Relation of food cost to healthfulness of diet among US women1–4

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ABSTRACT
Background: Few studies have evaluated the cost of a diet that may prevent cardiovascular disease. High scores on the Alternative Healthy Eating Index (AHEI) have been associated with lower rates of cardiovascular disease.

Objective: We sought to evaluate the cost of a dietary pattern that may prevent cardiovascular disease among women residing in the United States.

Design: By using food-cost data from the US Department of Agriculture, we explored relations between spending on food and AHEI scores among 78,191 participants in the Nurses’ Health Study. By using linear regression, we estimated the change in AHEI score for a $1 increase in spending on various food groups.

Results: Study participants in the highest energy-adjusted spending quintile spent 124% as much money each day as those in the lowest quintile. The difference in AHEI scores (10th–90th percentile) between all study participants was 30 index points (Spearman’s correlation coefficient between total spending and AHEI = 0.44). The difference in AHEI scores (10th–90th percentile) within each quintile of spending ranged from 25 to 29 index points. Greater spending on nuts, soy and beans, and whole grains was associated with a higher AHEI score. Greater spending on red and processed meats and high-fat dairy was associated with a lower AHEI score.

Conclusions: Although spending more money was associated with a healthier diet, large improvements in diet may be achieved with smaller improvements in spending. The purchase of plant-based foods may offer the best investment for dietary health.

INTRODUCTION

Recent studies have evaluated the cost of maintaining a healthy diet (1–14). Reports from the United Kingdom (1, 7, 8), Spain (6), France (5, 10, 13), and the Netherlands (4) all suggest that healthier diets cost more. In the United States, although multiple analyses suggest that diets rich in energy-dense foods, such as snacks and sweets, cost less than diets filled with fruit and vegetables (3, 9–12), it has also been reported that healthy diets can be obtained at different levels of spending (14–16).

Previous studies have defined a healthful diet in a variety of ways: for example, in terms of adherence to a Mediterranean-style diet (6, 14) or a Healthy Eating Index (6) or as reflected by intake of select macro- and micronutrients (13). We have developed an index that measures adherence to a healthy eating pattern; high scores were associated with lower rates of chronic disease, especially cardiovascular disease (CVD) (17). To assess the costs associated with a healthy diet, defined as one that may prevent CVD, we examined the relation between dietary cost and dietary index score among study participants in the Nurses’ Health Study.

SUBJECTS AND METHODS

Study population and Nurses’ Health Study questionnaire

The details of the study population have been described in detail (18–22). In brief, the Nurses’ Health Study began in 1976 when 121,700 female registered nurses aged 30–55 y and residing in 11 US states provided detailed information on their medical history and lifestyle. Every 2 y, follow-up questionnaires have been sent out to update information on potential risk factors and to identify newly diagnosed cases of CVD (defined as coronary artery disease plus stroke), cancers, and other diseases. In 1980, a 61-item food-frequency questionnaire (FFQ) was included to assess intake of specific foods. In 1984, the FFQ was expanded to include 116 food items. Similar questionnaires were used to update dietary intake in 1986, 1990, 1994, 1998, 2002, and 2006.

Demographic data were queried on different questionnaires: in 1992, study participants reported their highest level of education (registered nurse, bachelor’s, master’s, or doctorate); in 2000, they reported their marital status (single, widowed, divorced, separated, or never married), living situation (alone, with spouse, with other family, in a nursing home, or other living situation), and current employment situation (retired, full- or part-time nursing, full- or part-time non-nursing). Place of residence is reported during each questionnaire cycle. Race was most recently queried in 2004 (Spanish/Hispanic/Latina, white, African American or black, American Indian or Alaska native, Asian, Native Hawaiian or Pacific Islander, or other).

For this analysis, we analyzed study participants who returned the 2002 FFQ. We excluded those who left >10 items blank on the FFQ. In the first questionnaire cycle, 76,315 women returned the FFQ. Of those, 76,136 returned the FFQ in 2002. When 119,320 women returned the FFQ in 2004, 104,338 returned the FFQ in 2006. The details of the study population have been described in detail.
the FFQ and those with implausibly low or high scores for total food or energy intake (ie, <2094 kJ [500 kcal] or >14,650 kJ [3500 kcal]/d). The total number of study participants for this analysis was 78,191.

The study was approved by the Committee on the Use of Human Subjects in Research at Brigham and Women’s Hospital (Boston, MA). All subjects gave informed consent to participate.

**Dietary measurement and Healthy Eating Index**

To calculate participants’ intakes of specific foods, a commonly used unit or portion size for each food was specified on the FFQ (eg, one slice of processed meat or one hamburger patty), and the study participant was asked how often on average during the previous year she had consumed that amount. Nine responses were possible, ranging from “never” to “more than 6 times per day.” Missing responses were given a value of zero, representing never eaten or eaten less than once per month (23). The reproducibility and validity of the FFQs in measuring food intake have been described in detail (24–28).

The Alternative Healthy Eating Index (AHEI) is a measure of a participant’s adherence to intake of select foods and nutrients that have been associated with lower risk of chronic disease in clinical and epidemiologic investigations (17). The index is an alternative to the US Department of Agriculture’s (USDA’s) Healthy Eating Index (HEI), which measures adherence to its Dietary Guidelines for Americans (29). We have previously observed that, although adherence to the USDA’s guidelines, as reflected in high scores on the HEI, was not associated with a lower risk of major chronic disease (30), adherence to an alternative healthy eating pattern, as reflected in high scores on the AHEI, was associated with lower risk of major chronic disease (17). The AHEI incorporates some aspects of the HEI (eg, both the HEI and AHEI allot points for high intake of fruit and vegetables), but the AHEI also provides quantitative scoring for qualitative USDA recommendations (eg, the AHEI allot a certain number of points for choosing more fish, poultry, and whole grains) (17).

The AHEI reflects a study participant’s intake of fruit, vegetables, nuts, soy, beans, white and red meats, cereal fiber, trans unsaturated fatty acids, polyunsaturated and saturated fatty acids, and alcohol as well as years of multivitamin use. To calculate an AHEI score for each study participant from these 9 components, individual food items listed on the 2002 FFQ were assigned to their appropriate food group (eg, fruit or vegetables), and serving sizes and frequency on the FFQ were recorded. Nutrient intakes were calculated by multiplying the serving size of each food by the frequency of reported consumption. The nutrient content of each food was located in the Harvard University Food Composition Database, which was derived primarily from USDA sources (31). Eight of the 9 components in the AHEI contributed from 0 to 10 points to the total score. A score of 0 represented that the study participant did not meet the dietary intake found to decrease risk of chronic disease, whereas a score of 10 signified perfect adherence. Intermediate intakes were scored proportionately from 0 to 10. Duration of multivitamin use was scored either 2.5 (nonuse) or 7.5 (use ≥10 y). Component scores were summed so that the composite index ranged from a minimum score of 2.5 (worst eating pattern) to a maximum of 87.5 (best eating pattern).

**Cost of foods and amount of money spent on food**

The cost of each food on the 2002 FFQ was derived as follows: each food item was given an 8-digit USDA/National Health and Nutrition Examination Survey (NHANES) code that most closely matched the food item (32). The 2002 FFQ database was then merged with the 2001–2002 online USDA food-cost database, which has the costs of foods prepared at home and reported in the 2002 NHANES survey (33). Missing cost data for specific FFQ foods were assigned a value from the most closely related food. Of the 467 food items in the FFQ database, there were 27 which were not easily matched.

For FFQ food items that were not easily matched (eg, alcoholic beverages and specialty vegetable oils, such as grape seed oil and apricot kernel oil), the following approach was used: First, we went to the US Department of Labor Bureau of Labor Statistics to find national average prices in 2002 for foods in all US cities (34). For food items not found at the Bureau of Labor Statistics, we then went to online grocery stores (35, 36) located in 3 cities across the country (Washington, DC; Boise, ID; and San Diego, CA; if San Diego did not have a particular food item, we used Los Angeles, CA). We took the average price of the 3 locations for the average price of the particular food in 2009 dollars. For beer, Budweiser (Anheuser-Busch Inc, St Louis, MO) was used, because this is the most widely consumed beer in the United States (37). For condiments, the cheapest available at the particular supermarket was used. Because the online grocery stores did not have specialty oils, we used an online specialty products website (38). Because the online grocery stores also did not have liquor, we went to online websites (39–42) from across the country and found the average cost for Bacardi rum (Bacardi Global Brands, London, United Kingdom), the most widely consumed liquor in the United States (43). We translated fluid ounces into grams, per the USDA conversion (beer = 29.7 g; light beer = 29.5 g; wine = 29.4 g; liquor = 27.8 g). We then used ratios from the Consumer Price Index to convert prices from February 2009 ($/g) into prices for February 2002 ($/g) (34). Last, we multiplied $/g by 100 to arrive at the cost per 100 g FFQ food-item serving.

The total amount of money each study participant spent on individual foods prepared at home each day was estimated by multiplying the cost of each food by the frequency of consumption, taking into account the standard serving size. We created 6 major “cost” food groups that mirrored the AHEI food groups and found the amount of money spent on them each day. These groups included fruit and fruit juice, vegetables, poultry and fish, red and processed meat, alcohol, nuts, and soy and beans. In addition, we created 6 additional “cost” food groups that contribute directly to the nutrient components of the AHEI and found their cost. These groups included whole-grain products, refined grain products, snacks and sweets, high-fat dairy foods, low-fat dairy foods, and eggs (see the supplemental table under “Supplemental data” in the online issue for the composition of each food group). Foods that did not largely affect calculation of the AHEI scores (eg, coffee and tea, soda, potatoes) were not included in the analysis of cost in relation to AHEI. They accounted for 23% of total amount of money spent on food each day.

**Statistical analysis**

Study participants were divided into quintiles of calorie-adjusted 2002 AHEI score and quintiles of calorie-adjusted 2002...
dietary spending (US $/d), by using the residual method of calorie adjustment (44). The interpretation of the residual-adjusted daily dietary cost ($/d) is the amount of money spent on food by each participant if she were consuming a 1800 calorie diet (the median energy intake of the study population). We examined distributions of food intake and spending per day and plotted 2002 spending compared with the 2002 AHEI score. We examined Spearman’s correlations between spending and AHEI score, both of which were adjusted for caloric intake. We analyzed the relation of calorie-adjusted total spending on food to demographic variables (race, highest level of education, living situation, marital status, employment status) by performing one-factor analysis of variance. We also ran one-factor analysis of variance to assess for differences in calorie-adjusted total spending between the 50 US states where the study participants resided. We evaluated the relation between healthy eating, spending, and demographic variables by running 2 analysis of covariance models: both had race, employment status, living situation, marital status, education, and age as the independent variables; however, the first model had calorie-adjusted total spending on food each day as the continuous dependent outcome, whereas the second model had calorie-adjusted AHEI as the continuous dependent outcome.

We ran a stepwise multivariate linear regression model with calorie-adjusted AHEI as the continuous dependent variable and calorie-adjusted food group expenditures (US $/d) as the independent variables ($ value for inclusion and exclusion = 0.15). This model estimated which food groups offered the best investment for dietary health, if total spending on food was not capped.

Notably, this stepwise multivariate regression model had a variable representing the quantity of food consumed associated with both exposure and outcome; that is, food quantity factored into the calculation of both AHEI scores and food group spending. This condition raises the potential for correlated errors, which was recognized in earlier studies of diet and cost (45, 46) and which, in our analysis, was mitigated in 2 ways: First, coefficients for calculating the AHEI score were both positive and negative (ie, certain foods increased scores, whereas others decreased them), although those for cost were all positive. As such, a correlation of errors would not necessarily exist, and if it did, it would tend to be low. Second, variation in caloric intake can be considered a type of “error” because it is extraneous when one is interested in dietary quality independent of energy intake. Because the energy variation in AHEI scores and spending are correlated, adjustment for AHEI scores and total spending for each person’s total caloric intake by the residual method, as we did, reduces variation and correlated error (44, 47).

RESULTS

Characteristics of the 2002 study population are shown in Table 1. After adjustment for caloric intake, study participants in the highest AHEI quintile spent 24% more money each day on food prepared at home than those in the lowest quintile. Participants in the highest quintile had higher intakes of fruit and fruit juice, vegetables, poultry and fish, nuts, soy and beans, whole grain, and alcohol and lower intakes of red and processed meat, high-fat dairy, grains, and snacks and sweets. In comparison with the lowest AHEI quintile, the highest AHEI quintile had lower rates of angina, diabetes, and hypertension. Participants in the highest quintile were more likely to be currently married, living with their spouse, white, and to have gained additional education beyond their nursing degree. The Spearman’s correlation coefficient between energy-adjusted total spending and energy-adjusted AHEI score was 0.44 ($ value < 0.0001).

Study participants lived in all 50 US states. Study participants in one state did not appear to have a significantly different spending pattern than did participants in all other states. White study participants spent more money on food than did black or Asian participants. Increasing education, living with a spouse, being married, and working full-time or part-time were significantly associated with higher total spending on food, whereas retirement and widowhood were associated with lower overall spending. Increasing age was associated with a small decrease in spending (−0.04 US $/y; SE: 0.00; $ < 0.0001), so that after age was controlled for in a model of covariance, retirement was no longer associated with less spending compared with full-time nursing. Further adjustment in an analysis of covariance model with calorie-adjusted total spending as the dependent variable and race, employment status, living situation, marital status, education, and age as independent variables did not substantially alter these results (data not shown).

Increasing education was significantly associated with higher HEI scores, as was living with a spouse, when compared with living alone, and being married, when compared with widowhood ($ < 0.05). Asians had higher AHEI scores compared with white participants. Increasing age was associated with a small decrease in AHEI scores (−0.1 points/y; SE: 0.01; $ < 0.0001). In the analysis of covariance model with calorie-adjusted AHEI score as the dependent variable and demographic variables plus age as independent variables, increasing education remained associated with higher scores (data not shown).

Study participants’ adherence to a healthy eating pattern varied substantially (Figure 1). The median AHEI value was 44, with an interquartile range of 36–52. AHEI scores increased monotonically with increasing spending. The difference in AHEI scores (10th–90th percentile) among all study participants was 30 index points. Large differences in AHEI scores were seen within each spending quintile: the difference between the 10th and 90th percentiles of AHEI score in the lowest spending quintile was 25 index points, whereas in the highest quintile, the difference was 29 index points. The magnitude of the distribution of AHEI scores within each quintile of spending was similar. The associations between AHEI and spending changed little when we dichotomized study participants to caloric intakes above and below 1800 kcal/d (data not shown).

When we regressed AHEI score on spending on each food group, we observed that greater spending on nuts, soy and beans, and whole grains was associated with a higher AHEI score, and greater spending on red and processed meats and high-fat dairy was associated with a lower AHEI score (Table 2). Spending on alcohol, eggs, and low-fat dairy had little effect on AHEI score.

DISCUSSION

In this analysis of 78,191 women, we observed that, although spending more money is associated with a healthier diet, large improvements in diet may be achieved without increased
spending. A 20-point increase in the AHEI score, which may be seen at each level of total spending on food, has been shown to be associated with a 25% lower risk of CVD (17). Increased spending on nuts, soy and beans, and whole grains, and less spending on red and processed meats and high-fat dairy, may be the best investment for dietary health.

Previous studies have investigated the relation between the healthfulness of diet and its cost by linking local or national food prices to food items reported on a questionnaire (2, 3, 6, 11, 45, 48), diet record (5), 24-h recall (4), or face-to-face interview (4). Previous studies have also defined a healthful diet in a variety of ways: for example, in terms of adherence to a Mediterranean-style diet (6, 14) or HEI (6) or as reflected by intake of select macro- and micronutrients (13). Despite the different dietary instruments and measures of healthfulness, most (1, 4–8, 10, 13), but not all (14–16), studies to date have concluded that a healthier diet costs more. Some (3) but not all (4, 6) have also found that measures of high socioeconomic status are associated with healthier eating patterns.

Importantly, the metric used to measure food quantity and cost influences conclusions about cost and healthfulness (49). For example, the energy cost ($/kcal) of energy-light foods (kcal/g), such as produce, is likely higher than the energy cost of energy-dense foods, such as snacks, and an inverse association has repeatedly been seen between energy cost and energy density (2–4, 11, 50, 51). However, it has been argued that conclusions about diet and cost may not immediately follow because the total daily cost ($/d) of diets rich in energy-dense foods may be higher than that of diets filled with energy-light foods when energy-dense diets have higher total daily caloric intake (2, 15). Similar to previous findings (9, 10, 46), in our analysis we observed that higher daily costs were associated with higher intakes of energy-

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<th>TABLE 1: Characteristics of Nurses' Health Study participants in 2002</th>
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<td><strong>Alternative Healthy Eating Index score</strong></td>
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<td>Median amount spent (US$/d)</td>
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<td>Alternative Healthy Eating Index score</td>
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<td>Diet (servings/d)</td>
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<td>Fruit and fruit juice</td>
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<td>Red and processed meat</td>
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<td>Poultry and fish</td>
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<td>Nuts, soy, and beans</td>
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<td>Snacks and sweets</td>
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<td>Duration of multivitamin use (y)</td>
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<td>Caloric intake (kcal)</td>
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<td>Current smoker (%)</td>
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<td>Employed full-time (%)</td>
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<td>Retired (%)</td>
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<td>Living situation (%)</td>
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<td>With spouse</td>
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All values are means; SEs in parentheses. Alternative Healthy Eating Index scores were adjusted for caloric intake by the residual method.
light foods such as fruit and vegetables and lower intakes of energy-dense foods such as snacks and sweets, even when daily energy intake was held constant.

In the United States, the USDA reports that most consumers could eat a more healthful diet with the amount of money they are currently spending, and that many consumers could in fact spend less to eat healthfully (52). The USDA suggests that to make transitions to more healthful diets, individuals need to spend more on vegetables (especially those that are dark green or deep yellow, legumes, and a slight increase in potatoes), fruit, whole grains, nuts and nut butters, and low-fat milk products and less on meat, meat alternatives, and other foods (52). In our study, we observed that greater spending on nuts, soy and beans, and whole grains was associated with the greatest improvement in dietary healthfulness. Both of these food groups contribute to 2 categories in the AHEI scoring system (nuts, soy, beans, or cereal fiber and ratio of polyunsaturated to saturated fat), and thus increased spending on one of them offer a maximum increase in AHEI score of 20 points. Fish and poultry, vegetables, and fruit may also be associated with a wide range of costs, depending on the type and frequency of activity (62).

When compared with recommended preventive measures for CVD that apply to fractions of the population, dietary improvement may benefit the large majority of Americans. Such improvements may also have health benefits beyond reduction in cardiovascular risk. A previous analysis did not show a reduction in cancer risk associated with adherence to the AHEI (17); however, adherence was associated with a lower risk of diabetes (63) and Parkinson disease (64).

Because we did not have information on place of consumption, a limitation of our study was that we assumed that all foods reported on the FFQ were prepared at home. If we had divided consumption between food prepared at home and that eaten out, our estimates might have been higher or lower, but we do not have any information on how this might affect the estimates. A potential limitation of our study is that the associations for the full sample may not be applicable to the younger age group (65). Moreover, the degree of relative risk reduction through dietary improvement may also be associated with a wide range of costs, depending on the type and frequency of activity (62).

Greater spending on red and processed meats and high-fat dairy was associated with the largest reductions in dietary health, as represented by scores on the AHEI.

When compared with interventions recommended by the US Preventive Services Task Force and American Heart Association for the prevention of CVD (53, 54), dietary improvement may be dominant because there need not be any associated cost. Moreover, the degree of relative risk reduction through dietary improvement is on the same order of magnitude as recommended behavioral and pharmacologic interventions. For example, a 10-point increase in AHEI score is associated with a 14% (8–19%) reduction, whereas a 20-point increase is associated with a 25% (16–34%) reduction (17). By comparison, a daily aspirin reduces risk by 38% (29–45%) and costs $16 per year (55, 56). Cholesterol-lowering 3-hydroxy-3-methylglutaryl coenzyme A reductase inhibitor (statin) therapy is associated with a 20–27% risk reduction in coronary artery disease, with an estimated cost of $830/y (56–58). The cost of antihypertensive therapy to achieve a similar risk reduction in myocardial infarction may be more (57, 59, 60). Smoking cessation is associated with a 24–71% risk reduction depending on the number of years since cessation and may be associated with either a decrease in cost, if one only stops purchasing cigarettes, or potentially with an additional cost, if one purchases nicotine replacement products (57, 61). An increase in physical activity may also be associated with a wide range of costs, depending on the type and frequency of activity (62).

When compared with recommended preventive measures for CVD that apply to fractions of the population, dietary improvement may benefit the large majority of Americans. Such improvements may also have health benefits beyond reduction in cardiovascular risk. A previous analysis did not show a reduction in cancer risk associated with adherence to the AHEI (17); however, adherence was associated with a lower risk of diabetes (63) and Parkinson disease (64).
outside the home, our estimates of total food expenditures would have been higher. The 2002 Consumer Expenditure Survey reports that 40% of annual expenditures on food was spent outside of the home (65), and food eaten outside the home is more generally expensive than that prepared at home. Moreover, our estimates do not consider either the time cost (the value of one’s time spent purchasing food and preparing food) nor the capital cost (the cost associated with purchasing kitchen appliances and utensils) of preparing food at home. Our estimate of food expenditures thus likely underestimates the amount of money actually spent on food in 2002. However, because we saw similar magnitudes of improvement in diet score at each level of spending, to increase total expenditures by accounting for food eaten outside the home and for other costs would likely not substantially alter our conclusions.

Our estimates of the relation between the amount of money spent on food and diet healthfulness are also sensitive to the year in which they are studied, because relative prices of foods change over time (11). For example, from May to June 2010, the Consumer Price Index for fruit and vegetables decreased by 2.2%, whereas that for cereals decreased by 0.4% (34). Such changes, if large, may alter our estimates of which foods offer the best investment for dietary health.

In conclusion, we have previously reported that adherence to the AHEI is associated with a lower risk of CVD. Here, we observe that, although spending more money is associated with a healthier diet, large improvements in diet may be achieved without increased spending. The purchase of more nuts, soy and beans, and whole grains, and less spending on red and processed meats and high-fat dairy, may offer the best investment for dietary health. To implement cost-effective measures to decrease the burden of CVD, dietary change may be recommended with other behavioral and pharmacologic interventions.

The authors’ responsibilities were as follows—AMB, DEB, and WCW: hypothesis generation; AMB, MF, and WCW: data collection; AMB, DEB, BAR, and WCW: data analysis; and all authors: manuscript preparation. The authors had no conflicts of interest.

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