Dietary Quality Predicts Adult Weight Gain: Findings from the Framingham Offspring Study

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Abstract

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Objective: We tested the hypothesis that dietary quality, measured by adherence to the *Dietary Guidelines*, was related to weight change in adults.

Research Methods and Procedures: Dietary intake was assessed among 2245 adult men and women (average age, 49 to 56 years) in the Framingham Offspring cohort. Three-day dietary records were collected in 1984 to 1988 and again in 1991 to 1996. Weight change was measured over 8 years after each assessment. A five-point diet quality index (DQI) was computed based on mean nutrient intake levels from each set of diet records. One DQI point was contributed for each of five nutrients if intake met *Dietary Guidelines* for total and saturated fat, cholesterol, sodium, and carbohydrate. Gender-specific generalized estimating equations pooled data across the two assessments to relate DQI to 8-year weight gain.

Results: Men and women with higher DQI scores gained less weight during follow-up ($p < 0.05$). Average gain over 8 years was ~3 pounds among those with highest scores, compared with 5 to 8 pounds among those with lower scores. Smoking cessation was an important predictor of weight gain, accounting for about a 5- to 9-pound difference in weight gain.

Discussion: A high-quality diet, one that is consistent with the *Dietary Guidelines*, may help curb rising rates of obesity at the population level. Poor compliance with the *Guidelines*, rather than the guidelines themselves, is likely responsible for the weight gain observed in the American population. Adoption of an eating pattern consistent with the *Dietary Guidelines* should facilitate population weight control if sustained long term.

Key words: diet quality index, dietary guidelines, weight change, adherence, compliance

Introduction

Overweight is a major public health concern in the United States that has reached epidemic proportions (1). With the dramatic increase in the prevalence of overweight and obesity among U.S. adults during the past 2 decades (1,2), currently two-thirds of all U.S. adults are overweight, and 31% are obese (3). Most recently, it was reported that nine of every 10 men and seven of every 10 women will become clinically overweight in their lifetimes (4). Overweight and obesity are associated with a significant burden of comorbidity from cardiovascular disease, hypertension, diabetes, gallbladder disease, cancer, arthritis, and pulmonary dysfunction (5). Thus, obesity is considered one of the leading causes of preventable death in the U.S. (6). Population health promotion hinges on successful weight management and obesity prevention strategies.

Diet is one of many factors that contribute to obesity. Epidemiological evidence that specific aspects of diet promote the development of obesity is suggestive (7–9), but findings are variable, and studies are criticized for being highly confounded. Substantial controversy surrounds the role of dietary fat (9,10) and carbohydrate (11) in the etiology of obesity. Before the release of the *2005 U.S.*

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Dietary Guidelines (12), critics (13,14) questioned whether the dietary pattern advocated by the former *Guidelines* (15,16) was desirable for promoting healthy weight. It was argued that the mere promotion of the *Guidelines* without the widespread appreciation of nuances related specifically to the quality and type of fat and carbohydrate in the diet contributed to the dramatic weight gain experienced by the U.S. population (13,14).

The complexity of the relationship between diet and obesity has prompted the application of novel research strategies (8,9). Emerging nutrition research methods now provide a more comprehensive measure of overall dietary quality and may make a valuable contribution to the study of obesity. This prospective study assessed the relationship between 8-year weight change among Framingham Study participants and adherence to the fourth edition of the *Dietary Guidelines* (17) measured using a published five-point diet quality index (DQI)[1] (18).

Research Methods and Procedures

The Framingham Study

The Framingham Study is a longitudinal population-based observational study that began in 1948 in Framingham, MA. In 1971, a second-generation cohort was recruited into the Framingham Offspring/Spouse (FOS) study ($n = 5124$) (19). The FOS cohort is the subject of these analyses. Cohort members are examined in the clinic every 4 years, on average, where they undergo a standardized protocol for data collection approved by the Boston University Institutional Review Board. Dietary information was ascertained at Exam 3 (1984 to 1988) and again at Exam 5 (1991 to 1996). Exam 3 included 3873 people, approximately two-thirds of whom contributed dietary data. A comparable proportion of participants provided dietary records at Exam 5. Follow-up was assessed over two 8-year intervals out to Exam 7 (1998 to 2001), for a total of 16 years.

Diet Assessment

Dietary intake was assessed using a standardized protocol and 3-day dietary records (20). Participants were instructed by a nutritionist to keep a record of food intake over 2 weekdays and 1 weekend day while maintaining their usual diet. Portion sizes were estimated using a validated food portion visual (21). Nutrient calculations were performed using the Minnesota Nutrition Data System software (NDS version 2.6) (22). Three-day mean estimates of energy and nutrient intake were determined for each individual at each exam. Alcohol intake was measured in grams and converted to drinks.

[1] Nonstandard abbreviations: DQI, diet quality index; FOS, Framingham Offspring/Spouse; PAI, physical activity index; GEE, generalized estimating equation.

Anthropometry

Body weight was measured in the clinic using a calibrated spring balance scale, with participants wearing hospital gowns. Standing height was measured using a stationary anthropometer. BMI was calculated as weight (kilograms)/height (meters) squared. Weight change was computed over two 8-year intervals as Exam 5 weight − Exam 3 weight and as Exam 7 weight − Exam 5 weight.

Covariables

Physical activity was measured using a standardized questionnaire to determine estimates of activity based on a 24-hour history. A physical activity index (PAI) was calculated from the number of hours spent doing specific activities that were categorized and weighted according to oxygen consumption required to perform them (23). PAI scores can range from 24 (total bed rest) to 120 (heavy physical activity all day). Because physical activity was not measured at Exam 3, Exam 2 values were substituted in these analyses, adhering to the analytic approach routinely used in Framingham. Smoking behavior and menopausal status were self-reported at each clinic visit. A self-reported behavioral variable that measured intentional changes in eating habits "to be healthier" was used as a measure of dietary restraint.

Study Sample

The sample included 990 men and 1255 women who contributed data over one or two 8-year follow-up intervals, yielding 1847 female observations and 1433 male observations. Risk factor profiles of those who were included in the study were not different from profiles of the overall cohort ($p > 0.2$). Thus, the individuals included were considered representative of all FOS participants. Some 120 individuals were excluded because they either had or developed cancer. (All individuals with cancer were excluded except for those with non-malignant skin cancer.)

Statistical Analyses

A five-point DQI score (18) was computed at Exam 3 and again at Exam 5 to evaluate adherence to nutrient recommendations outlined in the fourth edition of the *U.S. Dietary Guidelines* (17). This edition of the *Guidelines* was the first to specify the nutrient targets represented by the DQI score. However, nutrition education messages promoting food intake patterns consistent with these nutrient targets were highly consistent across earlier versions of the *Guidelines* that were available to the population as early as 1980 and throughout the data collection period in Framingham. One DQI point was contributed for each of five nutrients if mean intake levels met established *Guidelines* [total fat (<30% kcal),

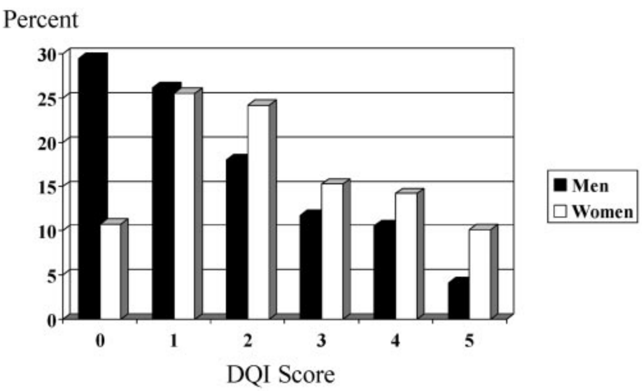

Figure 1: Distribution of DQI scores.

saturated fat (<10% kcal), cholesterol (<300 mg/d), sodium (<2400 mg/d), and carbohydrate (>50% kcal)]. DQI scores ranged from 0 to 5, in increments of 1 unit, with a higher score indicating a higher quality diet with greater adherence to the *Guidelines*.

Weight change over 8 years of follow-up was the main outcome variable. Gender-specific, multivariable generalized estimating equations (GEEs; proc genmod in SAS) (24) modeled the weight change experience between Exams 3 and 5 and between Exams 5 and 7 using updated dietary and covariate information in each set of analyses. Because GEE allows for multiple measurements on each individual and uses all available information at a given exam, data were pooled across the two time intervals to test whether DQI scores would predict weight change over 8 years. Analytical models controlled for age, BMI, smoking cessation, alcohol intake, physical activity, intentional changes in eating behavior, and menopausal status (women only). The DQI partially controls for energy intake given that three of the five DQI components are nutrient densities, yet we included energy intake in our models to fully adjust for its effect. Secondary analyses evaluated four separate gender-specific models evaluating 8-year weight change without pooling, weight change over 16 years of continuous follow-up, and the impact of adding other nutrients, including calcium and fiber, to the DQI score.

Results

Baseline Characteristics of the Sample

Dietary quality was relatively low in the cohort, and the distribution of DQI scores differed by gender (Figure 1). Women were more likely to achieve higher dietary quality than were men. The majority of men (56%) scored 0 or 1, whereas one-half of all women scored either 1 or 2. Only 15% of men and 24% of women achieved a DQI score of 4 or higher.

Characteristics of study participants are displayed in Tables 1 and 2 according to DQI score, with significant trends noted for most characteristics in both genders. These data demonstrate the utility of the DQI as a measure of dietary exposure. As expected, men who achieved higher DQI scores consumed less total and saturated fat, less cholesterol, less sodium, and more carbohydrate. They also ate fewer total calories yet increased the fiber density of their diets. Protein intake was relatively stable across DQI groups. Men who achieved higher dietary quality tended to be older and to weigh slightly less. They were also more likely to report that they had changed their eating habits in pursuit of health benefits. BMI, education, and physical activity measures were fairly consistent across DQI subgroups. Patterns relating DQI score to overweight/obesity status and smoking behavior were not consistently observed. Overweight and obesity were prevalent in all subgroups, together affecting roughly 70% of all men.

Among women, nutrient profiles across DQI subgroups were similar to the men's data. Higher DQI scores were characterized by reduced intake of energy, fats, cholesterol, and sodium, along with higher intakes of carbohydrate and higher fiber density. Women who achieved higher dietary quality tended to be older than their counterparts whose diets were more divergent from the *Guidelines*. As a result, proportionately more women in the higher DQI categories were postmenopausal. The prevalence of overweight was notably lower among women (<50% on average) than among men. Women with better dietary quality were more likely to report health consciousness that contributed to intentional changes in their diets.

Longitudinal Analyses

On average, men and women gained weight across all DQI categories. Women gained more weight over time than men did, with average gains of 5.2 (±14.0) and 4.3 (±13.0) pounds, respectively. Individuals who achieved higher quality diets gained less weight over 8 years than individuals with poorer quality diets (Figure 2; p for trend < 0.01 in both genders). Women with the highest DQI score gained 3.3 (±17.4) pounds on average, compared with 8.0 (±13.0) pounds gained by women with the lowest DQI score. Men with the highest DQI score gained 2.7 (±10.1) pounds, whereas men with the lowest dietary quality gained 5.1 (±13.3) pounds.

In multivariate GEE models, dietary quality displayed a significant inverse relationship with weight change in both men and women (Table 3). Higher DQI was associated with less weight gain over time (regression coefficient for a 1-unit difference in DQI score, $\beta = -0.48$ for men and -0.60 for women; $p < 0.05$). In both genders, smoking cessation was an important predictor of weight gain ($\beta =$ 5.13 for men and 8.78 for women; $p < 0.01$). Subjective reports of intentional changes in diet seemed to be related to weight gain, particularly among men (regression coefficient $\beta = 2.20$; $p < 0.01$). This behavioral variable contributed

Table 1. Characteristics of FOS men by DQI score (mean ± standard deviation)*

Characteristic	0 (n = 422)	1 (n = 375)	2 (n = 258)	3 (n = 168)	4 (n = 151)	5 (n = 59)	p for Trend
Age	49.3 ± 9.5	51.7 ± 10.2	51.2 ± 9.4	53.5 ± 9.2	55.3 ± 9.0	56.1 ± 9.9	<0.0001
Weight (pounds)	184.9 ± 26.2	181.5 ± 26.1	184.2 ± 28.3	184.1 ± 24.0	178.4 ± 23.4	175.7 ± 21.8	0.0479
BMI (kg/m^2)	27.4 ± 3.7	27.3 ± 3.4	27.6 ± 3.9	27.5 ± 3.5	26.8 ± 3.4	26.9 ± 3.0	0.3993
Overweight† (%)	74.6	75.7	76.0	76.8	69.5	67.8	0.8421
Obese‡ (%)	18.7	20.8	23.3	20.2	15.9	15.3	0.7195
Education (years)	14.6 ± 3.1	14.6 ± 2.8	14.3 ± 3.0	14.9 ± 3.0	15.0 ± 2.7	14.9 ± 3.3	0.0903
PAI	35.8 ± 6.8	35.7 ± 6.3	36.1 ± 6.9	36.5 ± 7.1	35.6 ± 6.1	36.0 ± 6.1	0.5348
Smoker (%)	27.0	18.6	17.7	19.5	21.7	7.1	0.0009
Quit smoking (%)	9.2	5.9	5.0	7.1	8.0	5.1	0.3354
Intentionally changed diet§ (%)	53.3	57.1	66.7	73.8	80.8	86.4	<0.0001
Nutrient intake							
Energy (kcal)	2622 ± 639	2199 ± 541	2038 ± 630	2043 ± 602	2066 ± 541	1573 ± 466	<0.0001
Total fat (%)	39.7 ± 4.9	37.7 ± 5.0	34.0 ± 5.4	28.8 ± 3.9	25.0 ± 4.0	23.1 ± 3.7	<0.0001
Saturated fat (%)	14.4 ± 2.4	13.1 ± 2.3	11.1 ± 2.5	9.3 ± 1.9	7.9 ± 1.9	7.3 ± 1.6	<0.0001
Cholesterol (mg)	440 ± 119	278 ± 94	246 ± 92	229 ± 96	188 ± 59	152 ± 58	<0.0001
Sodium (mg)	4226 ± 1245	3592 ± 993	3115 ± 1104	3161 ± 1222	3154 ± 1030	1862 ± 427	<0.0001
Carbohydrate (%)	40.2 ± 5.8	42.7 ± 6.9	45.2 ± 7.7	50.0 ± 8.6	56.5 ± 7.7	59.5 ± 6.3	<0.0001
Protein (%)	16.7 ± 3.1	16.5 ± 3.4	16.6 ± 4.0	16.9 ± 4.4	16.9 ± 4.5	17.3 ± 4.3	0.5342
Fiber (g/1000 kcal)	6.7 ± 1.8	7.6 ± 2.2	8.3 ± 2.8	9.4 ± 3.3	10.8 ± 3.5	11.3 ± 3.6	<0.0001
Alcohol (g)	16.8 ± 21.6	13.9 ± 19.6	17.5 ± 25.1	18.1 ± 24.9	10.8 ± 16.2	6.4 ± 9.2	0.0054

FOS, Framingham Offspring/Spouse; DQI, diet quality index; PAI, physical activity index.
* Data represent pooled baseline estimates from each of two 8-year follow-up periods.
† Overweight defined as 25.0 ≤ BMI < 30.0.
‡ Obese defined as BMI ≥ 30.0.
§ Reported having intentionally changed eating habits "to be healthier."

less to weight gain among women and was of marginal statistical significance (regression coefficient $\beta = 1.16$; $p = 0.09$). In women, postmenopausal status was a significant predictor of weight gain (regression coefficient $\beta = 3.22$; $p < 0.001$) whereas physical activity was protective (regression coefficient for a 1-unit difference in PAI, $\beta = -0.147$; $p < 0.05$). Energy intake was included as a covariate but was not predictive of weight change beyond its association with the DQI score. Because DQI is a marker of energy intake, consideration of energy in the model did not contribute more to the variability in weight gain observed. We note that energy intake in the FOS population was highly variable. Finally, we tested for interactions of DQI score with all other covariates and found none.

Secondary analyses yielded results that were consistent with the primary analyses presented here. We arrived at the same conclusions about the importance of the DQI score and the covariates described above whether we examined weight change in each separate 8-year period (non-pooled data) or over the entire 16-year period extending from Exam 3 out to Exam 7. Finally, the addition of other nutrients implicated in weight control, such as fiber and calcium, to the DQI score did not alter or enhance our findings.

Discussion

Energy balance is crucial to efforts to control body weight. These data demonstrate that achieving a high-quality diet that is consistent with population-based dietary guidance appears similarly important for minimizing weight gain in the long run. Men and women whose diets were markedly divergent from the *Dietary Guidelines* were likely to gain substantially more weight as they aged compared with those who adopted the recommended lower fat, carbohydrate-rich dietary pattern. We note that, regardless of dietary adherence, all subgroups of men and women gained

Table 2. Characteristics of FOS women by DQI score (mean ± standard deviation)*

Characteristic	0 (n = 198)	1 (n = 472)	2 (n = 446)	3 (n = 282)	4 (n = 262)	5 (n = 187)	p for Trend
Age	48.9 ± 10.2	49.6 ± 10.1	51.7 ± 9.8	52.8 ± 9.9	54.1 ± 9.1	55.7 ± 9.2	<0.0001
Weight (pounds)	146.9 ± 33.2	145.0 ± 26.8	141.8 ± 24.9	141.6 ± 24.8	143.0 ± 25.8	142.1 ± 24.4	0.1417
BMI† (kg/m^2)	25.8 ± 5.8	25.5 ± 4.9	25.1 ± 4.5	25.4 ± 4.6	25.4 ± 4.6	25.7 ± 4.3	0.0042
Overweight‡ (%)	42.9	42.8	41.7	46.1	45.8	52.9	0.0009
Obese§ (%)	18.2	14.2	15.0	15.6	14.1	15.5	0.3598
Education (years)	13.9 ± 2.4	13.8 ± 2.2	13.6 ± 2.2	13.8 ± 2.3	14.0 ± 2.2	13.8 ± 2.2	0.5070
PAI	33.6 ± 4.4	33.4 ± 4.4	33.7 ± 4.5	34.0 ± 5.5	33.7 ± 5.1	33.4 ± 5.1	0.6608
Smoker (%)	25.9	26.6	24.6	22.1	17.7	20.9	0.0315
Quit smoking (%)	9.6	11.9	8.1	5.3	4.6	6.4	0.0009
Postmenopausal (%)	49.5	47.5	60.1	61.7	67.9	74.3	<0.0001
Intentionally changed diet¶ (%)	60.6	65.9	73.5	73.8	86.6	92.0	<0.0001
Nutrient intake							
Energy (kcal)	2143 ± 503	1758 ± 402	1482 ± 382	1511 ± 404	1531 ± 442	1335 ± 379	<0.0001
Total fat (%)	41.0 ± 5.0	38.9 ± 5.0	36.6 ± 5.2	31.5 ± 4.0	26.2 ± 4.7	23.1 ± 4.6	<0.0001
Saturated fat (%)	14.8 ± 2.5	13.5 ± 2.4	12.5 ± 2.6	10.4 ± 2.4	8.2 ± 1.9	7.0 ± 1.8	<0.0001
Cholesterol (mg)	412 ± 114	250 ± 85	192 ± 69	175 ± 69	154 ± 67	134 ± 58	<0.0001
Sodium (mg)	3517 ± 903	3026 ± 790	2304 ± 778	2255 ± 783	2454 ± 862	1732 ± 438	<0.0001
Carbohydrate (%)	40.3 ± 6.0	42.5 ± 6.2	44.6 ± 7.0	50.1 ± 6.4	55.3 ± 7.7	59.6 ± 5.9	<0.0001
Protein (%)	17.1 ± 3.2	17.1 ± 3.8	17.3 ± 3.9	17.0 ± 4.6	18.0 ± 4.8	18.3 ± 4.1	<0.0001
Fiber (g/1000 kcal)	7.0 ± 1.8	7.7 ± 2.3	8.4 ± 2.5	9.6 ± 3.0	11.4 ± 4.0	12.4 ± 4.1	<0.0001
Alcohol (g)	8.5 ± 12.4	7.4 ± 10.8	6.2 ± 10.4	7.5 ± 14.6	5.7 ± 10.1	3.2 ± 6.9	<0.0001

FOS, Framingham Offspring/Spouse; DQI, diet quality index; PAI, physical activity index; GEE, generalized estimating equation.
* Data represent pooled baseline estimates from each of two 8-year follow-up periods.
† Mean BMI values appear similar across DQI groups when baseline data are pooled, yet GEE analyses suggest a significant trend. This is due to the differential patterns of weight gain between Exams 3 and 5. Low DQI groups have lower weight at Exam 3 but gain the most weight by Exam 5; thus, after pooling, the means are similar.
‡ Overweight defined as 25.0 ≤ BMI < 30.0.
§ Obese defined as BMI ≥ 30.0.
¶ Reported having intentionally changed eating habits "to be healthier."

weight. Although dietary quality was shown to modify the amount of weight gain, other factors are clearly operating, including the fact that caloric intake increased over time in all subgroups.

Although weight change was highly variable across almost 2 decades in the Framingham Study, our data clearly show that men and women who were most successful at minimizing aging-related weight gain were those who ate a diet that was close to or consistent with U.S. nutrition policy guidelines. Thus, a high-quality diet that is low in total and saturated fat, low in cholesterol and sodium, and relatively higher in carbohydrate and fiber density can protect Americans from gaining excessive amounts of weight into the future.

DQI and the Dietary Guidelines

Indices of diet quality assess compliance with expert dietary guidance based on the role of nutrients in disease prevention (25). These have gained popularity in recent years as researchers have sought to examine dietary exposures in the context of overall eating patterns (25,26). Although several indices are available (27–30), we used the five-point DQI (18) to test our specific hypothesis. This index is simple to calculate and interpret and has been used previously to predict other health outcomes (25). As opposed to other indices that include assessments of food group intake including fruits and vegetables, the DQI was well suited to the nutrient data available from multiple-day

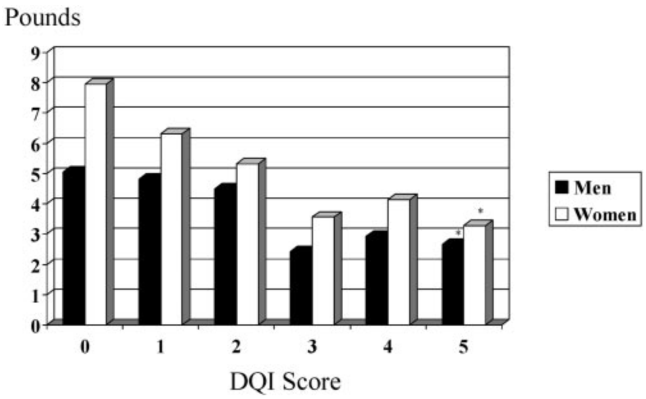

Figure 2: Eight-year weight gain by DQI score and gender. * *p* for trend in weight gain across DQI scores 0.0025 for men and <0.0001 for women.

dietary records in Framingham. Because the DQI is a marker for the quality of the overall dietary pattern, we did not attempt to tease out the individual contribution of component nutrients to weight gain.

The specific nutrients featured in the DQI and their recommended intake levels reflect the food-based *Dietary Guidelines for Americans* that were consistently promoted to the American population from 1980 on (31). The DQI's focus is on moderating consumption of dietary lipids, cholesterol, and sodium while encouraging proportionally more complex carbohydrate in the diet. These national health promotion guidelines were advocated by numerous expert groups over the years, including those striving for cardiovascular disease risk reduction (32,33). The graphic representation of the *Guidelines*, the *Food Guide Pyramid* (16), embodied these nutrient goals and provided specific food-based recommendations to encourage consumers to choose a diet that was varied, balanced, and moderate.

In recent years, the *Dietary Guidelines* and the *Food Guide Pyramid* were criticized (13,14), and alternative sets of nutritional guidelines were proposed (13). The *Pyramid*, which promoted a lower-fat eating plan built on a base of carbohydrate-rich foods, was blamed for causing unrestrained consumption of refined foods and sugars and for driving food cravings that lead to overeating. These consequences were suggested as the driving forces behind the national epidemics of obesity and diabetes (14). Yet, the counter-argument provided by Goldberg et al. (34) calls attention to the fact that the diets of most Americans fall far short of the guidelines illustrated by the *Pyramid*.

Arguments in favor of abandoning the *Pyramid* and adopting alternatives such as a Mediterranean-style diet are debatable because these alternatives are likely to even be

Table 3. Multivariate influence of lifestyle variables on 8-year weight gain

	Men (n = 1433)			Women (n = 1847)		
Variable*	**Parameter estimate†**	**SE**	***p***	**Parameter estimate**	**SE**	***p***
Age	−0.2873	0.0331	<0.0001	−0.4370	0.0499	<0.0001
BMI‡	0.1503	0.1143	0.1884	−0.1431	0.0953	0.1332
Physical activity	0.0189	0.0410	0.6455	−0.1474	0.0629	0.0191
Alcohol intake	−0.0080	0.0154	0.6021	−0.0864	0.0230	0.0002
Smoking cessation§	5.1314	1.7002	0.0025	8.7848	1.2426	<0.0001
Intentional change in diet¶	2.2021	0.6934	0.0015	1.1558	0.6812	0.0897
Postmenopausal				3.2215	0.9209	0.0005
Energy intake (kcal)	−0.0004	0.0006	0.4547	−0.0004	0.0008	0.5968
Average DQI score	−0.4775	0.2138	0.0255	−0.5961	0.2253	0.0081

SE, standard error; DQI, diet quality index.

* All variables are continuous with the exception of smoking cessation, intentional change in diet, and menopausal status, which are dichotomous categorical variables.

† Parameter estimates and tests of significance for a given predictor assume that all remaining predictor variables are already in the model. Parameter estimates are unstandardized. For continuous variables, the parameter estimate reflects the change in the outcome (weight) resulting from a 1-unit increase in the predictor variable. For discrete variables, the parameter estimate describes the difference in weight change between groups.

‡ BMI in kg/m^2.

§ Individuals who smoked at baseline and quit smoking during follow-up, compared with all others.

¶ Self-reported intentional change in eating habits "to be healthier."

more out of reach for millions of Americans, particularly those from lower socioeconomic strata (35). This comment is substantiated by our data, showing that the clear majority of Americans were struggling even to approximate a high-quality diet. Nonetheless, those adults who did embrace the *Dietary Guidelines* gained less weight as they aged. For those individuals, eating according to the *Guidelines* was linked with perceived health benefits, a predominant motivating theme driving weight control.

In contrast to the usual food intake patterns characterizing the U.S. population, the adoption of a higher-carbohydrate, lower-fat eating pattern consistent with the *Dietary Guidelines* has the ability to facilitate weight control in the population if desired eating behaviors are adopted and sustained over many years. Although we did not specifically test the effectiveness of a low-carbohydrate, higher-fat eating plan, our data do not suggest that approach as a successful strategy for long-term weight control or avoidance of obesity for the general population because those characteristics are consistent with a lower DQI score. Thus, although we remain uncertain as to the long-term benefits of other diet plans, we believe that the *Dietary Guidelines* are defendable as a strategy for population-based health promotion and weight control.

Gender-Specific Findings

Consistent with prior observations in Framingham (36), women achieved higher dietary quality than men. We note that it is particularly challenging for men to meet all DQI cut-off points because two of the five nutrient goals are based on absolute intake levels. Thus, the cholesterol and sodium guidelines may be harder for men to achieve simply because they consume more total calories. Closer inspection of our data suggests, however, that the most readily adopted guideline was lowering dietary cholesterol intake. Among those men and women who met only one of the five DQI goals, 71% of men and 78% of women met the dietary cholesterol guideline (data not shown). In contrast, only ~2% to 4% of men and women in this category met the total fat or saturated fat guidelines. At the opposite end of the spectrum, among those earning a DQI score of 4, the guideline that most frequently eluded participants was for lowering sodium intake.

Despite this apparent gender difference in diet quality, women tend to gain more weight over time than men do. This observation reflects the important influence of other contributors to energy balance and weight management that are gender-specific, including menopausal status. The average age of our sample suggests that many women may be going through the menopause during follow-up, offering a likely explanation for the observed gender difference in weight gain.

Compared with overweight men, overweight women in our sample seemed more likely to adopt healthier eating patterns as a strategy to manage their weight. Older adults in general, and postmenopausal women in particular, seem to be embracing diet-related health promotion messages more fully because they seem more willing and able to adopt the *Dietary Guidelines* than younger adults. Thus, dietary quality appears particularly important to emphasize with older women as they face the weight control challenges that often coincide with menopause.

Men who self-reported that they were changing their diets for health conscious reasons seemed more likely to gain weight than those who did not report a similar level of dietary restraint. We noted, however, that the majority of men for whom this behavioral variable was highly significant were still in the lowest DQI categories (scores of 0 to 2). For these men, their self-perceived level of dietary change was somewhat distorted because it was not consistent with a high-quality diet. This observation is consistent with our finding that many men have adopted the “low cholesterol” message without necessarily lowering their caloric or fat intake. Thus, although we were able to control for potential confounding due to health consciousness in our analyses, it was our objective measure of dietary quality, the DQI, which predicted weight gain, not the individual’s impression of attempted behavior change. Additional research is needed to understand whether perceptions of healthy eating were also driven by the adoption of fad diets that, in the long run, contributed to weight gain. Nonetheless, nutrition education campaigns and macro-level interventions are needed to support the messages embodied by the *Dietary Guidelines*. By providing a clear and consistent understanding of what constitutes healthy eating, the widespread adoption of the *Guidelines* may be achievable at the population level.

Smoking cessation was a salient predictor of weight gain in both genders. All other features being equal, smokers who quit were destined to gain ~5 to 9 pounds more, on average, for men and women, respectively, than their counterparts who continued to smoke or never smoked. Thus, smoking cessation had triple the impact on weight gain that would be expected comparing a woman who achieved the lowest DQI score to one who scored the highest, that difference being ~3 pounds. Comprehensive behavioral interventions that address multiple risk behaviors in a coordinated fashion may be most successful at achieving both obesity risk reduction and overall population health promotion. We note that even with the impact of smoking cessation taken into account in the model, dietary quality was still predictive of weight gain.

DQI and Health Outcomes

The use of a DQI in the setting of obesity research is relatively novel. Kant (25) recently reviewed the literature on epidemiological studies relating diet quality scores to health outcomes. Among 26 published papers, more than one-half were prospective, and the most common health outcomes examined were mortality, cardiovascular disease risk, and cancer incidence. Most studies reported an inverse association between healthier diets and these outcomes, but the magnitude of risk reduction was modest and was attenuated with control for confounding. To date, no studies, to our knowledge, have examined the relationship of dietary quality with weight gain, changes in BMI, or the development of obesity.

The association between BMI and diet quality has been explored in cross-sectional studies, yet the cross-sectional data do not provide consistent evidence of an association (37). Thus, prospective studies of weight change and better control for confounding are needed. A different analytical approach that uses empirically derived eating patterns based on factor or cluster analysis has provided some new insight into diet-obesity relationships (38,39), yet prospective studies using this approach are few, and findings are inconsistent.

Strengths and Limitations

The strength of these observations lies in the 16 years of accumulated follow-up and the repeated measures of diet and lifestyle behaviors that were pooled to examine dietary quality in relation to 8-year weight change in Framingham Study participants. We adjusted for health consciousness by incorporating a measure of intentional dieting into our models. Furthermore, we used direct measures of weight obtained by standardized protocols, as opposed to self-reported changes in weight. Long-term, population-based follow-up data measuring differences in dietary quality provide a unique contribution to our understanding of diet's relationship to weight control in light of the important, but limited, data from weight loss intervention trials that are plagued by small sample sizes, high drop-out rates, and follow-up that rarely exceeds 1 year (40–43).

Finally, we acknowledge the limitation of using food records to estimate nutrient intake, given that they tend to underestimate intake by ~20% (44). In that case, our estimates of diet quality likely underestimate the impact of adherence on weight change. Nonetheless, our data suggest that the five-point DQI is a good predictive measure that discriminates dietary quality in the population. Although the DQI does not include a specific measure of fruit and vegetable intake, higher scores reflecting higher-carbohydrate, lower-fat nutrient profiles are likely markers of a more plant-based diet pattern. Additional research exploring weight gain associated with diet quality indices in other populations is warranted.

Conclusions

It is imperative that researchers and health professionals work together to identify and implement creative strategies that will help more Americans integrate the *Dietary Guidelines* into their everyday lives. Understanding the specific messages underlying the recommended sources of macronutrients is essential to help guide daily food choices. Health promotion strategies that combine a lower-fat diet rich in nutritious whole grains and carbohydrates derived from fruits, vegetables, and legumes with other healthy lifestyle behaviors, including regular physical activity and sensible approaches to smoking cessation, must be advocated to the public in a consistent manner in an effort to curtail rising rates of obesity and comorbidity as the population ages. Yet, strategies to facilitate the adoption and maintenance of healthy eating behaviors require interventions that target much more than individual behavior change. Environmental and policy changes are essential. In all regards, the newly released *2005 Dietary Guidelines* stand to contribute positively to population health promotion.

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