Prospective Study of Major Dietary Patterns and Stroke Risk in Women

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Background and Purpose**—**Many foods have been suggested to influence the risk of stroke. However, no previous studies have examined the relationship between overall dietary patterns and risk of stroke.

Methods**—**Using dietary information collected in 1984 from 71 768 women aged 38 to 63 years without a history of cardiovascular disease or diabetes in 1984, we conducted factor analysis and identified 2 major dietary patterns: "prudent" and "Western." We calculated scores for each participant for each pattern and prospectively examined their associations with stroke risk using a proportional hazard model, adjusting for other stroke risk factors.

Results**—**The prudent pattern was characterized by higher intakes of fruits, vegetables, legumes, fish, and whole grains, whereas the Western pattern by higher intakes of red and processed meats, refined grains, and sweets and desserts. During 14 years of follow-up, we identified 791 incidents of stroke, with 476 ischemic and 189 hemorrhagic strokes. After adjusting for potential confounders, we observed a relative risk (RR) of 1.58 (95% CI, 1.15 to 2.15; $P=0.0002$ for trend) for total strokes and 1.56 (95% CI, 1.05 to 2.33; $P=0.02$ for trend) for ischemic stroke when comparing the highest with lowest quintiles of the Western pattern. For the prudent pattern, the RRs comparing extreme quintiles were 0.78 (95% CI, 0.61 to 1.01) for total stroke and 0.74 (95% CI, 0.54 to 1.02) for ischemic stroke.

Conclusions**—**These data suggest that a dietary pattern typified by higher intakes of red and processed meats, refined grains, and sweets and desserts may increase stroke risk, whereas a diet higher in fruits and vegetables, fish, and whole grains may protect against stroke. **(*Stroke*. 2004;35:2014-2019.)**

Key Words: diet ■ epidemiology ■ risk factors

Stroke is the third leading cause of death in the United States, and incidence is higher in women than men.[1] Even among stroke survivors, quality of life is diminished greatly in many who are left with permanent disability. Thus, primary stroke prevention has become a major public health priority. Several foods and nutrients have been linked to stroke risk; therefore, dietary modification may be an important way to reduce risk of stroke.[2–4] These include an inverse relationship between fish,[2] fruits and vegetables,[3] and whole grain intake[4] and stroke risk. Because nutrients and foods are consumed in combination, their cumulative effects on disease risk may be best investigated by considering the entire eating pattern.[5] In previous analyses, major dietary patterns derived from factor analysis have predicted coronary heart disease risk.[6]

In this study, we used factor analysis[7] to identify major dietary patterns in a large cohort of women. We then prospectively assessed the association between these major dietary patterns and the risk of total and subtypes of stroke.

Materials and Methods

Subjects

The Nurses' Health Study (NHS) began in 1976, when 121 700 female nurses aged 30 to 55 in 11 states responded to a questionnaire regarding medical history and lifestyle.[8] The NHS was approved by the institutional review board of the Brigham and Women's Hospital in Boston, Mass. Since 1976, questionnaires have been sent biennially to update this information. Follow-up was completed for >95% of the potential person time. In 1984, a food frequency questionnaire (FFQ) with 116 items was sent to participants. FFQs were sent subsequently every 2 to 4 years.

For the present analysis, women were included if they had <70 missing items in the 1984 FFQ and a total energy intake range between 2060 and 14 420 kJ per day (500 and 3500 kcal per day). We excluded women with a history of stroke, diabetes, or coronary heart disease. Thus, 71 768 women were included with follow-up for up to 14 years, from 1984 to 1998.

Dietary Intake Assessment

The FFQ was designed to assess average food intake during the previous year. A standard portion size was given for each food item, and 9 possible frequency responses were available. Total energy intake was

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calculated by summing up energy intakes from all foods. Foods from FFQs were classified into 36 to 42 food groups on the basis of nutrient profiles or culinary usage. Foods that did not fit into any of the groups or that may represent distinctive dietary behaviors, including each type of alcoholic beverage, were left as individual categories (eg, pizza, tea) and entered as separate food groups. Similar food groupings have been used in previous studies.[6,9] Vitamin and mineral supplements were not included as food groups. Previous validation studies among NHS cohort members revealed good correlation between nutrients assessed by similar FFQs and multiple weeks of food records completed during the previous year.[10]

Case Ascertainment

Nonfatal strokes for which confirmatory information was obtained by telephone or letter but for which no medical records were available were regarded as probable. Deaths were ascertained by reports of relatives or postal authorities and a search of the National Death Index. For fatal strokes, confirmatory information was obtained by telephone interview, letter, medical records, or death certificate. When only death certificate information was available, fatal strokes were regarded as probable. Approximately 17% of all strokes were classified as probable. Confirmed and probable strokes were combined in our analyses.

Strokes were confirmed by medical records according to the criteria of the National Survey of Stroke and classified as subarachnoid hemorrhages, intraparenchymal hemorrhages, ischemic strokes (thrombotic or embolic), or stroke of undetermined type.[11] For each subtype of stroke, a definite diagnosis was made when computed tomography (CT) scan, MRI, angiography, surgery, or autopsy confirmed the lesion, and if such confirmation was lacking, a probable diagnosis was made.

Statistical Analysis

Dietary patterns were generated by factor analysis (principal components) on the basis of these food groups. This method was based primarily on the correlation between the food groups. To achieve better interpretability, we used an orthogonal rotation procedure[12] that results in factors (ie, dietary patterns) that are not correlated with each other. We determined the number of factors to retain by the amount of variation explained by each pattern and the natural interpretation of each pattern generated. The factor score for each pattern was calculated by summing intakes of food groups weighted by their factor loadings,[7] and each woman received a factor score for each identified pattern. Good reproducibility of the patterns generated by this method has been demonstrated in a parallel cohort of men.[13] Factor analysis was conducted using SAS PROC FACTOR (SAS Institute).[14] Please see the Appendix for the factor loading matrix for FFQ 1984–1994.

We used a Cox proportional hazard model to assess associations between dietary pattern scores and risk of total and subtypes of stroke. In this analysis, we used dietary patterns derived from the 1984 FFQ to examine long-term association between diet and stroke.

Regression analyses were adjusted for age, smoking status (never, past, current smokers ≤14 cigarettes per day, 15 to 24 cigarettes per day, >25 cigarettes per day), body mass index (BMI; 5 categories), menopausal status (premenopause, postmenopause without postmenopausal hormone therapy, current user of postmenopausal hormone therapy, past user of postmenopausal hormone therapy), aspirin use (yes/no), energy intake (quintiles), alcohol intake (nondrinkers, drinkers ≤5 g per day, 5.1 to 15 g per day, >15 g per day), and hours of moderate and vigorous physical activity at baseline. We did not adjust for history of hypercholesterolemia, hypertension, and diabetes in the models to avoid overcontrolling for intermediates in causal pathways.

In addition, we stratified the analysis by smoking status, physical activity, history of hypercholesterolemia, history of hypertension, history of diabetes, overweight status (BMI=25 as cutoff), and physical activity level (using the median as cutoff) to explore different associations by these factors. We also examined combined effects of risk factors and dietary pattern scores with joint classification.

Results

Between 1984 and 1998, we documented 791 incident cases of stroke, of which 476 cases were classified as ischemic, 189 as

TABLE 1. Age-Standardized Baseline Characteristics by Quintiles of Pattern Score

	Prudent			Western		
	Q1	Q3	Q5	Q1	Q3	Q5
BMI	24.8	24.8	25.0	24.5	24.7	25.4
Moderate/vigorous physical activity (hours per week)	2.0	2.3	2.7	2.6	2.3	2.2
Current smokers (%)	30	23	18	19	24	28
Family history of myocardial infarct (%)	15	15	17	16	15	16
History of hypertension (%)	17	19	23	22	19	18
History of high cholesterol (%)	6	7	9	10	7	6
Multivitamin use (%)	31	37	43	44	37	32
Food and nutrient* consumption						
Total energy (kjoule)	6199	7249	8618	5237	7090	9895
Glycemic load	148	140	137	144	141	139
Alcohol (g)	5	7	9	7	7	7
Sodium (mg)	1700	1800	1886	1719	1803	1859
Saturated fat (g)	24	22	20	20	22	24
Monounsaturated fat (g)	24	23	20	20	23	24
Polyunsaturated fat (g)	11	12	12	11	12	12
Total vegetables (servings per day)	1.4	2.7	5.3	3.0	2.9	3.1
Fruits (servings per day)	0.7	1.3	2.3	1.6	1.4	1.3
Processed meats (servings per day)	0.3	0.3	0.3	0.1	0.3	0.6
Red meats (servings per day)	0.6	0.6	0.6	0.3	0.6	1.0
Fish (servings per day)	0.2	0.3	0.5	0.4	0.3	0.3

*Nutrient consumption is energy adjusted.

TABLE 2. RRs (95% CI) for Stroke According to Quintiles of Dietary Pattern Score

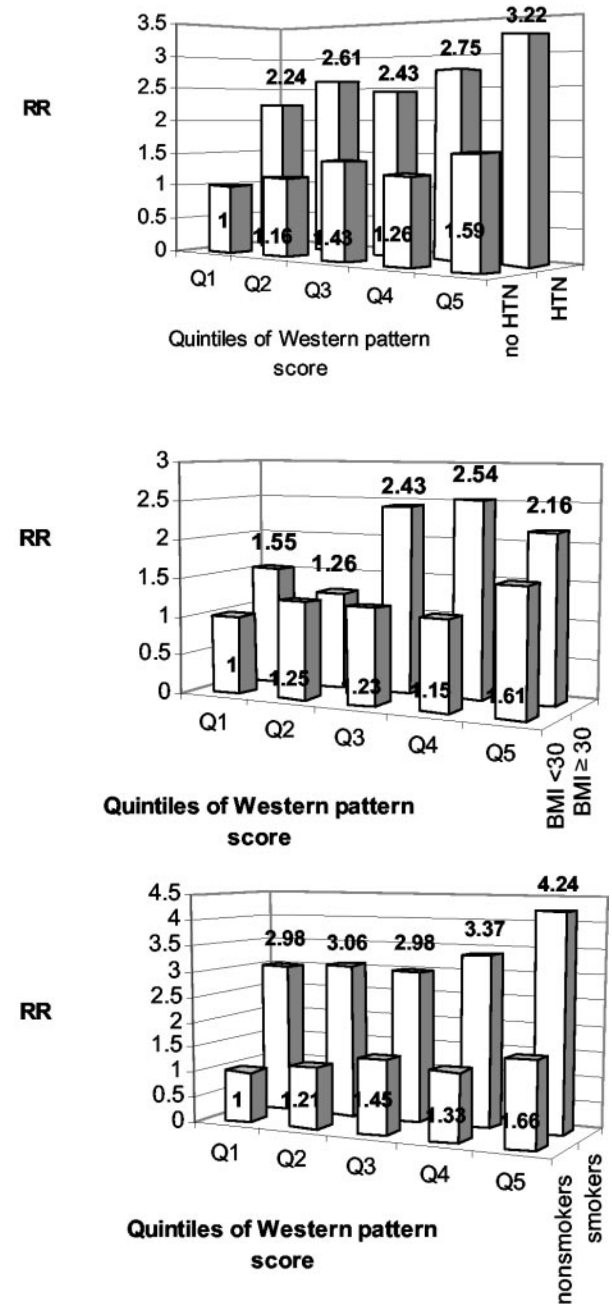
	Q1	Q2	Q3	Q4	Q5	*P* for Trend
Prudent						
All strokes						
No. of cases	156	156	177	156	146	
Age- and energy-adjusted	1	0.88	0.95	0.79	0.70 (0.55–0.90)	0.02
Multivariate*	1	0.93	1.04	0.87	0.78 (0.61–1.01)	0.13
Ischemic						
No. of cases	93	90	108	97	88	
Age- and energy-adjusted	1	0.85	0.95	0.80	0.68 (0.50–0.94)	0.045
Multivariate*	1	0.89	1.02	0.85	0.74 (0.54–1.02)	0.13
Hemorrhagic						
No. of cases	41	42	42	31	33	
Age- and energy-adjusted	1	0.93	0.94	0.65	0.67 (0.41–1.10)	0.18
Multivariate*	1	1.01	1.05	0.76	0.79 (0.47–1.30)	0.51
Western						
All strokes						
No. of cases	156	165	154	159	157	
Age- and energy-adjusted	1	1.26	1.40	1.64	2.00 (1.48–2.72)	$<$0.0001
Multivariate*	1	1.18	1.27	1.41	1.58 (1.15–2.15)	0.0002
Ischemic						
No. of cases	98	101	96	86	95	
Age- and energy-adjusted	1	1.24	1.43	1.45	1.95 (1.32, 2.88)	0.0002
Multivariate*	1	1.16	1.30	1.26	1.56 (1.05–2.33)	0.02
Hemorrhagic						
No. of cases	37	38	36	38	40	
Age- and energy-adjusted	1	1.24	1.40	1.65	2.23 (1.19–4.16)	0.006
Multivariate*	1	1.13	1.24	1.35	1.63 (0.86–3.09)	0.098

*Adjusted for age, smoking status, BMI, menopausal status, aspirin use, energy intake, alcohol intake, and hours of moderate and vigorous physical activity.

hemorrhagic, and 126 strokes that lack clear documentation of type by imaging studies or medical records. The prudent pattern was characterized by higher intakes of fruits, vegetables, whole grains, fish, and poultry. The Western pattern was characterized by higher intakes of red and processed meats, refined grains, full-fat dairy products, and desserts and sweets. These patterns remained stable in our population throughout the follow-up period. At baseline, women with high prudent pattern scores tended to be more physically active, use multivitamins regularly, and were less likely to smoke (Table 1). However, women with high Western pattern scores were more likely to smoke, less likely to use multivitamins, and were less physically active.

After adjusting for age and energy, an inverse association was observed between the prudent pattern and total and the 2 subtypes of strokes (Table 2). The relative risk (RR) comparing top to bottom quintile of prudent pattern score was 0.70 (95% CI, 0.55 to 0.90; $P=0.02$ for trend) for total stroke and 0.68 (95% CI, 0.50 to 0.94; $P<0.05$ for trend) for ischemic stroke. After adjusting for potential confounders, the RRs were slightly attenuated, but the test of trend was no longer significant (RR comparing top with bottom quintile 0.78; 95% CI, 0.61 to 1.01 for total stroke; $P=0.13$ for trend). Similar results were observed with the prudent pattern for ischemic and hemorrhagic strokes. Positive associations were observed between the Western pattern and stroke (Table 2). After adjusting for lifestyle and other stroke risk factors, women in the highest quintile of the Western pattern score had 1.58 times (95% CI, 1.15 to 2.15; $P=0.0002$ for trend) the risk of developing any type of stroke compared with those in the lowest quintile. Similarly, the RR of ischemic stroke was 1.56 (95% CI, 1.05 to 2.33; $P=0.02$ for trend) for the same comparison. The Western pattern also appeared to have a positive association with hemorrhagic stroke, although the test for trend was not significant, probably because of the small number of cases. We observed similar results when we analyzed fatal and nonfatal cases separately. When we excluded probable cases from the analysis, results did not change substantially. When we explored possible differential association by various risk factors such as hypertension, smoking, and obesity using stratified analysis, we generally found inverse associations for the prudent pattern and positive associations for the Western pattern. There were no significant interactions.

With joint classification of dietary pattern scores and selected risk factors for stroke, we were able to compare combinations of favorable versus unfavorable risk profiles (Figure). Women with the combination of hypertension and a high Western pattern score had >3 times the risk of ischemic stroke compared with nonhypertensive women with a low Western pattern score. Smokers with a high Western pattern score have >4 times the risk of ischemic stroke compared with nonsmokers with a low Western pattern score. Obese individuals with a high Western pattern score have more than twice the risk of ischemic stroke than nonobese individuals with a



Multivariate RR of ischemic stroke according to joint classifications of Western patterns and history of hypertension (HTN), smoking, and BMI.

low Western pattern score. When we assessed joint classification of prudent pattern score and risk factors, individuals with the risk factors were at higher risk for stroke, but no association was noted with the prudent pattern.

We also assessed associations between intake of various types of meat and ischemic stroke. When all red and processed meats were combined, women who consumed ≥1 serving of these foods per day had an RR of 1.86 (95% CI, 0.90 to 3.83; P=0.005 for trend). When the Western pattern was adjusted additionally for red and processed meats, it remained positively associated with ischemic stroke (RR comparing top to bottom quintile 1.71; 95% CI, 0.81 to 3.58; P=0.03 for trend). This suggests that the increased risk conferred by a high Western pattern score was not explained completely by red and processed meats and that other components of the Western pattern were important. In an additional analysis, we used cumulative averages of dietary pattern scores obtained from all 4 FFQs collected between 1984 and 1994 to predict stroke risk and found similar albeit slightly weaker results, suggesting long-term diet is more relevant in predicting stroke risk than recent diets alone. We also conducted an analysis in which energy intake was adjusted using the residuals of pattern score (an alternative method for adjusting for energy intake) as predictor of stroke risk, and the results were similar.

Discussion

We found that a high Western dietary pattern score, characterized by high intake of red and processed meats, refined grains, high-fat dairy products, and sweets and desserts, is associated with an increased risk of ischemic stroke. Conversely, there was a suggestion of reduced risk with a high prudent pattern score. These associations were independent of established cardiovascular risk factors. Because a number of foods have been shown to be associated with stroke, the use of dietary patterns allows for examining the combined effect of foods. Correlation among foods facilitates rather than impedes the factor analysis deriving dietary patterns. In addition, overall dietary patterns are easier to recommend to the public than individual foods or nutrients.

Few data are available on the components of the Western pattern and risk of stroke. In a case–control study, increased risk was seen with meat consumption >4 times per week, but the association was no longer significant when ischemic and intracerebral hemorrhagic strokes were analyzed separately.[15] On the other hand, in a case–control study of men at high risk for coronary heart disease, saturated fatty acid levels in serum showed a positive although nonsignificant association with stroke risk.[16] The Western pattern has been shown previously to be associated with higher fasting insulin and C-reactive protein (CRP) levels.[17] Other data suggest an association between hyperinsulinemia (ie, insulin resistance) or CRP and stroke risk[18,19]. Therefore, the higher risk of ischemic stroke observed with the Western pattern in this study may be mediated partially by insulin response or the inflammation process.[18–21]

A number of the components of the prudent pattern have been associated with a lower risk of stroke. This may explain the suggested inverse association we observed between the prudent pattern and reduced risk of stroke. Fruits and vegetables have been associated with reduced risk in prospective studies in men and women.[3] Epidemiological evidence also exists for increased whole grain intake and a lower risk of ischemic stroke in women.[4] Multiple studies have pointed toward an inverse association between fish intake and stroke risk.[22,23]

Our purpose was to identify actual eating patterns in our cohort and examine their ability to predict disease risk. The factor analysis approach of generating dietary pattern involves several arbitrary but important decisions, such as consolidating food items into food groups, the number of food groups to include, and the number of factors to extract. Nevertheless, this method has been shown to generate patterns that were predictive of diseases in the expected direc-tions.[6,9] This study used data collected prospectively with little loss to follow-up. We also controlled extensively for lifestyle and risk factors that may confound the diet and stroke association. Because dietary patterns may vary in different populations, our results need to be verified in other populations.

Summary

These data suggest that major dietary patterns influence risk of stroke. A diet higher in red and processed meats, refined grains, and sweets and desserts may increase stroke development, especially ischemic stroke. On the other hand, a diet higher in fruits, vegetables, whole grains, and fish may protect against stroke. Because similar risk associations were observed previously with coronary heart disease[6] and colon cancer,[24] it is advisable to avoid the Western dietary pattern to lower risk of these diseases.

Appendix

TABLE 3. Factor-Loading Matrix for FFQ 1984–1994

	Factor 1 (Prudent)				Factor 2 (Western)			
Foods	1984	1986	1990	1994	1984	1986	1990	1994
Other vegetables	0.69	0.75	0.68	0.68	—*	—	—	—
Leafy vegetables	0.68	0.68	0.67	0.60	—	—	—	—
Cruciferous vegetables	0.61	0.59	0.61	0.63	—	—	—	—
Yellow vegetables	0.56	0.60	0.64	0.66	—	—	—	—
Fruits	0.55	0.55	0.55	0.62	—	—	—	—
Fish	0.52	0.54	0.52	0.43	—	—	—	—
Legumes	0.51	0.49	0.55	0.60	0.19	0.20	0.15	0.15
Tomatoes	0.48	0.57	0.51	0.46	0.17	0.16	0.16	—
Poultry	0.45	0.42	0.42	0.32	—	—	—	—
Garlic	0.41	N/A	N/A	0.26	—	N/A	N/A	—
Salad dressings	0.39	0.41	0.38	0.24	—	—	—	—
Whole grains	0.35	0.34	0.35	0.42	—	—	—	—
Organ meats	0.23	—	—	—	—	—	—	—
Refined grains	—	—	—	—	0.58	0.57	0.52	0.44
Processed meats	—	—	—	—	0.56	0.57	0.58	0.57
Red meats	—	—	—	—	0.56	0.56	0.60	0.61
French fries	—	—	—	—	0.47	0.47	0.46	0.47
Condiments	—	0.19	—	—	0.44	0.33	0.36	0.29
Desserts and sweets	—	—	—	—	0.43	0.49	0.46	0.46
Potatoes	—	—	0.19	0.25	0.41	0.39	0.34	0.34
Full fat dairy products	—	—	—	—	0.36	0.40	0.45	0.43
Pizza	—	—	—	—	0.35	0.34	0.35	0.33
Sweetened beverages	−0.17	—	—	—	0.33	0.34	0.33	0.33
Margarine	—	—	—	—	0.33	0.31	0.33	0.34
Mayonnaise	0.20	0.21	—	—	0.32	0.33	0.34	0.27
Eggs	0.16	—	—	—	0.29	0.32	0.41	0.41
Snacks	—	—	—	—	0.28	0.31	0.29	0.33
Butter	—	—	—	—	0.24	0.25	0.29	0.27
Cream soups	—	—	—	—	—	0.30	0.32	0.35
Cereal	—	—	—	0.20	—	—	—	—
Low-fat dairy products	0.28	0.26	0.28	0.37	—	—	—	—
Fruit juice	0.21	0.22	0.19	0.26	—	0.15	0.15	0.15
Nuts	0.16	0.20	0.15	—	0.16	0.23	0.23	0.29
Artificially sweetened beverages	—	—	—	—	—	—	—	—
Beer	—	—	—	—	—	—	—	—
Coffee	—	—	—	—	—	—	—	—
Wine	0.15	—	—	—	—	—	—	—
Liquor	—	—	—	—	—	—	—	—
Tea	—	—	—	—	—	0.16	—	—
Other soups	N/A†	0.27	N/A	—	N/A	0.28	N/A	—
Water	N/A	N/A	0.30	0.35	N/A	N/A	—	—
Olive oil	N/A	N/A	0.35	0.21	N/A	N/A	—	—

*Values <0.15 is omitted for simplicity.
†Not available in the FFQ.

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