values are percent or means (95% CIs).
†Data missing for two participants.
‡Data available for 92.4% of participants.
§Data available for 98.4% of participants.
HDL, high-density lipoprotein; LDL, low-density lipoprotein; NHANES, National Health and Nutrition Examination Survey.

for micronutrients and fiber was performed by dividing absolute intake by total energy intake and multiplying by 2000 to obtain intake per 2000 kcal.

The main analysis compared energy-adjusted dietary intakes of those with and without diabetes. Secondary analyses compared absolute dietary intakes of those with and without diabetes and absolute and energy-adjusted dietary intakes by the categories of HbA1c level described above. Pairwise comparisons were performed only after a statistically significant global test. Subgroup analyses

Table 2 Demographic and medical characteristics by glycemic level of non-pregnant adults 20+ years old from NHANES 2013–2016*

	No diabetes	Pre-diabetes		Diabetes		
	HbA1c<5.7%	HbA1c≥5.7% and <6.5%	HbA1c<6.5%	HbA1c≥6.5% and <9.0%	HbA1c≥9.0%	P value (ANOVA)
n (unweighted)	2422	928	417	405	125	
Sex						
Male (%)	48.8 (46.8 to 50.8)	45.8 (41.3 to 50.3)	49.5 (43.3 to 55.7)	53.2 (46.3 to 60.2)	55.3 (41.9 to 68.7)	0.448
Female (%)	51.2 (49.2 to 53.2)	54.2 (49.7 to 58.7)	50.5 (44.3 to 56.7)	46.8 (39.8 to 53.7)	44.7 (31.3 to 58.1)	
Age (years)	42.9 (41.8 to 44.0)	54.7 (53.1 to 56.3)	58.8 (57.3 to 60.4)	60.9 (59.3 to 62.4)	53.2 (50.6 to 55.8)	**<0.001**
Race						
Non-Hispanic white (%)	68.9 (63.4 to 74.4)	57.2 (50.9 to 63.5)	68.6 (61.1 to 76.2)	66.7 (59.5 to 73.9)	43.9 (29.5 to 58.3)	**0.003**
Non-Hispanic black (%)	8.7 (6.1 to 11.4)	18.0 (13.5 to 22.6)	11.1 (7.7 to 14.5)	13.5 (8.4 to 18.5)	20.0 (13.6 to 26.4)	
Mexican American (%)	8.1 (5.6 to 10.6)	9.5 (5.7 to 13.4)	7.8 (4.0 to 11.6)	8.4 (4.8 to 12.0)	16.4 (8.8 to 24.1)	
Other (%)	14.3 (11.6 to 16.9)	15.3 (12.4 to 18.2)	12.4 (7.8 to 17.1)	11.4 (7.9 to 15)	19.7 (10.6 to 28.7)	
Education†						
≤High school diploma (%)	33.0 (27.6 to 38.4)	43.6 (38.5 to 48.7)	39.0 (33.3 to 44.7)	46.2 (39 to 53.4)	47.2 (36.0 to 58.4)	**<0.001**
>High school diploma (%)	67.0 (61.6 to 72.4)	56.4 (51.3 to 61.5)	61.0 (55.3 to 66.7)	53.8 (46.6 to 61.0)	52.8 (41.6 to 64.0)	
Income‡						
<3 times the poverty rate (%)	49.2 (44.4 to 53.9)	56.0 (48.9 to 63.1)	54.8 (48.0 to 61.6)	52.5 (43.0 to 62.0)	67.1 (52.9 to 81.3)	0.065
≥3 times the poverty rate (%)	50.8 (46.1 to 55.6)	44.0 (36.9 to 51.1)	45.2 (38.4 to 52.0)	47.5 (38.0 to 57.0)	32.9 (18.7 to 47.1)	
Food security§						
Full food security (%)	75.1 (72.2 to 78.0)	72.4 (68.4 to 76.4)	74.3 (68.6 to 80.1)	67.8 (59.7 to 76.0)	49.1 (34.0 to 64.1)	**0.010**
Marginal to very low food security (%)	24.9 (22.0 to 27.8)	27.6 (23.6 to 31.6)	25.7 (19.9 to 31.4)	32.2 (24.0 to 40.3)	50.9 (35.9 to 66.0)	
Routine place to go for healthcare (%)	80.3 (78.1 to 82.6)	85.9 (84.0 to 87.9)	89.6 (85.9 to 93.2)	96.3 (94.1 to 98.5)	86.8 (79.7 to 93.9)	**<0.001**
Diabetes¶						
Insulin use (%)			8.2 (3.9 to 12.5)	58.1 (47.2 to 68.9)	78.7 (70.4 to 86.9)	**<0.001**
Any diabetes medication (%)			40.6 (32.7 to 48.5)	79.7 (72.9 to 86.4)	83.1 (76.3 to 89.9)	**<0.001**
Time since diagnosis (years)			3.8 (2.8 to 4.8)	9.6 (8.3 to 10.8)	10.9 (9.1 to 12.8)	**<0.001**
Blood pressure						
Systolic blood pressure (mm Hg)	118.9 (118.1 to 119.7)	126.3 (125.1 to 127.6)	128.4 (126.1 to 130.6)	132.7 (129.9 to 135.5)	131.4 (126.2 to 136.6)	**<0.001**
Diastolic blood pressure (mm Hg)	68.7 (67.8 to 69.5)	69.8 (68.4 to 71.1)	68.1 (66.4 to 69.7)	69.7 (67.9 to 71.5)	74.9 (73.0 to 76.8)	**<0.001**
Hypertensive (%)	24.9 (21.9 to 27.8)	47.9 (43.0 to 52.9)	66.8 (60.3 to 73.2)	71.1 (63.2 to 78.9)	63.2 (52.8 to 73.7)	**<0.001**
Cholesterol						
HDL (mg/dL)	56.5 (55.5 to 57.4)	53.1 (51.6 to 54.7)	52.4 (49.8 to 54.9)	48.2 (46.0 to 50.4)	45.0 (42.2 to 47.8)	**<0.001**
LDL (mg/dL)	111.8 (109.8 to 113.7)	119.4 (116.7 to 122.0)	108.6 (104.5 to 112.8)	99.6 (93.6 to 105.6)	118.3 (107.9 to 128.8)	**<0.001**

Continued

Table 2 Continued

	No diabetes	Pre-diabetes	Diabetes			
	HbA1c<5.7%	HbA1c≥5.7% and <6.5%	HbA1c<6.5%	HbA1c≥6.5% and <9.0%	HbA1c≥9.0%	P value (ANOVA)
Total cholesterol (mg/dL)	189.1 (186.8 to 191.3)	197.6 (194.2 to 200.9)	188.2 (182.3 to 194.1)	178.2 (171.1 to 185.2)	199.7 (186.8 to 212.6)	**<0.001**
Triglycerides (mg/dL)	105.6 (101.7 to 109.4)	124.8 (118.1 to 131.5)	137.0 (124.4 to 149.6)	158.0 (131.3 to 184.8)	198.1 (154.6 to 241.5)	**<0.001**

Bold text indicates statistical significance at the P < 0.05 level.
*Values are percent or means (95% CIs).
†Data missing for two participants.
‡Data available for 92.4% of participants.
§Data available for 98.4% of participants.
¶P values for diabetes groups only.
ANOVA, analysis of variance; HbA1c, glycohemoglobin A1c; HDL, high-density lipoprotein; LDL, low-density lipoprotein; NHANES, National Health and Nutrition Examination Survey.

were performed by stratifying by, but not adjusting for, age, race, and sex for both absolute and energy-adjusted intake. An additional subgroup analysis was performed comparing those with prior knowledge of their diabetes status (self-reported diagnosis, use of insulin, or use of other diabetes medication) at the time of the examination compared with those diagnosed during the examination.

RESULTS

Baseline characteristics

There were 947 individuals with diabetes, representing 17.5% of the unweighted study population. Compared with those without diabetes, those with diabetes were older, less likely to have more than a high school diploma (table 1). Those with diabetes were less likely to have full food security, and more likely to have a routine place to go for healthcare. Those with diabetes had higher systolic, but not diastolic blood pressure, and were more likely to have hypertension. Those with diabetes had lower HDL, LDL, and total cholesterol, but higher triglycerides. About two-thirds of those with diabetes had a self-reported diagnosis of diabetes, the others mainly had a laboratory test (fasting blood glucose, OGTT, or HbA1c) consistent with diabetes. Nearly two-thirds of persons with diabetes self-reported use of at least one diabetes medication, and about a third reported using insulin.

Among those with diabetes, those with an HbA1c greater than 9.0% were different from those with HbA1c less than 6.5% on several dimensions (table 2). Those with an HbA1c greater than 9.0% had longer disease duration, were twice as likely to report using some diabetes medication, and nearly 10 times more likely to report using insulin than those with an HbA1c less than 6.5%. They were younger, less likely to be white, and less likely to have full food security than those with an HbA1c less than 6.5%. Those with an HbA1c greater than 9.0% had lower HDL, and higher LDL, total cholesterol, and triglycerides than those with an HbA1c less than 6.5%.

Dietary intake

There were no significant differences in energy-adjusted macronutrient intake between those with and without diabetes (table 3). Both groups consumed about 16% of calories from protein, 35% of calories from fat, and 47% of calories from total carbohydrates. In both groups, total sugar accounted for about 20% of calories, and unsaturated fat accounted for about 20% of calories. Both groups consumed about 16 g of fiber per 2000 kcal. Those with diabetes consumed about 7% more calcium (988 mg/day) and about 5% more sodium (3607 mg/day) than those without diabetes (p=0.033 and 0.026, respectively). Among those with diabetes, those with an HbA1c greater than 9.0% consumed about 4% less magnesium than those with an HbA1c less than 6.5% and had a significantly lower overall HEI-2015 diet score (table 4). There were no consistent, statistically significant, or clinically relevant differences in absolute dietary

Table 3 Energy-adjusted dietary intake by diabetes status in non-pregnant adults 20+ years old from NHANES 2013–2016 crude and adjusted for age, race, and sex*

	Crude			Adjusted (age, race, sex)		
	No diabetes	**Diabetes**	**P value**	**No diabetes**	**Diabetes**	**P value**
n (unweighted)	3352	947		3352	947	
Energy (kcal/day)	2178 (2133 to 2223)	2018 (1932 to 2105)	**0.005**	2195 (2153 to 2236)	2115 (2027 to 2204)	0.131
Protein (% kcal)	16.0 (15.7 to 16.4)	16.2 (15.7 to 16.8)	0.514	16.0 (15.7 to 16.4)	16.3 (15.7 to 16.9)	0.543
Total carbohydrates (% kcal)	47.1 (46.5 to 47.6)	46.8 (45.9 to 47.7)	0.625	47.1 (46.5 to 47.7)	46.9 (45.9 to 47.9)	0.699
Total sugar (% kcal)	20.4 (19.8 to 21.0)	19.4 (18.2 to 20.6)	0.137	20.4 (19.8 to 21.0)	19.5 (18.2 to 20.9)	0.236
Fiber (g/2000 kcal)	16 (16 to 17)	17 (16 to 18)	0.160	16 (16 to 17)	16 (15 to 17)	0.666
Fat (% kcal)	35.0 (34.7 to 35.4)	35.8 (34.9 to 36.7)	0.079	34.9 (34.6 to 35.3)	35.3 (34.5 to 36.2)	0.363
Saturated fat (% kcal)	11.4 (11.2 to 11.6)	11.6 (11.3 to 12.0)	0.142	11.4 (11.2 to 11.5)	11.6 (11.3 to 12.0)	0.150
Monounsaturated fat (% kcal)	12.3 (12.1 to 12.4)	12.6 (12.2 to 12.9)	0.105	12.2 (12.1 to 12.4)	12.3 (11.9 to 12.6)	0.946
Polyunsaturated fat (% kcal)	8.1 (7.9 to 8.3)	8.3 (8.0 to 8.6)	0.293	8.1 (7.9 to 8.2)	8.1 (7.7 to 8.5)	0.860
Cholesterol (mg/2000 kcal)	280 (270 to 291)	305 (285 to 325)	**0.035**	280 (270 to 290)	296 (274 to 318)	0.196
Calcium (mg/2000 kcal)	922 (894 to 951)	969 (913 to 1025)	0.122	921 (896 to 946)	988 (930 to 1045)	**0.033**
Potassium (mg/2000 kcal)	2539 (2483 to 2594)	2687 (2592 to 2783)	**0.015**	2513 (2459 to 2567)	2513 (2412 to 2614)	0.994
Magnesium (mg/2000 kcal)	294 (286 to 302)	296 (285 to 308)	0.739	292 (285 to 300)	284 (272 to 295)	0.266
Sodium (mg/2000 kcal)	3420 (3351 to 3488)	3548 (3429 to 3667)	0.102	3425 (3359 to 3492)	3607 (3475 to 3740)	**0.026**
Overall HEI-2015 diet score†	44.2 (43.4 to 45.0)	44.1 (42.8 to 45.4)	0.828	44.0 (43.2 to 44.8)	42.2 (40.7 to 43.7)	**0.021**

Bold text indicates statistical significance at the $P < 0.05$ level.
*Values are means (95% CIs).
†Range=0 (worst) to 100 (best).
HEI-2015, Healthy Eating Index-2015; NHANES, National Health and Nutrition Examination Survey.

Table 4 Energy-adjusted dietary intake by glycemic level in non-pregnant adults 20+ years old from NHANES 2013–2016 adjusted for age, race, and sex*

	No diabetes	Pre-diabetes	Diabetes			
	HbA1c<5.7%	HbA1c≥5.7% and <6.5%	HbA1c<6.5%	HbA1c≥6.5% and <9.0%	HbA1c≥9.0%	P value (ANOVA)
n (unweighted)	2422	928	417	405	125	
Energy (kcal/day)	2189 (2142 to 2235)	2216 (2132 to 2300)	2095 (1978 to 2213)	2151 (1997 to 2305)	2094 (1918 to 2269)	0.556
Protein (% kcal)	16.1 (15.6 to 16.5)	15.9 (15.4 to 16.4)	16.2 (15.4 to 17.1)	16.0 (15.4 to 16.6)	17.2 (15.9 to 18.5)	0.440
Total carbohydrates (% kcal)	46.9 (46.2 to 47.6)	47.9 (46.7 to 49.0)	46.3 (45.2 to 47.3)	48.3 (46.9 to 49.7)	45.6 (43.2 to 48.1)	0.051
Total sugar (% kcal)	20.2 (19.5 to 20.9)	21.1 (20.1 to 22.1)	20.2 (19.1 to 21.3)	19.1 (17.4 to 20.8)	19.4 (16.3 to 22.5)	0.098
Fiber (g/2000 kcal)	16 (16 to 17)	15 (15 to 16)	16 (15 to 17)	16 (15 to 17)	15 (13 to 18)	0.209
Fat (% kcal)	34.9 (34.6 to 35.3)	35.0 (34.1 to 36.0)	35.0 (33.9 to 36.1)	35.3 (34.0 to 36.6)	36.8 (34.7 to 38.9)	0.493
Saturated fat (% kcal)	11.3 (11.1 to 11.5)	11.7 (11.2 to 12.1)	11.7 (11.2 to 12.3)	11.5 (11.0 to 12.1)	12.0 (11.1 to 12.8)	0.203
Monounsaturated fat (% kcal)	12.3 (12.1 to 12.4)	12.1 (11.7 to 12.5)	12.1 (11.6 to 12.5)	12.2 (11.7 to 12.7)	13.1 (12.2 to 14.0)	0.174
Polyunsaturated fat (% kcal)	8.1 (7.9 to 8.3)	8.0 (7.7 to 8.3)	7.8 (7.4 to 8.3)	8.3 (7.8 to 8.9)	8.2 (7.6 to 8.9)	0.268
Cholesterol (mg/2000 kcal)	277 (264 to 290)	290 (272 to 308)	296 (266 to 326)	296 (267 to 324)	309 (270 to 348)	0.610
Calcium (mg/2000 kcal)	927 (896 to 958)	899 (869 to 929)	1016 (927 to 1104)	972 (884 to 1060)	905 (821 to 989)	0.124
Potassium (mg/2000 kcal)	2527 (2473 to 2581)	2461 (2372 to 2550)	2515 (2398 to 2633)	2492 (2331 to 2653)	2516 (2360 to 2673)	0.639
Magnesium (mg/2000 kcal)	297 (288 to 305)	275 (265 to 285)	283 (268 to 298)	282 (268 to 297)	272 (246 to 299)	**0.007**
Sodium (mg/2000 kcal)	3412 (3341 to 3482)	3476 (3352 to 3600)	3521 (3362 to 3680)	3678 (3482 to 3874)	3771 (3492 to 4051)	0.144
Overall HEI-2015 diet score†	44.6 (43.7 to 45.6)	41.5 (40.2 to 42.8)	42.1 (40.4 to 43.8)	42.4 (40.4 to 44.3)	39.0 (37.0 to 41.1)	**0.001**

Bold text indicates statistical significance at the $P < 0.05$ level.
*Values are means (95% CIs).
†Range=0 (worst) to 100 (best).
ANOVA, analysis of variance; HbA1c, glycohemoglobin A1c; HEI-2015, Healthy Eating Index-2015; NHANES, National Health and Nutrition Examination Survey.

intake between those with and without diabetes or across levels of HbA1c (online supplemental tables 1–3). Further adjustment for education, access to healthcare, and duration of diabetes yielded similar results as adjusting for age, race, and sex alone (online supplemental table 1). Those with diabetes had a lower overall HEI-2015 diet score than those without diabetes.

Subgroup analysis

Men with diabetes consumed fewer calories, carbohydrates (specifically sugar), and less magnesium overall compared with men without diabetes (online supplemental table 4). Men with diabetes had higher energy-adjusted cholesterol and potassium intake than men without diabetes. Women with diabetes consumed fewer calories, potassium, and magnesium overall compared with women without diabetes. Women with diabetes did not have statistically significantly different energy-adjusted macronutrient and micronutrient intake than women without diabetes. There were no consistent differences in dietary intake (absolute or energy adjusted) comparing those with and without diabetes by age group or race (online supplemental tables 5–8). Among those with diabetes, there were no consistent differences in dietary intake (absolute or energy adjusted) or diet quality comparing those with and without prior knowledge of their diabetes status (online supplemental table 9).

DISCUSSION

In this nationally representative sample, there were no substantial or consistent differences in the dietary intake of macronutrients or micronutrients between US adults with and without diabetes. Similarly, macronutrient intake did not vary consistently by HbA1c level or by diabetes status within strata of age, race, and sex. Furthermore, we did not find significant differences in carbohydrate intake (total carbohydrates, sugar, or fiber) between those with or without diabetes. These results suggest that those with diabetes are not consuming significantly different macronutrients or micronutrients than those without diabetes. However, those with diabetes had lower diet quality and were less likely to have full food security with fewer than half of those with HbA1c>9.0% having full food security.

To our knowledge, we provide the first report on direct comparisons between the diets of those with and without diabetes among US adults. An analysis of longitudinal dietary trends from 1988 to 2012 using NHANES showed that, over the last few decades, patients both with and without diabetes consumed less fiber and more sodium, calcium, and cholesterol.[17] A recent systematic review analyzed 11 studies (after screening roughly 12 000) and found that those with diabetes do not meet recommendations for specific food groups.[5] They consumed, on average, 0.5–2.5 servings a day under the nationally recommended amounts of fruits, vegetables, dairy, and grains and more than a serving a day over the recommended amounts of meat.[5]

Strengths of this study include the use of a large, nationally representative survey. This allowed analysis of dietary intake both by diabetes status and across the spectrum of diabetes based on HbA1c. In the overall analyses, as well as subgroup analyses, there was adequate statistical power as indicated by small CIs around mean estimates. This study also has several limitations. First, NHANES does not distinguish between type 1 and type 2 diabetes. However, in the USA, approximately 90%–95% of patients with diabetes have type 2 diabetes.[18] Hence, we report the dietary intake of adults with diabetes. Second, we analyzed mean estimates of intake using a single dietary recall, rather than individuals' usual intake. Third, given that NHANES is a cross-sectional survey, we were unable to evaluate changes in diet before and after the diagnosis of diabetes. However, among those with diabetes, there were not consistent differences in the diets among those with and without knowledge of their diabetes status at the NHANES examination.

Future studies should incorporate community-level food environment data to understand the contribution of access to nutrient-dense foods to dietary patterns among people with and without diabetes. Also, longitudinal studies could be valuable to track if the diets of those with diabetes significantly change after diagnosis.[19] Our study also highlights the importance of including persons with diabetes in dietary intervention studies, to ensure that broad population-based recommendations reflect the needs of this group.

While previous dietary recommendations were often nutrient focused, both the ADA and the USDA's recent recommendations increasingly focus on a broader approach.[1–3] These results further support this general approach to encourage a variety of healthful eating patterns emphasizing a variety of options, rather than a prescriptive diabetes-specific diet.[1 3] Implementing this approach in the population will likely require enhanced targeted efforts to improve the dietary intake of persons with diabetes, as well as broad efforts to improve the dietary intake of the general population.

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