

Adherence to 2005 *Dietary Guidelines for Americans* is associated with a reduced progression of coronary artery atherosclerosis in women with established coronary artery disease^{1–4}

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ABSTRACT

Background: A premise of the 2005 *Dietary Guidelines for Americans* (DGA) is chronic disease prevention.

Objective: The goal was to determine whether a diet meeting the DGA is associated with less atherosclerotic lesion progression.

Design: We used the data from 224 postmenopausal women with established coronary artery disease enrolled in the Estrogen Replacement and Atherosclerosis Study. Atherosclerosis progression was defined by repeated measures of quantitative angiography over a 3-y period. Adherence to the key DGA recommendations was measured by using the DGA Adherence Index (DGAI; possible range: 0–20), with each component weighted equally, and the modified DGAI score (wDGAI; possible range: –0.19–0.51), with each component weighted based on its relation to atherosclerosis progression. Mixed-model regression analyses were performed to assess the association between diet and atherosclerosis progression.

Results: No women consumed a diet meeting all of the DGA recommendations. The mean (range) of the DGAI score was 14.1 (8.0–19.0). DGAI was not associated with atherosclerosis progression ($P = 0.44$), whereas wDGAI was inversely associated; a 1-SD difference in wDGAI was related to 0.049-mm less narrowing of the coronary arteries (SE = 0.017, $P = 0.004$).

Conclusions: In postmenopausal women with established heart disease, under the assumption that all DGA recommendations are similarly effective, overall adherence was not associated with atherosclerosis progression. However, assigning differential weights to the DGA recommendations, the adherence was significantly associated with slower atherosclerosis progression. Assuming equity of associations between all dietary recommendations and disease outcomes is a limitation in accurately examining the effectiveness of the DGA. *Am J Clin Nutr* 2009;90:193–201.

INTRODUCTION

One of the underlying premises of the 2005 *Dietary Guidelines for Americans* (DGA) is chronic disease prevention (1, 2). Whether or not dietary guidelines can affect disease progression among individuals with existing disease has yet to be adequately studied (3–5). Single dietary components are associated with reduced heart disease progression (4–9), which is the major cause of death in developed and now developing countries (10, 11). However, evidence relating overall adherence to dietary recommendations and coronary artery atherosclerotic lesion progression is lacking (12).

To address the question of adherence to dietary recommendations and its association with health outcomes, Kennedy

et al (13) proposed the use of a dietary index—the Healthy Eating Index—as a measure of adherence to the 1995 DGA. Fogli-Cawley et al (14) developed a dietary index—the 2005 DGA Adherence Index (DGAI)—to assess adherence to the 2005 DGA and showed cross-sectional associations with risk factors of chronic diseases in a population-based cohort (14, 15). The dietary index technique has proven to be useful at measuring adherence to dietary recommendations and at testing the hypothesis that diets concordant with them have a favorable effect on sustaining heart health in a general population (14–16).

Dietary indexes are constructed by summing scores based on adherence to individual dietary recommendations. Contributions of individual components to a total score are frequently considered of equal weight in calculating an index score. This construction leads to the biologically implausible assumption that adherence to each recommendation is associated to the same extent with all health outcomes considered (17). The use of prior knowledge to construct a summary measure of overall diet is a strength of this approach. The assumption of equal weights is a potential weakness of the index approach, limiting our ability to evaluate the effectiveness of adherence to dietary recommendations in both clinical and general populations. In contrast with the a priori criterion-based approach, dietary pattern analyses have been widely used as data-driven approach to obtain summary variables of dietary factors (18, 19). Therefore, there are advantages to using a hybrid method consisting of a criteria-based approach and a data-driven approach, where a priori criteria are used to score adherence to dietary recommendations and a data-driven approach is used to derive weights of the components.

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Using the dietary index approach, we tested the hypothesis that consuming a diet consistent with the current DGA recommendations is associated with a reduced progression of atherosclerosis in postmenopausal women with established coronary artery atherosclerosis. Given the aforementioned limitations of the dietary index approach, we took a novel hybrid approach with a priori-based criteria to score adherence to dietary recommendations and with data-driven weights on each component of a dietary index.

SUBJECTS AND METHODS

Subjects

The subjects in this study were participants in the Estrogen Replacement and Atherosclerosis (ERA) study—a randomized, double-blind, placebo-controlled trial of hormone replacement therapy in postmenopausal women with established heart disease. The study design and primary results have been reported previously (20). Briefly, 309 postmenopausal women aged <80 y who were not receiving estrogen-replacement treatments and had one or more segments with an epicardial coronary stenosis of $\geq 30\%$ of the luminal diameter were eligible for the study. They were enrolled in 1995–1996 from 6 US sites: the University of Alabama, Birmingham, AL; Carolinas Medical Center, Charlotte, NC; Moses Cone Health System, Greensboro, NC; Hartford Hospital, Hartford, CT; Forsyth Memorial Hospital, Winston-Salem, NC; and Wake Forest University School of Medicine, Winston-Salem, NC. Women with one or more of the following conditions were excluded from the trial: known or suspected breast or endometrial carcinoma, previous or planned coronary bypass surgery, a history of deep vein thrombosis or pulmonary embolism, symptomatic gallstones, a serum aspartate aminotransferase concentration >1.5 times normal, a fasting triacylglycerol concentration >400 mg/dL, a serum creatinine concentration >2.0 mg/dL, left main stenosis $>70\%$, uncontrolled hypertension, or uncontrolled diabetes. Eligible subjects were randomly assigned to receive 1) 0.625 mg conjugated equine estrogen, 2) 0.625 mg conjugated equine estrogen plus 2.5 mg medroxyprogesterone acetate, or 3) placebo. The subjects were followed for a mean (\pm SD) 3.3 ± 0.6 y. Neither treatment had a significant effect on the progression of coronary atherosclerosis (20). The institutional review board at each participating center approved all study procedures, and all participants in the ERA study gave informed consent.

At baseline, the participants completed standard interviews on drug use, diseases history, and physical activity frequency (Physical Activity Scale for Elderly; PASE) (21, 22); completed a semiquantitative food-frequency questionnaire (FFQ) to assess dietary intake (23, 24); and underwent clinical examinations and laboratory testing to measure cardiovascular disease risk factors, sex hormones, and inflammatory biomarkers.

For the current analyses, we excluded 61 women for whom follow-up coronary angiography was not available (including 12 women who died before follow-up angiography). Also excluded were 24 women who either did not complete the FFQ at baseline ($n = 13$), reported extreme energy intakes (<500 or >4500 kcal/d; $n = 7$), or had missing information of factors needed for calculation of a dietary index or for statistical adjustment (weight, height, physical activity, and education status;

$n = 4$). For this study, complete data were available for 224 women. Total energy intake and dietary index components were not significantly different between the included and excluded subjects among those with dietary data ($P > 0.2$). No significant differences were observed for other baseline characteristics, except for aspirin use (54% and 73% for the included and excluded, respectively; $P = 0.003$).

Dietary assessment and DGAI

Habitual food consumption and nutrient intakes were assessed at baseline with an interviewer-administered 126-item FFQ (25). Participants were asked to choose 1 of 9 categories to indicate how often, on average, they had consumed given amounts of various specified foods during the past year. Other questions asked about supplements, including multivitamin supplements, and specific foods, including breakfast cereals, margarine, and vegetable oil used for frying or baking. Nutrient intakes were calculated by multiplying the reported frequency of consumption for each food item with each prespecified portion size and the nutrient composition for that item. The reproducibility and validity of measuring dietary variables were described in detail previously (23, 24). For example, in our study population, the correlation between dietary and plasma $n-3$ long-chain polyunsaturated fatty acids was 0.41 (26). This value is similar to that observed previously in a study of questionnaire validation (27).

The DGAI is an index that measures adherence to 20 key dietary recommendations in the 2005 DGA (1). Components related to nondietary behaviors, such as food safety, or those for special populations, such as lactating or pregnant women, were not included in the DGAI. We modified the original DGAI developed by Fogli-Cawley et al (14) so that each component has a continuous score from 0 to 1, instead of discrete scores of 0, 0.5, or 1 (Table 1 for the algorithm).

Of the 20 DGAI components, each of the 11 “Food Group” items was assigned a score of 0–1.0 on the basis of adherence to each recommendation for food group consumption, depending on the estimated energy requirement of each individual. DGA defines patterns of the recommendations for 10 levels of daily energy requirements to maintain body weight. Therefore, first, the caloric need of each subject was estimated by using a published equation for Estimated Energy Requirement (EER), which is dependent on sex, height, weight, age, and physical activity level (28). Physical activity level was determined by responses to the PASE questionnaire. Second, based on the calculated EER and calorie-specific DGA diet pattern, criteria of adherence to food group recommendations were assigned to each subject. Finally, adherence to each recommendation of 11 items was scored proportionally with a value that ranged from 0 to 1. The sum of the 11 scores was considered a measure of adherence to the “Food Group” recommendations. For the food groups starchy vegetables, meat and beans, total grains, and dairy products, overconsumption was penalized by reducing the score proportionally for scores up to 1.25 times higher than recommended consumption. A maximum penalty of 0.5 was assigned to those consuming ≥ 1.25 times the recommendation. Nine “Healthy Choice” items assessed adherence to recommendations of nutrient intake. The recommended intake of sodium for elderly and hypertensive persons is <1500 mg/d

TABLE 1Criteria of 20 Dietary Guidelines for Americans Adherence Index (DGAI) components for individuals with an 1800-kcal/d caloric requirement to maintain body weight¹

DGAI components ²	Criteria for diet with an 1800-kcal/d EER ³	
	0 point	1.0 point
DGAI score ⁴		
Food Group score ⁵		
Dark green vegetables (cups/wk)	0	≥3.0
Orange vegetables (cups/wk)	0	≥2.0
Legumes (cups/wk)	0	≥3.0
Other vegetables (cups/wk)	0	≥6.5
Starchy vegetables (cups/wk) ⁶	0	2.5
Fruit (cups/d)	0	≥6.5
Variety (no. of components) ⁷	0	6
Meat and beans (oz/d) ⁶	0	4.5
Dairy products (cups/d) ⁶	0	2.5
All grains (oz/d) ⁶	0	5.5
Added sugar (% of energy)	≥7.5%	≤5.0%
Healthy Choice score ⁸		
Whole grains (% of grains)	0%	≥50%
Fiber intake (g/1000 kcal/d)	0	≥14
Total fat (% of energy)	≤10%, ≥45%	≥20%, ≤35%
Saturated fat (% of energy)	≥15%	≤10%
<i>trans</i> Fat (% of energy)	≥1.5%	≤1%
Cholesterol intake (mg/d)	≥450	≤300
Low-fat products (%) ⁹	0%	≥75%
Sodium intake (mg/d)	≥3450	≤2300
Alcohol consumption (drinks/d)	≥1.5	≤1.0

¹ The DGAI was calculated as the sum of 20 components with a possible score of 0 to 20; EER, estimated energy requirement per day calculated on the basis of formula provided from National Research Council (28).

² 1 cup = 237 mL (US), 0.946 cup in a metric unit; 1 kcal = 4.184 kJ; 1 oz = 28.35 g; 1 drink = 355 mL regular beer, 118 mL wine, or 45 mL distilled spirits.

³ Criteria of the food group components were determined on the basis of EER; the DGA determines 10 different criteria for 10 daily EER levels of 1400–3200 kcal incremented by 200 kcal (5.86–13.39 MJ by 0.84 MJ). The criteria based on intermediate EER were proportionately determined between the 2 criteria based on the EERs provided by the DGA; for example, the criteria for individuals with an EER of 1900 kcal were set middle values of the criteria for EER of 1800 and 2000 kcal. The criteria for individuals with an EER <1400 or >3200 kcal were set equal to criteria for individuals with daily EERs of 1400 and 3200 kcal, respectively. Intermediate intakes between criteria for 0 and 1.0 points were scored proportionately between 0 and 1.0.

⁴ Total score of the 20 components.

⁵ Total score of the 11 components below.

⁶ Overconsumption more than recommendation was penalized. Consumption ≥1.25 times recommendations was scored as 0.5. Intermediate consumption was scored proportionally between 0.5 and 1.0.

⁷ Variety is determined as the sum of scores of 6 fruit and vegetable components.

⁸ Total score of the 9 components below.

⁹ Adherence to recommendations of lean-fat meat and low-fat dairy product choice was the sum of adherences, calculated separately. For each adherence to recommendations of low-fat dairy product choices (%) and lean fat (%) meat product choices: ≥75% assigns 0.5 point to an individual, 0% assigns 0 points to an individual; intermediate %, proportionate score between 0 and 0.5. Sum of the 2 scores had a possible range from 0 to 1 and is considered the component score (14).

The change in the criterion for sodium intake component to 1500 mg/d did not appreciably change the results of our analyses. Adherence to each item was scored proportionally by a value that ranged from 0 to 1 on the basis of predetermined cutoffs of the 9 recommendations that were not based on estimated energy requirements. The maximum possible DGAI score is 20.

Outcome measurement

At baseline and at the end of follow-up, each woman underwent coronary angiography using a standardized protocol to measure luminal diameters of up to 10 proximal epicardial

segments (mean: 9.3 segments per women) and the degree of stenosis as a percentage of the reference diameter (29). Review and analyses of the paired films were performed by using a previously validated system of cine projectors (SME-3500; Sony, Park Ridge, NJ) and software (QCAPlus; Sanders Data Systems, Palo Alto, CA), giving a mean intraoperator difference equal to 0.02 mm between blinded duplicate measurements of minimum diameter for vessels with lesions. All measurements were performed by operators blinded to the temporal sequence of the films. Segments totally occluded at baseline or affected by intervening coronary interventions were excluded from the analyses. In total, repeated measures of 2054 segments were used for the analyses.

Statistical analysis

All statistical analyses were performed by using SAS software (version 9.13; SAS Inc, Cary, NC). For descriptive purposes, baseline characteristics of the study population are presented as means or frequencies by DGAI tertile categories. Associations between the total DGAI score and subjects' characteristics were tested by age-adjusted regression analyses, in which the DGAI score and each variable was modeled as a dependent variable and independent variable, respectively; each categorical variable was converted to dummy variables as appropriate. Dietary factors including total energy intake, each dietary component of DGAI, and scores of food group and healthy choice components were described by means and SDs in strata of the 3 DGAI tertile categories. Associations between the total DGAI score and each of the dietary factors were described by partial Spearman correlation coefficients adjusted for age.

To examine the association between the total DGAI score and the change in minimal diameter over the period of follow-up, repeated-measures regression analyses were performed with a mixed-model procedure using PROC MIXED; the technique accounted for multiple correlated observations of each individual (10 coronary segments and 2 time points) (30). The variance-covariance matrix of the 20 correlated observations was estimated from the sum-of-squares cross-products matrix under the unstructured assumption, which provided the best goodness-of-fit compared with other common assumptions, according to Akaike Information Criteria. The main independent variable was the standardized DGAI score. Standardization allows interpretation of the regression slope as the strength of association based on a 1-SD difference in DGAI score. The DGAI variable was included in the model as a single variable (*DGAI*) and cross-product term with time (*time* × *DGAI*). The regression coefficient of *time* × *DGAI* allows testing associations between the DGAI score and change of minimal diameters over time. The analyses were adjusted for each coronary segment and selected covariates. The selection of covariates was determined by examining a change in the regression coefficient of *time* × *DGAI* (31). Briefly, we excluded covariates one-by-one in a backward manner from the fully adjusted model. The covariate with the least influence on the regression coefficient was excluded from the model. The reduced model was considered the next adjusted model. This repetitive procedure was stopped when exclusion of any one of covariates yielded change in the regression coefficient by >0.002. The model with the remaining covariates was considered the final model. The selected covariates were as follows: age categories (<60, 60–64.9, 65–69.9, or ≥70 y), study site [Charlotte, NC (referent); Winston-Salem, NC; Hartford, CT; Greensboro, NC], reported use of a cholesterol-lowering drug (yes or no), education status (less than high school, high school level, or at least college level), frequency of walking (days per week, continuous), current smoking status (yes or no), reported history of chest pain (yes or no), total energy intake (quartiles), systolic blood pressure (continuous), and casual glucose concentration (continuous). Other covariates, which did not meet our selection criteria, included the following: experimental arms (hormone replacement therapies), race-ethnicity, physical activity level determined by PASE, cumulative exposure of smoking (pack-years, continuous), other reports of disease diagnoses and gynecological or cardiovascular surgeries, other

reports of dietary supplement or medication use for cardiovascular health, age of menopause, body mass index (in kg/m²), waist circumference, duration of follow-up, blood pressure, fasting glucose, fasting insulin, serum triglyceride, serum HDL cholesterol, and sex hormones including estradiol, estrogen, and progesterin. We examined statistical interactions involving selected factors, such as coronary segments, medications and clinical conditions, including a cross-product term in the same regression model. Because no significant interactions were observed, the results are not presented.

Weighted DGAI

To address the limitations of the DGAI associated with assigning an equal weight to each of 20 components, we created a modified index by assigning a different weight based on the relation of each component to atherosclerosis progression. To develop the wDGAI (Step I), we first performed a regression analysis including all the DGAI components, except for a variety component, which was created from a score of the sum of fruit and vegetables components. The model included the 19 DGAI component scores (*DGAI_i*, *i* = 1–19) and each time interaction (*time* × *DGAI_i*), in addition to the selected covariates. Second, 19 regression coefficients of the *time* × *DGAI_i* were saved as weights; a positive weight indicates that better adherence to the component was associated with slower atherosclerosis progression, with control for adherence to the other components; a negative weight indicates that better adherence to the component resulted in more atherosclerosis progression. Third, the weights were multiplied by the DGAI component scores of each individual. Finally, the products were summed to create the wDGAI. To allow for a direct comparison of the wDGAI and the DGAI, both of these indexes were standardized to let the mean and SD equal 0 and 1, respectively.

To examine the association between the modified index and atherosclerosis progression (Step II), we repeated the analyses described above using the wDGAI in place of the original DGAI. The regression analysis was repeated by including both the DGAI and wDGAI to examine which one had a higher predictive capability of minimal diameter change. SEs of the regression coefficients should incorporate the uncertainty of the first step (development of the wDGAI) and the second step (application of the wDGAI). This need was addressed by a nested bootstrap technique to obtain pooled SEs from the 2 steps as described elsewhere (*see* Supplemental Tables 1 and 2 under “Supplemental data” in the online issue) (32–36). Cross-validation analyses were repeated for the 2-step approaches, where the 2 steps were set independent by iteratively splitting our study population (37). Although the association was attenuated by holding independency between the 2 steps, our results were not affected substantially (*see* Supplemental Table 3 under “Supplemental data” in the online issue).

Our study had a statistical power of 0.67, 0.80, and 0.89 to detect regression coefficients of 0.030, 0.035, and 0.040, respectively, based on a 1-SD difference in DGAI score, with a pooled SD of 0.20 obtained from a residual matrix of the repeated-measures regression model. The regression coefficient of ≥0.030 for the interaction term (*time* × *DGAI* or *time* × *wDGAI*) would be clinically meaningful based on past studies using quantitative coronary angiography (38). A possible increase in type 1 error due to a small

sample size was unlikely in the results of our regression analyses according to Hotelling-Lawley-McKeon approximation of *F* statistics in a study with small sample size (30). Influence analyses were performed by calculating Cook's distance (30, 39). The exclusion of those with a high Cook's distance did not affect our conclusion (*see* Supplemental Table 4 under "Supplemental data" in the online issue). According to bias estimates by bootstrapping analyses, the bias of our estimates of regression coefficients was negligible (*see* Supplemental Tables 1 and 2 under "Supplemental data" in the online issue).

RESULTS

Age-adjusted descriptive subject characteristics are presented according to tertile categories of DGAI score in **Table 2**. None of the women reported adherence to all of the recommendations. The mean (\pm SD) DGAI was 14.1 ± 2.1 , which indicated that, on average, our study population was adherent to about two-thirds of the 20 DGA key dietary recommendations. Compared with those with lower DGAI score, those with higher DGAI scores were more likely to be older ($P < 0.03$), have a college education ($P = 0.002$), use cholesterol lowering drugs ($P =$

TABLE 2

Baseline characteristics for postmenopausal women with established coronary artery atherosclerosis enrolled in the Estrogen Replacement and Atherosclerosis Trial ($n = 224$) by tertile of the Dietary Guidelines for Americans Adherence Index (DGA)

	DGA tertile group			<i>P</i> ¹
	First	Second	Third	
Median DGAI	12.2 (8.0–13.5)	14.3 (13.5–15.1)	16.1 (15.1–19.0)	
Number of subjects	73	73	73	
Number of coronary segments	704	716	715	
Age (y) ²	64.1 \pm 6.9	66.3 \pm 6.8	66.6 \pm 6.9	0.026
Follow-up duration (y) ²	3.3 \pm 0.01	3.4 \pm 0.01	3.4 \pm 0.01	0.805
Exam sites [<i>n</i> (%)]				
Charlotte	23 (32.0)	31 (43.1)	18 (25.0)	
Winston-Salem	31 (40.8)	20 (26.3)	25 (32.9)	
Hartford	5 (16.7)	9 (30.0)	16 (53.3)	
Greensboro	15 (32.6)	15 (32.6)	16 (34.8)	0.06
Experimental arms [<i>n</i> (%)]				
Placebo	23 (30.7)	29 (38.7)	23 (30.7)	
Equine estrogen	30 (39.0)	20 (26.0)	27 (35.1)	
Progesterone and equine estrogen	21 (29.2)	26 (36.1)	25 (34.7)	0.47
Education [<i>n</i> (%)]				
Less than high school	40 (47.1)	19 (22.4)	26 (30.6)	
High school level education	26 (29.6)	34 (38.6)	28 (31.8)	
College level education	8 (15.7)	22 (43.1)	21 (41.2)	<0.01
Current smoking [<i>n</i> (%)]				
Yes	29 (61.7)	12 (25.5)	6 (12.8)	
No	45 (25.4)	63 (35.6)	69 (39.0)	<0.01
Cholesterol-lowering drug [<i>n</i> (%)]				
Yes	23 (29.5)	19 (24.4)	36 (46.2)	
No	51 (34.9)	56 (38.4)	39 (26.7)	0.01
History of chest pain [<i>n</i> (%)]				
Yes	43 (36.8)	39 (33.3)	35 (29.9)	
No	31 (29.0)	36 (33.6)	40 (37.4)	0.376
Walking frequency (d/wk) ²	2.4 \pm 0.3	3.3 \pm 0.3	3.2 \pm 0.3	0.026
BMI (kg/m ²) ²	29.2 \pm 0.8	30.9 \pm 0.8	29.4 \pm 0.8	0.860
Waist circumference (cm) ²	93.9 \pm 1.8	93.6 \pm 1.8	92.9 \pm 1.8	0.696
Systolic blood pressure (mm Hg) ²	135.4 \pm 2.0	132.4 \pm 2.0	133.4 \pm 2.0	0.469
Diastolic blood pressure (mm Hg) ²	74.5 \pm 1.0	74.6 \pm 1.0	73.6 \pm 1.0	0.527
Total cholesterol (mg/dL) ^{2,3}	217.0 \pm 4.9	214.8 \pm 4.8	219.3 \pm 4.9	0.749
Triglyceride (mg/dL) ^{2,3}	180.8 \pm 12.5	192.3 \pm 12.4	209.1 \pm 12.5	0.113
HDL cholesterol (mg/dL) ^{2,3}	45.4 \pm 1.4	45.4 \pm 1.4	42.4 \pm 1.4	0.132
LDL cholesterol (mg/dL) ³	138.7 \pm 4.5	131.9 \pm 4.5	135.6 \pm 4.5	0.617
Glucose concentration (mg/dL) ²	117.3 \pm 5.1	125.0 \pm 5.1	116.0 \pm 5.1	0.874

¹ *P* for associations with the DGAI score tested by age-adjusted linear regression for continuous variables except for age and age-adjusted multivariate analysis of variance for categorical variables.

² Continuous variables are presented as mean \pm SE and are adjusted for age categories (<60, \geq 60 to <65, \geq 65 to <70, and \geq 70 y).

³ Three, 2, 3, and 17 individuals were missing measures of total cholesterol, triglyceride, HDL-cholesterol, and LDL-cholesterol concentrations, respectively.

0.01), and walk more frequently ($P = 0.03$). They were less likely to be current smokers ($P < 0.001$).

At least 70% of the study subjects adhered to the recommendations (score > 0.9) for "other vegetables" (which included iceberg lettuce and tomatoes), dietary cholesterol and sodium, percentage of energy from total fat, percentage energy of from saturated fat, and alcohol consumption (Table 3). Few subjects adhered to the recommendations for starchy vegetables and dairy products, with $< 10\%$ of subjects receiving scores > 0.9 . The low scores for starchy vegetables were due to overconsumption, whereas the low scores for dairy products were due to underconsumption. Weak correlations were observed between the overall DGAI score and intakes of many of the component nutrients and foods, including starchy vegetables, percentage of energy from total fat, sodium intake, and alcohol consumption. This is likely attributable to the limited variability for the component or to less influence on total score relative to the other components.

The weights assigned to the index components are shown in Table 4. By definition, 1 is considered an equal weight for each component to calculate the original DGAI. The regression coefficients between the DGAI components and atherosclerosis progression are also presented as weights assigned to each component to calculate the wDGAI. None of the regression coefficients was statistically significantly different from 0 when entered simultaneously in the

regression model, and they varied among the DGAI components, ranging from -0.068 (fruit) to 0.153 (% of energy from total fat). Adherence to recommendations of whole grains, total fat intake, and cholesterol intake showed associations with slower atherosclerosis progression; a difference in the component score of 1 was related to less narrowing of the coronary arteries by 0.076 mm (SE = 0.042 , $P = 0.08$), 0.153 mm (SE = 0.079 , $P = 0.05$), and 0.0125 mm (SE = 0.069 , $P = 0.07$).

The regression analyses yielded no significant association between the original DGAI and minimal diameter change over the period of the study follow-up ($P = 0.44$) (Table 5). In contrast, the wDGAI calculated from the sum of products of the weights and component score was significantly associated with slower progression of atherosclerosis. A 1-SD difference in the wDGAI score was related to less narrowing of the coronary arteries by 0.049 mm (bootstrap SE = 0.017 , $P = 0.004$). The similar estimates of regression coefficients for wDGAI were obtained, even when both the original DGAI and wDGAI scores were included in the same regression model.

DISCUSSION

No significant association was identified between the DGAI as a measure of diet consistent with the 2005 DGA and narrowing of

TABLE 3

Age-adjusted Dietary Guidelines for Americans Adherence Index (DGA) component scores > 0.9 and Spearman correlations between the total DGAI score and dietary variables in postmenopausal women with established coronary artery atherosclerosis enrolled in the Estrogen Replacement and Atherosclerosis Trial ($n = 224$)¹

DGA component ²	DGA tertile group			> 0.9 points ³	r^4
	First	Second	Third		
DGA score median	12.2 (8.0–13.5)	14.3 (13.5–15.1)	16.1 (15.1–19.0)		1.0
Energy intake (kcal/d)	1525.8 \pm 67.2	1711.4 \pm 66.7	1707.1 \pm 66.8		0.17
Estimated energy requirement (kcal/d)	1849.5 \pm 28.6	1849.6 \pm 28.4	1833.9 \pm 28.4		0.02
Food Group point	5.8 \pm 0.1	7.3 \pm 0.1	8.3 \pm 0.1		0.80
Dark green vegetables (cups/wk)	2.2 \pm 0.4	3.3 \pm 0.4	5.4 \pm 0.4	115 (51.3)	0.44
Orange vegetables (cups/wk)	1.2 \pm 0.3	2.2 \pm 0.3	4.5 \pm 0.3	111 (49.6)	0.49
Legumes (cups/wk)	1.4 \pm 0.2	2.0 \pm 0.2	2.9 \pm 0.2	68 (30.4)	0.36
Other vegetables (cups/wk)	11.3 \pm 1.0	15.6 \pm 1.0	20.9 \pm 1.0	202 (90.2)	0.30
Starchy vegetables (cups/wk)	4.6 \pm 0.3	4.8 \pm 0.3	4.5 \pm 0.3	15 (6.7)	0.09
Fruit (cups/d)	1.3 \pm 0.2	2.6 \pm 0.2	3.0 \pm 0.2	142 (63.4)	0.57
Variety (no. of components)	3.6 \pm 0.1	4.5 \pm 0.1	5.0 \pm 0.1	26 (11.6)	0.70
Meat and beans (oz/d)	4.4 \pm 0.3	4.8 \pm 0.3	5.0 \pm 0.3	38 (17.0)	0.34
Dairy products (cups/d)	0.9 \pm 0.1	1.2 \pm 0.1	1.3 \pm 0.1	11 (4.9)	0.31
All grains (oz/d)	3.5 \pm 0.2	3.9 \pm 0.2	4.4 \pm 0.2	30 (13.4)	0.24
Added sugar (% of energy)	13.5 \pm 1.0	10.2 \pm 0.9	7.9 \pm 0.9	70 (31.3)	0.34
Healthy Choice points	6.0 \pm 0.1	7.0 \pm 0.1	8.0 \pm 0.1		0.75
Whole grains (% of grains)	19.9 \pm 2.2	25.8 \pm 2.2	45.1 \pm 2.2	52 (23.2)	0.52
Fiber intake (g/1000 kcal/d)	10.0 \pm 0.4	12.9 \pm 0.4	15.0 \pm 0.4	100 (44.6)	0.62
Total fat (% of energy)	31.0 \pm 0.7	27.1 \pm 0.7	23.8 \pm 0.7	176 (78.6)	0.11
Saturated fat (% of energy)	10.7 \pm 0.3	8.7 \pm 0.3	7.4 \pm 0.3	166 (74.1)	0.50
trans Fat (% of energy)	2.1 \pm 0.1	1.6 \pm 0.1	1.1 \pm 0.1	54 (24.1)	0.61
Cholesterol intake (mg/d)	223.4 \pm 13.0	221.2 \pm 12.9	194.6 \pm 12.9	199 (88.8)	0.23
Low-fat products (%)	40.6 \pm 2.3	56.1 \pm 2.3	69.8 \pm 2.3	38 (17.0)	0.59
Sodium intake (mg/d)	1761.9 \pm 83.8	1995.1 \pm 83.2	1956.1 \pm 83.3	179 (79.9)	0.00
Alcohol (drinks/d)	0.1 \pm 0.0	0.1 \pm 0.0	0.1 \pm 0.0	218 (97.3)	-0.06

¹ A brief description of DGA, Food Group, and Healthy Choice are given in Subjects and Methods and provided by Fogli-Cawley et al (14).

² 1 cup = 237 mL (US), 0.946 cup in a metric unit; 1 kcal = 4.184 kJ; 1 oz = 28.35 g; 1 drink = 355 mL regular beer, 118 mL wine, or 45 mL distilled spirits.

³ Values are the number of subjects with a DGA component score > 0.9 points; percentages in parentheses.

⁴ Age-adjusted Spearman correlations with the total DGA score; $> |0.14|$ was statistically significant ($P > 0.05$).

TABLE 4

Weights assigned to each component of the original Dietary Guidelines for Americans Adherence Index (DGAI) and the weighted DGAI (wDGAI) in postmenopausal women with established coronary artery atherosclerosis enrolled in the Estrogen Replacement and Atherosclerosis Trial ($n = 224$)

DGAI component	Original DGAI	wDGAI ¹
Dark green vegetables	1	0.003 (0.047)
Orange vegetables	1	-0.027 (0.041)
Beans and legumes	1	0.002 (0.046)
Starchy vegetables	1	-0.019 (0.100)
Other vegetables	1	0.028 (0.074)
Fruit	1	-0.068 (0.062)
Variety	1	0 ²
Meat	1	-0.004 (0.065)
Dairy products	1	0.008 (0.060)
All grain	1	0.033 (0.064)
Added sugar (% of energy)	1	0.019 (0.032)
Whole grains (% of grains)	1	0.076 (0.042)
Fiber intake (per 1000 kcal)	1	0.014 (0.113)
Total fat (% of energy)	1	0.153 (0.079)
Saturated fat (% of energy)	1	0.019 (0.075)
trans Fat (% of energy)	1	-0.029 (0.036)
Cholesterol	1	0.125 (0.069)
Low-fat products (%)	1	-0.032 (0.066)
Sodium intake	1	-0.014 (0.065)
Alcohol	1	0.031 (0.110)
Possible total score ³	0–20	-0.19–0.51
Observed value ⁴	14.1 (8.0–19.0)	0.21 (0.12–0.38)

¹ Weights are regression coefficients (SE) estimated by repeated-measures regression analysis including minimal diameter (outcome), all components together, and selected covariates of age categories (<60, 60–64.9, 65–69.9, or ≥70 y), study site (3 levels), education status (3 levels), frequency of walking (days per week, continuous), cigarette smoking status (yes or no), energy intake (quartiles), systolic blood pressure (continuous), casual glucose concentration (continuous), self-report of cholesterol-lowering drug use (yes or no), and self-report of chest pain (yes or no).

² A variety component was not included because it is the sum of the 6 components of vegetables and fruit.

³ The ranges are based on the assignment of 0 or 1 points to all components.

⁴ Values are means; ranges in parentheses.

coronary arteries after a mean 3.3-y follow-up period in postmenopausal women with established coronary artery atherosclerosis. However, adherence to an index that was weighted by dietary recommendations based on their association with heart disease risk (wDGAI) was significantly associated with reduced progression of atherosclerosis. These findings suggest that certain dietary recommendations may help limit atherosclerotic lesion progression, but assuming equity of associations between all dietary recommendations may limit our ability to identify the relation between the DGA and chronic disease prevention accurately.

The differential weighting is a novel approach to address the limitation of dietary indexes to assess healthy dietary patterns. Past studies taking the dietary index approach used indexes defined on the basis of predetermined criteria and applied equal weights for each of the individual components (17). Equality in weights is biologically implausible, because adherence to each dietary recommendation is not necessarily of equal importance for the reduction of specific disease progression or overall chronic disease risk. In our data set, this apparent weakness with respect to atherosclerotic lesion progression was addressed by assigning

TABLE 5

Results of regression coefficients (SE) from repeated-measures regression analyses to examine the association between each of the standardized Dietary Guidelines for Americans Adherence Index (DGAI) and weighted DGAI (wDGAI) values and changes in minimal diameters of coronary arteries in the postmenopausal women with established coronary artery atherosclerosis enrolled in the Estrogen Replacement and Atherosclerosis Trial ($n = 224$)

	Original DGAI		wDGAI	
	β (SE) ¹	<i>P</i>	β (SE) ¹	<i>P</i>
Crude	-0.002 (0.013)	0.897	-0.029 (0.015)	0.059
Multivariate model 1 ²	-0.007 (0.014)	0.636	-0.045 (0.017)	0.010
Multivariate model 2 ³	-0.011 (0.014)	0.441	-0.049 (0.017)	0.004

¹ SEs of the coefficients for wDGAI and DGAI were estimated by 2-stage (nested) bootstrap analyses.

² Multivariate model 1 included age categories (<60, 60–64.9, 65–69.9, or ≥70 y), study site (3 levels), education status (3 levels), frequency of walking (days per week, continuous), cigarette smoking status (yes or no), energy intake (quartiles).

³ Multivariate model 2 included the variables in model 1 plus systolic blood pressure (continuous), casual glucose concentration (continuous), self-report of cholesterol-lowering drug use (yes or no), and self-report of chest pain (yes or no).

data-driven weights to the index components on the basis of results from regression analyses. Therefore, because we combined a priori criterion-based and data-driven approaches to calculate a dietary index, our approach is a novel hybrid of these 2 types of dietary pattern analysis. The value of such an approach will ultimately be determined by the consistency of findings among independent cohorts.

Of the components of the overall index, adherence to individual recommendations for total fat, whole grain, and cholesterol recommendations were found to be inversely associated with atherosclerosis progression. The observation of whole grain was expected and consistent with past studies using diseased populations (40–42), whereas past observations relating total fat and cholesterol intake to progression are inconsistent and controversial (5). From these data, we cannot determine whether the putative factors are these dietary components or if these dietary components are surrogate markers for other dietary components and are more amenable to detection with an FFQ. The collinearity of dietary components is well established and potentially contributes to this uncertainty (43, 44).

In our study, no women reported complete adherence to all dietary recommendations. This is consistent with past studies suggesting a less than robust compliance with the diet and lifestyle recommendations and individual variability (45–49). Selected dietary recommendations have been shown to improve heart disease risk factors, such as achieving and maintaining recommended plasma lipid and lipoprotein concentrations, BMI, and blood pressure, in clinical trials of dietary counseling or other types of extensive support to ensure compliance (50, 51). Nonetheless, despite established efficacy, nationwide studies have shown that adherence to these recommendations is poor. National Health and Nutrition Examination Survey data indicated that only 20% of hypertensive adults committed to a diet concordant with the Dietary Approaches to Stop Hypertension (DASH) eating pattern highlighted in the 2005 DGA (52). Similar

observations were made among the Women's Health Initiative participants (45–47). Reports from the Nurses' Health Study and the 2000 National Behavioral Risk Factor Surveillance observed that only 3% of each study population was categorized to a low-risk or a healthy lifestyle group according to criteria based on both dietary and nondietary (eg, smoking and physical activity) (48, 49) factors. These observations and ours indicate the need for clinical practice and public health policy to foster improved adherence to dietary recommendations and other healthy lifestyle behaviors.

The main strength of our study was the use of longitudinal data from angiography as a measure of atherosclerosis progression rather than surrogate measures of heart disease, such as conventional risk factors. An additional strength of this work was the use of the wDGAI. This comprehensive measure of adherence to current dietary recommendations was designed to be independent of actual energy intake and was previously shown to favorably predict chronic disease risk factors in healthy adults (14, 15). Last, by generating and using individual weight factors for each component of the index, we were able to directly address the major limitation of the criterion-based indexes that rely on equal weights for each component (17).

The major limitation of our study was the relatively small sample size, which may have resulted in marginal statistical power to detect modest associations, were they to exist, with diet. We were also unable to assess potential residual confounding in the data set because of complex medical conditions. However, our sensitivity analyses and confounder selection indicated that this limitation was not substantial. The accuracy and precision of FFQ measures could influence the results, because FFQ use is not necessarily suitable for estimating absolute intakes. As with all FFQ data, the results should be interpreted cautiously. Another limitation was the potential lack of generalizability of our findings to other clinical populations with diseases and general populations without diseases because of the highly selective nature of the study cohort. Our study cohort was derived from a randomized trial of estrogen replacement therapy; therefore, the study subjects were highly selected based on a variety of inclusion and exclusion criteria and included only those participants who had established coronary artery atherosclerosis and completed the repeated measures of angiography (20). Finally, although not unique to different cohorts, our study population had an unbalanced distribution of some DGAI components. For example, 97% of subjects received >0.9 points for the recommendation of alcohol consumption. Thus, adherence to this component could not be evaluated for an association with atherosclerosis progression in our population because of insufficient variability among study subjects. On the basis of these limitations, it will be of interest to see this approach applied to other independent data sets.

In conclusion, as assessed by using the wDGAI score, but not the DGAI score, postmenopausal women with established coronary artery atherosclerosis consuming diets more, rather than less, consistent with the 2005 DGA showed a slower rate of atherosclerosis progression over a mean 3.3-y follow-up period. From a clinical and public health perspective, modifying the approach to analyze dietary data using the assumption that not all components have an equal weight in describing diet-disease relations may improve the predictive ability. Although the generalizability of the approach is an important limitation, our

study supports the concept that not all dietary recommendations are equally related to disease progression. Our findings highlight the need for the development of more sophisticated approaches to the assessment of dietary recommendations on disease progression and other chronic disease outcomes.

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