Continuing Education Questionnaire, page 1361

Dietary patterns predict the development of overweight in women: The Framingham Nutrition Studies

PAULA A. QUATROMONI, DSc, RD; DONNA L. COPENHAFER, PhD; RALPH B. D'AGOSTINO, PhD; BARBARA E. MILLEN, DrPH, RD, FADA

ABSTRACT

Objective To investigate relationships between dietary patterns and the development of overweight.
Design Longitudinal analyses during 12 years of follow-up involved the identification of dietary patterns at baseline using cluster analysis applied to a 145-item semiquantitative food frequency questionnaire.
Subjects/setting 737 non-overweight women in the Framingham Offspring/Spouse cohort (mean age, 45 years).
Main Outcome Measure Development of overweight (BMI≥25) at follow-up.
Statistical Analyses Relative risks were calculated using Proc Genmod and multivariate models comprehensively considered potential confounders.
Results Five dietary patterns were identified among the cohort at baseline: Heart Healthy, Light Eating, Wine and Moderate Eating, High Fat, and Empty Calorie. Over 12 years, the crude risk of becoming overweight was 29% overall, ranging from 22% of women in the Wine and Moderate Eating cluster to 41% of women in the Empty Calorie cluster. Compared with women who ate a lower-fat, nutritionally varied Heart Healthy diet, women who ate an Empty Calorie diet that was rich in sweets and fats with fewer servings of nutrient-dense fruits, vegetables, and lean food choices were at higher risk for developing overweight [RR 1.4, 95% CI (0.9, 2.2)] after adjusting for age, smoking status, physical activity, menopausal status, energy intake, intentional dieting, and usual weight pattern. Women who ate an Empty Calorie dietary pattern were also younger and were more likely to smoke.
Conclusions Behavioral interventions for weight management and obesity prevention may be enhanced by creatively targeting differences in eating patterns, dietary quality, and other lifestyle behaviors of distinct subgroups of the population. *J Am Diet Assoc. 2002;102:1240-1246.*

Overweight is a major public health problem in the United States that has reached epidemic proportions (1-5). The prevalence of overweight and obesity among US adults has increased dramatically during the past two decades (1,6), and currently more than half of all US adults are overweight (7) and 22% are obese (8). Overweight and obesity are associated with numerous adverse health outcomes, including cardiovascular disease, hypertension, diabetes, gallbladder disease, cancer, arthritis, and pulmonary dysfunction (4,7,9,10). Obesity has been labeled "an under-recognized contributor" to high blood cholesterol levels and heart disease risk (11) and is considered one of the leading causes of preventable death in the United States (12,13).

Recommendations for the prevention and management of a number of chronic health conditions specifically recommend weight loss as the cornerstone of therapy (12,14,15). Yet, successful interventions to prevent or reduce the prevalence of overweight and obesity are lacking. Although federal health authorities have targeted a reduction in the prevalence of overweight as a national health objective (16), means to achieve this goal have not become a significant public health priority (1).

Epidemiological evidence linking diet with the development of obesity is suggestive (17-19), but findings are variable and studies seem confounded. Two important reviews underscored the need for innovative approaches for studying the complex relationship between diet and body fatness (18,19). In general, current epidemiological methods are considered inadequate for validly assessing the relationship between dietary fat and obesity (18). Lack of attention to important confounders, including other components of diet (fiber and alcohol intakes, for example) and behavioral variables such as physical activity and intentional dieting, are limitations of earlier research (19).

This prospective study used an innovative analytical strategy to explore the relationship between the total diet and the

P. A. Quatromoni is an assistant professor and B. E. Millen is a professor and director of The Framingham Nutrition Studies, Department of Social and Behavioral Sciences, Boston University School of Public Health, Boston, Mass. D. L. Copenhafer is a research associate and R. B. D'Agostino is a professor, Department of Mathematics and Statistics, Boston University, Boston, Mass.

Address correspondence to Paula A. Quatromoni, DSc, RD, Department of Social and Behavioral Sciences, Boston University School of Public Health, 715 Albany St, Boston, MA 02118.

Table 1
Baseline prevalence of overweight and obesity among all women eligible for inclusion in the study base[a] (N=1,510)

	BMI[b]	Heart Healthy (n=304)	Light Eating (n=722)	Wine and Moderate Eating (n=53)	High Fat (n=303)	Empty Calorie (n=128)
		%				
Normal weight	<24	44.7	48.5	50.9	56.1	42.2
	24.0-24.9	8.9	11.9	11.3	7.6	6.3
Overweight	25-29.9	32.2	25.4	13.2	24.8	28.9
Obese	≥30	14.1	14.3	24.5	11.6	22.7

[a]Eligibility required complete FFQ data enabling participation in cluster analysis and complete data for calculating BMI at baseline (Exam 3) and follow-up (Exam 6).
[b]BMI=Body Mass Index, defined as weight (kg)/height (m^2).

Table 2
Baseline age-adjusted daily consumption of food groupings, by cluster

Food Groupings	Heart Healthy (n=136)	Light Eating (n=350)	Wine and Moderate Eating (n=27)	High Fat (n=170)	Empty Calorie (n=54)
	least square mean[a] (95% CI)				
Vegetables	3.73 (3.49, 3.96)	2.54 (2.40, 2.69)*	2.65 (2.12, 3.18)*	2.65 (2.44, 2.86)*	2.49 (2.11, 2.86)*
Fruits and low-fat milk	4.44 (4.17, 4.71)	2.37 (2.20, 2.54)*	2.57 (1.97, 3.18)*	2.36 (2.12, 2.60)*	2.35 (1.92, 2.78)*
Other low-fat foods	4.88 (4.55, 5.21)	2.54 (2.34, 2.75)*	2.38 (1.64, 3.12)*	2.23 (1.93, 2.52)*	2.32 (1.79, 2.85)*
Legumes, soups and miscellaneous foods	0.36 (0.32, 0.39)	0.21 (0.18, 0.23)*	0.23 (0.15, 0.31)*	0.17 (0.14, 0.20)*	0.23 (0.17, 0.28)*
Refined grains, soft margarine, and oils	3.43 (3.14, 3.73)	2.61 (2.43, 2.79)*	2.62 (1.97, 3.28)*	3.55 (3.28, 3.81)	3.25 (2.79, 3.72)
Diet beverages and firm vegetable fats	2.22 (1.89, 2.55)	3.22 (3.01, 3.42)*	3.08 (2.36, 3.81)*	4.19 (3.90, 4.48)*	3.67 (3.15, 4.19)*
Sweets and animal fats	1.38 (1.11, 1.65)	1.18 (1.01, 1.35)	2.46 (1.86, 3.06)*	4.82 (4.58, 5.06)*	3.25 (2.82, 3.68)*
Desserts	0.92 (0.75, 1.10)	1.10 (0.99, 1.21)	0.63 (0.25, 1.02)	1.30 (1.14, 1.45)*	1.44 (1.16, 1.71)*
Sweetened beverages	0.33 (0.25, 0.41)	0.26 (0.21, 0.31)	0.26 (0.08, 0.44)	0.31 (0.24, 0.38)	2.56 (2.43, 2.69)*
Wine and cholesterol-rich foods	0.46 (0.39, 0.53)	0.51 (0.46, 0.55)	2.72 (2.57, 2.86)*	0.38 (0.33, 0.44)	0.39 (0.28, 0.50)
High-fat dairy and snack foods	0.74 (0.64, 0.84)	0.82 (0.76, 0.88)	0.94 (0.72, 1.17)	0.72 (0.63, 0.81)	0.84 (0.68, 1.00)
Meats and mixed dishes	0.69 (0.62, 0.77)	0.69 (0.64, 0.73)	0.82 (0.66, 0.99)	0.85 (0.79, 0.92)*	0.94 (0.68, 1.06)*
Fattier poultry and beer	0.14 (0.09, 0.20)	0.24 (0.21, 0.27)*	0.18 (0.06, 0.31)	0.15 (0.10, 0.20)	0.16 (0.07, 0.25)

[a]Least square mean number of servings/d.
*Mean is significantly different ($P<.05$) from the mean in the Heart Healthy cluster.

development of overweight among women. Cluster analysis was used to characterize dietary exposure in terms of overall dietary patterns, and potential sources of confounding were carefully examined.

METHODS

This study explored relationships between dietary patterns and the development of overweight [defined as Body Mass Index (BMI)≥25] among female participants in the Framingham Offspring/Spouse study (FOS). FOS Exam 3 (1984-1988) served as baseline with follow-up assessed over 12 years to Exam 6 (1996-1999). At baseline, participants were grouped into one of five clusters based on food intake patterns identified from individual responses to a food frequency questionnaire. Women who were not overweight (BMI<24) at baseline comprised the cohort of interest for these analyses. Twelve-year risks of becoming overweight were compared across the five dietary clusters of women.

The Framingham Study

The Framingham Study was initiated in 1948 as a longitudinal population-based study of cardiovascular disease. The original Framingham cohort consisted of 5,209 men and women who represented a two-thirds random sample of the residents of the town of Framingham, Mass. In 1971, 5,124 Framingham Study offspring and their spouses were recruited to participate in the Framingham Offspring/Spouse (FOS) study (20).

Members of the FOS cohort are examined every 4 years, on average. At each exam, they undergo a standardized protocol involving a complete physical, laboratory tests, noninvasive diagnostic testing, and updating of medical histories and other pertinent information. Extensive dietary information was collected from participants at Exam 3. At that time, there were 2,537 females survivors (age range 30 to 89 years) who were eligible to participate in the exam; 1,956 women participated (83% of eligible women). Of those examined 93% (n=1,828) contributed baseline dietary data for these analyses.

Instruments

The self-administered Framingham food frequency questionnaire (FFQ) is a modified version of the original Willett questionnaire (21). This instrument was validated in the Framingham Offspring cohort (22). It contains 145 individual food items or food groupings with 7 nonoverlapping response categories, ranging from "rarely or never use" to use "4 or more times each day." Respondents report how often, on average, they consumed a standard portion of each item or grouping during the past year. Reported frequencies were used to estimate the number of usual daily servings of each item.

Cluster Analysis

Analytical details of the cluster technique and its validation were previously published (23-25). We identified 5 clusters of women in this cohort and have shown that they differ from one another with respect to overall patterns of food consumption, levels of nutrient intake, and consistency with national nutrition policy guidelines for a healthful diet (23,24). Because the dietary quality of the food choices that define the dietary patterns spans a spectrum of desirability, names were assigned to the clusters to label them with respect to dietary quality. In this cohort, we characterized the following dietary patterns: Heart Healthy, Light Eating, Wine and Moderate Eating, High Fat, and Empty Calorie.

To briefly summarize our methods, 145 FFQ food item listings were first classified into 42 nutrient-based food categories. Food items in a particular category contained similar levels of macronutrients and key micronutrients. An estimate of the usual number of daily servings for each of the 42 food categories was derived for each woman by summing across the category's component items, weighted by the individual frequency responses.

We used two methods to identify dietary patterns. First, VARCLUS (26) identified and grouped the 42 food categories that women consumed with a similar level of frequency. This SAS procedure is similar to a factor analysis, with the added requirement that food categories are separated into nonoverlapping groups. The VARCLUS technique does not require that foods be eaten at the same time of day, at the same meal, or in similar quantities. Thus, foods that appear in the same cluster were consumed with a similar daily frequency (ie, relatively frequent consumption vs relatively infrequent consumption). For example, women who reported relatively higher daily intakes of fish also reported relatively higher daily intakes of other lower-fat foods including skinless poultry, whole grains, and low-fat dairy foods. Using this method, 13 food groupings were identified, each containing multiple food categories.

In the second step, Ward's clustering method (27) was used to separate women into nonoverlapping groups based on similarities in their frequency of consumption of the 13 food groupings. This method considered how women differed in their consumption of the food groupings using the pseudo-t^2 statistic, a criterion for identifying the optimal number of clusters of women with distinctive food consumption patterns. Five clusters of women were identified through this process.

Body Weight

BMI was calculated as weight(kg)/height(m^2). Body weight was measured in the clinic using a calibrated spring balance scale with participants wearing lightweight hospital gowns. Standing height was measured using a stationary anthropometer. Participants stood erect with their head positioned in the Frankfurt plane.

Among the cohort of 1,828 women who participated in the cluster analysis at baseline, a subset of 1,510 women had complete BMI data at follow-up and were eligible for inclusion in this longitudinal study. Risk factor profiles of the 1,510 women who were included in the study were not different from profiles of the overall cohort of 1,828 women (P>.2 for age, physical activity, current dieting, intentional change in eating habits, usual weight pattern, and smoking status within each cluster). Thus, the women included in this study were considered representative of all women who were clustered.

From the study base of 1,510 women, 634 were excluded because they were overweight (BMI ≥25) at baseline (Table 1). We also excluded 139 women in the BMI range between 24.0 and 24.9 to reduce the influence of baseline BMI on the outcome of interest. Thus, the study cohort contained 737 women (BMI<24), representing 49% of the study base.

Covariables

FOS dietary data sets also include information on energy and nutrient intake, including alcohol consumption, derived separately from a 24-hour dietary recall for estimating group means (22). In addition, the Framingham Food Habit Questionnaire (FHQ) provides self-reported information on dietary behav-

Table 3
Baseline age-adjusted nutrient intake profiles, by cluster[a]

Nutrient	Heart Healthy (n=136)	Light Eating (n=350)	Wine and Moderate Eating (n=27)	High Fat (n=170)	Empty Calorie (n=54)
	← least square mean (95% CI) →				
Energy (kcal)	1,665 (1,548; 1,783)	1,530 (1,457; 1,603)	1,667 (1,404; 1,930)	1,691 (1,586; 1,796)	1,728 (1,541; 1,916)
Protein (%)	17.5 (16.6, 18.5)	17.3 (16.7, 18.0)	16.2 (14.0, 18.4)	15.6 (14.7, 16.5)*	15.4 (13.8, 17.0)*
Carbohydrate (%)	45.1 (43.2, 47.1)	42.3 (41.1, 43.5)*	38.5 (34.2, 42.9)*	42.0 (40.2, 43.7)*	45.7 (42.6, 48.8)
Total Fat (%)	36.7 (35.0, 38.4)	38.6 (37.5, 39.7)	38.6 (34.7, 42.4)	41.7 (40.2, 43.3)*	37.7 (35.0, 40.5)
Saturated Fat (%)	11.8 (10.9, 12.6)	13.1 (12.5, 13.6)*	13.8 (11.9, 15.7)	15.5 (14.7, 16.3)*	13.4 (12.1, 14.8)*
Alcohol (%)	2.1 (1.2, 2.9)	3.0 (2.4, 3.5)	8.0 (6.1, 9.9)*	1.8 (1.0, 2.5)	2.4 (1.1, 3.8)
Fiber (g)	12.2 (11.1, 13.4)	9.6 (8.9, 10.3)*	10.0 (7.4, 12.6)	9.1 (8.0, 10.1)*	8.5 (6.7, 10.4)*
Cholesterol (mg)	240.5 (206.3, 274.5)	235.5 (214.3, 256.7)	306.7 (230.3, 383.1)	282.2 (251.8, 312.7)	280.7 (226.2, 335.1)
Sodium (mg)	2,367 (2,155; 2,580)	2,190 (2,058; 2,321)	1,934 (1,461; 2,407)	2,294 (2,105; 2,483)	2,063 (1,726; 2,400)
Vitamin C (mg)	125.1 (115.5, 134.7)	103.6 (97.6, 109.5)*	108.5 (87.1, 129.9)	107.5 (98.9, 116.0)*	118.6 (103.3, 133.8)
Folate (μg)	225.4 (200.4, 250.5)	191.1 (175.7, 206.7)*	219.9 (164.1, 275.8)	172.9 (150.6, 195.1)*	176.1 (136.4, 215.9)*
Calcium (mg)	744.3 (666.9, 821.8)	645.0 (597.1, 693.0)*	625.9 (453.3, 798.6)	731.7 (662.8, 800.5)	651.9 (528.8, 775.0)

[a]Group mean nutrient intake levels estimated from 24-hour dietary recalls (ref 28).
*Mean is significantly different ($P<.05$) from the mean in the Heart Healthy cluster.

Table 4
Age and age-adjusted profiles of interpersonal and behavioral characteristics at baseline, by cluster

Risk Factor	Heart Healthy (n=136)	Light Eating (n=350)	Wine and Moderate Eating (n=27)	High Fat (n=170)	Empty Calorie (n=54)
	← least square mean (95% CI) →				
Age (y)	48.3 (46.6, 50.1)	45.7 (44.7, 46.6)*	46.4 (43.0, 49.9)	45.4 (43.9, 46.9)*	41.4 (39.1, 43.7)*
BMI	21.6 (21.3, 21.8)	21.7 (21.6, 21.9)	21.5 (21.0, 22.1)	21.3 (21.1, 21.6)	21.4 (21.0, 21.8)
Physical Activity Index[a]	34.9 (34.1, 35.7)	33.8 (33.3, 34.3)*	34.0 (32.1, 35.9)	33.6 (32.9, 34.4)*	33.5 (32.2, 34.8)
	← % →				
Current dieter[b]	11.3	7.1	2.7	5.7*	8.3
Changed eating habits[c]	77.7	63.3*	63.3	50.0*	39.8*
Fluctuating weight[d]	9.3	12.7	6.5	8.2	10.1
Current smoker	15.1	26.4*	25.1	42.1*	46.4*
Postmenopausal	40.9	42.2	42.8	39.6	43.2

[a]Physical Activity Index (PAI) measured at Exam 2. PAI scores ranged from 24 (total bed rest) up to 120.
[b]Currently on "a diet," self-reported on the Framingham Food Habit Questionnaire.
[c]Self-reported intentional change in eating habits to be more healthful.
[3]Self-reported usual weight pattern described as "fluctuating" (±10 lb or more), in contrast to "stable" (±5 lb or less).
*Mean is significantly different ($P<.05$) from the mean in the Heart Healthy cluster.

Table 5
Twelve-year development of overweight among women who were not overweight[a] at baseline

	Heart Healthy (n=136)		Light Eating (n=350)		Wine and Moderate Eating (n=27)		High Fat (n=170)		Empty Calorie (n=54)	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Cases	33	24	106	30	6	22	47	28	22	41
	← Relative Risk[b] (95% CI) →									
Crude	1.0		1.3 (0.9, 1.8)		0.9 (0.4, 2.0)		1.1 (0.8, 1.6)		1.7 (1.1, 2.6)	
Age adjusted	1.0		1.2 (0.9, 1.7)		0.9 (0.4, 2.0)		1.1 (0.8, 1.6)		1.6 (1.0, 2.5)	
Multivariate model[c]	1.0		1.1 (0.8, 1.6)		0.9 (0.4, 2.1)		1.0 (0.7, 1.5)		1.4 (0.9, 2.2)	

[a]BMI <24.
[b]Relative Risks were calculated using the SAS procedure PROC GENMOD using the 'Log' link function (26).
[c]Multivariate model adjusts for baseline age, smoking status, physical activity, energy intake, self-reported weight pattern (fluctuating vs stable), intentional dieting, and menopausal status.

ioral characteristics that were used to inform these analyses, including recent, intentional changes in eating habits "to be healthier," adherence to a modified diet (current dieting, including low-calorie or weight-loss diets), and description of usual weight patterns: stable (±5 pounds) vs fluctuating (±10 pounds) body weight.

Physical activity was measured using a standardized questionnaire to determine estimates of activity in a usual day 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 (sedentary, slight, moderate, or heavy) and weighted according to oxygen consumption required to perform them (28). PAI scores ranged from 24 (total bed rest) to 120. Because physical activity was not measured at FOS 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 variables.

Analyses

As previously published, the Heart Healthy dietary pattern most closely approximated the Food Guide Pyramid's dietary recommendations for healthful eating (23,29) and thus was considered the reference pattern for all analyses. Age-adjusted mean levels of food grouping consumption, nutrient intake, and risk factors were computed for each cluster. For continuous variables, we used analysis of covariance (GLM in SAS) (26) to compute the least square means. For dichotomous variables, proportions were computed using logistic regression models. Relative risks for the development of overweight were computed using SAS Proc Genmod with the Log link function (26) using the Heart Healthy cluster as the reference group. Analytic models explored interaction and confounding and considered the following covariates at baseline: age, total energy intake (from 24-hour recall), physical activity, cigarette smoking, menopausal status, current dieting, intentional changes in eating habits, and usual weight pattern. Values for energy intake and the physical activity index were log-transformed to improve normality.

RESULTS

Table 2 displays daily servings of food groupings consumed by women in the 5 dietary pattern clusters. Women in the Heart Healthy cluster consumed more servings of vegetables, fruits, low-fat milk, and other low-fat and fiber-rich foods (including whole grains, fish, low-fat cheeses, lean poultry, and legumes) with fewer servings of diet beverages and firm vegetable fats than women in each of the other 4 clusters. Women in the High Fat and Empty Calorie clusters consumed noticeably higher amounts of animal and vegetable fats, sweets and desserts, and meats and mixed dishes. Those in the Empty Calorie cluster also drank more sweetened beverages. More moderate eating patterns were observed among women in the Light Eating cluster and those in the Wine and Moderate Eating cluster, with the exceptions of higher consumption of beer and poultry with skin in the Light Eating group and higher wine consumption in the Wine and Moderate Eating group.

Notable differences in food intake were reflected in differences in nutrient intake across the clusters (Table 3). On average, women in the Heart Healthy cluster achieved a more favorable nutrient intake profile comprised of lower fat, saturated fat, and cholesterol intake, higher carbohydrate and fiber intake, and greater micronutrient density than achieved by women in most other clusters. Despite somewhat lower energy intakes noted among women in the Light Eating cluster, fat and saturated fat intakes were proportionately higher and micronutrient density was lower. Those in the Wine and Moderate Eating group consumed a markedly higher amount of alcohol.

Diets of women in the High Fat cluster contained the highest amounts of total and saturated fat. These women and those in the Empty Calorie cluster had relatively lower fiber intakes and micronutrient density. Further, while women in the Empty Calorie cluster had higher saturated fat intakes than women in the Heart Healthy group, their carbohydrate intakes were similar. Yet, the contribution of concentrated sweets to the carbohydrate intake in the Empty Calorie cluster provides an important contrast to the complex carbohydrate content contributed by the predominant food choices of Heart Healthy women.

Interpersonal and behavioral profiles also differed according to dietary patterns, even among this cohort of nonoverweight women (Table 4). Women in the Heart Healthy cluster were older and were slightly more physically active than women in most other dietary groups. Those in the Empty Calorie cluster were the youngest. Heart Healthy women were more likely to report being on "a diet." Overall, the prevalence of dieting was low, with few women reporting that they were on a physician-prescribed or self-prescribed diet. In contrast, a much higher proportion of women reported intentionally changing their eating habits to achieve better health, with women in the Heart Healthy cluster most likely to report such changes.

The majority of women reported that their usual weight pattern was relatively stable. The Light Eating cluster contained the highest percentage of women with fluctuating weight. Smoking was notably less common among Heart Healthy women, and substantially more women in the High Fat and Empty Calorie clusters smoked. Menopausal status was not different across clusters of women.

Development of Overweight

Over 12 years, 214 cases of overweight developed in this cohort (Table 5). The crude rate in the overall cohort was 29%. Rates were lowest among women in the Wine and Moderate Eating cluster and highest among those in the Empty Calorie cluster. These data translate to a 17% absolute increase in risk among women who ate an Empty Calorie diet compared with those who followed a Heart Healthy pattern.

The relative risk for developing overweight was higher among women who consumed an Empty Calorie dietary pattern compared with women who ate a Heart Healthy diet (Table 5). The magnitude of the increased risk among women in the Empty Calorie cluster was slightly attenuated in the multivariate model adjusting for age, menopausal status, and various behavioral factors. There was no evidence of increased risk associated with any of the other dietary patterns observed.

DISCUSSION

This study used an analytic approach to dietary exposure measurement that considered overall patterns of food intake and multiple aspects of dietary behavior. We believe that our understanding of the complex relationships between diet and the development of overweight was informed by the cluster analytic approach. Discrete exposure categories were differentiated and differences noted among dietary clusters in these subgroup analyses were completely consistent with data published earlier on the overall cohort of 1,828 women (23). In these analyses, at least two dietary patterns were found to be discernibly different with respect to predicting overweight risk.

Compared with a lower-fat, nutritionally varied Heart Healthy pattern, an Empty Calorie diet that deviated markedly from current guidelines for a balanced, nutrient-dense diet was associated with a 40% increase in overweight risk over baseline. We noted differences in overweight risk in the presence of differences in food consumption patterns, risk factor profiles, and dietary behavioral characteristics. Our findings suggest that the overall nature of the food consumption pattern, when considered within the context of other dietary and behavioral characteristics, may be an important predictor of health risk. New data from Kant et al (30) clearly support this notion, demonstrating that consumption of a diet containing higher amounts of foods recommended by population-based dietary guidelines is associated with decreased mortality in women.

The dietary pattern approach has the ability to guide intervention planning for obesity prevention and treatment by identifying less desirable food behaviors and dietary characteristics among subgroups of the population most at risk. Here, we characterize at least one dietary pattern that predicts risk (Empty Calorie) and showcase a reference dietary pattern associated with relatively lower risk (Heart Healthy) for becoming overweight. Young women who consumed a diet that contained more sweetened beverages, sweets rich in fats, and empty-calorie snack foods with inadequate amounts of nutrient-dense fruits, vegetables, and fiber-rich foods were more likely to become overweight than women whose diets more closely approximated current dietary guidelines.

This research identified other important behaviors that may predict the development of overweight, including smoking behavior and a weight pattern that typically fluctuates. In multivariate models adjusting for dietary patterns and the other covariates (data not shown), risk for becoming overweight was about 20% higher among women who were smokers at baseline compared with nonsmokers. Risk was twice as high among those reporting chronic patterns of weight fluctuation in contrast to those with a history of weight stability.

The dietary pattern considered most effective for the prevention and treatment of obesity is one that is both appropriate in energy content and adequate in terms of macronutrient and micronutrient requirements (5). This type of pattern was modeled by women in our Heart Healthy cluster. As Lichtenstein et al (31) recently pointed out, a comprehensive focus on the quality of the overall diet is often lost in our national "obsession" with reducing fat intakes. In fact, a low-fat diet is not necessarily a nutritionally optimal diet for health promotion, in terms of total energy intake or intake levels of other nutrients such as fiber, vitamins, and minerals known to influence disease risk. This is a central consideration that may be overlooked in traditional epidemiological analyses that focus on a single predictor nutrient, such as total fat, as the primary exposure nutrient and disregard other aspects of the dietary profile that may also confer health risk.

This research evaluated potential sources of confounding that have previously eluded researchers, including intentional dieting, smoking behavior, menopausal status, and physical activity. Because we measured self-reported intentional changes in eating behaviors, we were able to consider confounding by health-consciousness. Willett (19) identified this important source of unmeasured confounding as problematic for studies of diet and obesity. Of concern is the fact that individuals are often aware of the outcome of interest (body weight) and have conscious control over its primary determinants (physical activity, total energy intake, and dietary fat intake). Willett argues that most studies are not designed in a way that can consider this type of confounding, and thus are flawed. In our cohort, women did not necessarily equate intentional changes in eating behaviors with dieting. The reported prevalence of dieting was markedly discrepant from the reported prevalence of intentional change in eating habits.

It was notable that more women in the Light Eating cluster described their usual weight pattern as fluctuating rather than stable. This indication of weight cycling may explain the counterintuitive findings of a modest increase in risk among women in the Light Eating cluster (in crude and age-adjusted models), despite a reported energy intake that was substantially less and an eating pattern that seemed more "light" than "excessive" in terms of food group consumption. It may be that these women were reporting their self-perceived "usual" food intake as instructed by the FFQ. In contrast, their weight gain experience may be more influenced by alternating periods of dieting and binge-eating with resultant weight fluctuation.

If that is the case, it is possible that we did not accurately capture the dietary behaviors that might better characterize the binge-eating episodes of women in this particular cluster. Thus, the Light Eating pattern we identified may not truly represent what might otherwise be suggestive of a protective or "dieting" pattern. Note, too, that the nutrient intake profiles of Light Eating women (assessed independently using a 24-hour dietary recall) were not necessarily low in fat density. Nor were they as abundant with fruits, vegetables, legumes, and other low-fat foods as the Heart Healthy pattern.

Some degree of measurement error is inherent with any self-reported assessment of dietary intake. Yet, our independent assessments of nutrient intake derived from 24-hour recalls were largely consistent with the eating patterns that emerged from the cluster analysis using FFQ data, lending support to their validity. We (24,25) and others (32) have already demonstrated the validity and reliability of this analytical approach for characterizing dietary patterns using FFQ data. Nonetheless, if nondifferential misclassification of dietary exposure did occur, the result would be to attenuate the findings in the direction of the null (33). In that case, the true relationship between eating behavior and the development of overweight would be more dramatic than observed here.

This research used extensive dietary data collected in a large, population-based cohort of women. Because the FOS cohort is composed almost exclusively of non-Hispanic white adults, we may not be able to be generalize our findings to other racial cohorts. Nonetheless, this racial group has experienced a large increase in overweight prevalence nationally (1,6). Their dietary and body weight experiences are particularly informative to the extent that they are representative of the national population of white adults.

Because of the small number of women in the Wine and Moderate Eating cluster, precision was severely limited in this subgroup. Based on the confidence interval widths, relative risks for the Light Eating, High Fat, and Empty Calorie clusters were estimated more precisely. Of the 3 relatively precise results, the point estimate for the Empty Calorie pattern is most suggestive of an effect. Separate analyses that included the 139 women in the BMI range of 24 to 24.9 at baseline yielded results that were highly consistent with those reported here.

We focused these analyses on a single outcome: the development of overweight. Here, only the Empty Calorie dietary pattern was shown to be appreciably associated with overweight risk when compared with a Heart Healthy eating plan. Yet these data are the first in a series of prospective analyses currently underway to examine relationships between dietary patterns and other health outcomes, including absolute change in body weight over time. Until we know how the Light Eating, Wine and Moderate Eating, and High Fat patterns relate to other aspects of morbidity, we are unable to advocate any dietary pattern other than the Heart Healthy pattern.

APPLICATIONS

Understanding overall dietary patterns seems to be important to guide the development of targeted weight-control strategies. We have identified a link between the risk of becoming overweight and an eating pattern that is rich in fats and sweets and lacking adequate servings of fruits, vegetables, fiber-rich whole grains, and lean protein selections. This increased risk is noted in contrast to a dietary pattern consumed by women who choose a diet that is closer to the expert dietary recommendations for health promotion.

We advocate the continued application and further development of the cluster analysis technique for discerning population eating patterns. We encourage other researchers to consider this approach as they explore relationships between dietary patterns, health, and disease.

References

1. Mokdad AH, Serdula MK, Dietz WH, Bowman BA, Marks JS, Koplan JP. The spread of the obesity epidemic in the United States, 1991-1998. *JAMA.* 1999;282:1519-1522.

2. Allison DB, Fontaine KR, Manson JE, Stevens J, VanItallie TB. Annual deaths attributable to obesity in the United States. *JAMA.* 1999;282:1530-1538.

3. Stamler J. Epidemic obesity in the United States. *Arch Intern Med.* 1993;153:1040-1043.

4. Rippe JM. The obesity epidemic: Challenges and opportunities. *J Am Diet Assoc.* 1998;98(Suppl 2):S5.

5. Coulston AM. Obesity as an epidemic: Facing the challenge. J Am Diet Assoc. 1998; 98(Suppl 2):S6-S8.

6. Kuczmarski RJ, Flegal KM, Campbell SM, Johnson CL. Increasing prevalence of overweight among US adults. The National Health and Nutrition Examination Surveys, 1960-1991. *JAMA.* 1994;272:205-211.

7. Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The disease burden associated with overweight and obesity. *JAMA.* 1999;282:1523-1529.

8. Koplan JP, and Dietz WH. Caloric imbalance and public health policy. *JAMA.* 1999;282:1579-1581.

9. Pi-Sunyer FX. Health implications of obesity. *Am J Clin Nutr.* 1991; 53:1595S-1603S.

10. St. Jeor ST, Brownell KD, Atkinson RL, Bouchard C, Dwyer J, Foreyt JP, Heber D, Kris-Etherton P, Stern JS, Willett W. Obesity Workshop III. AHA Prevention Conference III. Behavior change and compliance: Keys to improving cardiovascular health. *Circulation.* 1993;88:1391-1396.

11. Denke MA, Sempos CT, Grundy SM. Excess body weight. An Underrecognized contributor to high blood cholesterol levels in white American men. *Arch Intern Med.* 1993;153:1093-1103.

12. The National Heart, Lung, and Blood Institute Expert Panel on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults. Executive summary of the clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. *J Am Diet Assoc.* 1998;98:1178-1191.

13. Rippe JM, Crossley S, Ringer R. Obesity as a chronic disease: Modern medical and lifestyle management. *J Am Diet Assoc.* 1998;98(Suppl 2):S9-S15.

14. Seim HC, Holtmeier KB. Treatment of obesity in the elderly. *Am Fam Physician.* 1993;47:1183-1189.

15. Kochar MS. Hypertension in elderly patients. The special concerns in this growing population. *Postgrad Med.* 1992;91:393-400.

16. Office of Disease Prevention and Health Promotion, U.S. Department of Health and Human Services. Healthy People 2010. *http://web.health.gov/healthypeople/.* Accessed November 1999.

17. Lissner L, Heitmann BL. Dietary fat and obesity: evidence from epidemiology. *Eur J Clin Nutr.* 1995;49:79-90.

18. Seidell JC. Dietary fat and obesity: An epidemiologic perspective. *Am J Clin Nutr.* 1998; 67(Suppl):546S-550S.

19. Willett WC. Is dietary fat a major determinant of body fat? *Am J Clin Nutr.* 1998; 67(Suppl):556S-562S.

20. Kannel WB, Feinleib M, McNamara PM, Garrison RJ, Costal W. An investigation of coronary heart disease in families: the Framingham Offspring Study. *Am J Epidemiol.* 1979;110:281-290.

21. Willett WC, Sampson L, Stampfer MJ, Rosner B, Bain C, Witschi J, Hennekens CH, Speizer F. Reproducibility and validity of a semiquantitative food frequency questionnaire. *Am J Epidemiol.* 1985;122:51-65.

22. Posner BM, Martin-Munley SS, Smigelski C, Cupples LA, Cobb JL, Schaefer E, Miller DR, D'Agostino RB. Comparisons of techniques for estimating nutrient intake – The Framingham Study. *Epidemiology.* 1992;3:171-177.

23. Millen BE, Quatromoni PA, Gagnon DR, Cupples LA, Franz MM, D'Agostino RB. Dietary patterns of men and women suggest targets for health promotion. *Am J Health Promotion.* 1996;11:42-52.

24. Millen BE, Quatromoni PA, Copenhafer DL, Demissie S, O'Horo CE, D'Agostino RB. Validation of a dietary pattern approach for evaluating nutritional risk. The Framingham Nutrition Studies. *J Am Diet Assoc.* 2001;101:187-94.

25. Quatromoni PA, Copenhafer DL, Demissie S, D'Agostino RB, O'Horo CE, Nam BH, Millen BE. The internal validity of a dietary pattern analysis. The Framingham Nutrition Studies. *J Epidemiol Community Health,* 2002;56:381-388.

26. SAS Institute Inc. *SAS User's Guide, version 6, vols 1 & 2.* 4th ed. Cary, NC: SAS Institute, 1989.

27. Ward JH. Hierarchical grouping to optimize an objective function. *J Am Stat Assoc.* 1963;58:236-244.

28. Kannel WB and Sorlie P. Some health benefits of physical activity. The Framingham Study. *Arch Intern Med.* 1979;139:857-861.

29. *Food Guide Pyramid: A Guide to Daily Food Choices.* Washington, DC: US Dept of Agriculture, Human Nutrition Information Service; 1992. Home and Garden Bulletin No. 252.

30. Kant AK, Schatzkin A, Graubard BI, Schairer C. A prospective study of diet quality and mortality in women. *JAMA.* 2000;283:2109-2115.

31. Lichtenstein AH, Kennedy E, Barrier P, Danford D, Ernst ND, Grundy SM, Leveille GA, Van Horn L, Williams CL, Booth SL. Dietary fat consumption and health. *Nutr Rev.* 1998;(II)S3-28.

32. Hu FB, Rimm E, Smith-Warner SA, Feskanich D, Stampfer MJ, Ascherio A, Sampson L, Willett WC. Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. *Am J Clin Nutr.* 1999;69:243-249.

33. Hebert JR, Miller DR. Methodologic considerations for investigating the diet-cancer link. *Am J Clin Nutr.* 1988;47:1068-1077.

This work was supported by the American Dietetic Association Foundation with funds from the Kraft Foods Fellowship program and the Jean Hankin Nutritional Epidemiology Award. The Framingham Nutrition Studies are funded by National Heart, Lung and Blood Institute grants and contracts R01-HL60700.