Annals of Internal Medicine

Single-Component Versus Multicomponent Dietary Goals for the Metabolic Syndrome

A Randomized Trial

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Background: Few studies have compared diets to determine whether a program focused on 1 dietary change results in collateral effects on other untargeted healthy diet components.

Objective: To evaluate a diet focused on increased fiber consumption versus the multicomponent American Heart Association (AHA) dietary guidelines.

Design: Randomized, controlled trial from June 2009 to January 2014. (ClinicalTrials.gov: NCT00911885)

Setting: Worcester, Massachusetts.

Participants: 240 adults with the metabolic syndrome.

Intervention: Participants engaged in individual and group sessions.

Measurements: Primary outcome was weight change at 12 months.

Results: At 12 months, mean change in weight was −2.1 kg (95% CI, −2.9 to −1.3 kg) in the high-fiber diet group versus −2.7 kg (CI, −3.5 to −2.0 kg) in the AHA diet group. The mean between-group difference was 0.6 kg (CI, −0.5 to 1.7 kg). During the trial, 12 (9.9%) and 15 (12.6%) participants dropped out of the high-fiber and AHA diet groups, respectively ($P = 0.55$). Eight participants developed diabetes (hemoglobin A_{1c} level ≥6.5%) during the trial: 7 in the high-fiber diet group and 1 in the AHA diet group ($P = 0.066$).

Limitations: Generalizability is unknown. Maintenance of weight loss after cessation of group sessions at 12 months was not assessed. Definitive conclusions cannot be made about dietary equivalence because the study was powered for superiority.

Conclusion: The more complex AHA diet may result in up to 1.7 kg more weight loss; however, a simplified approach to weight reduction emphasizing only increased fiber intake may be a reasonable alternative for persons with difficulty adhering to more complicated diet regimens.

Primary Funding Source: National Heart, Lung, and Blood Institute.

Ann Intern Med. 2015;162:248-257. doi:10.7326/M14-0611 **www.annals.org**
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Healthy diet and lifestyle behaviors are the cornerstone of cardiometabolic health, and strong evidence supports the efficacy of the American Heart Association (AHA) diet in preventing and treating the metabolic syndrome (1, 2). However, the various AHA dietary recommendations may create adherence challenges (3, 4). The AHA dietary goals include consuming vegetables and fruits; eating whole grains and high-fiber foods (≥30 g/d); eating fish twice weekly; consuming lean animal and vegetable proteins; reducing intake of sugary beverages; minimizing sugar and sodium intake; maintaining moderate to no alcohol intake; consuming 50% to 55% of calories from carbohydrates, 15% to 20% of calories from protein, and 30% to 35% of calories from fat; and limiting saturated fat to less than 7% of energy, trans fat to less than 1% of energy, and cholesterol to less than 300 mg/d.

Few studies have explored weight loss outcomes as they relate to different dietary messages, such as "eat more of this" (permissive) or "do not eat that" (restrictive), and which, if any, of these messages result in collateral effects on other unadvised healthy diet components. Spring and colleagues (5) found that a group encouraged to eat more fruits and vegetables, while reducing sedentary time, made greater improvements in all behaviors (including untargeted and unadvised aspects) than the group encouraged to reduce saturated fat and increase physical activity. The permissive dietary advice in Spring and colleagues' study (that is, increase fruit and vegetable intake) had more collateral effects than the restrictive advice (that is, reduce saturated fat intake).

Our study compared the efficacy of 2 approaches for dietary change in participants with the metabolic syndrome: a fiber-focused diet and the AHA diet (6). We hypothesized that the fiber-focused group would be superior to the AHA intervention for weight loss, dietary quality, metabolic health, and adherence at 12 months.

See also:

Summary for Patients I-30

METHODS

Design Overview

This randomized, controlled trial compared a single-goal dietary recommendation to increase fiber intake (≥30 g/d) with the multicomponent AHA dietary guidelines for persons with the metabolic syndrome. Participants were randomly assigned at baseline to either a high-fiber diet (n = 121) or the AHA diet (n =

119). Research staff assessing outcomes were blinded to the intervention assignment. The study protocols were approved by the University of Massachusetts Medical School Institutional Review Board, and the study's data safety and monitoring board reviewed each adverse event, which was reported to the Institutional Review Board. All participants gave informed consent.

Setting and Participants

Participants were recruited in 10 waves between June 2009 and January 2012 from Worcester, Massachusetts (ClinicalTrials.gov: NCT00911885; completed on 1 June 2009). Eligible participants were adults who met criteria for the metabolic syndrome (7), had a body mass index (BMI) of 30 to 40 kg/m^2, were aged 21 to 70 years, had a physician's approval to participate, and were nonsmokers for 30 days or more. Exclusion criteria were clinically diagnosed diabetes or a fasting blood sugar level of 7 mmol/L (126 mg/dL) or more, an acute coronary event within the previous 6 months, pregnancy or lactation, the polycystic ovary syndrome, plans to move out of the area during the study, a medical condition that precludes dietary recommendations, major depression or suicidality, participation in any weight loss program, previous bariatric surgery or use of weight loss medication, and an eating disorder.

Randomization and Interventions

Figure 1 shows how many participants were recruited, randomly assigned, and included in the analyses. Of the 1777 persons screened, 240 fulfilled the study criteria, gave consent, and were enrolled in the trial. Participants were stratified by sex and BMI categories (25 to 29.9 kg/m^2 vs. ≥30 kg/m^2). Within each stratum, participants were randomly assigned to the 2 interventions in randomly permuted block sizes of 6 through the RALLOC procedure using Stata, version 11.0 (StataCorp) (8), to ensure that the distributions of sex and BMI were similar between the 2 interventions.

The primary outcome was weight loss at 12 months. A treatment goal for all participants was weight loss of 7% of baseline body weight; the AHA recommendation was weight loss of 6% to 10% for participants with the metabolic syndrome (9). The AHA diet group was given individualized caloric goals to achieve weight loss. The high-fiber diet group's goal was to consume 30 grams or more of fiber per day. No caloric goals were given to these participants.

Intervention Format and Treatment Fidelity

The intervention consisted of 2 individual sessions and 12 group sessions described elsewhere (10). The number and length of the sessions were determined on the basis of our experience in conducting dietary interventions in similar populations (11, 12). Treatment fidelity was monitored by provider and auditor checklists. All sessions were audio-recorded, with 10% of the sessions randomly selected for review by an auditor.

EDITORS' NOTES

Context

A simple set of dietary changes may be easier to follow and promote greater weight loss than more complex dietary instructions.

Contribution

Participants lost similar amounts of weight when randomly assigned to dietary instructions focused on increasing fiber intake or the more complex instructions of the American Heart Association diet. Weight loss was, however, slightly greater with the latter approach.

Caution

The study was unable to conclude that weight loss with the 2 diets was equivalent.

Implication

A simple diet may be a reasonable alternative for persons who are unable or unwilling to try more complex dietary interventions.

High-Fiber Diet

Participants randomly assigned to the high-fiber diet group received instructions on how to increase their fiber intake, and no physical activity recommendations were made (13, 14). To avoid any potential bias, we structured each session to discuss a specific fiber theme with accompanying packets. Audited recordings showed that deviation was minimal; more than 98% of the time, questions not relevant to fiber intake were redirected by the dietitian to include healthy options with fiber.

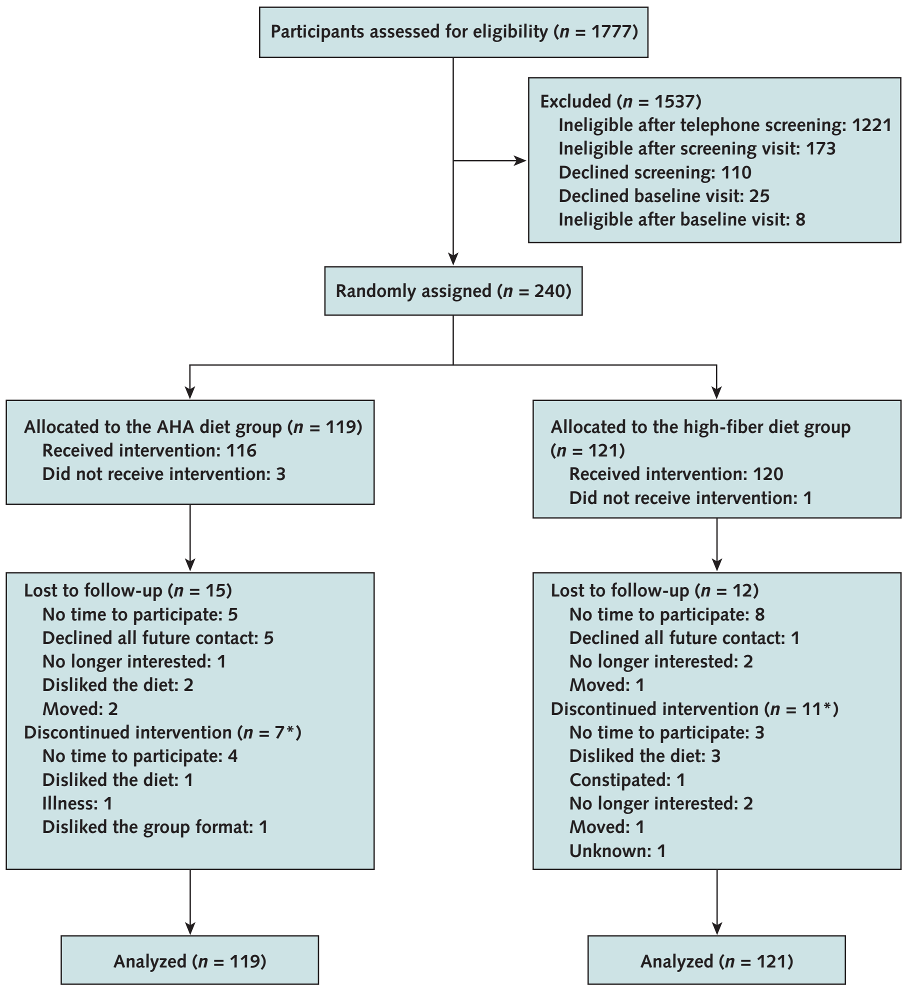
AHA Diet

Participants randomly assigned to the AHA diet group received instructions for the AHA diet, including increasing fiber. Energy intake goals were calculated and provided to the participant by estimating the daily calories needed to maintain the participant's baseline weight and subtracting 500 to 1000 calories per day to achieve a weekly weight loss of 0.5 to 0.9 kg. Each participant was given a customized goal of saturated fat grams allowed per day (7% of estimated calories), and no physical activity recommendations were made.

Outcome Measures

At the baseline and 3-, 6-, and 12-month visits, body weight and height were measured using a calibrated balance scale. Participants wore light clothes and removed shoes for height and weight measurements. Three unannounced 24-hour recalls were done on randomly selected days within a 3-week period (2 weekdays and 1 weekend) around the baseline and 6- and 12-month visits, plus 1 recall at the 3-month visit. Recalls were conducted by dietitians blinded to participants' intervention group and trained to use the Nutrition Data System for Research software, versions 2008 to 2012 (University of Minnesota Nutrition Coordinating

Figure 1. Study flow diagram.



AHA = American Heart Association.
* The 7 AHA diet participants and 11 high-fiber diet participants who discontinued the intervention continued to be followed in the study and attended visits.

Center). The dietary recalls were done by telephone, and participants were provided with 2-dimensional food portion models before the call. Dietary quality was measured by the Alternative Healthy Eating Index (15, 16). Physical activity was assessed in the same call as the 24-hour dietary assessment. We have used this validated method in several previous studies (17–21).

At each visit, use of medications and dietary supplements was documented by self-report and original container label information. Laboratory data consisted of fasting glucose level, fasting plasma insulin level, Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) score, hemoglobin A_{1c} (HbA_{1c}) level, lipid levels, high-sensitivity C-reactive protein (hsCRP) level, interleukin-6 level, tumor necrosis factor–α (TNF-α) receptor 2 level, and blood pressure. The concentration of hsCRP was measured using an immunoturbidimetric assay on the Roche P-Modular system (Roche Diagnostics). Interleukin-6 and TNF-α receptor 2 levels were measured by an enzyme-linked immunosorbent assay (R&D Systems).

Statistical Analysis

The required number of participants for each group was estimated on the basis of the primary outcome measure, which was change in body weight. Sample size was calculated using the method developed by Frison and Pocock (22). We assumed an SD of 14.3 kg for body weight and an autocorrelation coefficient between pretreatment and posttreatment weight of 0.95. With 95 complete participants per group, the hypothesized between-group difference in the change in body weight (1.6 kg) could be detected with more than 80% power at a 5% significance level. Considering a possible attrition rate of 20%, the number of participants in each group must be at least 120. Thus, a total of 240 participants were enrolled in the study.

All analyses were conducted by using SAS, version 9.2 (SAS Institute). Comparisons between groups for baseline characteristics were done by using *t* tests for continuous variables or chi-square tests for categorical variables. Linear mixed models (PROC MIXED) were

Table 1. Selected Baseline Characteristics of Participants, by Group

Variable	Overall (*n* = 240)	AHA (*n* = 119)	High Fiber (*n* = 121)
Mean age (SD), *y*	52.2 (10.1)	52.5 (9.9)	52.0 (10.3)
Age, *n* (%)			
20–40 y	27 (11.3)	12 (10.1)	15 (12.4)
41–50 y	66 (27.5)	35 (29.4)	31 (25.6)
51–60 y	95 (39.6)	46 (38.7)	49 (40.5)
61–70 y	52 (21.7)	26 (21.8)	26 (21.5)
Sex, *n* (%)			
Male	67 (27.9)	34 (28.6)	33 (27.3)
Female	173 (72.1)	85 (71.4)	88 (72.7)
Race/ethnicity, *n* (%)*			
White	208 (87.4)	106 (89.8)	102 (85.0)
Other	30 (12.6)	12 (10.2)	18 (15.0)
Marital status, *n* (%)*			
Married	162 (68.1)	83 (70.3)	79 (65.8)
Not married	78 (31.9)	35 (29.7)	41 (40.0)
Highest education level, *n* (%)*			
High school or less	33 (13.9)	13 (11.1)	20 (16.7)
College	86 (36.3)	38 (32.5)	48 (40.0)
Postgraduate	118 (49.8)	66 (56.4)	52 (43.3)
Mean BMI (SD), *kg/m²*	35.0 (2.9)	34.9 (3.1)	35.0 (2.8)
BMI, *n* (%)			
30.0–35.0 kg/m²	118 (49.2)	61 (51.3)	57 (47.1)
35.1–40.0 kg/m²	122 (50.8)	58 (48.7)	64 (52.9)
Employment status, *n* (%)*			
Employed	186 (78.5)	93 (78.8)	93 (78.2)
Unemployed	51 (21.5)	25 (21.2)	26 (21.9)
Annual income, *n* (%)			
$0–30 000	24 (10.0)	12 (10.1)	12 (9.9)
$30 001–50 000	43 (17.9)	19 (16.0)	24 (19.8)
$50 001–75 000	40 (16.7)	20 (16.8)	20 (16.5)
>$75 000	79 (32.9)	43 (36.1)	36 (29.8)
Unclear	54 (22.5)	25 (21.0)	29 (24.0)
Mean systolic BP (SD), *mm Hg*	135.9 (9.8)	135.2 (10.6)	136.6 (9.0)
Mean diastolic BP (SD), *mm Hg*	80.4 (8.8)	80.0 (8.6)	80.8 (8.9)
Mean HDL cholesterol level (SD)			
mmol/L	1.2 (0.2)	1.2 (0.2)	1.3 (0.3)
mg/dL	47.7 (10.0)	46.5 (8.9)	48.9 (10.9)
Median triglyceride level (IQR)			
mmol/L	1.5 (1.0)	1.6 (1.0)	1.4 (1.0)
mg/dL	135.5 (90.5)	139.0 (86.0)	125.0 (90.0)
Median fasting blood glucose level (IQR)			
mmol/L	5.4 (0.8)	5.3 (0.9)	5.5 (0.7)
mg/dL	98.0 (15.0)	96.0 (17.0)	99.0 (13.0)
Mean HbA_{1c} level (SD), %	5.7 (0.4)	5.7 (0.4)	5.7 (0.4)
Median insulin level (IQR), *pmol/L*	76.4 (83.3)	76.4 (76.4)	79.9 (76.4)
Median HOMA-IR score (IQR)	2.8 (2.6)	2.9 (2.3)	2.8 (2.4)
Mean dietary intake (SD)			
AHEI score†	36.9 (10.9)	37.2 (11.1)	36.6 (10.8)
Energy, *kcal/d*	1880.1 (641.5)	1957.7 (708.5)	1803.7 (560.5)
Energy from fat, %	33.0 (5.8)	33.1 (5.6)	32.9 (6.0)

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Table 1–Continued

Variable	Overall (*n* = 240)	AHA (*n* = 119)	High Fiber (*n* = 121)
Energy from saturated fat, %	11.5 (2.7)	11.6 (2.8)	11.4 (2.6)
Energy from carbohydrates, %	47.2 (7.2)	47.2 (7.4)	47.3 (7.0)
Energy from protein, %	17.4 (4.2)	17.1 (4.1)	17.8 (4.3)
Total fiber, *g/d*	19.1 (6.9)	19.5 (7.3)	18.8 (6.5)
Mean duration of total physical activity (SD), *min/wk*	211.3 (107.1)	217.2 (110.3)	205.5 (104.1)
Mean duration of leisure time physical activity (SD), *min/wk*	18.9 (25.2)	18.9 (25.0)	18.9 (25.6)
The metabolic syndrome criteria, *n (%)*			
Waist circumference ≥40 in for men and ≥35 in for women	229 (95.4)	112 (94.1)	117 (96.7)
Fasting glucose level of 5.5–6.9 mmol/L (100.0–126.0 mg/dL)	156 (65.0)	77 (64.7)	79 (65.4)
Systolic BP ≥130 mm Hg or diastolic BP ≥85 mm Hg	239 (100.0)	119 (100.0)	120 (100.0)
HDL cholesterol level <1.0 mmol/L (40.0 mg/dL) for men and <1.3 mmol/L (50.0 mg/dL) for women	138 (57.5)	70 (58.8)	68 (56.2)
Triglyceride level ≥1.7 mmol/L (150.0 mg/dL)	153 (63.8)	77 (64.7)	76 (62.8)
≥3 of these criteria	240 (100.0)	119 (100.0)	121 (100.0)

AHA = American Heart Association; AHEI = Alternate Healthy Eating Index; BMI = body mass index; BP = blood pressure; HbA_{1c} = hemoglobin A_{1c}; HDL = high-density lipoprotein; HOMA-IR = Homeostasis Model Assessment of Insulin Resistance; IQR = interquartile range.
* Missing data.
† Measures dietary quality.

used to evaluate intervention effects on change in body weight. Participant identification was included as a random effect, with time (baseline and 3-, 6-, and 12-month visits), group (high-fiber diet vs. AHA diet), and time-by-group interactions included as fixed effects. Similar analyses were done for other outcome variables, such as dietary quality and metabolic measures. For data that were right-skewed, which included HOMA-IR score, fasting plasma glucose level, fasting plasma insulin level, triglyceride levels, hsCRP level, interleukin-6 level, and TNF-α receptor 2 level, we used log-γ models (PROC GLIMMIX) (23). To determine whether there were between-group differences in adherence to the dietary goals, we compared groups by using the proportion of participants who met the 13 AHA goals with logistic regression models for repeated measures fitted by generalized estimating equations and included terms for time, group, and time-by-group interaction.

Primary results presented under the mixed-model analysis assume that missing data follow a missing-at-random framework. We conducted sensitivity analyses to explore how primary results might change under various informative missing scenarios. We used the multiple imputation–based SAS macro MIWithd developed by Roger (24, 25). Under 2 of the missing-not-at-random scenarios, missing weights for participants who stopped their diets and left the trial were multiply imputed using a reference group defined as the group of 18 participants who stopped their diets but remained in the trial. All multiple imputation analyses were done by using 1000 imputations and 1000 iterations in the Markov chain Monte Carlo burn-in and 500 iterations between imputations.

Role of the Funding Source

The National Heart, Lung, and Blood Institute supported this research but had no role in the design, conduct, or analysis of the study or the decision to submit the manuscript for publication.

RESULTS

The 1-year study completion rate was 89%; 12 participants (9.9%) dropped out of the high-fiber diet group and 15 participants (12.6%) dropped out of the AHA diet group (P = 0.55). The average age of participants was 52 years, mean BMI was 35 kg/m^2, 72% were women, and 86% had at least a college education (see Table 1). Average caloric intake was 1880 kcal/d, and total dietary fiber intake was 19.1 g/d. No meaningful between-group differences were found for baseline characteristics.

Body Weight and Waist Circumference

At 3 months, mean change in weight in the high-fiber diet group was −1.6 kg (95% CI, −2.4 to −0.8 kg) compared with −2.0 kg (CI, −2.8 to −1.2 kg) in the AHA diet group; the mean between-group difference was 0.4 kg (CI, −0.6 to 1.5 kg). Weight loss was maintained in both groups at 6 and 12 months. At 12 months, weight loss was −2.1 kg (CI, −2.9 to −1.3 kg) and −2.7 kg (CI, −3.5 to −2.0 kg) for the high-fiber and AHA diet groups, respectively; the mean between-group difference was 0.6 kg (CI, −0.5 to 1.7 kg). The sensitivity analysis conducted to explore the robustness of these results to inform missingness provided similar estimates of the between-group differences in weight loss at 12 months but with wider confidence limits (Appendix Table 1, available at www.annals.org). Reduction in waist circumference at 12 months was greater in the AHA diet group than the high-fiber diet group (mean group difference, 0.5 inches [CI, 0.1 to 1.0 inches]). For more details, see Table 2 and Figure 2.

Dietary Intake

Participants in both treatment groups decreased their total caloric intake over the 1-year study duration: −200.0 kcal/d (CI, −313.2 to −86.9 kcal/d) versus −464.6 kcal/d (CI, −578.0 to −351.2 kcal/d) for the high-fiber and AHA diet groups, respectively (mean between-group difference, 264.6 kcal/d [CI, 104.4 to 424.7 kcal/d]). The reduction in total caloric intake was greater in the AHA diet group, and the groups differed at 3, 6, and 12 months. At 3 months, the total dietary fiber intake increased by 7.1 g/d (CI, 5.0 to 9.2 g/d) versus 2.7 g/d (CI, 0.5 to 4.8 g/d) among participants in the high-fiber and AHA diet groups, respectively (mean between-group difference, 4.4 g/d [CI, 1.5 to 7.4 g/d]). The insoluble fiber intake increased by 5.5 g/d (CI, 3.8 to 7.1 g/d) versus 2.7 g/d (CI, 1.0 to 4.4 g/d) among participants in the high-fiber and AHA diet groups, respectively (mean between-group difference, 2.7 g/d [CI, 0.4 to 5.1 g/d]). Further, the soluble fiber intake increased by 1.7 g/d (CI, 1.0 to 2.3 g/d) versus −0.1 g/d (CI, −0.7 to 0.6 g/d) among participants in the high-fiber and AHA diet groups, respectively (mean between-group difference, 1.7 g/d [CI, 0.8 to 2.6 g/d]). We found a significant between-group difference in the percentage of calories from carbohydrates at 3 months (3.3% [CI, 1.6% to 5.0%] for the high-fiber diet group vs. −0.7% [CI, −2.4% to 1.0%] for the AHA diet group; mean between-group difference, 4.0% [CI, 1.6% to 6.4%]). Percentage of calories from protein was also significant at the 3- and 6-month visits. For more information about between-group differences at 3, 6, and 12 months, see Table 2.

Blood Pressure and Metabolic Measures

Both diastolic and systolic blood pressures decreased during the trial, with no between-group differences. Fasting plasma insulin level; HOMA-IR score; HbA_{1c} level; total, low-density lipoprotein, and high-density lipoprotein cholesterol levels; triglyceride levels, hsCRP level; interleukin-6 level; and TNF-α receptor 2 level also had no between-group differences (Table 2).

Medication Use and Physical Activity

At baseline, 44.5% of participants received antihypertensive medication in the AHA diet group compared with 47.9% in the high-fiber diet group, whereas 39.5% received lipid-lowering medication in the AHA diet group compared with 39.7% in the high-fiber diet group. No changes in the use of these 2 medication types during the trial were seen. Two participants in the high-fiber diet group added medications: 1 added glipizide, 2.5 mg/d, 10 days before their final measurements; the other added metformin, 850 mg/d, 3 months before final measurements. Data from these 2 participants did not affect final group results. No within- or between-group differences were found for total and leisure-time physical activity over time (data not shown).

Session Attendance and Adherence

For both groups, mean attendance was 7.9 of 14 sessions (SD, 3.9). The proportion of participants meeting the AHA dietary goals increased (Appendix Table 2, available at www.annals.org), and no meaningful between-group differences were observed.

Adverse Events

A total of 16 "nondiabetes" adverse events were reported. It was determined that the causes of these adverse events were not treatment-related. Adverse events by group were summarized in Appendix Table 3 (available at www.annals.org). In total, 8 participants met the criteria for diabetes (HbA_{1c} level ≥6.5%) during the trial: 7 in the high-fiber diet group and 1 in the AHA diet group ($P = 0.066$) (Appendix Table 4, available at www.annals.org).

DISCUSSION

No clear between-group differences were found, suggesting that a dietary intervention focusing on a targeted fiber goal may be able to achieve clinically meaningful weight loss similar to the widely applied, but more intense, AHA dietary guidelines. The present study also offers insight similar to Spring and colleagues' findings (5) that dietary instructions targeting 1 area of diet may have collateral positive effects on other nontargeted dietary behaviors.

However, the ways in which the dynamic of a diet are changed by the addition or removal of a nutrient to the diet are not completely understood and deserve further study. For example, increases in sugar intake were seen at the population level during the time when low-fat diets were highly recommended (26). A dietary message that focuses on 1 dietary component, such as dietary fiber, is permissive—it encourages an increase in a healthy behavior—versus the AHA diet's restrictive message, which advises persons to limit an unhealthy behavior. Our findings are consistent with several meta-analyses that found little to no difference in diet studies comparing low-fat, low-carbohydrate, or Mediterranean diets on weight loss (27).

Both intervention groups showed improvement in insulin resistance and fasting plasma insulin level during the trial. We were encouraged to see the decline of the fasting plasma insulin level and the HOMA-IR score in the high-fiber diet group at 12 months, possibly due to the longer-term effect of dietary fiber. Long-term improvements in insulin resistance and fasting plasma insulin level have significant clinical implications for patients with the metabolic syndrome (7). National survey data indicate that the current average daily intake of dietary fiber is only 16 grams (28–32), and a 2013 AHA report with national age-stratified data showed that only 7.1% of adults aged 40 to 59 years consumed 30 grams or more of fiber per day (33). As our study showed, increasing dietary fiber (34) may accompany other healthy dietary changes, with the potential to significantly improve metabolic health and positively affect public health.

Generalizability is limited because the sample consisted mostly of white women who were well-educated. Baseline fiber intake and dietary quality were already greater than the national average in our sample. We are unaware of data to support whether the same re-

Table 2. Change From Baseline for Primary and Secondary Outcomes During the Dietary Trial in Worcester, Massachusetts, 2009–2014*

Outcome	3 mo		
	AHA	High Fiber	Between-Group Difference
Anthropometric			
Weight, *kg*	−2.0 (−2.8 to −1.2)	−1.6 (−2.4 to −0.8)	0.4 (−0.7 to 1.5)
Waist circumference, *in*	−0.8 (−1.1 to −0.5)	−0.3 (−0.6 to 0.0)	0.5 (0.1 to 1.0)
BMI, *kg/m²*	−0.7 (−0.9 to −0.4)	−0.6 (−0.8 to −0.3)	0.1 (−0.3 to 0.5)
Daily dietary intake			
AHEI score	3.3 (0.9 to 5.8)	4.5 (2.1 to 6.9)	1.2 (−2.2 to 4.6)
Dietary fiber, *g*	2.7 (0.5 to 4.8)	7.1 (5.0 to 9.2)	4.4 (1.5 to 7.4)
Cereal fiber, *g*	3.2 (2.1 to 4.3)	3.3 (2.2 to 4.4)	0.1 (−1.5 to 1.6)
Insoluble fiber, *g*	2.7 (1.0 to 4.4)	5.5 (3.8 to 7.1)	2.7 (0.4 to 5.1)
Soluble fiber, *g*	−0.1 (−0.7 to 0.6)	1.7 (1.0 to 2.3)	1.7 (0.8 to 2.6)
Fruit, *servings*	0.0 (−0.3 to 0.3)	0.3 (0.0 to 0.6)	0.3 (−0.1 to 0.7)
Vegetables, *servings*	0.8 (0.4 to 1.2)	0.2 (−0.2 to 0.6)	−0.6 (−1.1 to 0.0)
Total energy, *kcal*	−407.2 (−514.9 to −299.4)	−200.5 (−307.0 to −94.0)	206.6 (55.1 to 358.1)
Carbohydrates, %	−0.7 (−2.4 to 1.0)	3.3 (1.6 to 5.0)	4.0 (1.6 to 6.4)
Protein, %	3.1 (2.0 to 4.2)	0.5 (−0.5 to 1.6)	−2.5 (−4.1 to −1.0)
Fat, %	−2.0 (−3.5 to −0.5)	−3.2 (−4.7 to −1.8)	−1.3 (−3.3 to 0.8)
Saturated fat, %	−2.3 (−3.0 to −1.6)	−2.4 (−3.1 to −1.7)	−0.1 (−1.1 to 0.9)
White meat–red meat ratio	0.3 (−0.1 to 0.6)	0.4 (0.0 to 0.7)	0.1 (−0.4 to 0.5)
BP			
Systolic BP, *mm Hg*	−2.5 (−4.5 to −0.6)	−1.5 (−3.5 to 0.5)	1.0 (−1.7 to 3.8)
Diastolic BP, *mm Hg*	−1.7 (−3.3 to −0.1)	−0.8 (−2.4 to 0.9)	0.9 (−1.4 to 3.2)
Metabolic			
Fasting glucose level, *mg/dL*†‡	1.2 (−0.7 to 2.9)	−1.7 (−3.9 to 0.5)	−2.9 (−5.8 to 0.0)
HbA_{1c} level, %	NA	NA	NA
Fasting plasma insulin level, *pmol/L*†	NA	NA	NA
HOMA-IR score†	NA	NA	NA
Blood lipid levels			
HDL cholesterol level, *mg/dL*§	−1.4 (−2.5 to −0.2)	−1.5 (−2.7 to −0.4)	−0.1 (−1.8 to 1.5)
LDL cholesterol level, *mg/dL*§	−1.8 (−6.1 to 2.4)	0.2 (−4.1 to 4.4)	2.0 (−4.0 to 8.0)
Total cholesterol level, *mg/dL*§	−5.9 (−10.8 to −1.1)	−1.8 (−6.7 to 3.1)	4.1 (−2.8 to 11.0)
Triglyceride level, *mg/dL*†‖	−9.4 (−18.9 to −0.5)	−0.7 (−10.1 to 8.1)	8.0 (−3.7 to 20.9)
Inflammation			
hsCRP level, *nmol/L*†	NA	NA	NA
TNF-α receptor 2 level, *pg/mL*†	NA	NA	NA
IL-6 level, *pg/mL*†	NA	NA	NA

AHA = American Heart Association; AHEI = Alternate Healthy Eating Index; BMI = body mass index; BP = blood pressure; HbA_{1c} = hemoglobin A_{1c}; HDL = high-density lipoprotein; HOMA-IR = Homeostasis Model Assessment of Insulin Resistance; hsCRP = high-sensitivity C-reactive protein; IL = interleukin; LDL = low-density lipoprotein; NA = not available; TNF-α = tumor necrosis factor-α.
* Values are adjusted means (95% CIs). The between-group difference was calculated by subtracting the values for the AHA group from those for the high-fiber group.
† A log-γ model was used to analyze these variables.
‡ To convert to mmol/L, multiply by 0.0555.
§ To convert to mmol/L, multiply by 0.0259.
‖ To convert to mmol/L, multiply by 0.0113.

sults could be hypothesized for other groups with a higher burden of adverse cardiometabolic health.

Drawbacks to the fiber-focused message may include missed information about other important dietary metrics. However, our study showed that untargeted aspects of diet improved in the high-fiber diet group (for example, the ratio of white vs. red meat consumed), possibly due to substituting high-fiber foods for less healthy foods. The exact amount of information to deliver in a dietary intervention remains an elusive question. The challenge is to identify the ideal amount of information to change behavior without overwhelming the participant (35). Finally, we note that a diagnosis of diabetes using an HbA_{1c} level of 6.5% or more was not defined during the trial until 2012 (36). We, therefore, had 6 patients with diabetes at baseline.

Although the primary goal of our study (for the high-fiber diet group to achieve superior weight loss) was not met, we found that a single component dietary intervention can achieve clinically meaningful weight loss similar to that of the multicomponent AHA diet. We were encouraged by the improvements in blood pressure, dietary quality, and insulin resistance, all of which are integral in the prevention of diabetes and cardiovascular disease and management of the metabolic syndrome.

Table 2–Continued

6 mo			12 mo		
AHA	High Fiber	Between-Group Difference	AHA	High Fiber	Between-Group Difference
−2.8 (−3.5 to −1.9)	−2.3 (−3.1 to −1.5)	0.4 (−0.6 to 1.6)	−2.7 (−3.5 to −2.0)	−2.1 (−2.9 to −1.3)	0.6 (−0.5 to 1.7)
−0.9 (−1.3 to −0.6)	−0.4 (−0.7 to 0.0)	0.6 (0.1 to 1.0)	−0.4 (−0.7 to −0.1)	0.1 (−0.2 to 0.5)	0.5 (0.1 to 1.0)
−1.0 (−1.2 to −0.7)	−0.8 (−1.1 to −0.5)	0.1 (−0.3 to 0.5)	−1.0 (−1.2 to −0.7)	−0.8 (−1.0 to −0.5)	0.2 (−0.2 to 0.6)
6.0 (3.5 to 8.5)	8.0 (5.5 to 10.4)	1.9 (−1.6 to 5.5)	5.4 (2.9 to 8.0)	5.2 (2.6 to 7.8)	−0.2 (−3.9 to 3.4)
0.9 (−1.2 to 3.1)	6.4 (4.3 to 8.5)	5.5 (2.4 to 8.5)	1.3 (−0.9 to 3.5)	4.7 (2.5 to 6.9)	3.4 (0.3 to 6.5)
1.8 (0.7 to 3.0)	2.8 (1.7 to 3.9)	1.0 (−0.6 to 2.6)	1.6 (0.5 to 2.8)	1.4 (0.2 to 2.5)	−0.3 (−1.9 to 1.4)
1.3 (−0.4 to 3.1)	5.0 (3.3 to 6.7)	3.6 (1.2 to 6.0)	1.4 (−0.4 to 3.1)	3.8 (2.1 to 5.5)	2.4 (−0.1 to 4.9)
0.0 (−0.6 to 0.7)	1.4 (0.7 to 2.0)	1.4 (0.4 to 2.3)	0.3 (−0.4 to 1.0)	0.9 (0.3 to 1.6)	0.6 (−0.3 to 1.6)
0.1 (−0.2 to 0.4)	0.4 (0.1 to 0.7)	0.4 (−0.1 to 0.8)	0.1 (−0.2 to 0.4)	0.3 (0.0 to 0.6)	0.2 (−0.2 to 0.7)
0.6 (0.2 to 1.0)	0.4 (0.0 to 0.8)	−0.2 (−0.8 to 0.3)	0.6 (0.2 to 1.0)	0.4 (0.0 to 0.8)	−0.2 (−0.8 to 0.4)
−421.2 (−531.5 to −311.0)	−130.0 (−239.3 to −20.7)	291.2 (135.9 to 446.5)	−464.6 (−578.0 to −351.2)	−200.0 (−313.2 to −86.9)	264.6 (104.4 to 424.7)
−0.5 (−2.3 to 1.3)	1.8 (0.0 to 3.5)	2.2 (−0.2 to 4.7)	0.7 (−1.1 to 2.5)	1.6 (−0.2 to 3.4)	0.9 (−1.6 to 3.5)
2.1 (1.0 to 3.2)	0.3 (−0.8 to 1.4)	−1.8 (−3.4 to −0.3)	2.1 (1.0 to 3.3)	1.2 (0.1 to 2.3)	−0.9 (−2.5 to 0.7)
−1.2 (−2.7 to 0.3)	−1.8 (−3.3 to −0.3)	−0.5 (−2.7 to 1.6)	−2.0 (−3.6 to −0.5)	−3.1 (−4.6 to −1.5)	−1.1 (−3.3 to 1.1)
−1.6 (−2.3 to −0.9)	−1.6 (−2.3 to −0.9)	0.0 (−1.0 to 1.0)	−1.9 (−2.6 to −1.2)	−1.8 (−2.5 to −1.1)	0.1 (−0.9 to 1.1)
0.3 (0.0 to 0.7)	0.4 (0.1 to 0.8)	0.1 (−0.4 to 0.6)	0.3 (0.0 to 0.7)	0.3 (0.0 to 0.7)	0.0 (−0.5 to 0.5)
−4.2 (−6.2 to −2.3)	−2.8 (−4.8 to −0.8)	1.5 (−1.4 to 4.3)	−3.1 (−5.1 to −1.1)	−3.5 (−5.5 to −1.5)	−0.4 (−3.2 to 2.4)
−1.3 (−2.9 to 0.4)	−1.1 (−2.8 to 0.6)	0.2 (−2.2 to 2.5)	−2.2 (−3.8 to −0.5)	−2.5 (−4.2 to −0.9)	−0.4 (−2.7 to 2.0)
2.4 (0.2 to 4.5)	1.9 (−0.2 to 4.0)	−0.4 (−3.5 to 2.7)	2.5 (0.4 to 4.5)	0.7 (−1.6 to 2.9)	−1.8 (−4.8 to 1.4)
0.0 (0.0 to 0.0)	0.0 (0.0 to 0.0)	0.0 (−0.1 to 0.1)	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.1)	0.0 (0.0 to 0.1)
−18.7 (−29.9 to −8.3)	−4.9 (−18.0 to 6.9)	12.5 (−1.4 to 29.9)	−11.1 (−22.9 to −0.7)	−15.3 (−27.8 to −4.2)	−4.9 (−16.7 to 9.7)
−0.6 (−1.0 to −0.2)	−0.1 (−0.6 to 0.4)	0.5 (−0.1 to 1.1)	−0.3 (−0.7 to 0.1)	−0.5 (−1.0 to −0.1)	−0.2 (−0.7 to 0.3)
−1.4 (−2.5 to −0.2)	−0.6 (−1.8 to 0.6)	0.8 (−0.9 to 2.4)	−0.5 (−1.7 to 0.6)	−0.8 (−2.0 to 0.3)	−0.3 (−1.9 to 1.4)
−1.5 (−5.9 to 2.9)	−3.2 (−7.5 to 1.2)	−1.7 (−7.9 to 4.5)	1.7 (−2.6 to 6.1)	−1.1 (−5.4 to 3.3)	−2.8 (−9.0 to 3.4)
−3.2 (−8.2 to 1.8)	−4.9 (−9.9 to 0.2)	−1.7 (−8.7 to 5.4)	−1.5 (−6.4 to 3.5)	−4.0 (−9.0 to 1.0)	−2.6 (−9.6 to 4.5)
−1.0 (−12.2 to 9.3)	−4.7 (−14.0 to 3.9)	−3.7 (−15.7 to 9.7)	−11.4 (−21.4 to −2.0)	−7.6 (−16.8 to 1.1)	3.2 (−8.6 to 16.1)
−3.8 (−7.6 to −0.9)	−2.8 (−6.7 to 0.9)	1.9 (−2.8 to 7.6)	0.0 (−3.8 to 3.8)	−0.9 (−5.7 to 2.8)	−0.9 (−6.7 to 4.8)
−80.1 (−154.2 to −8.0)	−22.6 (−107.2 to 59.3)	55.5 (−51.6 to 167.1)	−59.7 (−152.9 to 30.4)	−90.0 (−173.2 to −9.4)	−32.9 (−148.8 to 88.6)
0.0 (−0.3 to 0.3)	0.3 (0.1 to 0.5)	0.3 (−0.1 to 0.6)	−0.1 (−0.4 to 0.2)	0.0 (−0.2 to 0.2)	0.1 (−0.2 to 0.5)

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Disclaimer: The contents of this study are solely the responsibility of the authors and do not necessarily represent the official views of the National Heart, Lung, and Blood Institute.

Acknowledgment: The authors thank the participants for their contributions to the study; Penny Rosenzweig, MS, RD, and Judith C. Palken, MNS, RD, LDN, for delivering the nutritional interventions; Vijayalakshmi Patil, MS, for coordinating nutritional classes; Nancy Mecone, BSN, and Annabella Aguirre, MT, ACSP, MBA, for clinical measurements, blood draws, and catalog samples; Don Northway and Kristie Capurso for participant recruitment; and the data safety and monitoring board members—Cara B. Ebbeling, PhD, RD, Edward Stanek III, PhD, and James Chesebro, MD—for their unyielding support during the trial.

Grant Support: By the National Heart, Lung, and Blood Institute (grant 1R01HL094575; Dr. Ma).

Disclosures: Disclosures can be viewed at www.acponline.org/authors/icmje/ConflictOfInterestForms.do?msNum=M14-0611.

Reproducible Research Statement: *Study protocol and statistical code*: Available from Dr. Ma (e-mail, yunsheng.ma@umassmed.edu). *Data set*: Not available.

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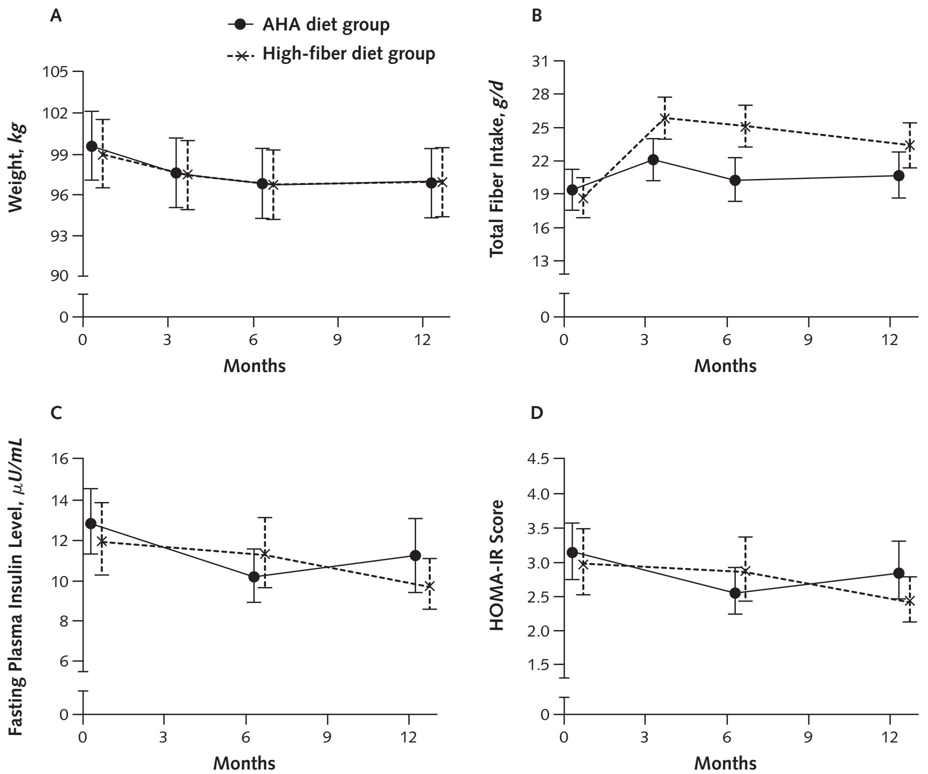
Figure 2. Outcomes over time during the trial.



Adjusted means are presented, and bars indicate 95% CIs. To convert μU/mL into pmol/L, multiply by 7.175. AHA = American Heart Association; HOMA-IR = Homeostasis Model Assessment of Insulin Resistance. **A.** Weight. **B.** Dietary fiber. **C.** Fasting plasma insulin level. **D.** HOMA-IR score.

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Appendix Table 1. Partial Sensitivity Analysis Results for the Between-Group Difference for Weight Loss (in kg) at 12 mo*

Scenario	Estimate (95% CI)	*P* Value
MAR†	0.67 (−0.63 to 1.97)	0.31
MNAR		
CDC/CIR‡	0.61 (−0.63 to 1.85)	0.33
J2C§	0.57 (−0.68 to 1.81)	0.37
LMCF‖	0.67 (−0.62 to 1.96)	0.31

CDC = copy difference from control; CIR = copy increments in reference; J2C = jump to control; LMCF = last mean carried forward; MAR = missing at random; MNAR = missing not at random.
* All sensitivity analyses were done using the multiple imputation–based SAS macro MIWithd (SAS Institute) by Roger (24) and Carpenter et al (25). All multiple imputation analyses used 1000 imputations.
† Missing data after dropout were multiply imputed under a MAR framework (e.g., joint distribution of participants' observed outcomes and outcomes after discontinuation was assumed to follow a multivariate normal distribution with a mean and covariance matrix from their randomized treatment group).
‡ After patients discontinued the diet, their mean increments copied those from the reference group (the group of 18 participants who discontinued the diet but continued to be followed in the trial).
§ After patients discontinued the diet, their mean response distribution became that of the reference group (the group of 18 participants who discontinued the diet but continued to be followed in the trial).
‖ Participants' means after discontinuation were all set to the marginal mean for their randomized treatment group at their last observed measurement. The variance–covariance matrix remained that for their randomized treatment group.

Appendix Table 2. Participants Who Met Goals Over Time Points, by Group*

Goal	Baseline		3 mo		6 mo		12 mo	
	AHA (n = 119)	High Fiber (n = 121)	AHA (n = 119)	High Fiber (n = 121)	AHA (n = 119)	High Fiber (n = 121)	AHA (n = 119)	High Fiber (n = 121)
Total vegetable and fruit intake ≥5 cups	15 (13)	16 (13)	30 (25)	22 (19)	15 (13)	24 (20)	21 (18)	20 (17)
Whole-grain, high-fiber food intake (≥30 g/d of total fiber)	7 (6)	8 (7)	24 (20)	34 (28)	17 (14)	29 (24)	12 (10)	18 (15)
Fish intake, especially oily fish (2 servings/d)	53 (45)	41 (34)	22 (18)	22 (18)	36 (30)	34 (28)	33 (28)	39 (32)
Lean animal and vegetable protein intake	1 (0.84)	1 (0.83)	8 (7.00)	11 (9.00)	6 (5.00)	4 (3.00)	6 (5.00)	9 (7.00)
Reducing sugary beverages (compared with baseline)	–	–	76 (64)	85 (70)	74 (62)	75 (62)	80 (67)	80 (66)
Reducing sugar intake	–	–	80 (52)	73 (48)	76 (54)	65 (46)	74 (54)	62 (46)
Sodium intake <1500 mg/d	6 (5)	4 (3)	21 (18)	24 (20)	13 (11)	11 (9)	17 (14)	10 (8)
Consuming moderate to no alcohol (no drinks)	67 (56)	61 (50)	92 (77)	100 (83)	72 (61)	84 (69)	86 (72)	79 (65)
50%–55% of calories from carbohydrates	27 (23)	37 (31)	17 (14)	28 (23)	22 (18)	19 (16)	9 (8)†	25 (21)†
15%–20% of calories from protein	54 (45)	59 (49)	30 (25)	44 (36)	43 (36)‡	59 (49)‡	34 (29)	47 (39)
30%–35% of calories from fat	42 (35)	46 (38)	29 (34)	30 (25)	28 (24)	33 (27)	27 (23)	18 (15)
Saturated fat intake limited to <7% of energy, and trans fat intake limited to <1% of energy	3 (3)	4 (3)	41 (34)	41 (34)	33 (28)	32 (26)	41 (34)	42 (35)
Cholesterol intake <300 mg/d	75 (63)	80 (66)	89 (75)	99 (82)	79 (66)	75 (62)	74 (62)	75 (62)

AHA = American Heart Association.
* Values are numbers (percentages).
† P < 0.010, determined from the chi-square test.
‡ P < 0.050, determined from the chi-square test.

Appendix Table 3. Adverse Events*

Participant	Sex	Study Group	Date of Event	Description
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2	Female	AHA	5 August 2010	Hysterectomy
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4	Male	AHA	7 July 2010	Pneumonia
5	Female	High fiber	7 January 2011	Bronchitis
6	Female	High fiber	9 March 2011	Mucocele of appendix and partial removal of intestine
7	Female	AHA	23 January 2011	Lung cancer
8	Female	High fiber	7 September 2011	Form of colitis in first 2 in of colon
			28 April 2012	Shortness of breath†
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11	Female	High fiber	3 April 2012	Shoulder reconstruction
12	Female	High fiber	11 February 2012	Stress and chest pain
13	Female	AHA	7 August 2012	Kidney stones
14	Female	High fiber	24 October 2012	Hiatal hernia
15	Female	High fiber	20 December 2012	Shoulder replacement

AHA = American Heart Association.
* Does not include diabetes. Events were categorized as adverse events or serious adverse events; no serious adverse events occurred.
† Results of diagnostic studies were normal.

Appendix Table 4. Participants Diagnosed With Diabetes on the Basis of an HbA_{1c} Level ≥6.5%*

Participant	Study Group	HbA_{1c} Level, %			Diabetes Medication Use
		Baseline	6 mo	12 mo	
Diabetes diagnoses at baseline					
100240	High fiber	**6.6**	6.5	6.8	–
100962	High fiber	**6.5**	7.7	7.1	Glipizide, 2.5 mg/d, at 12 mo only
101122†	AHA	**6.6**	6.9	6.8	–
101256	High fiber	**6.8**	6.6	6.9	–
101533	AHA	**6.6**	7.1	6.9	Metformin, 500 mg/d, at baseline and 3, 6, and 12 mo
101587	High fiber	**6.8**	6.9	6.5	Metformin, 850 mg/d, at 12 mo only
Diabetes diagnoses at 6 mo					
100278	High fiber	6.3	**6.6**	6.8	–
100512	High fiber	6.2	**6.5**	6.2	–
100789	High fiber	6.3	**6.5**	6.6	–
101027	High fiber	6.2	**6.6**	6.1	–
101518	AHA	5.8	**6.5**	6.1	–
Diabetes diagnoses at 12 mo					
100300	High fiber	6.3	6.3	**6.6**	–
100644	High fiber	6.4	6.3	**6.6**	–
101369	High fiber	6.2	6.3	**6.5**	–

AHA = American Heart Association; HbA_{1c} = hemoglobin A_{1c}.
* A diagnosis of diabetes using HbA_{1c} levels was not defined during the trial until 2012. This diagnosis was defined on the basis of Table 2 of reference 36. Bolded values signify an initial HbA_{1c} level ≥6.5%, which is diagnostic of diabetes.
† This participant had another adverse event in addition to diabetes.

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Obtaining of funding: Y. Ma, B.C. Olendzki, W. Li, S.L. Pagoto.
Administrative, technical, or logistic support: P.A. Merriam.
Collection and assembly of data: B.C. Olendzki, G.M. Persuitte, P.A. Merriam, G.F. Olendzki.

Appendix Table 1. Partial Sensitivity Analysis Results for the Between-Group Difference for Weight Loss (in kg) at 12 mo*

Scenario	Estimate (95% CI)	*P* Value
MAR†	0.67 (−0.63 to 1.97)	0.31
MNAR		
CDC/CIR‡	0.61 (−0.63 to 1.85)	0.33
J2C§	0.57 (−0.68 to 1.81)	0.37
LMCF‖	0.67 (−0.62 to 1.96)	0.31

CDC = copy difference from control; CIR = copy increments in reference; J2C = jump to control; LMCF = last mean carried forward; MAR = missing at random; MNAR = missing not at random.
* All sensitivity analyses were done using the multiple imputation–based SAS macro MIWithd (SAS Institute) by Roger (24) and Carpenter et al (25). All multiple imputation analyses used 1000 imputations.
† Missing data after dropout were multiply imputed under a MAR framework (e.g., joint distribution of participants' observed outcomes and outcomes after discontinuation was assumed to follow a multivariate normal distribution with a mean and covariance matrix from their randomized treatment group).
‡ After patients discontinued the diet, their mean increments copied those from the reference group (the group of 18 participants who discontinued the diet but continued to be followed in the trial).
§ After patients discontinued the diet, their mean response distribution became that of the reference group (the group of 18 participants who discontinued the diet but continued to be followed in the trial).
‖ Participants' means after discontinuation were all set to the marginal mean for their randomized treatment group at their last observed measurement. The variance–covariance matrix remained that for their randomized treatment group.

Appendix Table 2. Participants Who Met Goals Over Time Points, by Group*

Goal	Baseline		3 mo		6 mo		12 mo	
	AHA (*n* = 119)	High Fiber (*n* = 121)	AHA (*n* = 119)	High Fiber (*n* = 121)	AHA (*n* = 119)	High Fiber (*n* = 121)	AHA (*n* = 119)	High Fiber (*n* = 121)
Total vegetable and fruit intake ≥5 cups	15 (13)	16 (13)	30 (25)	22 (19)	15 (13)	24 (20)	21 (18)	20 (17)
Whole-grain, high-fiber food intake (≥30 g/d of total fiber)	7 (6)	8 (7)	24 (20)	34 (28)	17 (14)	29 (24)	12 (10)	18 (15)
Fish intake, especially oily fish (2 servings/d)	53 (45)	41 (34)	22 (18)	22 (18)	36 (30)	34 (28)	33 (28)	39 (32)
Lean animal and vegetable protein intake	1 (0.84)	1 (0.83)	8 (7.00)	11 (9.00)	6 (5.00)	4 (3.00)	6 (5.00)	9 (7.00)
Reducing sugary beverages (compared with baseline)	–	–	76 (64)	85 (70)	74 (62)	75 (62)	80 (67)	80 (66)
Reducing sugar intake	–	–	80 (52)	73 (48)	76 (54)	65 (46)	74 (54)	62 (46)
Sodium intake <1500 mg/d	6 (5)	4 (3)	21 (18)	24 (20)	13 (11)	11 (9)	17 (14)	10 (8)
Consuming moderate to no alcohol (no drinks)	67 (56)	61 (50)	92 (77)	100 (83)	72 (61)	84 (69)	86 (72)	79 (65)
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