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Changes in Nutrient Intake and Dietary Quality among Participants with Type 2 Diabetes Following a Low-Fat Vegan Diet or a Conventional Diabetes Diet for 22 Weeks

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ABSTRACT

Background Although vegan diets improve diabetes management, little is known about the nutrient profiles or diet quality of individuals with type 2 diabetes who adopt a vegan diet.

Objective To assess the changes in nutrient intake and dietary quality among participants following a low-fat vegan diet or the 2003 American Diabetes Association dietary recommendations.

Design A 22-week randomized, controlled clinical trial examining changes in nutrient intake and diet quality.

Subjects/setting Participants with type 2 diabetes (n=99) in a free-living setting.

Research design and methods Participants were randomly assigned to a low-fat vegan diet or a 2003 American Diabetes Association recommended diet.

Main outcome measures Nutrient intake and Alternate Healthy Eating Index (AHEI) scores were collected at baseline and 22 weeks.

Statistical analyses performed Between-group t tests were calculated for changes between groups and paired comparison t tests were calculated for changes within-group. Pearson's correlation assessed relationship of AHEI score to hemoglobin A1c and body weight changes.

Results Both groups reported significant decreases in energy, protein, fat, cholesterol, vitamin D, selenium, and sodium intakes. The vegan group also significantly reduced reported intakes of vitamin B-12 and calcium, and significantly increased carbohydrate, fiber, total vitamin A activity, beta carotene, vitamins K and C, folate, magnesium, and potassium. The American Diabetes Association recommended diet group also reported significant decreases in carbohydrate and iron, but reported no significant increases. The vegan group significantly improved its AHEI score ($P<0.0001$), while the American Diabetes Association recommended diet group did not ($P=0.7218$). The difference in AHEI score at 22 weeks between groups was significant ($P<0.0001$). With both groups combined, AHEI score was negatively correlated with both changes in hemoglobin A1c value ($r=-0.24$, $P=0.016$) and weight ($r=-0.27$, $P=0.007$).

Conclusions Vegan diets increase intakes of carbohydrate, fiber, and several micronutrients, in contrast with the American Diabetes Association recommended diet. The vegan group improved its AHEI score whereas the American Diabetes Association recommended diet group's AHEI score remained unchanged.

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Vegetarian diets are associated with reduced risk of some cancers (1-5), heart disease (6), type 2 diabetes (4,7), and overweight (8,9). Most research on the nutrient intake of vegetarian diets has focused on self-selected, long-term vegetarians. Less is known about the nutritional changes of individuals during the transition to a vegetarian or vegan diet. Furthermore, because a vegetarian or vegan diet has been shown to be helpful in managing diabetes (10,11) and heart disease (2), as well as reducing plasma cholesterol concentrations (11,12) and body weight (13), it is important to assess the nutrient effects of such a diet in comparison with more conventional therapeutic regimens used for these conditions. The nutrient intake of individuals adopting a therapeutic vegan diet has been studied in clinical trials related to prostate cancer (14), weight loss (15), and heart disease/cholesterol-lowering (2,11). Little is known about the nutrient profiles of individuals with diabetes adopting a low-fat vegan diet and how this diet's nutrient profile compares to the dietary recommendations set forth by the American Diabetes Association (16) for people with type 2 diabetes.

The overall diet quality of vegan diets compared to other therapeutic diets has not been measured. Several diet quality indexes are available, including the Healthy Eating Index (HEI) (17), Recommended Food Score (18), and the Alternate Healthy Eating Index (AHEI) (19). These indexes estimate chronic disease risk based on several dietary behaviors. The HEI, one of the first and most widely used indexes of overall healthful nutrition, is only weakly correlated with chronic disease risk (20,21). Therefore, researchers have developed alternatives to the HEI. The AHEI has been shown to be a better predictor of risk of cardiovascular disease and other major chronic diseases (22), compared with the HEI, and a better predictor of the occurrence of inflammation (23) than the HEI or Recommended Food Score. The AHEI is a nine component dietary index used to rate foods and macronutrients related to chronic disease risk. Using dietary intake, researchers can use the AHEI to produce a dietary score ranging from 2.5 to 87.5 (19).

Therefore, a group of individuals with type 2 diabetes who followed a low-fat, vegan diet or the 2003 dietary recommendations of the American Diabetes Association was studied. Because a vegan diet has been shown to be effective in the treatment of diabetes (10), it is therefore important to examine the nutrient adequacy and quality of this diet. A diet used to treat one chronic disease (eg, type 2 diabetes) should ideally be effective at preventing other chronic diseases (eg, cardiovascular disease) as well and should also provide adequate macro- and micronutrients. The goal of this research was to examine the nutritional adequacy and quality of a low-fat vegan diet compared to the dietary recommendations of the American Diabetes Association.

MATERIALS AND METHODS

Participants

The methods have been described elsewhere (10). Briefly, 99 men and women with type 2 diabetes (fasting plasma glucose concentration >124.2 mg/dL (6.9 mmol/L) on two occasions or a prior diagnosis of type 2 diabetes with the use of hypoglycemic medications for ≥6 months) were recruited to participate in a study examining the effect of a low-fat, low-glycemic-index vegan diet on hemoglobin A1c levels. Participants were recruited through newspaper advertisements in the Washington, DC, area. Exclusion criteria included a hemoglobin A1c level of <6.5% or >10.5%, current smoking, drug or alcohol abuse, insulin use >5 years, pregnancy, current use of a low-fat vegetarian diet, or an unstable medical status. The study protocol was approved by the George Washington University Institutional Review Board and all participants provided written, informed consent.

Diets, Assessment, and Instruction

Participants were randomly assigned to the vegan diet or a diet that followed 2003 American Diabetes Association guidelines. The vegan diet consisted of grains, fruit, vegetables, and legumes. Participants were instructed to avoid animal products, limit high-fat foods, and favor foods with a low glycemic index value. There were no restrictions on portion sizes or energy intake.

The American Diabetes Association diet was individualized, based on body weight and lipid profile, according to 2003 American Diabetes Association guidelines. American Diabetes Association participants who were overweight (body mass index ≥25) were prescribed a diet with an energy deficit of 500 to 1,000 kcal. The exchange system was used to provide the recommended energy and carbohydrate and saturated fat grams each participant required. Each meal plan was individualized to the participant's current food and eating habits. Neither group received prepared meals. Rather, participants prepared foods at home and/or ate at restaurants. Participants were asked to maintain baseline levels of physical activity for 22 weeks.

Before randomization, participants completed a practice 3-day weighed dietary record that included 1 weekend day and 2 weekdays, which was reviewed by a registered dietitian (RD). Participants then completed a baseline food record. After randomization, participants met individually with an RD experienced in the use of the assigned diet to develop individualized meal plans. Participants then met with their assigned diet groups, led by an RD and physician, each week for 1 hour for discussions, cooking demonstrations, and meal planning. Meeting topics were similar for both groups and included tips on eating out, healthful cooking ideas, finding support from friends and family, grocery store tours, and problem-solving activities. Meetings continued for 22 weeks. Participants completed additional 3-day dietary records at 11 and 22 weeks. All participants were provided with a vitamin B-12 supplement (100 μg) to be taken every other day and were asked to limit alcohol intake to two drinks per day for men or one drink per day for women. Participants were asked if they had regularly taken their vitamin B-12 supplement when they were called on their last dietary recall.

Dietary Adherence

Adherence to the diet was assessed based on 22-week dietary records and 24-hour recalls that were conducted by telephone by an RD at Week 4, 8, 13, and 20 (one per week). Participants were unaware of when the calls were going to be made. The study RD used the multiple-pass method to collect the recalls. Vegan participants were considered adherent if they reported an absence of animal products on recalls and 22-week food records, as well as saturated fat intake ≤5% of energy, total fat intake ≤25%, and cholesterol intake of ≤50 mg on their 22-week food records. American Diabetes Association diet participants were considered adherent if they had an average daily energy intake of no more than 200 kcal in excess of their prescribed intakes and saturated fat intake ≤10% of energy on their 22-week food records. Individuals who attended fewer than 10 of the 22 weekly meetings were considered nonadherent on either diet. A Nutrition Coordinating Center-certified RD analyzed all 3-day dietary records and diet recalls using Nutrition Data System for Research software version 5.0 (Food and Nutrient Database 35, 2004, Nutrition Coordinating Center, University of Minnesota, Minneapolis) (24). Quality control was conducted for both the dietary records and recalls. For the food records, a second RD reviewed the food records compared to what was entered into the nutrient database. Discrepancies were addressed and missing foods were added. A second RD also reviewed the dietary recalls for any data entry issues related to portion sizes or amounts.

Nutrient Intake and Other Measures

Nutrient intake at baseline and 22 weeks was calculated from the 3-day food records, averaging values for each 3-day period. AHEI scores were calculated for each participant based on food categories, including vegetables (servings per day), fruit (servings per day), nuts and soy protein (servings per day), ratio of white to red meat (grams), cereal fiber (grams per day), trans fat (percent of energy), and ratio of polyunsaturated to saturated fatty acids (grams). Each of these categories received a score ranging from zero to 10 (19). Although baseline multivitamin use was obtained, duration of multivitamin use was not and supplement use was not collected at 22 weeks. Alcohol use was not included in the analysis, because both groups received the same recommendations (ie, limiting alcohol intake to one drink or equivalent per day for women and two per day for men). These variables were not expected to vary according to diet group. Dietary supplement use was excluded from both the nutrient and AHEI analyses.

Other measures, such as demographic data, hemoglobin A1c, lipid levels, blood pressure, urinary albumin, weight, medication use, hip and waist circumference, and physical activity, were measured at baseline and 22 weeks and have been reported elsewhere (10). Hemoglobin A1c was obtained after a 12-hour fast and was assayed at baseline, 11 weeks, and 22 weeks. At the same time points, body weight was determined in a paper gown, without shoes using a digital scale accurate to 0.1 kg. During the 22-week study, the research endocrinologist adjusted diabetes medications in cases of hypoglycemia, as previously reported (10).

Statistical Methods

A power analysis was conducted using an 80% chance of detecting a significant 1.5% between-group difference in hemoglobin A1c and revealed a need for 49 participants per group. Between-group t tests were calculated for each measure to determine whether the changes associated with the vegan diet were different than those associated with the American Diabetes Association diet. Within each diet group, paired comparison t tests were calculated to test whether the changes from baseline to 22 weeks were significantly different from zero. The primary analysis of the main endpoint was based on intention-to-treat and included all participants. In cases where participants did not complete 22-week dietary records, baseline values were brought forward. An α of .05 was used for all statistical tests, with no adjustment for multiple comparisons. Pearson's correlation assessed whether changes in AHEI score were significantly correlated with hemoglobin A1c and body weight changes for all participants together and for each diet group. SAS was used for all analyses (version 8.2, 2001, SAS Institute, Inc, Cary, NC).

RESULTS

Of 1,049 individuals screened by telephone, 99 met participation criteria. Of these participants, 49 were randomly assigned to the vegan group and 50 were assigned to the American Diabetes Association diet group. Baseline demographic information is reported in Table 1. At 22 weeks, complete nutrient data were available for 46 vegan participants and 42 American Diabetes Association diet group participants. An analysis limited to study completers did not substantially change the outcomes.

Adherence and medication changes and changes in hemoglobin A1c level and weight during the 22-week study are described elsewhere (10). Briefly, criteria for dietary adherence were met by 33 vegan (67%) and 22 American Diabetes Association ADbA diet (44%) participants. Diabetes medication changes (primarily because of hypoglycemia) were reported by 21 vegan (43%) and 13 American Diabetes Association diet (26%) participants. Among all participants, hemoglobin A1c value dropped 0.96 percentage points in the vegan group and 0.56 points in the American Diabetes Association diet group (P=0.089). Among those participants without a medication change, the vegan group saw a significant decrease in hemoglobin A1c value compared to the American Diabetes Association group (−1.23 vs −0.38 points, respectively; P=0.01). There was also a significant decrease in weight among the vegan group as compared to the American Diabetes Association diet group (−6.5 kg vs −3.1 kg, respectively; P<0.01).

Nutrient Intake at Baseline and 22 Weeks

There was no significant difference in nutrient intake between groups at baseline. The vegan group reduced mean reported intake of energy, protein, fat (total, saturated, monounsaturated, polyunsaturated, and *trans*), cholesterol, vitamins D and B-12, calcium, selenium, and sodium. The group increased mean reported intake of carbohydrate, soluble and insoluble fiber, total vitamin A

Table 1. Baseline demographic data for vegan and American Diabetes Association (ADbA) diet group participants in a study of nutrient intake and dietary quality among persons with type 2 diabetes

Characteristic	Vegan group (n=49)	ADbA group (n=50)	*P* value[a]
	← *mean (range)* →		
Age (y)	56.7 (35-82)	54.6 (27-80)	0.29
	← *n (%)* →		
Sex			0.26
Male	22 (45)	17 (34)	
Female	27 (55)	33 (66)	
Race, ethnicity			0.71[b]
Black, non-Hispanic	22 (45)	22 (44)	
White, non-Hispanic	21 (43)	22 (44)	
White, Hispanic	4 (8)	2 (4)	
Asian, non-Hispanic	2 (4)	4 (8)	
Marital status			0.08
Not married	20 (41)	26 (52)	
Married	29 (59)	24 (48)	
Education			0.69
High school, partial or graduate	6 (12)	3 (6)	
College, partial or graduate	26 (53)	25 (50)	
Graduate degree	17 (35)	22 (44)	
Occupation			0.04
Service occupation	3 (6)	7 (14)	
Technical, sales, administrative	16 (33)	18 (36)	
Professional or managerial	15 (31)	21 (42)	
Retired	15 (31)	4 (8)	
Mean body mass index	33.9	35.9	0.18

[a]*P* values refer to *t* test for continuous variables and χ^2 for categorical variables.
[b]*P* value calculated for race distribution; for ethnicity (Hispanic vs non-Hispanic), *P*=0.39.

activity, beta carotene, vitamins C and K, folate, magnesium, and potassium. The American Diabetes Association diet group reported significant reductions in energy, carbohydrate, protein, fat (total, saturated, monounsaturated, polyunsaturated, and *trans*), cholesterol, vitamin D, iron, selenium, and sodium. The American Diabetes Association diet group reported no significant increases in intake of any measured nutrient (Table 2).

The vegan group reduced its reported mean intake of total fat, *trans* fat, saturated fat, monounsaturated fatty acid, protein, cholesterol, and vitamin D to a greater degree than did the American Diabetes Association diet group (Table 2). There were also significant differences for carbohydrate, soluble and insoluble fiber, total vitamin A activity and beta carotene, folate, magnesium, iron, potassium, with the vegan group increasing intakes of these nutrients and the American Diabetes Association diet group decreasing or having no change in intakes. The vegan group increased vitamin C to a greater degree than did the American Diabetes Association diet group and the American Diabetes Association diet group reduced sodium intake to a greater degree, compared to the vegan group. There were no significant differences in changes in energy, polyunsaturated fatty acid (PUFA), vitamins E, K, B-6, and B-12, calcium, zinc, or selenium intake between groups.

To assess whether vegan and American Diabetes Association diet participants were meeting current Dietary Reference Intakes (DRI), 22-week data were divided by sex and compared to the DRI for the 51- to 70-year age reference group (Table 3). Both groups met recommended intakes for protein based on Estimated Average Requirement and ≥10% of total energy. Male and female vegan participants met Adequate Intakes for dietary fiber (30 g/day for men and 21 g/day for women) but the American Diabetes Association diet group did not. Both groups met DRI recommendations for vitamins A, K, C, B-6, and folate, iron, and selenium. Both male and female American Diabetes Association diet members and female vegan members met vitamin B-12 recommendations with vegan men consuming slightly less than recommended values (2.1±2.4 μg/day). Men and women in the vegan group did not meet zinc requirements whereas American Diabetes Association diet participants did. For magnesium, only female vegan participants met recommended intakes. Neither group met the DRI for vitamins D or E, calcium, or potassium and both groups exceeded the sodium recommendations.

AHEI

The vegan group improved in every AHEI food category, including significant increases in vegetable, fruit, nut and soy protein, and cereal fiber intakes; a decrease in *trans* fat intake; and an increase in the PUFA-to-saturated fat ratio (Table 4). These results were reflected in AHEI score categories as well. The American Diabetes Association diet group showed changes in one food group (in-

Table 2. Macro- and micronutrient unsupplemented dietary changes within and between vegan and American Diabetes Association (ADbA) diet groups at baseline and 22 weeks in a study of nutrient intake and dietary quality among persons with type 2 diabetes

Nutrient[b]	Vegan Group (n=49)			ADbA Group (n=50)			Mean effect size[d]	*P* value[a]
	Baseline	22 wk[c]	Difference	Baseline	22 wk[c]	Difference		
	mean±standard deviation							
Energy (kcal)	1,745.5±463.3	1,432.3±423.5	−313.2±411.6***	1,844.3±598.7	1,458.3±450.9	−385.9±498.5***	72.8 (−109.9 to 255.3)	0.43
Carbohydrate (g)	202.8±66.9	244.8±70.6	41.9±70.3***	210.0±71.8	169.5±57.0	−40.5±63.1***	82.5 (55.9 to 109.1)	<0.0001
Protein (g)	77.2±25.9	52.8±16.5	−24.4±25.1***	84.8±26.8	73.7±22.5	−11.0±22.9**	−13.4 (−22.9 to −3.8)	<0.0001
Total fat (g)	71.3±27.6	31.6±20.8	−39.6±32.1***	73.7±33.3	55.6±23.9	−18.1±28.8***	−21.5 (−33.7 to −9.3)	0.0001
Saturated fat (g)	23.5±10.1	6.8±6.1	−16.7±10.9***	22.9±11.5	15.9±7.3	−6.9±10.8***	−9.8 (−14.1 to −5.5)	<0.0001
Monounsaturated fat (g)	27.6±12.3	11.7±9.8	−15.9±15.6***	28.9±14.0	22.2±10.2	−6.8±11.6***	−9.2 (−14.7 to −3.7)	0.001
Polyunsaturated fat (g)	14.1±6.3	10.2±5.9	−3.9±7.2***	15.5±7.3	12.7±6.1	−2.8±6.5**	−1.1 (−3.8 to 1.6)	0.42
Trans fat (g)	4.4±2.8	1.6±1.9	−2.9±2.9***	4.3±2.8	2.9±2.2	−1.3±2.5***	−1.5 (−2.6 to −0.4)	0.007
Cholesterol (mg)	295.7±212.1	45.4±102.6	−250.3±221.9***	310.2±192.9	202.6±105.7	−107.6±167.5***	−142.7 (−221.0 to −64.4)	0.001
Total fiber (g)	18.9±6.5	35.4±14.4	16.4±12.4***	18.7±6.9	18.3±7.7	−0.4±7.4	16.9 (12.8 to 20.9)	<0.0001
Soluble fiber (g)	5.1±1.9	8.8±3.4	3.8±3.4***	4.8±1.8	4.7±2.1	−0.1±1.9	3.8 (2.7 to 4.9)	<0.0001
Insoluble fiber (g)	13.6±5.1	26.2±11.3	12.6±9.5***	13.7±5.4	13.5±5.9	−0.2±5.8	12.8 (9.7 to 15.9)	<0.0001
Total vitamin A activity (μg retinol equivalents)	1,273.9±1,621.2	1,442.2±1,381.9	168.3±2,160.4*	1,437.5±3,379.8	1,052.3±1,172.9	−385.2±3,843.2	553.5 (−770.9 to 702.0)	0.01
Beta carotene equivalents (μg)	4,502.1±4,562.3	7,387.9±5,740.5	2,885.8±7,284.8**	4,911.5±4,789.5	4,250.0±3,516.3	−661.5±4,999.5	3,547.3 (1,059.4 to 6,035.2)	0.006
Vitamin D (μg)	4.7±3.4	1.9±2.3	−2.8±3.7***	4.7±3.4	3.7±2.2	−0.9±3.2*	−1.8 (−3.2 to −0.4)	0.01
Vitamin E (mg)	9.8±19.2	10.6±19.1	0.8±4.2	7.7±4.3	7.8±6.2	0.1±6.5	0.8 (−1.4 to 2.9)	0.48
Vitamin K (μg)	148.4±139.2	272.8±293.0	124.3±290.8**	188.2±173.9	215.4±218.7	27.2±211.8	97.1 (−4.2 to 198.4)	0.06
Vitamin C (mg)	79.3±50.8	129.9±75.6	50.6±74.8***	86.4±51.5	92.9±67.3	6.6±66.5	44.0 (15.8 to 72.2)	0.002
Vitamin B6 (mg)	1.7±0.8	1.8±0.7	0.02±0.81	1.8±0.6	1.7±0.7	−0.01±0.9	0.02 (−0.31 to 0.37)	0.87
Dietary folate equivalents (μg)	597.9±409.9	701.8±338.3	103.9±440.8***	573.6±397.3	513.9±413.6	−59.7±568.9	163.6 (−67.8 to 279.1)	<0.0001
Vitamin B-12 (μg)	6.1±5.6	2.4±3.2	−3.8±5.9***	6.4±8.4	5.3±3.9	−1.1±8.7	−2.7 (−5.7 to 0.3)	0.07
Calcium (mg)	761.6±357.0	607.8±256.4	−153.8±350.1**	686.9±313.9	653.3±342.9	−33.7±332.0	−120.1 (−256.2 to 15.9)	0.08
Magnesium (mg)	278.3±124.9	364.2±117.3	85.9±132.6***	283.9±106.8	274.4±106.3	−9.5±95.7	95.5 (49.5 to 141.6)	<0.0001
Iron (mg)	15.7±8.1	16.8±5.8	1.1±8.2	15.3±5.8	13.5±5.6	−1.8±6.2*	2.9 (−0.01 to 5.8)	0.05
Zinc (mg)	11.7±7.2	8.3±3.5	−3.3±7.4**	11.0±5.3	9.7±3.9	−1.4±5.2	−1.9 (−4.5 to 0.6)	0.13
Selenium (μg)	113.6±40.3	73.9±27.7	−39.6±39.8***	130.1±70.9	108.3±43.2	−21.8±69.4*	−17.8 (−40.5 to 4.8)	0.12
Sodium (mg)	3,199.7±994.9	2,850.2±1,045.5	−349.5±925.1**	3,562.8±1,255.4	2,694.6±924.3	−868.2±1,131.5***	518.7 (105.9 to 931.5)	0.01
Potassium (mg)	2,413.3±720.0	2,816.6±836.6	403.3±779.5***	2,450.2±707.2	2,299.2±682.9	−151.0±699.1	554.3 (259.1 to 849.6)	0.0003

[a]*P* values are for *t* tests of comparisons of between-group (vegan vs ADbA diet) changes (baseline to 22 weeks).
[b]Dietary data was reported from 3-day food records.
[c]The 22-week data included all individuals with data at baseline (n=49 for the vegan group and n=50 for the ADbA group).
[d]Lower confidence level to upper confidence level. Monounsaturated fat.
**P*<0.05.
***P*<0.01.
****P*<0.001.
NOTE: Information from this table is available online at www.adajournal.org as part of a PowerPoint presentation.

Table 3. Twenty-two–week unsupplemented nutrient intake and Alternate Healthy Eating Index (AHEI) score by sex compared to current Dietary Reference Intake (DRI) recommendations for the 51- to 70-year age reference group among vegan and American Diabetes Association (ADbA) diet participants in a study of nutrient intake and dietary quality among persons with type 2 diabetes

	Vegan Group 22-Week Intake (n=49)		ADbA Group 22-Week Intake (n=50)		
Nutrient[a]	Men	Women	Men	Women	DRI
	← *mean±standard deviation* →				
Energy (kcal)	1,547.5±474.7	1,330.4±350.8	1,718.3±530.0	1,324.4±341.2	NA[b]
Carbohydrate (g)	256.7±81.2	234.3±59.4	186.3±73.4	160.8±45.4	130 g/d
Protein (g)	57.4±17.3 (14.8% of total energy)	48.7±14.9 (14.6% of total energy)	90.2±24.8 (21.0% of total energy)	65.3±15.9 (19.7% of total energy)	EAR[c] Men: 46 g/d, Women: 38 g/d AI[d] Men: 56 g/d, Women: 46 g/d; or 10% of total energy
Total fat (g)	35.6±22.9	28.1±18.5	66.5±24.9	50.0±21.7	NA
Saturated fat (g)	7.2±5.4	6.5±6.7	20.1±8.0	13.8±6.0	NA
Monounsaturated fat (g)	13.4±11.5	10.1±7.9	26.8±10.2	19.8±9.6	NA
Polyunsaturated fat (g)	11.7±7.5	8.7±4.0	13.8±7.1	12.1±5.5	NA
Trans fat (g)	1.5±1.4	1.6±2.3	3.3±2.1	2.8±2.2	NA
Cholesterol (mg)	37.6±80.3	52.3±120.2	257.4±101.1	174.4±97.8	NA
Total fiber (g)	37.4±15.1	33.5±13.9	18.0±7.7	18.5±7.8	Men: 30 g/d, Women: 21 g/d
Soluble fiber (g)	9.9±3.8	7.8±2.8	4.6±2.3	4.7±2.0	NA
Insoluble fiber (g)	21.2±11.7	25.3±11.2	13.2±5.8	13.7±6.1	NA
Total vitamin A Activity (μg retinol equivalents)	1,325.2±1,200.3	1,549.5±1,530.2	1,211.0±1,590.5	981.1±930.2	Men: 700 retinol equivalents/d, Women: 900 retinol equivalents/d
Beta carotene equivalents (μg)	6,780.5±5,476.3	7,925.2±6,020.0	4,228.6±3,302.9	4,261.0±3,671.3	NA
Vitamin D (mcg)	1.9±2.4	2.0±2.1	4.2±2.7	3.4±2.4	10 μg/d
Vitamin E (mg)	8.6±4.4	12.4±26.0	7.2±4.8	8.0±6.9	15 mg/d
Vitamin K (μg)	249.9±277.6	292.9±310.0	198.2±128.9	224.3±254.4	Men: 120 μg/d, Women: 90 μg/d
Vitamin C (mg)	115.6±76.5	142.6±73.8	92.3±73.8	93.3±65.0	Men: 90 mg/d, Women: 75 mg/d
Vitamin B-6 (mg)	1.8±0.7	1.8±0.7	1.7±0.5	1.8±0.8	Men: 1.7 mg/d, Women: 1.5 mg/d
Dietary folate equivalents (μg)	720.4±340.6	684.7±337.6	438.0±250.8	547.9±465.8	400 μg/d
Vitamin B-12 (μg)	2.1±2.4	2.6±3.8	7.0±5.0	4.4±2.8	2.4 μg/d
Calcium (mg)	630.2±252.8	587.9±262.9	726.0±391.5	615.8±314.5	1,200 mg/d
Magnesium (mg)	389.5±120.1	341.9±112.2	312.0±133.7	255.0±84.9	Men: 420 mg/d, Women: 320 mg/d
Iron (mg)	18.7±5.9	15.1±5.2	15.0±5.6	12.8±5.5	8 mg/d
Zinc (mg)	9.5±3.6	7.3±3.1	11.2±4.2	8.8±3.7	Men: 8 mg/d, Women: 11 mg/d
Selenium (μg)	79.5±28.6	69.1±26.5	132.0±55.5	96.1±29.4	55 μg/d
Sodium (mg)	3,096.2±1,187.7	2,632.6±867.4	3,180.1±1,115.4	2,444.5±704.6	1,300 g/d
Potassium (mg)	2,954.5±801.0	2,694.7±864.0	2,544.1±734.4	2,173.0±629.5	4,700 mg/d
AHEI score	52.7±16.4	55.3±19.4	29.4±18.5	36.7±2.2	NA

[a]Dietary data were reported from 3-day food records.
[b]NA=not applicable.
[c]EAR=Estimated Average Requirements.
[d]AI=Adequate Intakes. DRI for protein based on 0.8 g/kg body weight for the reference body weight.
NOTE: Information from this table is available online at www.adajournal.org as part of a PowerPoint presentation.

Table 4. Changes in Alternate Healthy Eating Index (AHEI) categories and scores within and between vegan and American Diabetes Association (ADbA) diet groups at baseline and 22 weeks, in a study of nutrient intake and dietary quality among persons with type 2 diabetes

	Vegan Group (n=49)			ADbA Group (n=50)				
Food group	**Baseline**	**22 wk**[a]	**Difference**	**Baseline**	**22 wk**[a]	**Difference**	**Mean effect size**[b]	***P* value**[c]
Vegetables								
Servings/d	2.6±1.5	5.9±3.2	3.3±2.8***	3.1±1.6	3.1±1.5	−0.06±1.9	3.4 (2.4 to 4.3)	<0.0001
AHEI score[d]	5.2±2.9	8.7±1.8	3.5±5.3***	6.1±2.8	5.9±2.6	−0.2±3.3	3.7 (2.6 to 4.5)	<0.0001
Fruit								
Servings/d	1.3±1.2	2.6±1.8	1.3±1.7***	1.4±0.9	1.7±1.3	0.3±1.3	1.0 (0.4 to 1.6)	0.001
AHEI score	3.2±2.9	5.9±3.7	2.7±3.6***	3.5±2.4	4.2±3.0	0.7±3.1	2.0 (0.7 to 3.4)	0.003
Nuts and soy protein								
Servings/d	0.9±1.9	1.9±2.0	1.0±2.7**	0.8±1.7	1.2±1.6	0.4±1.4	0.6 (−0.2 to 1.5)	0.14
AHEI score	3.0±3.9	7.6±3.6	4.5±5.4***	3.5±4.1	5.4±4.5	1.9±4.6**	2.7 (0.7 to 4.7)	0.009
Ratio of white to red meat								
White:red	10.6±27.4	0.3±0.8	−10.3±27.5**	12.7±35.8	3.6±7.9	−9.1±35.6	−14.0 (−1.2 to 11.6)	0.85
AHEI score	4.6±3.6	8.6±3.1	4.0±4.5***	5.0±3.6	5.4±3.5	0.36±3.9	3.6 (1.9 to 5.3)	<0.0001
Cereal fiber								
g/d	7.2±4.1	10.3±5.5	3.1±5.9***	7.9±4.5	7.2±4.2	−0.6±5.1	3.8 (1.6 to 5.9)	0.001
AHEI score	4.4±2.6	6.0±2.7	1.6±3.3***	4.8±2.6	4.5±2.7	−0.3±3.0	1.9 (0.7 to 3.2)	0.003
***Trans* fat**								
% of energy	0.02±0.01	0.01±0.01	−0.01±0.01***	0.02±0.01	0.02±0.01	−0.002±0.011	−0.01 (−0.02 to −0.01)	<.0001
AHEI score	5.2±2.6	8.1±2.7	2.9±3.2***	5.7±2.5	6.3±2.4	0.6±2.7	2.3 (1.1 to 3.4)	0.0002
Polyunsaturated to saturated fat ratio								
Polyunsaturated:saturated	0.7±0.3	1.9±0.7	1.2±0.7***	0.7±0.3	0.8±0.3	0.1±0.3**	1.1 (0.9 to 1.3)	<.0001
AHEI score	5.8±2.5	9.4±1.7	3.4±2.6***	6.6±2.3	7.4±2.2	0.8±2.3*	2.5 (1.6 to 3.5)	<.0001
Total AHEI score	31.6±11.8	54.1±17.9	22.5±18.7***	35.1±10.1	34.2±17.9	−0.9±18.1	23.5 (16.1 to 30.8)	<0.0001

[a]The 22-week data included all individuals with data at baseline (n=49 for the vegan group and n=50 for the ADbA group).
[b]Lower confidence level to upper confidence level.
[c]*P* values are for *t* tests of comparisons of between-group (vegan vs ADbA) changes (baseline to 22 weeks).
[d]A score was assigned for each AHEI food category ranging from 0 to 10.
*$P<0.05$.
**$P<0.01$.
***$P<0.001$.
NOTE: Information from this table is available online at www.adajournal.org as part of a PowerPoint presentation.

creased PUFA-to-saturated fat ratio) and two AHEI score categories (increases in nuts and soy protein and PUFA-to-saturated fat ratio scores). Both groups reduced their white meat to red meat ratio (only significantly in the vegan group, largely reflecting a reduction in overall meat intake).

The vegan group had greater improvements in all AHEI categories and serving amounts, compared with the American Diabetes Association diet group, with the exception of the nuts and soy protein category. The vegan group significantly improved its overall AHEI score, while the American Diabetes Association group did not ($P<0.001$).

For all participants combined, AHEI score was negatively correlated with both changes in hemoglobin A1c ($r=-0.24$, $P<0.05$) and weight ($r=-0.27$, $P<0.01$). That is, an increase in AHEI score was associated with decreases in both hemoglobin A1c value and weight. There was no within-group correlation between AHEI score changes and changes in hemoglobin A1c value (vegan: $r=-0.18176$, $P=0.211$; American Diabetes Association: $r=-0.17707$, $P=0.219$) or changes in weight (vegan: $r=-0.23318$, $P=0.107$ and American Diabetes Association: $r=-0.19098$, $P=0.184$).

Although alcohol use was excluded from the dietary quality analyses, study participants reported little alcohol use on average. At 22 weeks, average alcohol intake for the vegan and American Diabetes Association diet groups (2.3 ± 5.5 and 2.5 ± 8.6 g/day, respectively, $P=0.9062$) was well below the quantities receiving the highest AHEI scores (1.5 to 2.5 drinks per day—about 22.5 to 37.5 g/day—for men and 0.5 to 1.5 drinks per day—7.5 to 22.5 g/day—for women).

DISCUSSION

Nutrient Intake

Past studies have shown that vegan diets have a high degree of acceptability among participants, with participants finding a vegan diet as acceptable as their usual intake (25) or as compared to a standard low-fat diet (26). Although both groups reduced their energy intake, they had very different micronutrient profiles. With the exception of carbohydrate, both groups reported similar changes in macronutrient intake—decreasing fats and protein intake—although to a greater degree in the vegan group. The small reported average cholesterol intake in the vegan group (45.4 mg/day) was partly attributable to small amounts of animal products consumed by some participants who were not fully adherent to the diet, as well as the fact that the Nutrient Data System for Research database may report small amounts of cholesterol in foods (eg, bread or pasta) that, in fact, may have had none. Similar nutrient changes were found in a study comparing the intakes of women following a low-fat vegan diet for 14 weeks to a low-fat diet based on National Cholesterol Education Program guidelines (similar to the current Therapeutic Lifestyle Change diet recommendations) (15).

In contrast to studies suggesting inadequate vitamin B-12 intake among some vegan groups (27,28), this study found that mean vitamin B-12 intake remained within the recommended range even without considering dietary supplements. This is most likely due to the inclusion of foods fortified with vitamin B-12 such as cereals and soymilks. Despite the popular expectation that vegan and vegetarian diets are low in iron, these findings confirm those of other studies that vegans may have higher intakes of iron when compared with omnivores (27). The iron that the vegan group was consuming at 22 weeks was, however, all in the nonheme form and therefore may not be as bioavailable as heme iron. Both groups decreased vitamin D intake, with the vegan group having a greater drop. Other studies have also found a low intake of vitamin D among those following a vegan diet (14,15). Both groups were well below current vitamin D recommendations before beginning their assigned diets as well as at the 22-week time point.

Regarding intakes of vitamins D and E, calcium, and potassium, our findings suggest that people following either a low-fat, low-glycemic index vegan diet or an American Diabetes Association recommended diet may wish to pay particular attention to these nutrients to ensure they meet their needs. Men and women following an American Diabetes Association recommended diet and men following a low-fat vegan diet may also wish to increase their intake of magnesium by including more fruits, vegetables, and whole grains. Because carbohydrate intake is restricted in the American Diabetes Association recommended diet, it is important that high-fiber carbohydrates be emphasized to meet fiber recommendations. People following a vegan diet may wish to emphasize foods rich in zinc to ensure they meet their needs.

The 2003 American Diabetes Association Guidelines, which were current at the time of study implementation, were used with American Diabetes Association diet group participants. Since then, the 2007 guidelines have been released (29). These guidelines have many similarities to the 2003 guidelines but there are some changes that may have influenced the nutrient intake of the American Diabetes Association diet group. Fiber has a greater emphasis in the updated diet recommendations. People with diabetes are encouraged to consume 14 g fiber per 1,000 kcal per day and have half of daily grain intake come from whole grains. Although Glycemic Index and Glycemic Load are not recommended as necessary components of healthful diet planning, the guidelines do state that use of Glycemic Index and Glycemic Load may provide a slight additional benefit over considering carbohydrate content alone. Finally, the 2007 American Diabetes Association guidelines state that everyone with diabetes should consume a diet with <200 mg cholesterol/day, whereas 2003 guidelines only recommended this level to those with elevated low-density lipoprotein cholesterol levels (29).

AHEI

The AHEI is strongly negatively associated with risk of major chronic diseases and cardiovascular disease but not most cancers (19). The AHEI has been shown to have an inverse relationship with estrogen receptor-negative breast cancer (30) but not genetically linked (ie, BRCA gene-associated) breast cancer (31). We found that AHEI score was negatively correlated with changes in hemoglobin A1c value and weight. Similar results were found in a study examining AHEI score and women with type 2 diabetes revealing that AHEI score was inversely correlated with the risk for type 2 diabetes (32).

Both groups reduced their white-meat-to-red-meat ratio, as scored by the AHEI. This does not necessarily reflect an increase in red meat intake in both groups. According to the AHEI scoring criteria, an individual who ate no meat at all (receiving a ratio of zero) or who ate less than two servings of meat in 1 month (equivalent to $\leq$5.7 g/day) would receive the highest AHEI score for that category. Therefore, for many participants, a decrease in their white-meat-to-red-meat ratio reflected a decrease in overall meat consumption (ratio going from less than zero to zero) and not an increase in red meat consumption.

McCullough and colleagues (19) reported AHEI scores for men and women in a 2002 study and reported risk of developing major chronic diseases and cardiovascular disease in each score quintile. When controlling for smoking, men in the highest AHEI score quintile (median score 52.3) had a relative risk of 0.80 for major chronic disease (95% confidence interval 0.71, 0.91; $P<0.001$) and a 39% lower risk of developing cardiovascular disease, compared with men in the lowest quintile (median score 31). With women, models that underwent multivariate adjustment were nonsignificant, but unadjusted analyses showed that women in the highest AHEI score quintile (median score 59.9) had a relative risk of 0.89 for major chronic disease (95% confidence interval 0.82, 0.96; $P=0.008$) and a 28% lower risk of developing cardiovascular disease compared with women in the lowest quintile (median score 25.4) (19). Even without the addition of multivitamin or alcohol AHEI scores (which would add to the total AHEI score), the male vegan group's mean score of 52.7$\pm$16.4 is in the second highest quintiles for men and the female vegan group's mean score of 55.3$\pm$19.4 is in the highest quintile as reported in the study by McCullough and colleagues (19). This score is associated with a low risk of developing major chronic disease and cardiovascular disease. The American Diabetes Association diet group's score remained unchanged and, with a mean of 29.4$\pm$18.5 for men and 36.7$\pm$2.2 for women, places them in the lowest quintile for men and the third quintile for women (19).

Although the vegan group significantly improved its AHEI score in every food category, of particular note is the increase in fruit and vegetable intake. Whereas the American Diabetes Association diet group did not have a significant improvement in the number of vegetables or fruit consumed, the vegan group had an increase from four servings of fruit and vegetables per day to seven and one half servings each day.

In this short-term study, it was not possible to correlate the AHEI with the occurrence of chronic diseases such as cancer or heart disease. It was possible, however, to correlate AHEI score with two factors that are associated with improvements in diabetes status, finding that AHEI score was correlated with changes in both weight and hemoglobin A1c value. This suggests that AHEI score may provide a useful tool in assessing dietary quality among people with diabetes and assessing future improvement in diabetes disease state.

The strengths of the study include a prospective design and an intention-to-treat analysis. The principal weakness is the reliance on self-reported dietary intake, which has been the subject of several critiques (33,34). This is an inevitable issue among individuals not confined to a metabolic ward. Reductions in clinical variables, such as weight, lipid concentrations, and hemoglobin A1c value, suggest that both groups made diet changes.

This study examined nutrient changes after 22 weeks in persons with type 2 diabetes. Future research should examine long-term dietary changes on both vegan and American Diabetes Association–recommended diets. This research should also examine long-term changes in clinical measures, such as hemoglobin A1c and lipid values, and examine these measures in relation to AHEI score.

CONCLUSIONS

Vegan and American Diabetes Association–recommended dietary profiles are very different in both macro- and micronutrient intakes. The vegan group had significant improvements in energy, total fat, *trans* fat, cholesterol, and fiber. The vegan group also saw significant improvements in intakes of several vitamins and minerals, including total vitamin A activity, beta carotene, vitamin K, vitamin C, folate, magnesium, potassium, and sodium. The American Diabetes Association–recommended diet group had significant improvements in energy, total fat, *trans* fat, cholesterol, and sodium intakes. Both groups had difficulty meeting the recommended intakes for vitamins D and E, calcium, and potassium and consumed too much sodium, albeit less than at baseline.

The vegan group improved all food group categories and saw a significant increase in AHEI score, which was associated with improvements in both weight and hemoglobin A1c value. The American Diabetes Association diet group saw no improvement in AHEI score. Because the AHEI is strongly negatively associated with risk of major chronic diseases (19), the results of this study suggest that, if followed for the long-term, a low-fat vegan diet may be associated with a reduced risk of major chronic diseases, particularly cardiovascular disease.

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