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Dietary glycemic index and load and risk of type 2 diabetes in older adults

Nadine R. Sahyoun, **Amy L. Anderson**, **Frances A. Tylavsky**, **Jung Sun Lee**, **Deborah E. Sellmeyer**, and **Tamara B. Harris for the Health ABC study**
Department of Nutrition and Food Science, University of Maryland, College Park, MD (NRS, ALA); Department of Preventive Medicine, University of Tennessee, Memphis, TN (FAT); Department of Foods and Nutrition, University of Georgia, Athens, GA (JSL); Division of Endocrinology, University of California, San Francisco, CA (DES); National Institute on Aging, National Institutes of Health, Bethesda, MD (TBH)

Abstract

Background—It is unclear whether immediate dietary effects on blood glucose influence risk of developing type 2 diabetes.

Objectives—The objective of this study was to examine whether the dietary glycemic index (GI) and glycemic load (GL) were associated with risk of type 2 diabetes in older adults.

Design—The Health, Aging and Body Composition Study is a prospective cohort study of 3075 adults age 70 to 79 at baseline (n=1898 for this analysis). Intake of specific nutrients and food groups and risk of type 2 diabetes over a 4-year period were examined according to dietary GI and GL.

Results—Dietary GI was positively associated with dietary carbohydrate, and negatively associated with intake of protein, total fat, saturated fat, alcohol, vegetables and fruit. Dietary GL was positively associated with dietary carbohydrate, fruit and fiber, and negatively associated with intake of protein, total fat, saturated fat and alcohol. Persons in the higher quintiles of dietary GI or GL did not show a significantly higher incidence of type 2 diabetes.

Conclusion—This study does not support a relationship between dietary GI or GL and risk of type 2 diabetes in older adults. Because dietary GI and GL show strong nutritional correlates, the overall dietary pattern should be considered.

Keywords

diet; glycemic index; glycemic load; type 2 diabetes; older adults

Introduction

The prevalence of type 2 diabetes, a metabolic disorder characterized by high blood glucose and insulin resistance, has more than doubled in the U.S. in the last 2 decades, and adults age 60 and older account for almost half of cases (1). While factors such as obesity, lack of physical activity, and smoking have been linked to the development of type 2 diabetes, the role of dietary carbohydrate remains unclear. Little relationship has been found between total carbohydrate intake and risk of type 2 diabetes (2). To determine whether the rate of digestion and absorption of different carbohydrate sources may influence risk, several studies have focused on the glycemic index (GI) and glycemic load (GL) (3,4).

Corresponding author: Nadine R. Sahyoun, PhD, RD, Associate Professor, University of Maryland Department of Nutrition and Food Science, 0112 Skinner Building, College Park, MD 20742, USA. Tel: 301-405-8774. Fax: 301-314-2471. E-mail: nsahyoun@umd.edu
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Long-term consumption of high-GI foods has been proposed to increase insulin demand, promote insulin resistance, impair pancreatic β-cell function and eventually lead to type 2 diabetes (2,4,5,6). However, studies on dietary GI and GL in relation to insulin resistance and risk of type 2 diabetes have had inconsistent results. In the Framingham Offspring Cohort Study, both dietary GI and GL were positively related to insulin resistance, while in the Zutphen Elderly, IRAS, Health ABC and Danish Inter99 studies, no associations were found (7,8,9, 10,11). Both dietary GI and GL were positively linked to incident type 2 diabetes in the Nurses' Health Study, but no relationships were seen in the ARIC, Iowa Women's Health Study and IRAS cohorts (4,12,13,14). In the Health Professionals Follow-up Study, the Nurses' Health Study II and the Melbourne Collaborative Cohort Study, dietary GI, but not GL, was positively associated with risk of type 2 diabetes (2,5,15).

Most international diabetes organizations advocate use of the GI in prevention and management of diabetes, but the American Diabetes Association (ADA) does not fully endorse the GI due to "insufficient information to determine whether there is a relationship between glycemic index or glycemic load of diets and the development of diabetes" (16,17,18). The 2005 USDA Dietary Guidelines emphasize the need for additional research on the dietary GL in relation to risk of type 2 diabetes (19).

Few studies on the dietary GI and GL and risk of type 2 diabetes have been conducted in older adults, despite the high incidence of type 2 diabetes and demonstrated influence of lifestyle on risk of type 2 diabetes in this age group (20,21,22). The purpose of the current study was to examine whether the dietary GI and GL were associated with incident type 2 diabetes over 4 years of follow-up in a cohort of older adults.

Subjects and methods

Study population

Participants age 70 to 79 were recruited for the Health, Aging and Body Composition (Health ABC) Study, a prospective cohort study, from a random sample of Medicare-eligible residents of selected areas of Pittsburgh, Pennsylvania, and Memphis, Tennessee. Individuals were eligible for Health ABC if they planned to remain in the area for at least 3 years and reported no life-threatening cancers and no difficulty with basic activities of daily living, walking 1/4 mile or climbing 10 steps. Those who used assistive devices were excluded, as were participants in any research studies which involved medications or modification of eating or exercise habits. Protocols were approved by institutional review boards at both study sites, and participants provided written, informed consent.

An interview on behavior, health status, and social, demographic and economic factors, and a clinical examination of body composition, biochemical variables including fasting serum glucose, weight-related health conditions and physical function were administered between 1997 and 1998, with annual follow-up assessments.

Results from baseline through year 6 of the Health ABC study were used in the current analyses. The sample size for this study was 1898, after excluding participants diagnosed with type 2 diabetes before dietary intake was assessed (n = 662); those with missing information on type 2 diabetes in years 3 through 6 (n = 60); men who reported an energy intake of less than 800 kcal/day or more than 4000 kcal/day and women who reported an energy intake of less than 500 kcal/day or more than 3500 kcal/day (n = 73); and those with incomplete information on other relevant behavioral or sociodemographic factors (n = 382).

Dietary assessment

Food intake was measured in year 2 of the Health ABC study with a 108-item food frequency questionnaire (FFQ), based on the validated Block questionnaire (Block Dietary Data Systems, Berkeley, CA) (23). The Block FFQ was modified specifically for the Health ABC study to include an age-appropriate food list. The food list was based on the NHANES III 24-hour recall data for non-Hispanic white and black residents of the Northeast and South over age 65. The FFQ was administered by a trained dietary interviewer, and interviews were periodically monitored to assure quality and consistency. Wood blocks, real food models, and flash cards were used to help participants estimate portion sizes. Nutrient and food group intakes, including daily servings of vegetables and frequency of fruit and fruit juice intake, were determined by Block Dietary Data Systems.

The GI of a food is defined as the 2-hour incremental area under the blood glucose curve after consumption of a food portion which contains a specific amount, usually 50 g, of available carbohydrate, divided by the corresponding area after consumption of a portion of a reference food, usually glucose or white bread, which contains the same amount of available carbohydrate, and multiplied by 100 to be expressed as a percentage. GI values for foods in the Health ABC study FFQ were compiled by the Clinical Nutrition Research Center of the University of North Carolina from the literature, and modified if necessary to better match FFQ foods (16). A computer program was written in SAS (SAS Institute Inc., Cary, NC) to calculate the dietary GI and GL for each participant. The program first determined the amount of available carbohydrate in one serving of each food by subtracting the amount of fiber from the amount of total carbohydrate per serving. To obtain the GL of a serving of the food, the amount of available carbohydrate per serving was multiplied by the food's GI value, and divided by 100. To determine the dietary GL for each subject, each food's GL was multiplied by the daily frequency of consumption of the food, and these products were summed over all foods. The dietary GI for each subject was computed by dividing dietary GL by daily total available carbohydrate intake and multiplying by 100. These methods of calculating dietary GI and GL are endorsed by a joint report of the Food and Agriculture Organization (FAO) and World Health Organization (WHO), and by the *International Table of Glycemic Index and Glycemic Load Values: 2002* (16,24).

Diagnosis of type 2 diabetes

In this study, type 2 diabetes was defined by 1) annual report of physician diagnosis, 2) reported use of exogenous insulin or oral hypoglycemic medication, assessed in years 2, 3, 5 and 6, or 3) in accordance with current ADA criteria, fasting serum glucose ^{3}126 mg/dl, measured in years 2, 4 and 6 (25).

Sociodemographic and lifestyle variables

Sociodemographic variables including age, gender, self-identified racial group and education, and lifestyle variables including smoking status, alcohol consumption, and physical activity were assessed at baseline of the Health ABC study. Lifetime pack-years of cigarette smoking were calculated by multiplying cigarette packs smoked per day by the number of years of smoking. Physical activity was evaluated by a standardized questionnaire specifically designed for the Health ABC study. This questionnaire was derived from the leisure time physical activity questionnaire and included activities commonly performed by older adults (26). The frequency, duration, and intensity of specific activities were determined, and approximate metabolic equivalent unit (MET) values assigned to each activity category to estimate weekly energy expenditure.

Statistical analysis

Characteristics of men and women were compared by Student's t test and chi-square test. Dietary GI and GL were adjusted for total calorie intake using the residuals method of Willett et al (27). Participants were categorized into quintiles of energy-adjusted dietary GI and GL, and baseline characteristics were examined according to dietary GI and GL. Means of quintiles 2 through 5 were compared to those of quintile 1 with Dunnett's test for continuous variables and chi-square test for categorical variables. Linear regression was used to assess trends of continuous variables in relation to dietary GI and GL, and Mantel-Haenszel chi-square test was used to examine trends of categorical variables across quintiles of dietary GI and GL.

To determine the risk of developing type 2 diabetes by quintile of energy-adjusted dietary GI and GL, multivariate logistic regression was used. Covariates included age, gender, race, clinical site, education, physical activity, baseline fasting glucose, BMI, alcohol consumption, total fiber intake, cereal fiber intake and smoking status. Dietary GI and GL were also analyzed as continuous variables in relation to risk. Interactions of dietary GI and GL with gender, race, and education were tested. Statistical significance was set at $p \leq 0.05$, and analyses were performed with SAS (version 9.1; SAS Institute Inc., Cary, NC).

Results

Table 1 shows characteristics of the study population, and Tables 2 and 3 present characteristics according to energy-adjusted dietary GI and GL. Persons in the higher quintiles of dietary GI were older, on average, less likely to be female or white, have a high school degree, or consume alcohol, and less physically active. They had a higher percent intake from carbohydrate, a lower percent intake from protein, total fat, and saturated fat, and lower consumption of vegetables and fruit. Persons with a higher dietary GL were also older, less likely to be white, have a high school degree, or consume alcohol, and had fewer lifetime pack-years of smoking. They also had a higher percent intake from carbohydrate, a lower percent intake from protein, total fat and saturated fat and a higher intake of fruit and fiber.

Table 4 shows the risk of developing type 2 diabetes according to energy-adjusted dietary GI and GL. Neither dietary GI nor dietary GL was significantly associated with risk, either before or after controlling for age, gender, race, clinical site, education, physical activity, baseline fasting glucose, BMI, alcohol consumption, and smoking status. Additional adjustment for total fiber or cereal fiber intake did not significantly alter results. Interactions of dietary GI or GL with gender, race and education were found not to be significant.

Discussion

Neither dietary GI nor dietary GL was associated with risk of developing type 2 diabetes in this cohort of well-functioning older adults. These findings support results of the Atherosclerosis Risk in Communities Study of adults age 45 to 64 at baseline, the Iowa Women's Health Study of women age 55 to 70 and the Insulin Resistance Atherosclerosis Study of adults age 40 to 69, as these studies did not show associations between dietary GI or GL and incident type 2 diabetes (12,13,14). Conversely, in the Nurses' Health Study of women age 40 to 65, those in the highest versus the lowest quintile of dietary GI or GL had an approximately 40 to 50% greater risk of developing type 2 diabetes after adjustment for cereal fiber intake, and similar positive relationships were seen between dietary GI and type 2 diabetes risk in the Health Professionals Follow-up Study of men age 40 to 75, the Nurses' Health Study II of women age 24 to 44, and the Melbourne Collaborative Cohort Study of adults age 40 to 69 (2,4,5,15).

In this study, both dietary GI and GL were negatively associated with intake of saturated fat, total fat and alcohol, factors that might adversely affect glucose metabolism. Dietary GI and GL were positively associated with dietary carbohydrate, and dietary GL was also positively associated with fruit and fiber intake, factors that might benefit glucose metabolism. Though diets with a lower GI or GL were expected to be more healthful, the higher the dietary GI or GL, the better the diet fit current dietary guidelines to limit intake of saturated fat, and in the case of dietary GL, to consume at least 14 grams of fiber per 1000 calories and to consume multiple servings of fruit per day (19). Thus, findings of this study demonstrate that a lower dietary GI or GL is not necessarily more compatible with current dietary guidelines.

Other studies have also found strong nutritional correlates of dietary GI and GL (2,4,5,8,15, 28,29,30). Schulz et al. positively correlated dietary GI with intake of white bread, beer, meat, fried potatoes, fat, alcohol and starch, and thus with a less healthful overall diet, and negatively correlated dietary GI with intake of fruit, fiber and low fat milk (28). Other studies also found positive associations of dietary GI with intake of bread and starch, and negative associations with fruit, fiber and low fat milk (2,4,5,8,15). Most studies, like this one, positively associated dietary GL with a more healthful overall diet, including higher intake of fiber and cereal fiber, and negatively associated dietary GL with intake of fat and alcohol (2,4,5,11).

Summary indicators such as dietary GI or GL may not provide sufficient information on the composition of the diet and its effect on risk of type 2 diabetes. It has been suggested that dietary GL provides little information beyond total carbohydrate intake (11,29). On the other hand, dietary GI, which does not reflect total carbohydrate intake, is thought to provide little insight into the overall insulin demand induced by total carbohydrate intake (2,4). Therefore, if the GI or GL is considered in research or in dietary recommendations, it should be in conjunction with national dietary guidelines (17,24).

Certain factors may have influenced study findings. This cohort included participants of similar age and functional status, with relatively narrow ranges of dietary GI and GL. Dietary GI quintile means ranged from approximately 50 to 60. Mayer-Davis et al., by contrast, found dietary GI quintile means that ranged from about 75 to 90, as did others, perhaps in part due to methodological differences in calculating dietary GI and GL (2,4,5,7,8,12,29). While the current study followed methods supported by several international organizations, some others have used a slightly different procedure (10). Dietary GL means in the current study ranged from approximately 95 to 160. Mayer-Davis et al. found dietary GL quintile means of about 90 to 300, and others also found larger and higher ranges of dietary GL compared to those of the current study (2,4,7,29). The homogeneity in this study population could have attenuated associations between dietary GI and GL and risk of type 2 diabetes (31).

As this study population consisted of relatively well-functioning older adults, selection bias, through exclusion of metabolically vulnerable subjects, could also have diminished associations between dietary GI or GL and risk of type 2 diabetes (32). Furthermore, as in other studies, this food frequency questionnaire was not specifically designed to measure dietary GI or GL, and may not have captured the total glycemic effect of the diet (11). Strengths of this study include its longitudinal design, unique age group and thorough diagnosis of type 2 diabetes that did not rely solely on self-reported information.

In conclusion, this study does not support a relationship between dietary GI or GL and risk of type 2 diabetes in older adults. Because dietary GI and GL each have strong and unique nutritional correlates, it may be important to examine the dietary pattern as a whole in addition to estimating the glycemic impact of dietary carbohydrate when evaluating the contribution of diet to risk of a complex chronic disease such as type 2 diabetes.

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References

1. U.S. Department of Health and Human Services. National Diabetes Surveillance System. [accessed 19 July 2006]. Internet http://www.cdc.gov/diabetes/statistics/prev/national/figpersons.htm
2. Salmeron J, Ascherio A, Rimm EB, et al. Dietary fiber, glycemic load, and risk of NIDDM in men. Diabetes Care 1997 Apr;20(4):545–50. [PubMed: 9096978]
3. Jenkins DJ, Wolever TM, Taylor RH, et al. Glycemic index of foods: a physiological basis for carbohydrate exchange. Am J Clin Nutr 1981 Mar;34(3):362–6. [PubMed: 6259925]
4. Salmeron J, Manson JE, Stampfer MJ, Colditz GA, Wing AL, Willett WC. Dietary fiber, glycemic load, and risk of non-insulin-dependent diabetes mellitus in women. JAMA 1997 Feb 12;277(6):472–7. [PubMed: 9020271]
5. Schulze MB, Liu S, Rimm EB, Manson JE, Willett WC, Hu FB. Glycemic index, glycemic load, and dietary fiber intake and incidence of type 2 diabetes in younger and middle-aged women. Am J Clin Nutr 2004 Aug;80(2):348–56. [PubMed: 15277155]
6. Brand-Miller JC. Glycemic load and chronic disease. Nutr Rev 2003 May;61(5 Pt 2):S49–55. [PubMed: 12828192]
7. McKeown NM, Meigs JB, Liu S, Saltzman E, Wilson PW, Jacques PF. Carbohydrate nutrition, insulin resistance, and the prevalence of the metabolic syndrome in the Framingham Offspring Cohort. Diabetes Care 2004 Feb;27(2):538–46. [PubMed: 14747241]
8. van Dam RM, Visscher AW, Feskens EJ, Verhoef P, Kromhout D. Dietary glycemic index in relation to metabolic risk factors and incidence of coronary heart disease: the Zutphen Elderly Study. Eur J Clin Nutr 2000 Sep;54(9):726–31. [PubMed: 11002385]
9. Liese AD, Schulz M, Fang F, et al. Dietary glycemic index and glycemic load, carbohydrate and fiber intake, and measures of insulin sensitivity, secretion, and adiposity in the Insulin Resistance Atherosclerosis Study. Diabetes Care 2005 Dec;28(12):2832–8. [PubMed: 16306541]
10. Sahyoun NR, Anderson AL, Kanaya AM, et al. Dietary glycemic index and load, measures of glucose metabolism, and body fat distribution in older adults. Am J Clin Nutr 2005 Sep;82(3):547–52. [PubMed: 16155266]
11. Lau C, Faerch K, Glumer C, et al. Inter99 study. Dietary glycemic index, glycemic load, fiber, simple sugars, and insulin resistance: the Inter99 study. Diabetes Care 2005 Jun;28(6):1397–403. [PubMed: 15920058]
12. Stevens J, Ahn K, Juhaeri, Houston D, Steffan L, Couper D. Dietary fiber intake and glycemic index and incidence of diabetes in African-American and white adults: the ARIC study. Diabetes Care 2002 Oct;25(10):1715–21. [PubMed: 12351467]
13. Meyer KA, Kushi LH, Jacobs DR Jr, Slavin J, Sellers TA, Folsom AR. Carbohydrates, dietary fiber, and incident type 2 diabetes in older women. Am J Clin Nutr 2000 Apr;71(4):921–30. [PubMed: 10731498]
14. Schulz M, Liese AD, Fang F, Gilliard TS, Karter AJ. Is the association between dietary glycemic index and type 2 diabetes modified by waist circumference. Diabetes Care 2006 May;29(5):1102–4. [PubMed: 16644644]
15. Hodge AM, English DR, O'Dea K, Giles GG. Glycemic index and dietary fiber and the risk of type 2 diabetes. Diabetes Care 2004 Nov;27(11):2701–6. [PubMed: 15505008]
16. Foster-Powell K, Holt SH, Brand-Miller JC. International table of glycemic index and glycemic load values: 2002. Am J Clin Nutr 2002 Jul;76(1):5–56. [PubMed: 12081815]
17. Sheard NF, Clark NG, Brand-Miller JC, et al. Dietary carbohydrate (amount and type) in the prevention and management of diabetes: a statement by the American Diabetes Association. Diabetes Care 2004 Sep;27(9):2266–71. [PubMed: 15333500]

18. Bantle JP, Wylie-Rosett J, Albright AL, et al. Nutrition recommendations and interventions for diabetes--2006: a position statement of the American Diabetes Association. Diabetes Care 2006 Sep; 29(9):2140–57. [PubMed: 16936169]
19. U.S. Department of Health and Human Services. U.S. Department of Agriculture. Dietary Guidelines for Americans. 6. Washington, DC: U.S. Government Printing Office; 2005.
20. American Diabetes Association. Diabetes Statistics. [accessed 23 May 2007]. Internet: http://www.diabetes.org/diabetes-statistics.jsp
21. McBean AM, Li S, Gilbertson DT, Collins AJ. Differences in diabetes prevalence, incidence, and mortality among the elderly of four racial/ethnic groups: whites, blacks, hispanics, and asians. Diabetes Care 2004 Oct;27(10):2317–24. [PubMed: 15451894]
22. Crandall J, Schade D, Ma Y, et al. Diabetes Prevention Program Research Group. The influence of age on the effects of lifestyle modification and metformin in prevention of diabetes. J Gerontol A Biol Sci Med Sci 2006 Oct;61(10):1075–81. [PubMed: 17077202]
23. Subar AF, Thompson FE, Kipnis V, et al. Comparative validation of the Block, Willett, and National Cancer Institute food frequency questionnaires : the Eating at America's Table Study. Am J Epidemiol 2001 Dec 15;154(12):1089–99. [PubMed: 11744511]
24. FAO/WHO. Carbohydrates in human nutrition: report of a joint FAO/WHO Expert Consultation, Rome, 14–18 April, 1997. Rome: Food and Agriculture Organization; 1998. Expert Consultation. FAO Food and Nutrition paper 66
25. Genuth S, Alberti KG, Bennett P, et al. Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. Follow-up report on the diagnosis of diabetes mellitus. Diabetes Care 2003 Nov; 26(11):3160–7. [PubMed: 14578255]
26. Taylor HL, Jacobs DR Jr, Schucker B, Knudsen J, Leon AS, Debacker G. A questionnaire for the assessment of leisure time physical activities. J Chronic Dis 1978;31(12):741–55. [PubMed: 748370]
27. Willett, WC. Nutritional epidemiology. 2. New York: Oxford University Press; 1998.
28. Schulz M, Liese AD, Mayer-Davis EJ, et al. Nutritional correlates of dietary glycaemic index: new aspects from a population perspective. Br J Nutr 2005 Sep;94(3):397–406. [PubMed: 16176611]
29. Mayer-Davis EJ, Dhawan A, Liese AD, Teff K, Schulz M. Towards understanding of glycaemic index and glycaemic load in habitual diet: associations with measures of glycaemia in the Insulin Resistance Atherosclerosis Study. Br J Nutr 2006 Feb;95(2):397–405. [PubMed: 16469159]
30. Feskens EJ, Du H. Dietary glycaemic index from an epidemiological point of view. Int J Obes (Lond) 2006 Dec;30(Suppl 3):S66–71.
31. Buyken AE, Liese AD. Dietary glycemic index, glycemic load, fiber, simple sugars, and insulin resistance: the Inter99 Study: response to Lau et al. Diabetes Care 2005 Dec;28(12):2986. [PubMed: 16331870]
32. Jenkins DJ, Kendall CW, Augustin LS, et al. Glycemic index: overview of implications in health and disease. Am J Clin Nutr 2002 Jul;76(1):266S–73S. [PubMed: 12081850]

Table 1

Characteristics of the study population[1]

	Men	Women
n	871	1027
Sociodemographic factors		
Age (years)[2]	75.3 ± 0.1	75.0 ± 0.1[3]
Race (% White)[4]	71.8	63.4[3]
Education (% completed high school)[4]	78.5	81.9
Behavioral factors[4]		
Smoking (lifetime pack-years)	25.5 ± 1.0	11.9 ± 0.7[3]
Alcohol (% any consumption)	62.6	47.8[3]
Physical activity (kcal/week)	1476 ± 73	782 ± 41[3]
Biochemical variables		
Fasting glucose (mg/dL)[2]	94.4 ± 0.3	91.3 ± 0.3[3]
Fasting insulin (μU/mL)[4]	7.7 ± 0.2	7.9 ± 0.2
Body composition[2]		
BMI (kg/m^2)	26.6 ± 0.1	27.0 ± 0.2[3]
Total body fat (%)	29.2 ± 0.2	40.3 ± 0.2[3]
Dietary factors[2]		
Total calorie intake (kcal)	2017 ± 22	1680 ± 18[3]
% kcal from carbohydrate	53.0 ± 0.3	53.9 ± 0.3[3]
% kcal from protein	14.2 ± 0.1	14.5 ± 0.1[3]
% kcal from fat	33.0 ± 0.2	33.2 ± 0.2[3]
% kcal from saturated fat	9.6 ± 0.1	9.4 ± 0.1[3]
Total dietary fiber (g)	18.2 ± 0.3	16.7 ± 0.2[3]
Daily servings of vegetables	3.0 ± 0.1	3.0 ± 0.1
Daily servings of fruit and fruit juice	1.8 ± 0.0	2.1 ± 0.0[3]
Unadjusted dietary glycemic index (glucose scale)	56.8 ± 0.1	55.8 ± 0.1[3]
Unadjusted dietary glycemic load (glucose scale)	140.8 ± 1.7	116.7 ± 1.4[3]

[1]Means ± SEM, unless otherwise specified.

[2]Values from year 2 of the Health ABC study.

[3]Significantly different from men, $P \leq 0.05$ (Student's *t* test for continuous variables and chi-square test for categorical variables).

[4]Values from baseline of the Health ABC study.

Table 2

Characteristics of participants according to energy-adjusted dietary glycemic index[1]

	Dietary glycemic index quintile 1	2	3	4	5	*P* value[2]
Dietary glycemic index[3]	50.5 ± 0.1	54.3 ± 0.0	56.2 ± 0.0	58.3 ± 0.0	61.8 ± 0.1	
N	379	381	378	380	380	
% Female	61.2	55.9	56.1	49.2[4]	48.1[4]	<0.0001
Risk factors for type 2 diabetes						
Age (years)[3]	75.0 ± 0.1	75.0 ± 0.1	75.3 ± 0.1	74.9 ± 0.1	75.5 ± 0.1	0.0216
Race (% White)[5]	69.1	71.9	69.3	67.4	58.4[4]	0.0006
Education (% completed high school)[5]	84.7	84.3	81.8	80.5	70.5[4]	<0.0001
Smoking (lifetime pack-years)[5]	18.9 ± 1.4	16.6 ± 1.4	18.3 ± 1.4	18.0 ± 1.4	18.7 ± 1.4	0.6635
Alcohol (% any consumption)[5]	64.1	61.4	52.9[4]	47.9[4]	46.6[4]	<0.0001
Physical activity (kcal/week)[5]	1196 ± 92	1200 ± 92	1104 ± 92	1065 ± 92	939 ± 92	0.0120
Fasting glucose (mg/dL)[3]	93.4 ± 0.5	92.9 ± 0.5	91.7 ± 0.5	93.0 ± 0.5	92.6 ± 0.5	0.2433
BMI (kg/m^2)[3]	27.2 ± 0.2	26.7 ± 0.2	26.7 ± 0.2	27.0 ± 0.2	26.5 ± 0.2	0.1247
Dietary factors[3]						
Total calorie intake (kcal)	1807 ± 33	1882 ± 33	1822 ± 33	1842 ± 33	1820 ± 33	1.0000
% kcal from carbohydrate	50.8 ± 0.4	52.8 ± 0.4[4]	53.5 ± 0.4[4]	54.6 ± 0.4[4]	55.7 ± 0.4[4]	<0.0001
% kcal from protein	14.9 ± 0.2	14.5 ± 0.2	14.5 ± 0.2	14.3 ± 0.2[4]	13.5 ± 0.2[4]	<0.0001
% kcal from fat	33.7 ± 0.4	33.6 ± 0.4	33.3 ± 0.4	32.7 ± 0.4	32.3 ± 0.4[4]	0.0001
% kcal from saturated fat	9.7 ± 0.1	9.6 ± 0.1	9.6 ± 0.1	9.4 ± 0.1	9.2 ± 0.1[4]	0.0002
Total dietary fiber (g)	16.7 ± 0.4	18.3 ± 0.4	17.4 ± 0.4	18.0 ± 0.4	16.7 ± 0.4	0.8560
Daily servings of vegetables	3.1 ± 0.1	3.2 ± 0.1	2.9 ± 0.1	3.1 ± 0.1	2.5 ± 0.1[4]	<0.0001
Daily servings of fruit and fruit juice	2.3 ± 0.1	2.3 ± 0.1	2.0 ± 0.1[4]	1.8 ± 0.1[4]	1.4 ± 0.1[4]	<0.0001

[1] Means ± SEM, unless otherwise specified.

[2] Linear regression was used for continuous variables, and Mantel-Haenszel chi-square test for trend across quintiles was used for categorical variables.

[3] Values from year 2 of the Health ABC study.

[4] Significantly different from quintile 1, $P \leq 0.05$ (Dunnett's test for continuous variables and chi-square test for categorical variables).

[5] Values from baseline of the Health ABC study.

Table 3

Characteristics of participants according to energy-adjusted dietary glycemic load[1]

	Dietary glycemic load quintile 1	2	3	4	5	*P* value[2]
Dietary glycemic load[3]	94.6 ± 0.9	117.1 ± 0.2	127.3 ± 0.1	138.2 ± 0.2	161.6 ± 0.9	
N	379	381	378	381	379	
% Female	52.5	58.8	55.0	58.5	45.7	0.0843
Risk factors for type 2 diabetes						
Age (years)[3]	74.8 ± 0.1	75.1 ± 0.1	74.9 ± 0.1	75.5 ± 0.1[4]	75.4 ± 0.1[4]	0.0012
Race (% White)[5]	68.1	71.1	72.8	61.7	62.5	0.0070
Education (% completed high school)[5]	81.8	81.1	82.5	80.3	76.0[4]	0.0549
Smoking (lifetime pack-years)[5]	23.9 ± 1.4	17.5 ± 1.4[4]	16.7 ± 1.4[4]	16.3 ± 1.4[4]	16.2 ± 1.4[4]	<0.0001
Alcohol (% any consumption)[5]	70.5	58.5[4]	52.4[4]	46.5[4]	45.1[4]	<0.0001
Physical activity (kcal/week)[5]	1244 ± 92	1055 ± 92	1034 ± 92	989 ± 92	1182 ± 92	0.9010
Fasting glucose (mg/dL)[3]	93.5 ± 0.5	92.8 ± 0.5	92.5 ± 0.5	91.6 ± 0.5[4]	93.2 ± 0.5	0.3554
BMI (kg/m^2)[3]	27.0 ± 0.2	27.0 ± 0.2	27.1 ± 0.2	26.6 ± 0.2	26.5 ± 0.2	0.1320
Dietary factors[3]						
Total calorie intake (kcal)	2061 ± 31	1637 ± 31[4]	1652 ± 32[4]	1812 ± 31[4]	2013 ± 31	1.0000
% kcal from carbohydrate	43.1 ± 0.4	49.9 ± 0.2[4]	53.9 ± 0.3[4]	57.8 ± 0.4[4]	62.7 ± 0.4[4]	<0.0001
% kcal from protein	15.2 ± 0.1	15.1 ± 0.1	14.4 ± 0.1[4]	13.8 ± 0.1[4]	13.3 ± 0.1[4]	<0.0001
% kcal from fat	40.2 ± 0.3	35.6 ± 0.3[4]	33.1 ± 0.3[4]	30.3 ± 0.3[4]	26.3 ± 0.3[4]	<0.0001
% kcal from saturated fat	11.5 ± 0.1	10.2 ± 0.1[4]	9.5 ± 0.1[4]	8.6 ± 0.1[4]	7.6 ± 0.1[4]	<0.0001
Total dietary fiber (g)	16.7 ± 0.4	15.5 ± 0.4	16.3 ± 0.4	18.0 ± 0.4[4]	20.7 ± 0.4[4]	<0.0001
Daily servings of vegetables	3.1 ± 0.1	2.9 ± 0.1	2.9 ± 0.1	2.8 ± 0.1	3.2 ± 0.1	0.6407
Daily servings of fruit and fruit juice	1.7 ± 0.1	1.9 ± 0.1	1.9 ± 0.1	2.2 ± 0.1[4]	2.2 ± 0.1[4]	<0.0001

[1] Means ± SEM, unless otherwise specified.

[2] Linear regression was used for continuous variables, and Mantel-Haenszel chi-square test for trend across quintiles was used for categorical variables.

[3] Values from year 2 of the Health ABC study.

[4] Significantly different from quintile 1, $P \leq 0.05$ (Dunnett's test for continuous variables and chi-square test for categorical variables).

[5] Values from baseline of the Health ABC study.

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Table 4

Relative risk of type 2 diabetes according to energy-adjusted dietary glycemic index and load

	Quintile					
	1	2	3	4	5	*P* value[1]
Dietary glycemic index (mean ± SEM)	50.5 ± 0.1	54.3 ± 0.0	56.2 ± 0.0	58.3 ± 0.0	61.8 ± 0.1	
Type 2 diabetes cases (n)	24	18	15	20	22	
OR (95% CI)[2]	1.0	0.7 (0.4,1.4)	0.6 (0.3,1.2)	0.8 (0.4,1.5)	0.9 (0.5,1.7)	0.7152
OR (95% CI)[3]	1.0	0.7 (0.4,1.4)	0.6 (0.3,1.2)	0.8 (0.4,1.4)	0.8 (0.4,1.5)	0.4671
OR (95% CI)[4]	1.0	0.8 (0.4,1.7)	0.7 (0.4,1.5)	0.8 (0.4,1.6)	1.0 (0.5,2.0)	0.8628
Dietary glycemic load (mean ± SEM)	94.6 ± 0.9	117.1 ± 0.2	127.3 ± 0.1	138.2 ± 0.2	161.6 ± 0.9	
Type 2 diabetes cases (n)	17	22	18	20	22	
OR (95% CI)[2]	1.0	1.3 (0.7,2.5)	1.1 (0.5,2.1)	1.2 (0.6,2.3)	1.3 (0.7,2.5)	0.1234
OR (95% CI)[3]	1.0	1.3 (0.7,2.6)	1.1 (0.5,2.1)	1.2 (0.6,2.4)	1.3 (0.7,2.5)	0.1372
OR (95% CI)[4]	1.0	1.5 (0.7,3.0)	1.0 (0.5,2.2)	1.5 (0.7,3.2)	1.3 (0.6,2.7)	0.1147

[1] Analysis of dietary glycemic index and load as continuous variables.

[2] Unadjusted model.

[3] Adjusted for age, gender, race, clinical site and education.

[4] Adjusted for age, gender, race, clinical site, education, physical activity, baseline fasting glucose, BMI, alcohol consumption, and smoking status.