Type of Vegetarian Diet, Body Weight, and Prevalence of Type 2 Diabetes

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OBJECTIVE — We assessed the prevalence of type 2 diabetes in people following different types of vegetarian diets compared with that in nonvegetarians.

RESEARCH DESIGN AND METHODS — The study population comprised 22,434 men and 38,469 women who participated in the Adventist Health Study-2 conducted in 2002–2006. We collected self-reported demographic, anthropometric, medical history, and lifestyle data from Seventh-Day Adventist church members across North America. The type of vegetarian diet was categorized based on a food-frequency questionnaire. We calculated odds ratios (ORs) and 95% CIs using multivariate-adjusted logistic regression.

RESULTS — Mean BMI was lowest in vegans (23.6 kg/m^2) and incrementally higher in lacto-ovo vegetarians (25.7 kg/m^2), pesco-vegetarians (26.3 kg/m^2), semi-vegetarians (27.3 kg/m^2), and nonvegetarians (28.8 kg/m^2). Prevalence of type 2 diabetes increased from 2.9% in vegans to 7.6% in nonvegetarians; the prevalence was intermediate in participants consuming lacto-ovo (3.2%), pesco (4.8%), or semi-vegetarian (6.1%) diets. After adjustment for age, sex, ethnicity, education, income, physical activity, television watching, sleep habits, alcohol use, and BMI, vegans (OR 0.51 [95% CI 0.40–0.66]), lacto-ovo vegetarians (0.54 [0.49–0.60]), pesco-vegetarians (0.70 [0.61–0.80]), and semi-vegetarians (0.76 [0.65–0.90]) had a lower risk of type 2 diabetes than nonvegetarians.

CONCLUSIONS — The 5-unit BMI difference between vegans and nonvegetarians indicates a substantial potential of vegetarianism to protect against obesity. Increased conformity to vegetarian diets protected against risk of type 2 diabetes after lifestyle characteristics and BMI were taken into account. Pesco- and semi-vegetarian diets afforded intermediate protection.

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Vegetarian diets may play a beneficial role in promoting health and preventing obesity (1–3). Vegetarianism encompasses a spectrum of eating patterns: from diets that leave out all animal meats and products (vegan) to diets that include eggs, milk, and milk products (lacto-ovo vegetarian) or even fish in addition to eggs, milk, and milk products (pesco-vegetarian). A previous study has indicated that BMI increases when a wider spectrum of animal products are eaten. Specifically, the European Prospective Investigation found that BMI was highest in meat eaters, lowest in vegans, and intermediate in fish eaters (4). The protective effects of vegetarianism against overweight may be due to avoidance of major food groups, displacement of calories toward food groups that are more satiating (5), or other factors.

Based on a review of experimental data, investigators have suggested that the portfolio of foods found in vegetarian diets may carry metabolic advantages for the prevention of type 2 diabetes (6). This notion has been confirmed in observational studies. In the Nurses Health Study, intakes of red meat and processed meats were associated with increased risk of diabetes (7). In a study of Seventh-Day Adventists, diabetes was less prevalent in vegetarian than in nonvegetarian churchgoers (8). Likewise, Fraser reported a lower prevalence of diabetes in vegetarians than in semi- or nonvegetarians (1) and Vang et al. (9) found that processed meat consumption was a risk factor for diabetes. However, these church-based cohorts were initiated in the 1960s–1970s and included primarily non-Hispanic whites. Furthermore, the type of vegetarianism or diabetes was not specified.

A pertinent question is whether vegetarian diets remain protective in current obesity-promoting environments and in diverse populations. We studied a Seventh-Day Adventist cohort that included a population of whom ~25% of subjects were black and that was characterized by vegetarian and nonvegetarian eating patterns. We hypothesized that more exclusively vegetarian diets, e.g., vegan, lacto-ovo, or pesco-vegetarian, are associated with lower prevalence of obesity and type 2 diabetes compared with semi- or nonvegetarian diets.

RESEARCH DESIGN AND METHODS

— The Adventist Health Study-2 cohort, initiated in 2002–2006, longitudinally follows 97,000 Adventist church members in the U.S. and Canada (10). Participants were recruited through their churches and were eligible if aged ≥30 years and proficient in English. The study was reviewed and approved by the institutional review board of Loma Linda University, Loma Linda, California, and informed consent was obtained.

These analyses are based on cross-sectional data obtained at baseline. Data were collected from a 50-page self-administered questionnaire (11).The questionnaire included sections on illness, diet, physical activity, demographics, height, and weight. Cases of diabetes were ascertained by asking whether a physician had ever diagnosed type 1 or type 2 diabetes and whether the respondent was treated for this in the last 12 months. Race and ethnicity were divided into the following categories: black

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(black/African American, West Indian/Caribbean, African, or other black) and non-black (white non-Hispanic, Hispanic, Middle Eastern, Asian, Native Hawaiian/other Pacific Islander, or American Indian). Education was categorized to high school or less, some college, and college or higher based on eight options. Income was categorized into earnings of ≤10,000, 11,000–30,000, 31,000–50,000, and ≥51,000 USD.

Table 1—*Distribution of participants by history of type 2 diabetes treated within 12 months in conjunction with nondietary variables*

	Type 2 diabetes reported	Not reported	*P*
N	3,430	57,473	
Age (years)	62.5 ± 11.8	56.1 ± 13.7	<0.0001
Female	61.7	63.3	0.0604
Black	32.5	23.4	<0.0001
BMI (kg/m^2)	32.1 ± 7.1	26.9 ± 5.7	<0.0001
Physical activity: METs			<0.0001
0–3.2	38.6	24.8	
3.2–8.6	23.2	24.5	
8.6–21.0	20.6	24.6	
>21.0	17.6	26.1	
Education			<0.0001
High school or less	26.0	17.9	
Some college	31.9	27.6	
College or higher	42.1	54.6	
Income			<0.0001
≤10,000 USD	25.0	19.5	
11,000–30,000 USD	42.9	36.3	
31,000–50,000 USD	19.0	23.6	
≥51,000 USD	13.1	20.6	
Television watching			<0.0001
None to <1 h/day	11.8	27.0	
1–2 h/day	42.9	47.4	
≥3 h/day	45.3	25.6	
Sleep			<0.0001
≤6 h/night	39.4	31.7	
7 h/night	28.8	36.8	
≥8 h/night	31.9	31.5	
Alcohol use in last 12 months	7.1	10.4	<0.0001

Data are means ± SD or percent unless otherwise indicated. Percentages might not total 100 because of rounding.

Assessment of lifestyle exposures

The food-frequency portion of the questionnaire covered 130 hard-coded foods or food groups that are commonly consumed and space for ~50 write-ins and are assessed for diet during the past year. For different food items, there were 7–9 frequency categories. A standard portion size was given for each item, and subjects could select that or a smaller or larger portion. Previous validation of the questionnaire pertained to nutrients including vitamin, antioxidant, and fatty acid intakes (12,13). Vegetarian status was categorized by defining vegans as subjects who reported consuming no animal products (red meat, poultry, fish, eggs, milk, and dairy products <1 time/month), lacto-ovo vegetarians as consuming dairy products and/or eggs ≥1 time/month but no fish or meat (red meat, poultry, and fish <1 time/month), pesco-vegetarians as consuming fish ≥1 time/month and dairy products and/or eggs but no red meat or poultry (red meat and poultry <1 time/month), semi-vegetarians as consuming dairy products and/or eggs and meat (red meat and poultry ≥1 time/month and <1 time/week), and nonvegetarians as consuming animal products (red meat, poultry, fish, eggs, milk, and dairy products >1 time/week). Alcohol was defined as consumption of any amount or none during the past 12 months.

Physical-activity questions were previously validated in non-black and black subjects (14,15). These were separated into six intensity levels, including napping, lying down, and light, moderate, vigorous, and extremely vigorous activity. Participants reported the amount of time spent in each type of activity on a normal weekday and on Saturday and Sunday. Moderate, vigorous, and extremely vigorous activities were assigned scores of 4, 8, and 10, respectively, to represent the approximate MET values expended and were weighted according to the amount of time spent in each activity to estimate average daily energy expenditure (information available in the online appendix [http://care.diabetesjournals.org/cgi/content/full/dc08-1886]). Participants reported average number of hours of sleep and hours per day of television watching. Responses were divided into three categories (≤6, 7, and ≥8 h of sleep and <1, 1–2, and ≥3 h of television watching).

Ascertainment of disease

A representative subgroup of 1,007 study subjects participated in a calibration study and provided blood samples for measurement of fasting serum glucose levels (16). The calibration sample was generated by a two-stage random-selection method involving church size and subjects within the church. Subjects who refused participation were replaced with individuals randomly chosen from the same church and matched by race, age, and sex.

We used a fasting glucose level ≥126 mg/dl to categorize subjects as probably diabetic. We attempted telephone interviews with subjects who, despite glucose measurements <126 mg/dl, reported a physician-based diagnosis of type 2 diabetes and subjects whose glucose measurement was ≥126 mg/dl but who did not report type 2 diabetes. Of subjects who had reported type 2 diabetes but had a low glucose level (n = 55), all 44 who were contacted confirmed that they had type 2 diabetes, whereas 9 could not be reached and 2 were too deaf to understand the question. Of subjects who did not report type 2 diabetes but had a high glucose level (n = 53), 38 had no knowledge of diabetes, were informed of diabetes by their physician after the questionnaire was administered, were informed only of a high or borderline glucose level, or had not been treated in the past 12 months; 1 had diabetes but had skipped that page of the questionnaire; 6

Table 2—*Unadjusted prevalence of type 2 diabetes and distribution of nondietary variables according to diet*

	Vegan	Lacto-ovo vegetarian	Pesco-vegetarian	Semi-vegetarian	Nonvegetarian	*P*
N	2,731	20,408	5,617	3,386	28,761	
Type 2 diabetes	2.9	3.2	4.8	6.1	7.6	<0.0001
Age in years	58.1 ± 13.3	58.1 ± 14.1	57.2 ± 13.8	57.7 ± 13.6	54.9 ± 13.2	<0.0001
Female	60.1	62.3	65.9	65.7	63.2	<0.0001
Black	19.9	12.5	34.9	15.0	31.2	<0.0001
BMI (kg/m^2)	23.6 ± 4.4	25.7 ± 5.1	26.3 ± 5.2	27.3 ± 5.7	28.8 ± 6.3	<0.0001
Physical activity: METS						<0.0001
0–3.2	24.8	26.3	24.3	26.8	25.2	
3.2–8.6	24.7	25.8	24.5	24.0	23.5	
8.6–21.0	24.8	24.6	24.6	23.7	24.3	
>21.0	25.7	23.3	26.6	25.6	27.1	
Education						<0.0001
High school or less	16.7	14.0	17.2	19.1	21.7	
Some college	26.7	24.2	26.1	28.5	30.7	
College or higher	56.6	61.8	56.7	52.4	47.6	
Income						<0.0001
≤10,000 USD	27.8	21.1	18.0	20.2	18.6	
11,000–30,000 USD	38.6	35.8	34.4	38.0	37.4	
31,000–50,000 USD	18.3	24.2	24.0	23.4	23.1	
≥51,000 USD	15.3	18.9	23.6	18.4	21.0	
Television watching						<0.0001
None to <1 h/day	49.5	36.0	26.8	25.2	16.9	
1–2 h/day	37.4	45.4	50.2	48.7	48.6	
≥3 h/day	13.2	18.6	23.0	26.1	34.5	
Sleep						<0.0001
≤6 h/night	25.8	25.3	34.9	29.8	37.3	
7 h/night	38.3	39.8	36.3	36.9	33.7	
≥8 h/night	35.9	34.9	28.9	33.4	29.0	
Alcohol use in last 12 months	1.1	2.9	7.1	8.6	17.1	<0.0001

Data are means ± SD or percent unless otherwise indicated.

were deceased; and 8 could not be reached.

Statistical analyses

The allocation of subjects into dietary categories required responses to questions regarding 27 variables including meat, fish and poultry, dairy, and egg consumption. Because on average ~7% data were missing for any particular variable, multiple imputation was used to fill missing information. For about half of these variables, we had a random subset of initially missing data filled in later by telephone and used this to guide the imputation (17). For other variables, we assumed that the data were missing at random, which, even if not quite correct, will have little influence when the missing data rate is small (17). The imputation algorithm included age, sex, race, and food groups (meat, fish, dairy, and eggs). These food groups were subdivided into blocks of variables for which we had the random subset of filled-in data and those for which we did not (e.g., fish variables that were included in those later filled in versus fish variables not so included) for purposes of imputation. The imputation software used was the Hmisc package for R, version 2.6.0 (18).

χ^2 tests and one-way ANOVA were used to analyze categorical and continuous variables, respectively. Multiple logistic regression analysis was used to obtain ORs and 95% CIs of the relation between characteristics, diet, and diabetes. All statistical testing was two-tailed. Analyses were performed using SPSS, version 13.0.

RESULTS — There were 83,031 subjects whose questionnaire responses allowed categorization by vegetarian or nonvegetarian diet. Of these, 1,427 did not respond to the diabetes ascertainment question. A further 634 who reported treatment for type 1 diabetes were excluded, and another 14,124, 4,638, 317, 852, and 136 were missing data regarding physical activity, income, education, television watching, and sleep, respectively. This left 22,434 men and 38,469 women. Of these 60,903 subjects, 3,430 (5.6%) reported type 2 diabetes.

Table 1 shows that participants treated for type 2 diabetes differed with regard to a variety of characteristics from those who did not report diabetes diagnosis. Only 1,070 (1.8%) participants had smoked one or more cigarettes daily in the past 12 months.

The consumption of major food groups differed among the dietary groups (data not shown). The prevalence of type 2 diabetes increased incrementally among vegans, lacto-ovo vegetarians, pesco-vegetarians, semi-vegetarians, and nonvegetarians (Table 2). This increase was concomitant to an incremental increase in mean BMI in the respective dietary groups; additionally, demographic and lifestyle characteristics differed among the dietary groups (Table 2). For BMIs ≥30 kg/m^2, the prevalence of diabetes was 8.0% in vegans, 9.4% in lacto-ovo

Table 3—*Multiple logistic regression analysis of the relation between diet and type 2 diabetes*

	OR (95% CI)*	OR (95% CI)†
Age	1.04 (1.04–1.05)	1.03 (1.03–1.04)
Female vs. male	0.67 (0.62–0.72)	0.78 (0.72–0.84)
Non-black vs. black	0.66 (0.61–0.72)	0.64 (0.59–0.69)
BMI	1.11 (1.11–1.12)	
Physical activity: METs		
3.2–8.6 vs. 0–3.2	0.85 (0.77–0.93)	0.76 (0.69–0.83)
8.6–21.0 vs. 0–3.2	0.77 (0.69–0.85)	0.65 (0.59–0.72)
>21.0 vs. 0–3.2	0.65 (0.58–0.72)	0.52 (0.47–0.58)
Education		
Some college vs. high school or less	1.00 (0.91–1.11)	1.04 (0.95–1.15)
College or higher vs. high school or less	1.00 (0.90–1.10)	0.95 (0.86–1.05)
Income (USD)		
11,000–30,000 vs. <10,000	0.87 (0.80–0.96)	0.82 (0.75–0.90)
31,000–50,000 vs. <10,000	0.77 (0.68–0.86)	0.72 (0.65–0.81)
≥51,000 vs. <10,000	0.66 (0.58–0.76)	0.61 (0.53–0.70)
Television watching (h/day)		
1–2	1.31 (1.16–1.47)	1.54 (1.37–1.73)
≥3	1.62 (1.44–1.83)	2.26 (2.01–2.54)
Sleep (h/night)		
7 vs. ≤6	0.83 (0.76–0.91)	0.77 (0.71–0.85)
≥8 vs. ≤6	0.94 (0.86–1.03)	0.86 (0.79–0.94)
Alcohol use during last 12 months vs. none	0.69 (0.60–0.80)	0.64 (0.55–0.73)
Diet		
Vegan vs. nonvegetarian	0.51 (0.40–0.66)	0.32 (0.25–0.41)
Lacto-ovo vegetarian vs. nonvegetarian	0.54 (0.49–0.60)	0.43 (0.39–0.47)
Pesco-vegetarian vs. nonvegetarian	0.70 (0.61–0.80)	0.56 (0.49–0.64)
Semi-vegetarian vs. nonvegetarian	0.76 (0.65–0.90)	0.69 (0.59–0.81)

*Adjusted for all factors. †Adjusted for all factors except BMI. OR, odds ratio.

vegetarians, 10.4% in pesco-vegetarians, 11.4% in semi-vegetarians, and 13.8% in nonvegetarians, indicating the same trend as that in the entire population. For BMIs <30 kg/m^2, the prevalence was 2.0, 2.1, 3.3, 3.7, and 4.6% in the groups, respectively.

In multiple logistic regression analysis, vegan, lacto-ovo, and pesco- and semi-vegetarian diets were associated with a lower prevalence of type 2 diabetes (Table 3). The vegetarian diets were more strongly associated with less diabetes when BMI was removed from the analyses (Table 3).

CONCLUSIONS — The main finding was that vegan and lacto-ovo vegetarian diets were associated with a nearly one-half reduction in risk of type 2 diabetes compared with the risk associated with nonvegetarian diets after adjustment for a number of socioeconomic and lifestyle factors, as well as low BMI, that are typically associated with vegetarianism. Pesco- and semi-vegetarian diets were associated with intermediate risk reductions: between one-third and one-quarter. These data indicate that vegetarian diets may in part counteract the environmental forces leading to obesity and increased rates of type 2 diabetes, though only vegan diets were associated with a BMI in the optimal range. Inclusion of meat, meat products, and fish in the diet, even on a less than weekly basis, seems to limit some of the protection associated with a vegan or lacto-ovo vegetarian diet. These findings may be explained by adverse effects of meat and fish, protective effects of typical constituents of vegan and lacto-ovo vegetarian diets, other characteristics of people who choose vegetarian diets, or a combination of these factors.

The notion that animal protein stimulates insulin secretion and possibly insulin resistance was proposed decades ago (19). However, a number of other dietary constituents are associated with protection against diabetes in observational studies or influence insulin sensitivity in food trials (6). Vegetarian diets are rich in vegetables and fruits, foods that reduce oxidative stress and chronic inflammation. The vegan group consumed ~650 g/day of fruits and vegetables, which is about one-third more than the amount consumed by nonvegetarians (data not shown). Observational evidence has shown that these dietary constituents are associated with a reduction in type 2 diabetes of ~40% (6). Vegetarian diets contain substantially less saturated fat than nonvegetarian diets, and saturated fatty acids have been shown to reduce insulin sensitivity, though a recent review concluded that some of the data supporting this idea was flawed (20). The vegetarian diet typically includes foods that have a low glycemic index such as beans, legumes, and nuts. We did not calculate the glycemic load of the diets. Though low-glycemic-response diets are associated with less prevalence of type 2 diabetes, cohort studies have not consistently found a relation between dietary glycemic index or load and risk of diabetes (21,22); furthermore, whether the glycemic response causes diabetes is not established.

Protection against type 2 diabetes associated with vegetarian diets is partly due to the lower BMI of vegetarians (Table 3), where the effects of diet when not adjusted for BMI were greater yet. Disentangling the effects of diet on insulin sensitivity independent of lower adiposity among vegetarians may be difficult. Only sparse data have investigated whether vegetarians matched to nonvegetarians with regard to adiposity differ in insulin resistance or sensitivity. In a study that matched vegetarians and nonvegetarians, nonvegetarians had higher insulin, glucose, and homeostasis model assessment values than vegetarians (23). Whether vegetarians and nonvegetarians were matched with regard to abdominal girth was not reported. The protective effect of vegetarianism in the current study was evident in individuals with BMI below or above 30 kg/m^2, further strengthening the notion that independent effects of the diet are present.

Church attendees tend to have higher body weight than nonattendees (24), and increasing trends in BMI in the general population have also been observed among Adventists (data not shown). Vegans were the only church members whose mean BMI was <25 kg/m^2. Previous studies have reported a difference of ~2 BMI units between vegans and meat eaters (4). In the current study, the difference of 5 BMI units may indicate greater protection in current environments where a variety of high-energy dense foods are available. Some evidence indicates a temporal relationship between initiating plant-based diets and leanness (2,3), though a randomized study found that a vegetarian diet did not improve long-term weight loss (25). As with most dietary trials, the participants' compliance to the diet declined substantially over time.

The present cohort is likely to be more homogenous than general populations regarding nondietary factors allowing comparisons between dietary groups to be less affected by other differences. This may be true regarding smoking and alcohol use, which are practices strongly discouraged by the church. One of the major confounders of diet and disease associations in observational studies is cigarette smoking. As the participants were almost exclusively nonsmokers, the confounding effects of smoking on body weight and risk of type 2 diabetes were avoided. The cohort exhibited an unusually wide range of dietary exposures and included one of the largest numbers of vegans studied in any sample. The results are likely to be generalizable given that we found expected relationships between diabetes and age, ethnicity, sex, BMI, physical activity, sleep, and television watching.

Study limitations

Our data are cross-sectional and do not allow causal inferences to be made. However, reverse causation is unlikely in that subjects diagnosed with diabetes would be less expected to differentially change their diet from vegetarian to omnivorous than subjects without diabetes. We were unable to assess physical activity for about one-sixth of the cohort because responses to one or more of the questions required for the calculation of MET units were missing. Food-frequency questionnaires involve a certain degree of measurement error; however, the ability to allocate subjects into a broad dietary pattern is probably very strong. All variables were self-reported; however, our calibration study found evidence for good validity for the diagnosis of diabetes. Diabetes may have been underreported in the vegan and other vegetarians because of their lower BMIs; however, this is unlikely to affect the study conclusions substantially given the association we observed between diet and diabetes in individuals with BMI both below and above 30 kg/m^2.

The cohort was not representative of the general population; i.e., participants were church attendees. Members who choose vegetarianism are likely to be more compliant with other church tenets and to differ from nonvegetarians with regard to major determinants of type 2 diabetes. This was indeed the case with regard to some factors; e.g., nonvegetarian diets were more associated with black ethnicity, less education, more television watching, and fewer hours of sleep than were vegetarian diets. On the other hand, nonvegetarians were younger and reported more physical activity and alcohol consumption, which are all established protective factors against type 2 diabetes. Nevertheless, the association between diet and type 2 diabetes remained strong after adjustment for these factors.

In conclusion, this study showed that all variants of vegetarian diets (vegan, lacto-ovo, and pesco- and semi-vegetarian) were associated with substantially lower risk of type 2 diabetes and lower BMI than nonvegetarian diets. The protection afforded by vegan and lacto-ovo vegetarian diets was strongest.

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