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Lower-Energy-Density Diets Are Associated with Higher Monetary Costs per Kilocalorie and Are Consumed by Women of Higher Socioeconomic Status

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ABSTRACT

Objective Diets of lower energy density are associated with higher diet quality, lower body weights, and better health outcomes. This study examined associations among dietary energy density, energy-adjusted diet costs, and socioeconomic indicators of study participants.

Design In this cross-sectional study, energy and nutrient intakes for 164 men and women aged 25 to 65 years were obtained using a food frequency instrument between June 2005 and September 2006. Dietary energy density (kcal/g) was calculated with and without beverages. Energy-adjusted diet costs ($/2,000 kcal) were calculated using food prices in Seattle, WA. Tertile splits of energy density and energy cost were analyzed using tests for linear trend. Linear regression models tested the association between education, income, and dietary variables, adjusting for age and sex.

Results Diets of lower energy density were associated with higher absolute nutrient intakes. Diets of lower energy density were also associated with higher energy-adjusted diet costs. Conversely, highest energy density diets were associated with lower intakes of micronutrients and fiber and lower costs. Education and household income showed a negative association with dietary energy density in regression models. Education and household incomes showed a positive association with the energy-adjusted cost of the diet. Education was a stronger predictor of both energy density and energy cost than was household income.

Conclusions Higher-quality diets were not only more costly per kilocalorie but were also consumed by persons of higher educational level. The influence of diet quality on health, observed in some epidemiologic studies, might be modulated by unobserved indexes of socioeconomic status.

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Studies on the social and economic determinants of health have shown that persons and groups of higher socioeconomic status (SES) have lower rates of obesity, type 2 diabetes, and cardiovascular disease (1). The literature suggests that some of the observed disparities in health may be related to disparities in diet quality (2-5). More affluent people are not only healthier and thinner but also consume higher-quality diets (6). It is not clear whether the more favorable health outcomes can be attributed to better diets, higher SES, or some combination of both (7).

The energy density of a diet (ie, available energy per unit weight) (8) is one indicator of diet quality. Lean meats, fish, low-fat dairy products, and fresh vegetables and fruit provide less energy per unit weight than do fast foods, sweets, candy, and desserts (9,10). Whereas energy-dense foods tend to be nutrient-poor, foods of low energy density provide more nutrients relative to kilocalories (11). An inverse relation between energy density and nutrient density has now been demonstrated both for individual foods (11) and for total diets (12).

Diets of low energy density and high nutrient content have been associated with less weight gain (13) and with lower rates of obesity (14-16), type 2 diabetes (17), cardiovascular disease (18-20), and some forms of cancer

(21). In contrast, energy-dense diets have been linked to higher obesity rates and higher disease risk (22). Improving diet quality by lowering its energy density is standard advice for weight control (23), cancer prevention (24), and better health (25).

However, higher quality diets of lower-energy-density are likely to cost more (2,26). Diets composed of whole grains, lean meats and fish, low-fat dairy products, and fresh vegetables and fruit are more costly per kilocalorie than are energy-dense diets rich in fats and sweets (27-32). In Europe, high nutrient content of the diet was strongly associated with higher diet costs, adjusted for energy (33-35). In the United States, the price disparity between foods of low vs high energy density continues to grow: A recent study showed that the lowest-energy-density foods, mostly fresh vegetables and fruit, increased in price by almost 20% over a 2-year period, whereas energy-dense sugars and fats did not (36,37).

The important question is whether higher-quality but more costly diets are more likely to be consumed by more affluent persons. A key challenge in nutritional epidemiology is to make sure that persons or groups characterized by a given eating pattern do not differ in some fundamental yet unobserved way from persons with another type of eating pattern. Given that higher SES groups often have both higher quality diets and lower disease risk, epidemiologic studies tend to treat SES as a potential confounder. To reveal associations between dietary exposures and chronic disease risk, studies have adjusted for SES (38) whenever such variables were available. Our study had a different purpose, focusing on indicators of SES as exposure variables, and exploring the association between SES measures and dietary energy density and energy-adjusted diet cost.

The hypothesis was that lower-energy-density diets would be associated with higher nutrient intakes—and with higher dietary energy costs. A related hypothesis was that diets with higher energy costs but that were also more nutrient-rich would be associated with higher educational levels and higher incomes. Clarifying the relation between SES variables, diet quality, and diet cost has many implications for studies of diet and disease risk and for the design of dietary strategies for health promotion.

METHODS

Participants

The study was based on a stratified sample of faculty and staff of a large public university in the Pacific Northwest. The sampling frame was stratified by ranges of university salaries, obtained from the publicly available payroll system. There were 20 salary strata, with means ranging from $1,408 per month to $13,924 per month, with participant recruitment based on random sampling within each strata. Whereas salary data were used for targeting recruitment letters, the key income variable in the final analyses was household income, not individual salaries (see below). Heights and weights for all participants were measured in the laboratory using a physician's 175-kg scale and stadiometer (Detecto, Webb City, MO). All participants were compensated $100 at the termination of the study. Because a key feature of the study was the estimation of diet costs using supermarket food prices, individuals who consumed away-from-home foods or beverages six times or more during the 1-week food record period were excluded. All procedures had been reviewed and approved by the university institutional review board.

Dietary Intake Assessment

Dietary intakes used in these analyses were obtained using the G-SEL version of the Fred Hutchinson Cancer Research Center food frequency instrument (FFQ). Participants received a 20-minute training by a registered dietitian on how to complete the FFQ during their first visit to the laboratory. The training involved a serving size photo booklet for reference. Participants completed the FFQ during this visit and project staff members were on hand during the administration of the questionnaire to answer questions and assist with serving size or frequency estimations. Participants recorded the frequency of consumption of 152 line-item foods and beverages and indicated portion size. Each questionnaire was reviewed for completion before the participant left the laboratory. Customized nutrient analysis software, developed by the Fred Hutchinson Cancer Research Center, links the FFQ food intake data to the nutrient database at the Nutrition Coordinating Center at the University of Minnesota (39,40). The Minnesota database is primarily derived from the US Department of Agriculture's National Nutrient Database for Standard Reference, maintained by the Nutrient Data Laboratory in Beltsville, MD, and supplemented with information from food manufacturers. To calculate individual nutrient intakes, the software multiplies frequency of use of each FFQ item by portion size and by the weighted vector of nutrient values for each component food. Each of the 384 component foods in is associated with an array of nutrient values, energy and water per 100-g serving.

Dietary Energy Density and Nutrient Content

Nutrient composition analyses of dietary intake data yielded dietary energy (in kilocalories), the weight of foods, beverages, and drinking water (in grams), and the estimated daily intakes of more than 45 macro- and micronutrients. Dietary energy density was calculated as available energy divided by the weight of foods and beverages. Calculations of energy density (kilocalories/gram) followed past models (10,16,41). Dietary energy density calculations were based on all foods and all beverages, with the exception of drinking water; and on foods only, excluding all beverages, both with and without energy content. In past studies (10,16), dietary energy density based on foods only was better correlated with indexes of diet quality, including micronutrient content (10,34).

Diet Cost Assessment

Mean daily diet costs were estimated by attaching a food price vector to the nutrient composition database. The Fred Hutchinson Cancer Research Center FFQ is composed of 152 line-item foods and 384 underlying component foods. For example, the nutrient composition of a composite item such as "apples, applesauce, and pears" is actually based on a weighted mean of underlying component foods, which include fresh apples, applesauce, fresh pears, and canned pears. The weights used in the construction of the FFQ are derived based on food consumption data (when available) or on expert judgment. Our method to estimated diet costs was based on attaching retail price for each of the 384 component food items in the FFQ nutrient composition database. Price collection methods are provided in detail elsewhere (37). The analyses were based on 2006 prices obtained at three different supermarket chains in the Seattle metropolitan region.

The monetary value for each diet was calculated in a manner analogous to that used to obtain nutrient values. Retail prices, expressed per 100-g edible portion, were added to the G-SEL nutrient database, to parallel nutrient values, expressed as amounts per 100 g edible portion. In this way, each of the 384 foods in the G-SEL database was associated with 45 nutrient vectors and a single cost vector, both expressed per 100-g edible portion. The final monetary variable associated with each individual's diet was the mean cost per day. For each diet, this variable was then divided by the individual's reported mean energy intake—in kilocalories—and multiplied by 2,000 to express the cost of the diet per 2,000 kcal of dietary energy.

Socioeconomic Measures

For each participant, self-reported education and household incomes were used as indicators of SES. The highest level of formal education was measured in nine categories ranging from "elementary school" to "doctorate degree (PhD, DPhil)." Options for reporting household incomes ranged from "less than $15,000 per year" in 10,000 increments to "$115,000 per year and above." For regression analyses these variables were recoded. Highest level of education completed was recoded into three categories relative to the attainment of a bachelor's (4-year) degree. Household income categories were recoded into four categories (see results below).

Statistical Analyses

All analyses were first conducted separately for men and women. Bivariate methods were used to explore the relationship between dietary energy density and energy-adjusted diet costs. Participants were stratified by sex-specific tertiles of energy density and energy-adjusted diet costs, as in past studies (10,16), and linear trend tests were used to identify significant differences in the mean intakes of macro- and micronutrients among tertiles. Data for men and women were combined to examine the crude relation between income, education, and measures of energy-adjusted diet cost and diet quality. Finally, linear regression models tested the association between SES variables and dietary energy density and energy-adjusted diet costs, with age, sex, and household size as covariates. SES variables were coded as dummy variables, with the lowest level used as the reference group. Race and ethnicity were not included as covariates, given that the sample was small and 85% white.

Table 1. Demographic and socioeconomic characteristics of men and women aged 25 to 65 years in a study examining the association among dietary energy density, energy-adjusted diet costs, and socioeconomic indicators of study participants

Characteristic	Men	Women	All
	←	*n*	→
Sample size	61	103	164
	←	*mean±standard deviation*	→
Age (y)	37.7±9.7	42.2±10.4	40.3±10.3
Body weight (kg)	77.7±10.8	73.9±18.5	75.4±16.1
Body mass index	25±2.8	26.6±6.3	26±5.3
No. of individuals residing in household[a]	2.1±1.1	2.4±1.4	2.3±1.3
	←	%	→
Self-reported very good or excellent health	82	76	78
Never smoked	64	67	66
Non-Hispanic white	85	82	83
Bachelor's degree or higher	92	85	89
Household income ≥$55,000/y	51	60	57

[a]Includes adults and children.

RESULTS

Study Participants

More than 3,000 introductory letters were sent to preselected respondents via campus mail. Of these, 350 persons responded by mail or by telephone and, depending on work schedules and other commitments, 259 were invited to attend an introductory orientation meeting and provide consent. Persons who never began study protocols; those who dropped out in the course of the 5-week study; those who failed to complete all questionnaires, including FFQs and diet records, or who did not keep food expenditure records for 4 weeks, were excluded from analysis. The final sample of 164 (103 women and 61 men) provided complete FFQs and 4-day diet records, and completed all demographic and behavior questionnaires.

Mean age of participants was 40.3 years (range 25 to 65 years). Mean age was 42.2 years for women and 37.7 years for men. Most men (92%) and most women (85%) had completed a bachelor's degree or higher. A majority of women (60%) and half of men (50%) had annual household incomes of $55,000 and above. Most men (85%) and women (82%) identified themselves as white, with the rest being Asian or Pacific Islander (6.8% of men, 12% of women) and African American (3.4% of men, 4% of women). Demographic and SES data are summarized in Table 1.

Energy and Nutrient Intakes

Daily energy intakes calculated, including all foods and all beverages except drinking water were 2,088 kcal (8.74 mJ) for men and 1,779 kcal (7.44 mJ) for women. Dietary energy density was 0.92 kcal/g (3.85 mJ/kg) for men and 0.85 kcal/g (3.56 mJ/kg) for women.

Daily energy intakes calculated for foods only and excluding all beverages were 1,806 kcal for men and 1,543

Table 2. Mean energy and nutrient intake and diet cost by tertile of dietary energy density (excluding beverages) for women and men

Women	Lowest tertile (n=34)	Middle tertile (n=35)	Highest tertile (n=34)	*P* value[a]
	←	*mean±standard deviation*	→	
Nutrient				
Dietary energy density (kcal/g)	1.04±0.11	1.32±0.08	1.69±0.19	<0.001
Total fat (g)	49.5±21.8	59.8±17.3	71.6±30.1	<0.001
Total saturated fatty acids (g)	15.0±6.6	18.8±6.1	22.6±10.0	<0.001
Total dietary fiber (g)	25.9±10.1	20.8±8.0	16.8±6.4	<0.001
Added sugars (g)	40.4±16.0	46.8±24.9	48.4±30.9	0.187
Vitamin A (μg RAE[b])	1,386±743	884±462	623±279	<0.001
Vitamin C (mg)	138±59	95±36	65±32	<0.001
Calcium (mg)	750±304	717±301	671±318	0.292
Iron (mg)	14±7	14±6	13±6	0.474
Potassium (mg)	2,790±931	2,332±763	1,899±717	<0.001
Dietary energy cost ($/2,000 kcal)	9.55±1.82	8.06±1.25	6.76±0.87	<0.001
Men	**Lowest tertile (n=20)**	**Middle tertile (n=21)**	**Highest tertile (n=20)**	***P* value[a]**
	←	*mean±standard deviation*	→	
Nutrient				
Dietary energy density (kcal/g)	1.19±0.10	1.42±0.09	1.84±0.25	<0.001
Energy (kcal)	1,760±614	1,758±518	1,902±846	0.505
Total fat (g)	58.5±24.9	65.7±18.2	86.5±38.5	0.003
Total saturated fatty acids (g)	17.3±8.5	20.7±4.9	27.0±11.5	0.001
Total dietary fiber (g)	28.2±11.0	23.6±10.7	19.2±9.9	0.008
Added sugars (g)	48.7±24.7	51.5±31.4	47.9±34.8	0.939
Vitamin A (μg RAE[b])	1,111±538	852±323	777±483	0.024
Vitamin C (mg)	112±51	98±56	64±27	0.002
Calcium (mg)	819±343	789±336	770±437	0.680
Iron (mg)	17±5	17±7	16±8	0.856
Potassium (mg)	2,807±1,071	2,465±854	2,098±1,018	0.026
Dietary energy cost ($/2,000 kcal)	7.82±1.28	7.74±1.27	6.71±1.15	0.006

[a]Test for trend based on test of linear change in mean across tertiles of dietary energy density.
[b]RAE=retinol activity equivalents.

kcal for women. Dietary energy density was 1.48 kcal/g (6.2 mJ/kg) for men and 1.35 kcal/g (5.6 mJ/kg) for women. These values are entirely consistent with prior research, sometimes based on far larger population samples (10).

Dietary energy density was positively associated with crude macronutrient intakes (in grams), also consistent with past studies (10,41). For both men and women, higher dietary energy density was associated with higher intakes of total fat and saturated fat and with lower intakes of dietary fiber, potassium, and vitamins A and C. Table 2 shows mean energy and nutrient intakes by sex-specific energy density tertiles, where energy density was calculated without beverages.

Diet Quality and Diet Cost

Daily diet cost was slightly higher for men ($6.72/day) than women ($6.21/day), reflecting the fact that men ate more. However, the difference reversed after adjusting for energy. For each 2,000 kcal of dietary energy, men spent $7.43 compared to $8.12 spent by women. The cost of dietary energy was negatively and significantly associated with dietary energy density in the sample of women. Table 2 shows that the mean energy cost ($/2,000 kcal) of the lowest tertile by energy density group was 41% higher than the energy cost of the highest tertile ($9.55 vs $6.76). Men showed similar, but weaker associations between energy density and energy cost.

The Figure shows the inverse relation between dietary energy density and energy-adjusted diet cost (r^2=0.37), one that was largely driven by a stronger correlation for women (r^2=0.51) but not for men (r^2=0.09). Men and women also showed differences in the slope of the relation between dietary energy density and energy cost. Each additional dollar in energy cost for women led to a decrease in energy density of 0.12 kcal/g (0.50 mJ/kg). In contrast, each additional dollar in energy cost for men led to a decrease in energy density of only 0.07 kcal/g (0.29 mJ/kg).

Diets that were more costly in terms of dollars per 2,000 kcal were also lower in energy density and contained higher levels of nutrients. Table 3 shows mean energy and nutrient intakes by sex-specific tertiles of dietary energy cost, calculated without beverages. For both women and men, higher energy costs were associated with significantly lower dietary energy density and with significantly higher intakes of vitamin C, potassium, and total fiber. Higher energy costs were also associated with significantly higher intakes of vitamin A and saturated fat in women.

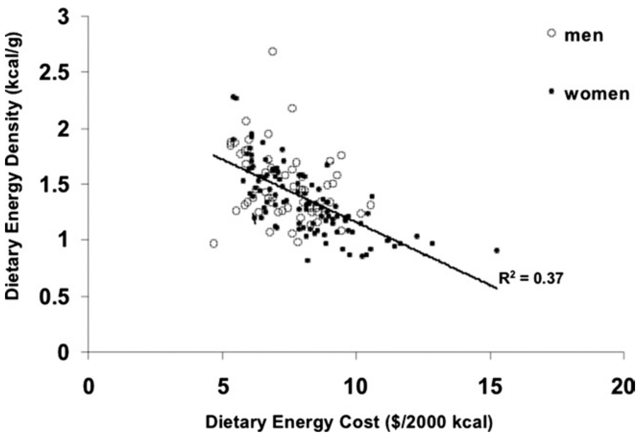

Figure. Dietary energy density is inversely correlated with diet cost. A scatterplot showing the relation between energy density (kcal/g) and diet cost adjusted for energy intake ($/2,000 kcal) for 164 subjects. Energy density calculated without beverages. Symbols indicate men (n=61) and women (n=103). Least-squares regression line fit to all data points. Correlation coefficient r^2=0.37.

SES, Dietary Energy Density, and Diet Cost

Higher education and incomes were associated with lower dietary energy density and higher energy costs. Table 4 shows the influence of education and income levels on dietary energy density, mean daily diet cost, and energy-adjusted diet costs. In these analyses, dietary energy density and cost were calculated without beverages and including all beverages except drinking water. As expected, the inclusion of beverages increased mean daily diet costs and energy-adjusted diet cost, whereas energy density was reduced.

Although daily diet cost followed no consistent trend with higher levels of income, energy-adjusted diet cost increased monotonically with income. Similarly, dietary energy density decreased monotonically with progressively higher levels of household income. Educational level showed similar associations with dietary measures. Notably, higher levels of education were associated with a higher cost per kilocalorie and progressively lower dietary energy density.

The associations between SES variables and dietary energy density were examined using regression models to control for covariates, shown in Table 5. Income effects were examined at three higher levels with reference to the lowest-income group. Similarly, education effects were examined at two higher levels with reference to the least-educated group. Again, analyses were conducted for dietary intakes excluding all beverages and including all beverages except water. Both analyses adjusted for age and household size and as covariates of education and household income.

In both analyses, sex was significantly associated with dietary energy density with women consuming lower-energy density diets than men. Both analyses also showed that the lowest-energy density diets were consumed by the most highly educated respondents, independent of income. The effect of education showed a dose-response pattern with higher levels of education linked to progressively lower dietary energy density.

Regression models then examined the relative effect of education and income on energy costs. As in the analysis of energy density, energy-adjusted diet costs were calculated with and without beverages, shown in Table 6. Both analyses revealed that sex was significantly associated with dietary energy cost, with women spending significantly more per 2,000 kcal (8.37 mJ) than men.

Both analyses also showed that higher household incomes were associated with progressively higher energy-adjusted diet costs. In the analysis including beverages, the monotonic positive association between income and diet cost was significant for the two highest income groups ($P<0.05$), who spent an additional $0.90 per 2,000 kcal (8.37 mJ) of dietary energy compared to the reference group.

Both analyses also showed a positive and significant effect of education on energy-adjusted diet cost that was independent of household income. In the analysis excluding beverages, both higher levels of education were associated with significantly higher spending on dietary energy. The two higher education groups spent nearly $1/2,000 kcal more than the reference group. The analysis including beverages also revealed higher spending among the more educated groups, with only the most highly educated group (postgraduate degrees) showing significantly higher energy-adjusted diet cost after adjusting for covariates.

DISCUSSION

Lower-energy-density diets were associated with higher nutrient intakes. In contrast, the more energy-dense diets contained more total fat and saturated fat but were lower in fiber and micronutrients. These findings that energy density and nutrient density of diets are inversely linked are entirely consistent with past data, based on much larger populations, and representative samples in the United States (10) and in France (34,35).

Our analyses included an important and sometimes underappreciated economic variable: food prices and diet costs. Dietary energy was strongly and negatively linked to energy-adjusted diet costs (Table 3). The most energy-dense diets with the lowest fiber and micronutrient content were associated with the lowest energy costs (Table 2). By contrast, higher-quality diets were associated with higher energy costs (34,35). This association between diet quality and energy cost was much stronger for women than for men.

Higher-quality diets were not only more costly per 2,000 kcal but were associated with higher SES of study participants. Education, rather than income, was the dominant factor. Regression models that adjusted for age and sex revealed that energy cost was positively associated with both education and household incomes but education showed the stronger effect. More highly educated respondents reported higher quality and therefore more costly diets, independent of household income level. The 2004 Consumer Expenditure Survey (42) reported that total expenditures on food in the United States for persons in the highest four income quintiles ranged from $5.04 to $7.70 per person per day. That range of incomes corresponded most closely to those in this study sample.

Whereas many prior studies have examined socioeconomic correlates of diet quality (2,43-45), fewer have included the intermediate variable of diet cost. This was likely due to the lack of appropriate methods for estimat-

Table 3. Mean energy and nutrient intake (excluding beverages) and diet cost by tertile of dietary energy cost for women and men

Women	Lowest tertile (n=34)	Middle tertile (n=35)	Highest tertile (n=34)	*P* value[a]
	←mean±standard deviation→			
Nutrient				
Dietary energy cost ($/2,000 kcal)	6.35±0.43	7.94±0.53	10.09±6.35	<0.001
Dietary energy density (kcal/g)	1.60±0.27	1.33±0.22	1.12±1.60	<0.001
Energy (kcal)	1,594±562	1,545±529	1,490±1,594	0.423
Total fat (g)	65.8±26.7	60.8±24.6	54.2±65.8	0.056
Total saturated fatty acids (g)	20.7±9.0	19.2±8.3	16.4±20.7	0.034
Total dietary fiber (g)	18.5±8.3	21.3±8.9	23.8±18.5	0.016
Added sugars (g)	50.9±27.8	45.1±27.2	39.6±50.9	0.060
Vitamin A (μg RAE[b])	637±342	994±552	1,259±727	<0.001
Vitamin C (mg)	64±33	102±40	132±64	<0.001
Calcium (mg)	661±285	738±316	738±661	0.302
Iron (mg)	12±5	14±7	14±12	0.219
Potassium (mg)	1,997±705	2,340±843	2,684±1,997	0.001
Men	**Lowest tertile (n=20)**	**Middle tertile (n=21)**	**Highest tertile (n=20)**	***P* value[a]**
	←mean±standard deviation→			
Nutrient				
Dietary energy cost ($/2,000 kcal)	5.96±0.53	7.42±0.45	8.90±0.67	<0.001
Dietary energy density (kcal/g)	1.58±0.29	1.51±0.39	1.35±0.18	0.017
Energy (kcal)	1,781±717	1,742±610	1,897±686	0.588
Total fat (g)	73.3±38.5	65.7±28.4	71.6±23.0	0.862
Total saturated fatty acids (g)	22.7±11.7	20.9±9.6	21.5±6.8	0.698
Total dietary fiber (g)	20.6±7.0	21.9±8.9	28.5±14.5	0.022
Added sugars (g)	44.7±31.8	49.9±30.1	53.6±29.3	0.361
Vitamin A (μg RAE[b])	779±451	954±522	1,002±421	0.137
Vitamin C (mg)	67±28	79±33	130±60	<0.001
Calcium (mg)	805±410	733±308	843±393	0.743
Iron (mg)	16±8	16±6	18±8	0.358
Potassium (mg)	2,192±808	2,257±867	2,932±1,189	0.019

[a]Trend test based on test of linear change in mean across tertiles of dietary energy cost.
[b]RAE=retinol activity equivalents.

Table 4. Unadjusted mean daily diet cost, dietary energy cost, and energy density (ED) (calculated excluding and including beverages) by categories of participant income and education level

	Diet Excluding All Beverages			Diet Including All Beverages Except Drinking Water		
Category	**Daily diet cost ($/d)**	**Energy cost ($/2,000 kcal)**	**Dietary ED (kcal/g)**	**Daily diet cost ($/d)**	**Energy cost ($/2,000 kcal)**	**Dietary ED (kcal/g)**
	←mean±standard deviation→					
Income						
$15,000-$44,999 (n=50)	6.57±2.75	7.59±1.54	1.42±0.30	7.56±2.86	7.78±1.47	0.94±0.22
$45,000-$74,999 (n=57)	6.31±2.28	7.71±1.44	1.43±0.29	7.62±2.64	7.99±1.53	0.87±0.21
$75,000-$104,999 (n=27)	6.16±2.63	8.06±2.01	1.41±0.37	7.79±2.71	8.67±1.96	0.79±0.20
≥$105,000 (n=30)	6.47±2.34	8.45±1.74	1.29±0.30	7.80±2.74	8.83±1.79	0.83±0.23
Education						
< Bachelor's degree (n=18)	5.63±2.15	7.07±1.46	1.66±0.42	6.86±2.47	7.39±1.74	1.02±0.23
Bachelor's degree (n=68)	6.50±2.48	7.92±1.77	1.42±0.27	7.80±2.71	8.17±1.68	0.87±0.21
Postgraduate degree (n=77)	6.51±2.56	8.00±1.55	1.32±0.28	7.77±2.77	8.40±1.64	0.85±0.22

ing the cost of individual diets. In the United States, data on the cost and quality of the diet are collected by different agencies, in different populations, and at different levels of demographic resolution. For example, the Consumer Expenditure Survey collects household data on food expenditures for the Consumer Price Index (46) but does not report quantities of foods purchased or collect food consumption data. The US Department of Agricul-

Table 5. The associations between participants' (N=164) socioeconomic status variables and dietary energy density (ED) (kcal/g) examined using two regression models to control for covariates[a]

	ED of Diet Excluding All Beverages				ED of Diet Excluding Water Only			
		95% confidence interval for β				95% confidence interval for β		
Variable	β	Lower	Upper	*P* value	β	Lower	Upper	*P* value
Sex[b]	−.16	−.25	−.07	0.001	−.09	−.15	−.02	0.008
Household income[c]								
$45,000-$74,900	−.01	−.10	.12	0.844	−.05	−.13	.03	0.200
$75,000-$104,900	−.02	−.16	.11	0.761	−.14	−.24	−.04	0.005
≥$105,000	−.03	−.17	.11	0.652	−.07	−.17	.04	0.195
Highest education[d]								
Bachelor's degree	−.27	−.42	−.11	0.001	−.14	−.26	−.03	0.014
Postgraduate degree	−.34	−.49	−.19	<0.001	−.16	−.27	−.05	0.006

[a]Both models adjusted for total weight of the diet, respondent's age, and household size.
[b]Reference group was men.
[c]Reference group are households with incomes between $15,000 and $44,900.
[d]Reference group was group attaining any level of education below a bachelor's (4-year) degree.

Table 6. Regression models examining the relative effect of participants' (N=164) education and income on energy-adjusted diet costs ($/2,000 kcal)[a]

	Energy-Adjusted Diet Cost Excluding All Beverages				Energy-Adjusted Diet Cost Excluding Water Only			
		95% confidence interval for β				95% confidence interval for β		
Variable	β	Lower	Upper	*P* value	β	Lower	Upper	*P* value
Sex[b]	.73	.19	1.26	0.009	.624	.08	1.17	0.025
Household income[c]								
$45,000-$74,900	.12	−.52	0.76	0.704	.23	−.41	0.87	0.470
$75,000-$104,900	.439	−.37	1.25	0.285	.89	.08	1.70	0.032
≥$105,000	.705	−.13	1.54	0.098	.91	.07	1.75	0.035
Highest education[d]								
Bachelor's degree	.99	.07	1.90	0.034	.89	−.03	1.80	0.059
Postgraduate degree	.97	.06	1.88	0.038	.99	.07	1.91	0.034

[a]Both models adjusted for total dietary energy, respondent's age, and household size.
[b]Reference group was men.
[c]Reference group are households with incomes between $15,000 and $44,900.
[d]Reference group was group attaining any level of education below a bachelor's (4-year) degree.

ture Continuing Survey of Food Intakes by Individuals collected individual-level dietary intake data but had no information on food expenditures. The US Department of Agriculture has been tracking food prices using the AC Nielsen Scantrack program and is in the process of calculating the prices of foods consumed by respondents in the National Health and Nutrition Examination Survey, using procedures similar to those outlined in our study. This new dataset will provide a way to analyze the relation between diet quality and imputed diet cost, following procedures similar to those in our study.

Published analyses of the relation between diet quality and diet cost, largely based on European populations, also estimated diet costs by merging food record data with national food prices (34,35). One such study (33) integrated a food price index into an otherwise conventional FFQ to estimate food costs in a population of Spanish adults. In common with Darmon and colleagues (23-32,34,35), the methods of Schröder and colleagues (33) relied on national food price data to estimate the food costs of the study population in northeastern Spain.

These observations confirm earlier findings on the positive association between diet quality and energy adjusted diet cost. Higher-cost diets have previously been shown to be lower in energy density (33) and higher in micronutrients and dietary fiber than lower-cost diets (34). Notably, vitamin C intake was strongly and positively associated with energy-adjusted diet cost. Dietary vitamin C is a proxy of fruit and vegetable consumption and an indicator of diet quality (10,47). Beyond nutrient-by-nutrient indicators of diet quality, studies on a large US food survey database have shown that dietary energy density is inversely associated with other conventional methods of overall diet quality (10).

Our study had some limitations. First, dietary intake and cost estimates were derived from a modified FFQ, an instrument that is subject to known biases (48,49). Second, our findings were based on a relatively small convenience sample of adults residing in and around Seattle, WA, who do not represent the national population. The sample was primarily white and highly educated, and although incomes tended to be higher than the national median, they were in line with state and local incomes (50). Third, the ability of this FFQ to accurately estimate costs is limited by the validity of the prices that were used in the database. For each food in the FFQ's database, dollar cost per 100-g edible portion was computed using local retail prices. The prices selected were always the lowest, nonsale price available for the product from one of the three largest supermarket chains in the Seattle metropolitan area. Thus, the prices used in estimating diet costs might not adequately reflect the prices paid by individuals. Finally, the modeling of diet cost was based on the strong assumption that most foods consumed, other than fast foods, were purchased at retail and prepared at home. The validity of the diet cost estimates for individuals who frequently consumed away-from-home foods and beverages would likely be low. It is worth noting that this limitation is common to epidemiologic studies on dietary exposures, including the Women's Health Initiative, which excluded women who frequently ate away from home (51).

Despite these limitations, our estimates of dietary energy density and diet cost were comparable to those obtained from other sources. For example, the estimates of dietary energy density were 1.48 kcal/g and 1.35 kcal/g for men and women, respectively. Using a similar method, Ledikwe and colleagues (41) obtained values of 1.91 kcal/g for men and 1.79 kcal/g for women based on the Continuing Survey of Food Intakes by Individuals dataset. The discrepancy between the average energy densities reported here and those reported by Ledikwe and colleagues might be due to the differences in socioeconomic characteristics between the present sample and that in the earlier study. Unlike the Continuing Survey of Food Intakes by Individuals dataset, our sample was composed mainly of white, affluent, and highly educated individuals who are more likely to consume diets of low energy density (6). More research on larger and more diverse populations will be needed to establish whether the trade-offs between cost and quality of the diet revealed our sample also exist in men and in lower-SES groups.

CONCLUSIONS

The finding that higher-quality diets were consumed by women of higher SES and are more costly per 2,000 kcal has implications for epidemiologic studies of diet and chronic disease. Nutritional epidemiology has historically been based on the premise that nutrient exposures are directly linked to health outcomes. However, nutritional status is also intimately linked to SES (52) and the findings reported here raise the possibility that the higher monetary cost of nutritious diets may provide one explanation for these observations. Future studies, based on more representative samples, will be needed to elucidate the connections between diet quality and diet cost across socioeconomic strata. A new and important opportunity for such analyses has been recently made possible with the creation of food prices corresponding to the dietary intake data from National Health and Nutrition Examination Survey (53).

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