

Adopting a Plant-Based Diet Minimally Increased Food Costs in WHEL Study

Joseph A. Hyder, MD, PhD; Cynthia A. Thomson, PhD; Loki Natarajan, PhD; Lisa Madlensky, PhD; Minya Pu, MS; Jennifer Emond, MS; Sheila Kealey, MPH; Cheryl L. Rock, PhD, RD; Shirley W. Flatt, MS; John P. Pierce, PhD; for the WHEL Study Group

Objective: To assess the cost of adopting a plant-based diet. **Methods:** Breast cancer survivors randomized to dietary intervention (n=1109) or comparison (n=1145) group; baseline and 12-month data on diet and grocery costs. **Results:** At baseline, both groups reported similar food costs and dietary intake. At 12 months, only the intervention group changed their diet (vegetable-fruit: 6.3 to 8.9 serv/d.;

fiber: 21.6 to 29.8 g/d; fat: 28.2 to 22.3% of E). The intervention change was associated with a significant increase of \$1.22/person/week (multivariate model, P=0.027). **Conclusions:** A major change to a plant-based diet was associated with a minimal increase in grocery costs.

Key words: breast cancer, fruit-vegetable consumption, grocery costs

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A healthy dietary pattern is well recognized as a potentially useful strategy in the prevention of chronic disease.¹ However, only about 5% of Americans have dietary patterns that adhere to the vegetable, fruit or dietary fat recommendations of the Healthy People 2010 dietary guidelines.² Numerous studies have developed interventions to help

people adopt and adhere to recommended intakes of vegetables, fruits, fiber, and energy from fat, although the majority have been unable to sustain changes in the longer term.³ The following key barriers to adherence have been identified: food taste, convenience, perceived nutritional value, and perceived costs, specifically perceived greater food costs associated with increased fruit and vegetable intake.⁴⁻⁶

Multiple observational studies relying on survey data have reported that people who purchase more vegetables and fruit have higher overall grocery expenditures, but they tend to be of higher socioeconomic status as well, which may confound this association.⁷⁻¹⁰ In ecologic-level analyses, energy-dense diets, typically low in vegetable-fruit intake, are considered to be less expensive on a per-calorie basis.¹¹ A recent focus group study conducted among African American, Hispanic, and white men and women in the

Joseph A. Hyder; Loki Natarajan; Lisa Madlensky; Minya Pu; Sheila Kealey; Cheryl L. Rock; Shirley W. Flatt; John P. Pierce, Moores UCSD Cancer Center, University of California, San Diego, La Jolla, CA. Cynthia A. Thomson, Arizona Cancer Center, Arizona Prevention Center, University of Arizona, Tucson, AZ. Jennifer Emond, Department of Family and Preventive Medicine, Division of Biostatistics, University of California, San Diego, La Jolla, CA.

Address correspondence to Dr Pierce, Moores UCSD Cancer Center, 3855 Health Sciences Drive, 0901, University of California, San Diego, La Jolla, CA 92093-00901. E-mail: jppierce@ucsd.edu

United States concluded that perceived high-cost and high-spoilage rates of fruits and vegetables deterred many participants from trying to meet dietary recommendations.¹² Yet, data from the US Department of Agriculture on actual costs of eating healthy, independent of socioeconomic status, suggest that an intake of 7 servings of vegetables and fruits per day (n=7195 homes) was associated with an average cost of only 64 cents/person per day.¹³ In the most relevant examination of this question, 20 families who increased the nutrient density of their diets showed no statistically significant increase in costs per calorie, although the analysis used local grocery store prices as a proxy for actual grocery expenditures.¹⁴ This suggests that higher costs may be more a perceived barrier rather than necessarily reflecting what will happen with major dietary change.

Some studies suggest that economic incentives, such as coupons, may be necessary to overcome the barrier of perceived higher costs to increasing vegetable and fruit intake.^{15,16} In this paper we present prospective data from the Women's Healthy Eating and Living (WHEL) Study, a large, randomized, controlled trial of whether adopting a plant-based dietary pattern would improve prognosis among women previously diagnosed with early stage breast cancer. Rather than use economic incentives as the main motivator for participants to make and maintain such a dietary change, an intensive one-on-one intervention delivered by lay counselors over the telephone emphasized overcoming barriers to health-behavior change. We report on the dietary changes achieved with this intervention approach and their impact on the participants' estimate of grocery costs over a 12-month period.

METHODS

Study Design and Population

Between 1995 and 2000, the Women's Healthy Eating and Living (WHEL) Study randomized 3088 women diagnosed with early stage breast cancer within the previous 4 years to either a diet intervention or comparison group.¹⁷ Eligibility criteria included diagnosis of a primary operable invasive breast carcinoma categorized using American Joint Committee on Cancer (edition IV) criteria as stage I (≥ 1 cm), stage II, or stage IIIA within the past 4

years; age at diagnosis between 18 and 70 years; treatment with axillary dissection and total mastectomy or lumpectomy followed by primary breast radiation; no current or planned chemotherapy; no evidence of recurrent disease or new breast cancer since completion of initial local treatment; and no other cancer in the past 10 years. Participants were recruited at 7 sites located in Arizona, California, Oregon and Texas.

The intervention group was asked to consume a daily intake of 5 vegetable servings, 2 cups (473 mL) of 100% vegetable juice, 3 fruit servings, 30 g of fiber, and 15-20% energy from fat, whereas the comparison group was advised to follow the 5-A-Day diet.^{18,19} The study anticipated that vegetable juice consumption would be the most challenging goal for most participants. Accordingly, to reduce barriers to adherence and provide options beyond purchasing fresh vegetable juice, which is expensive, the study bulk-purchased juice extractors and offered them to participants at a 25% discount over wholesale cost. However, the study did not offer coupons or any economic incentive to purchase food. Participant-centered counseling delivered over the telephone helped intervention participants maximize their dietary change.²⁰ This study was approved by the institutional review boards at all participating centers including University of California, San Diego; University of California, Davis; Stanford University / University of California, San Francisco; The University of Arizona; MD Anderson Cancer Center; Kaiser Permanente Northern California; and the Center for Health Research, Portland, Oregon.

Data Collection

This report examines data collected at baseline and 12 months in the WHEL study. At these time points, dietary intake was assessed on 94% of WHEL participants, and 85% of participants attended clinic visits (attendance was equivalent for intervention and comparison group participants). Before clinic visits, participants were mailed a series of questionnaires to complete and hand in when they attended the clinic. One questionnaire focused on patterns of food purchasing, preparation, and meal consumption including meals eaten at restaurants or take-out. Approximately 80% of the sample

attended the 12-month clinic visit, and this questionnaire was completed at baseline and 12 months for 72% of the intervention group and 74% of the comparison group participants. This report considers the 2254 women who had dietary intake and cost data at both baseline and 12 months.

Dietary assessment. The study used 3 separate measures to assess dietary intake: a set of 24-hour dietary recalls, a food frequency questionnaire, and plasma carotenoid concentrations, a recognized biomarker of vegetable and fruit intake.²¹ Using the biomarker of carotenoids as the gold standard, carotenoid assessment from the 24-hour dietary recall had a higher validity (0.44) than the FFQ (0.39) as well as less systematic error (28% vs 50%).²² Thus, our 24-hour recall methodology is our self-report measure of choice. In the full study population, we have reported that the study intervention was associated with a 65% increase in vegetable and fruit intake²³ and this change was validated with a 51% increase in plasma carotenoid concentrations.²¹

Four 24-hour dietary recalls were collected by telephone over a 3-week period before a participant's randomization (baseline) and again at 12 months; these recalls followed a standard protocol using trained dietary assessors who were blinded to diet group assignment and were not involved in the dietary counseling. The multi-pass Minnesota Nutrition Data System software was used for dietary data collection and for estimating nutrient intakes (NDS version 4.01, 2001, University of Minnesota, Minneapolis MN). Using the NDS database, we calculated serving sizes using metric weight, including all forms of vegetables and fruits (frozen, canned, fresh, or dried). We defined a vegetable serving as ½ cup of cut-up vegetables (90 g), 1 cup of raw leafy green vegetables (55 g); a fruit serving as ¼ cup of dried fruit (60 g), ½ cup of cut-up fruit (120 g); 1 cup melon (165 g), or 1 medium piece of fruit (120 g). We report 100% vegetable and fruit juices separately as total fluid ounces.

Grocery costs assessment. A feasibility study examining participants' collection of grocery store receipts identified significant data gaps. Nearly all participants were the primary food purchaser in their household and were confident that they could estimate how much they spent.

Accordingly, we developed questions that asked participants to provide an overall assessment of their household grocery costs as part of a food purchasing and preparation questionnaire that was self-completed and collected at clinic visits. The following 2 questions were used to estimate per person grocery expenditures: "For how many people is food purchased in your household?" and "Approximately how much does your household spend on grocery purchases each week?" Interpretation of these questions was left open to respondents, and the questionnaire did not query information on food stamp use, coupon use, or food pantry use. Weekly per-person grocery costs were then obtained by dividing the weekly amount spent on groceries by the number of people in the household for whom food was purchased; we imputed 7 missing values for the number of people in the household at 12 months (3 from intervention and 4 from comparison) using baseline values.

To determine the number of meals per week for which groceries were purchased, ie, meals prepared at home, participants were asked to indicate both the number of weekdays and weekend days they (1) ate breakfast at home, (2) prepared or ate lunch at home, and (3) prepared dinner at home.

Measurement of other variables. At the baseline and 12-month clinic visit, height and weight were measured using standard research procedures.¹⁷ BMI was calculated as weight (kg)/height (m²). Current physical activity was estimated using a brief self-reported personal habits questionnaire developed for the Women's Health Initiative²⁴ and validated for this study.²⁵ Other variables including age, education, race/ethnicity, were ascertained at enrollment using a general demographic questionnaire. Stage of breast cancer was collected from medical record review.

Statistical Analysis

Chi-square tests, Student's t-tests or Wilcoxon rank-sum tests were used to establish the comparability of the study groups in demographic, clinical, and diet-related characteristics at baseline. Paired and 2-sample t-tests (or Wilcoxon rank-sum tests) were used respectively to examine within- and between-group baseline to 12-month changes in diet and food costs.

Table 1
Comparability of WHEL Study Groups at Baseline

	Intervention Group (N =1109)		Comparison Group (N =1145)		P-value ^a
	N	%	N	%	
Race/ethnicity					
Non-Hispanic white	956	86.2	990	86.5	0.91
Other	153	13.8	155	13.5	
Education level					
No college degree	483	43.6	522	45.6	0.35
College degree	626	56.4	623	54.4	
Age at randomization (years)					
MEAN (SD)	1109	54.0(8.8)	1145	53.6(8.9)	0.25
Body mass index^b (kg/m²)					
17.5 – 24.9 (normal + underweight) ^c	475	42.8	512	44.7	0.56
25.0 – 29.9 (overweight)	347	31.3	357	31.2	
30.0 – 52.5 (obese)	287	25.9	276	24.1	
Physical activity,^d N(%)					
<300	313	28.6	320	28.7	0.89
300 – 900	362	33.1	361	32.2	
901 – 6420	418	38.2	438	39.1	
Household occupancy					
MEAN (SD)	1109	2.5(1.2)	1145	2.4(1.1)	0.33
Number of meals eaten/prepared at home (per week)					
MEAN (SD)	1109	14.4(4.5)	1145	14.3(4.4)	0.63
Weekly food cost per person at baseline					
MEAN ^e	1109	\$39.70	1145	\$39.70	0.98

Note.

- a** Chi-square and independent t-test P-values. No significant differences between intervention and comparison groups were found.
- b** Cutoff points defined by USDHHS²
- c** Normal = 18.5–24.9, underweight ≤ 18.5
- d** Measured in metabolic equivalents (METs)
- e** SD for intervention group was \$20.30 and \$24.60 for comparison group

Multiple linear regression models were used to test between-group differences in grocery costs at 12 months, after adjusting for potential confounders including initial cost (baseline), number of meals eaten or prepared at home per week at 12 months, education, clinical site, age at randomization, race/ethnicity, 12-month BMI, and physical activity level. The

outcome was log-transformed to ensure the residuals followed a normal distribution with a constant variance; Cook's distance was also plotted for outlier detection. Prior to transformation the variance of the residuals increased with fitted values of the outcome. Log-transforming the outcome stabilized the variance. All analyses were performed using R, version 2.5.1

Table 2
Baseline to 12-Month Changes in Dietary Pattern and Food Costs
by WHEL Study Group

	Intervention			Comparison		
	Baseline (mean, SD)	Month 12 (mean, SD)	P ^a	Baseline (mean, SD)	Month 12 (mean, SD)	P ^a
Total vegetable/ fruit servings/day	6.3 (3.0)	8.9 (3.4)	<0.0001	6.2 (2.8)	6.3 (2.8)	0.11
Daily juice con- sumption (ounces)	4.0 (4.6)	12.4 (7.0)	<0.0001	4.2 (4.8)	4.1 (4.70)	0.46
Percentage of calories from fat	28.2 (7.1)	22.3 (7.1)	<0.0001	28.5 (6.8)	28.2 (7)	0.20
Total daily fiber intake (g)	21.6 (8.5)	29.8 (10.2)	<0.0001	21.5 (8.1)	21.5 (8.3)	0.82
Total daily caloric intake (kcal)	1721.72 (385.55)	1617.49 (347.73)	<0.0001	1742.39 (410.29)	1620.96 (390.56)	<0.0001
Food cost per person per week (\$)	39.7 (24.6)	43.2 (21.5)	<0.0001	39.7 (20.3)	42.1 (20.5)	<0.0001

Note.

a P-values testing if there is a significant change from baseline to month 12 within each group based on paired t-tests.

(<http://www.R-project.org>).

RESULTS

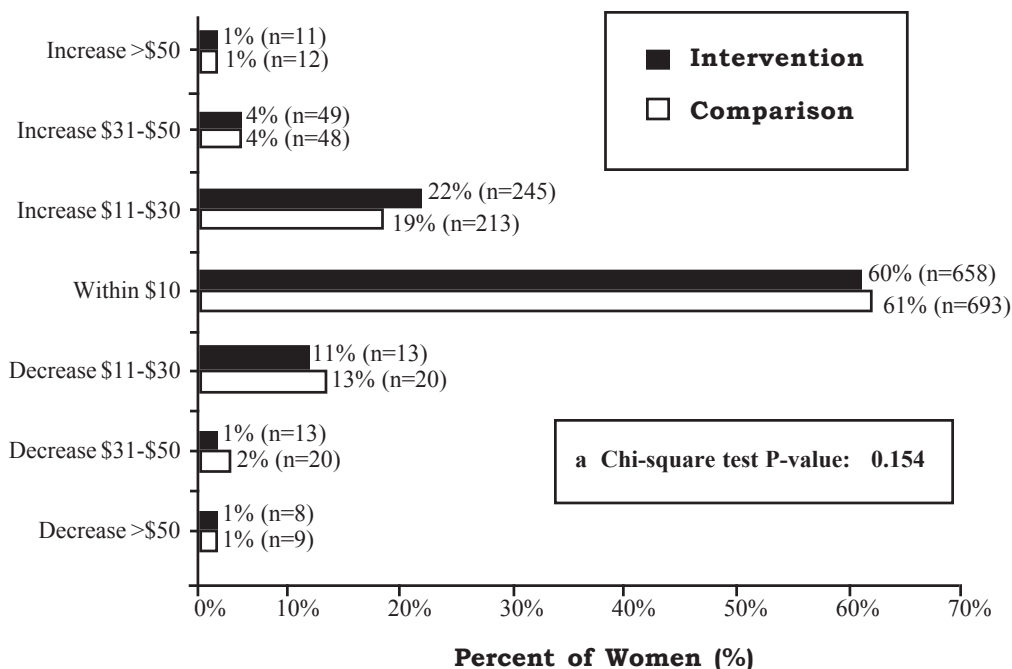
Breast cancer survivors with complete grocery costs data were comparable to the overall WHEL study population.¹⁷ The majority were non-Hispanic white females (86.3%), middle aged (mean 53.8 years), well educated (55.4% with a college degree), and overweight (56.2% with BMI>25.0) (Table 1). The intervention (n=1109) and comparison groups (n=1145) did not differ on the severity of their original breast cancer (not shown). Nor did they differ significantly at baseline on demographic characteristics or level of physical activity, household size or number of meals eaten and prepared at home each week (mean 14.4 ± 4.4 (SD) meals/wk) or weekly grocery expenditures at baseline (I=\$39.70 ± \$24.60 versus C=\$39.70 ± \$20.30; P=0.98).

As shown in Table 2, baseline consumption of vegetables and fruit did not differ significantly between the intervention and comparison groups (mean servings/d for intervention and comparison, respectively: 6.3, SD 3.0 versus 6.2, SD 2.8, P=0.29. Over half of all women (63.9%),

regardless of randomization group (P=0.58), consumed at least 5 servings of vegetables and fruit a day. At 12 months, participants in the intervention group increased their daily servings of vegetables and fruit, on average, to 8.9 (SD 3.4), for an increase of 2.5 (SD 3.2) servings per person per day from baseline levels (P<0.001). Conversely, the comparison group showed no significant change in intakes of vegetables and fruit over the same time period. Women in the comparison group averaged 6.3 (SD 2.8) daily servings, for an average per-person increase of 0.12 (SD; 2.6; P=0.11). Total vegetable and fruit intake in this analytical cohort of study participants reporting grocery cost data as compared to the total WHEL cohort showed no significant difference in mean consumption of these foods (data not shown) at baseline.

Comparison of juice consumption showed similar patterns. Baseline consumption did not differ by group (overall mean (SD): 4.14 (4.71) ounces, P=0.35), but after 12 months the mean (SD) consumption in the intervention group was 12.36 (7.04) ounces daily (mainly vegetable) versus 4.13 (4.70) ounces in the

Figure 1
Change in Food Costs from Baseline to Month 12, by Group^a



comparison group ($P < 0.001$).

Both study arms had comparable caloric intake at baseline (1721 vs 1742 kcals, $P = 0.22$). Although the dietary assessment indicated lower caloric intake at 12 months, the decrease was similar in both groups so that there was no significant difference between study groups at 12 months ($I = 1617$, $C = 1621$, $P = 0.83$). At baseline, percentage of energy intake from fat did not differ between groups, with the study sample reporting an average of 28.4% (SD: 7.0) of energy from fat. At baseline, 58.8% of participants in each group consumed the generally recommended level of <30% total energy intake from fat, but after 12 months, 86.2% in the intervention group met these guidelines, compared to 60.6% in the comparison group ($P < 0.001$). At 12 months, the intervention group reduced their mean percent energy intake from fat by 5.8 percentage points versus average 0.3 percentage point reduction in the comparison group, with mean percent energy

intake from fat of 22.3 (SD: 7.1) and 28.2 (SD: 7.0), respectively ($P < 0.001$).

Fiber intake also did not differ significantly across study groups at baseline, with an overall average daily intake of 21.6 g (SD: 8.3, $P = 0.80$). However, by 12 months the intervention group significantly increased ($P < 0.0001$) their mean daily total fiber intake by 8.1 g to 29.8 g (SD: 10.2) compared to no increase for the comparison group (21.5 g, SD: 8.3).

To validate reported intakes of vegetables and fruit, plasma carotenoids, lutein, beta-cryptoxanthin, lycopene, alpha-carotene and beta-carotene) were compared at baseline and 12 months. Carotenoid concentrations were equivalent across groups at baseline and increased 51% ($P < 0.001$) by 12 months in the intervention group only (not shown).

At 12 months, intervention-group participants reported spending a mean of \$43.24 [SD \$21.53] on groceries compared to the comparison-group mean of \$42.05 [SD \$20.45]. This difference of

Table 3
Linear Regression Modeling of Grocery Cost Per Person
(log transformed) at 12 Months for WHEL Study Participants

Model 1 ^a	(log) Grocery Cost (SE)	P-value
Group difference (intervention vs comparison)	0.037 (0.016) ^c	0.018
Baseline grocery costs (log)	0.613 (0.017)	<0.0001
Model 2 ^b	(log) Grocery Cost (SE)	P-value
Group difference (intervention vs comparison)	0.035 (0.016) ^c	0.027
Baseline grocery costs (log)	0.59 (0.018)	<0.0001
Meals prepared at home (at 12 months)	-0.001 (0.002)	0.487

Note.

- a** Adjusted for baseline grocery costs only; adjusted R² for the model =0.37
- b** Further adjusted for meals prepared at home at month 12, level of education, clinical site, age at randomization, race and 12-month measures of body mass index and physical activity (in metabolic equivalents); adjusted R² for the model =0.39
- c** After exponentiation, the estimates in Model 1 became exp (0.037) = 1.038, (ie, 3.8% higher costs in the intervention group), and the estimates in Model 2 became exp (0.035) = 1.036 (ie, 3.6% higher cost in the intervention group)

\$1.22 in the increase in reported grocery costs was statistically significant (I=\$3.55, SD: \$23.55, C=\$2.33, SD: \$18.70, P=0.007). We categorized the change in grocery costs per participant and present the proportion of each group in each of these categories (Figure 1). The majority of participants (~60%) in both groups reported a similar expenditure on grocery costs at both points in time (within \$10). The significant difference between the groups can be seen in the proportion with an \$11-30 difference on the second survey compared to baseline. An increase of this amount occurred with 22% of the intervention and 19% of the comparison group, and a decrease of this amount occurred with 11% of the intervention and 13% of the comparison group.

However, although there was no between-group change in the size of households over this time period (P=0.74), adherence to the study dietary pattern was associated with the intervention group’s significantly increasing the number of meals they prepared at home (I=+1.04, SD 3.7; C=+0.4 SD 3.8, P=0.001). In a regression model, we adjusted for baseline grocery costs, clinical site, age at randomization, race/ethnicity, education, 12-month values of the number of meals eaten or prepared at home, BMI, and

physical activity (Table 3). A Cook’s distance plot identified 4 potentially influential observations. Excluding these outliers did not change the results. Accordingly, the final model included all available data. After controlling for other variables, the 12-month weekly per-person grocery cost was 3.6% greater in the intervention group than in the comparison group (3.6%; 95 % CI: 0.4-6.8%; P=0.027).

DISCUSSION

The WHEL study intervention was successful in encouraging participants to adopt a plant-based dietary pattern whereas dietary intake in the comparison group was relatively unchanged. The intervention group increased daily intake of vegetables and fruit by 2.5 servings, reduced energy from fat by almost 6%, increased fiber intake by 8.1 g, and added an additional 8 ounces of juice. This dramatic dietary change was associated with an estimated increase of just over \$1/week in grocery costs per person. Given the very large study sample, this additional cost was statistically significant; however, this small amount would be unlikely to discourage shoppers from purchasing healthier options like vegetables and fruits.

This study uses self-reported dietary

intake from the sets of four 24-hour dietary recalls collected by telephone. However, the study also collected dietary data using a food frequency questionnaire. As self-reported dietary data are known to be prone to both random and systematic measurement error,^{22,26} the WHEL study collected blood samples from all participants and measured plasma carotenoids, a well-recognized biomarker of vegetable and fruit intake.²⁷ We used this biological measure in the comparison group to choose the self-reported measure with least random and systematic error.²² The validity problems of self-reported dietary measurement are exposed with the estimates of energy intake over the 2 study time points. In both groups, caloric intake declined by approximately 6% between baseline and 12 months, although we observed no between-group difference. Such declines are commonly observed with repeated self-reported dietary intake, and one of the reasons postulated for this is that participants try to reduce the participant burden associated with this reporting task.²⁸ Were such declines true, then we would expect that they would be associated with weight loss, all other things being equal. We have previously reported that there was less than 1 kg difference in body weight between the WHEL study's intervention and comparison groups at both the baseline and 12-month time-points.²⁹ Over 12 months, the WHEL study intervention was associated with a 51% increase in total plasma carotenoid concentration with no change in the comparison group.²¹ As carotenoids are not regulated in humans and vegetable and fruit intake is the major source, this biomarker data adds more evidence that the WHEL study intervention group achieved a major change to a plant-based dietary pattern.

For our measure of grocery costs, we asked participants to estimate their current household grocery costs at baseline and 12 months. The majority of participants were the primary food purchaser for their household. As such, they were in the best position to provide an accurate estimate of household grocery costs; however, such a measure is subject to recall and other biases. During the pilot study, we asked participants to keep grocery receipts but abandoned this measure as there were too many incomplete records to provide a reasonable assessment of

expenditures. Other studies estimated grocery costs for foods reported by dietary recall by checking the costs of these foods at a local supermarket. Such measures do not account for the many efforts people take to reduce their grocery costs, such as using coupons or other price discounting, or purchasing from alternative less expensive venues. Further, produce prices can vary dramatically with quality and freshness, seasonal availability, farmers market versus grocery versus convenience store sources, as well as with inventory levels, supply, and demand. Such price variations are particularly common for products with short shelf lives such as fresh produce. These price variations appear unrelated to the nutrient content of the food, but do influence food choices, although perhaps more among those of lower socioeconomic status than in our study population.^{30,31} Another approach has been to use ecological-level analyses of wholesale costs of food production to argue that increasing vegetables and fruit consumption must increase household grocery costs.^{11,30-32} However, there are many reasons that such a crude approach can lead to a biased estimate.

Our measure of cost also has limitations. Reported grocery costs are per-person estimates based on household costs, whereas dietary intake data are for a single member of the household. In addition, the cost data include only grocery purchases, whereas dietary data reflect all foods eaten whether in the house or outside the house. Although our measure of grocery costs is not optimal, we do confirm the results of the US Department of Agriculture study that there is little additional cost associated with increasing vegetable and fruit consumption, regardless of socioeconomic status.³³ The mean weekly food costs per person across groups in this study sample at baseline and 12 months ranged from \$39.70 to \$42.60, equivalent to the USDA \$37.70 low-cost food plan for 1999, when much of our data were being accrued.^{33,34}

Participants in our study were well educated, and most were from middle socioeconomic status groups. On average both study groups were eating healthy dietary patterns at baseline with an average of 6 vegetable/fruit servings and 28% energy from fat. Thus, their food purchasing habits will not be representative of the general population. Further, the study

used a participant-centered telephone counseling program to help women substantially change their diets. If participants considered price as a possible barrier to purchasing certain foods, counselors suggested lower-cost alternatives. Also, the study provided easy-to-prepare, healthy recipes emphasizing vegetables, fruits, legumes, and whole grains to facilitate experimentation and regular consumption; monthly cooking classes in the first year (attended by about half of study participants) featured these recipes. However, the intervention promoted consuming vegetable juice, emphasizing a variety of fresh vegetables. This was frequently reported by participants as burdensome, and many appeared to take the more costly option of purchasing juice. Further, time was more commonly mentioned as a barrier by our participants than cost was. Accordingly, both counselors and printed intervention material focused on quick and convenient sources of vegetables such as precut carrots and prewashed greens. Thus, if participants did not mention costs, our intervention did not promote the lowest-cost alternatives. Even with this emphasis, the additional costs of adhering to the study intervention were approximately \$1 per week. Nevertheless, caution is needed in generalizing our results to a population who might be very concerned about costs.

The factors that influence eating habits and food choices are many and diverse.¹⁰ Even if individuals can adopt healthier eating patterns at a similar cost, this does not mean they will do so. Our study demonstrates that motivated individuals can be encouraged to adopt a plant-based dietary pattern that involves a significant increase in vegetables, fruit, and fiber and reduction in fat, and that such a change does not necessitate an appreciable increase in household grocery expenditures. This suggests that concerns about the cost of adopting a healthy dietary pattern should not restrain public health efforts to improve dietary patterns to reduce health consequences

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