PRIMARY PREVENTION OF CORONARY HEART DISEASE IN WOMEN THROUGH DIET AND LIFESTYLE

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ABSTRACT

Background Many lifestyle-related risk factors for coronary heart disease have been identified, but little is known about their effect on the risk of disease when they are considered together.

Methods We followed 84,129 women participating in the Nurses' Health Study who were free of diagnosed cardiovascular disease, cancer, and diabetes at base line in 1980. Information on diet and lifestyle was updated periodically. During 14 years of follow-up, we documented 1128 major coronary events (296 deaths from coronary heart disease and 832 nonfatal infarctions). We defined subjects at low risk as those who were not currently smoking, had a body-mass index (the weight in kilograms divided by the square of the height in meters) under 25, consumed an average of at least half a drink of an alcoholic beverage per day, engaged in moderate-to-vigorous physical activity (which could include brisk walking) for at least half an hour per day, on average, and scored in the highest 40 percent of the cohort for consumption of a diet high in cereal fiber, marine n−3 fatty acids, and folate, with a high ratio of polyunsaturated to saturated fat, and low in trans fat and glycemic load, which reflects the extent to which diet raises blood glucose levels.

Results Many of the factors were correlated, but each independently and significantly predicted risk, even after further adjustment for age, family history, presence or absence of diagnosed hypertension or diagnosed high cholesterol level, and menopausal status. Women in the low-risk category (who made up 3 percent of the population) had a relative risk of coronary events of 0.17 (95 percent confidence interval, 0.07 to 0.41) as compared with all the other women. Eighty-two percent of coronary events in the study cohort (95 percent confidence interval, 58 to 93 percent) could be attributed to lack of adherence to this low-risk pattern.

Conclusions Among women, adherence to lifestyle guidelines involving diet, exercise, and abstinence from smoking is associated with a very low risk of coronary heart disease. (N Engl J Med 2000;343:16-22.)
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DESPITE dramatic declines, coronary heart disease remains the leading cause of death among men and women in the United States. Much effort has focused on the pharmacologic management of hypertension and blood lipid levels and on improved therapy for acute myocardial infarction and congestive heart failure. These treatments have proven benefit but are costly, may have side effects, and require medical intervention. Diet and lifestyle can also affect the incidence of coronary heart disease. Typically, behavioral risk factors are studied individually, but these types of behavior are often correlated, because people follow common lifestyle patterns.

In the present study, we assessed the effect of a combination of lifestyle practices on the risk of coronary heart disease. Specifically, we estimated the proportion of coronary events that could potentially be prevented by adherence to a set of dietary and behavioral guidelines. In secondary analyses, we also evaluated the effect of the practices on the risk of stroke.

METHODS

Population

The Nurses' Health Study cohort was established in 1976, when 121,700 U.S. female registered nurses 30 to 55 years of age provided detailed information by questionnaire. Every two years, we send follow-up questionnaires to update our information on potential risk factors and to identify newly diagnosed cases of various diseases.

Ascertainment of Risk and Preventive Factors

The 1976 questionnaire inquired about the nurses' height and weight and about myocardial infarction in a parent before the age of 60 years. Each follow-up questionnaire asked for updated information on weight for calculation of the body-mass index (the weight in kilograms divided by the square of the height in meters) as a measure of obesity.[1] Each questionnaire also inquired about cigarette smoking (including past smoking and the number of cigarettes smoked per day for current smokers), menopausal status (including the use of postmenopausal hormones), and physician-diagnosed hypertension and high cholesterol levels; self-reports of these diagnoses were quite accurate as compared with medical records.[2]

Information on physical activity was first obtained in 1980 and was updated in 1982, 1986, 1988, and 1992 with a previously validated questionnaire on the frequency of activity.[3-5] We estimated the amount of time per week spent in moderate-to-vigorous ac-

tivities requiring 3 or more MET per hour; this excluded walking at an easy or normal pace but included brisk walking at 5 km (3 mi) or more per hour.

In 1980 we assessed diet with a 61-item food-frequency questionnaire. In 1984 the questionnaire was expanded to 116 food items, and similar questionnaires were used to update information on diet in 1986 and 1990. The questionnaires also assessed the intake of multivitamin and single-vitamin supplements. The reproducibility and validity of the food-frequency questionnaires are high when compared with multiple one-week diet records and a variety of biochemical markers, as described in detail elsewhere.[6]

To calculate the intake of specific nutrients, we specified a common unit or portion size for each food on the questionnaire and asked the participant how often, on average, she had consumed that amount during the previous year. The nine response categories ranged from "never" to "six or more times per day." The intake of nutrients was computed by multiplying the frequency of consumption of each unit of food by its nutrient content. Beer, wine, and liquor were included in each of the food-frequency questionnaires to permit calculation of alcohol intake.

Definition of Low-Risk Groups

Our aim in this analysis was to estimate the effect of diet and lifestyle on the risk of coronary heart disease. Therefore, we did not consider the additional effect of pharmacologic agents, including aspirin or postmenopausal hormones, or medical conditions, such as hypertension and high cholesterol levels. However, all analyses were adjusted for those factors. We sought to limit the number of lifestyle and dietary variables, and we included only those with reasonable evidence supporting their effect on coronary heart disease, while recognizing that most such variables have never been tested in randomized trials.

For smoking, the low-risk group was defined as those who had stopped smoking or had never smoked. Cigarette smoking is a major risk factor for coronary heart disease[7] and stroke.[8] The risk declines after the cessation of smoking and approximates the level of those who have never smoked after 10 to 14 years.[9-11]

Moderate alcohol consumption is associated with a lower risk of coronary heart disease[12-14] and ischemic stroke[15] but can raise the risk of hemorrhagic stroke.[16] We considered women as being at low risk if they consumed an average of 5 g or more per day (a typical glass of wine has 11 g of alcohol). For simplicity, and because so few women in this cohort drank heavily (1.2 percent reported drinking more than 45 g of alcohol per day), we did not define an upper limit for alcohol consumption, although clearly this would be necessary in establishing public health guidelines.

For physical activity, we considered subjects to be at low risk if they engaged in an average of at least one half-hour per day of vigorous or moderate activity, including brisk walking. This cutoff point is consistent with various guidelines.[17,18] We have found that this level of activity is associated with a substantial reduction in the risk of coronary heart disease[5] and stroke (unpublished data).

Women with a body-mass index of less than 25, the standard cutoff point for overweight, were considered to be at low risk. We have previously found a significantly higher risk of coronary heart disease among women with a body-mass index of 23 to 24.9, as compared with women with a body-mass index of less than 21.[19] The cutoff point of 25 represents a higher-than-optimal level.

We considered subjects to be at low risk if they scored in the highest 40 percent of the cohort on a composite measure based on a diet low in trans fat and glycemic load (which reflects the extent to which diet raises blood glucose levels), high in cereal fiber, marine n−3 fatty acids, and folate, and with a high ratio of polyunsaturated to saturated fat. For each of these six dietary factors, we calculated the distribution according to quintiles within the cohort and assigned each woman a score of 1 to 5 corresponding to the quintile of intake, with 5 representing the most favorable quintile. The cutoff points for the most favorable quintile for each dietary factor were as follows: less than 1.56 percent of energy supplied by trans fat, a ratio of polyunsaturated to saturated fat of more than 0.43, consumption of more than 4.2 g of cereal fiber

per day, a glycemic load of less than 723 units per day, more than 0.1 percent of energy from marine n−3 fatty acids, and consumption of more than 525 μg of folate per day. For each participant, the quintile value for each nutrient was summed (with a higher score representing a lower risk), and the participants with dietary scores in the highest 40 percent were defined as the low-risk group with respect to diet. We and others have previously demonstrated the importance of each of these factors for the risk of coronary disease.[20-26]

Population for Analysis

We excluded women who left 10 or more items blank on the 1980 diet questionnaire, those with implausibly low or high scores for total food or energy intake (below 500 or above 3500 kcal per day), and those with previously diagnosed cancer, angina, myocardial infarction, stroke, or other cardiovascular diseases. We did not exclude women who reported high cholesterol levels or hypertension. Because diabetes increases the risk of coronary heart disease and can induce changes in diet and lifestyle, we excluded women who had diabetes at base line. Women given a diagnosis of diabetes during follow-up were included, but we used only the dietary information collected before the diagnosis. The final 1980 base-line population consisted of 84,129 women.

Ascertainment of End Points

We tried to review medical records for all reports of major coronary events (nonfatal myocardial infarction or death due to coronary heart disease) that occurred between the return of the 1980 questionnaire and June 1, 1994. The records were reviewed by study physicians who had no knowledge of the subjects' self-reported risk factors. Myocardial infarction was confirmed according to World Health Organization criteria, as follows: symptoms plus either diagnostic electrocardiographic changes or elevated cardiac-enzyme levels. Infarctions that required hospital admission and for which confirmatory information was obtained, but for which no medical records were available, were designated as probable (these amounted to 17 percent of all infarctions). We included all confirmed and probable cases. Deaths were identified from state vital records and the National Death Index or were reported by the subject's family or postal authorities. Information on the cause of death was available for more than 98 percent of deaths.

Confirmed deaths from coronary heart disease were defined as those caused by myocardial infarction according to hospital records or autopsy, or those for which coronary heart disease was listed as the cause of death and evidence of previous coronary disease was available. In addition to confirmed deaths from coronary heart disease, we included the deaths in which coronary heart disease was listed as the underlying cause but no records were available (15 percent of all deaths from coronary heart disease). We also included sudden deaths with no plausible cause other than coronary heart disease (12 percent of deaths from coronary heart disease). Analyses limited to confirmed cases yielded similar results, although with less precision.

Strokes were considered confirmed if they met the criteria of the National Survey of Stroke.[27] We excluded subdural hematomas and strokes caused by infection or neoplasia. Nonfatal strokes for which medical records were unavailable were defined as probable strokes and included in the analysis if they required hospitalization and were corroborated by letter or interview. Fatal strokes were confirmed by review of autopsy records, hospital records, or death certificates listing stroke as the underlying cause. In secondary analyses, strokes were added to coronary events to form the broader end point of cardiovascular events.

Statistical Analysis

The person-time for each participant was calculated from the date of return of the 1980 questionnaire to the date of the first coronary (or cardiovascular) event, death, or June 1, 1994, whichever came first. Women were classified in risk categories as described above. In multivariate models with pooled logistic regression, each

two-year interval was treated as an independent observation; we simultaneously adjusted for age, time period (seven time periods), presence or absence of a parental history of myocardial infarction before the age of 60 years, menopausal status and postmenopausal use or nonuse of hormones, presence or absence of hypertension, and the presence or absence of high cholesterol levels. In initial analyses, we calculated relative risks and 95 percent confidence intervals for categories within each factor of the low-risk profile, adjusting for the other coronary risk factors listed above, but not for the other components of the low-risk index. We then examined the low-risk group, with the various factors taken together.

We began by including only diet, smoking, and exercise. We then added body-mass index and, finally, alcohol use to examine all five factors simultaneously. In those analyses, we compared women in the low-risk category for each of the component variables with all other women, following a method previously used by Wacholder et al.[28] We calculated the population attributable risk,[29] an estimate of the percentage of coronary heart disease in this population that would not have occurred if all women had been in the low-risk group, on the assumption that there was a causal relation between the risk factors and coronary heart disease. We repeated the analysis among nonsmokers to estimate the proportion of coronary heart disease that could be prevented by adherence to the remainder of the guidelines.

To obtain the best estimate of long-term dietary intake, we used the cumulative-update method,[21] which takes the average of all previous dietary data. For example, for the interval from 1980 to 1984 we used the 1980 dietary data, and for the interval from 1984 to 1986 we used the average of 1980 and 1984. We used the same method for physical activity, which was updated in 1982, 1986, 1988, and 1992. For all other risk variables and covariates apart from diet and exercise, we used the most recent information. Body-mass index and smoking status were updated every two years, and alcohol intake was updated in 1984, 1986, and 1990.

RESULTS

During 14 years of follow-up, we documented 1128 coronary heart disease events (832 nonfatal myocardial infarctions and 296 deaths from coronary heart disease) in the study cohort. We also documented 705 strokes. Table 1 shows the estimates of the relative risk of a coronary event for each of the five factors considered in the low-risk profile and the proportion of the cohort in each risk category. These estimates have been adjusted for the other covariates but not for the other elements of the low-risk index. The most important single factor was cigarette smoking, with a relative risk of 5.48 for those smoking 15 or more cigarettes per day, as compared with nonsmokers. Even smoking 1 to 14 cigarettes per day tripled the risk. In this population, 41 percent of the coronary events could be attributed to current smoking.

In addition, each individual component of the low-risk profile showed a significant and substantial association with risk; each of the components of the dietary score was independently significant (data not shown). A gradient of risk was present within the categories of each variable that were included as low risk. For example, we included former smokers and those who had never smoked in the low-risk category, although former smokers were at significantly higher risk than those who had never smoked. Likewise, we included women who consumed more than 5 g of alcohol daily as being at low risk, although women consuming 5 to 9 g of alcohol daily were at higher

TABLE 1. DISTRIBUTIONS OF INDIVIDUAL MODIFIABLE RISK FACTORS AND RELATIVE RISK OF CORONARY EVENTS IN THE NURSES' HEALTH STUDY, 1980 TO 1994.

FACTOR	RELATIVE RISK (95% CI)*	PERCENTAGE IN EACH CATEGORY†
Dietary score (quintile)‡		
1	1.90 (1.55–2.34)	20
2	1.50 (1.21–1.88)	17
3	1.57 (1.29–1.91)	28
4	1.23 (0.98–1.55)	16
5	1.0 (reference)	20
Exercise (hr/wk)§		
<1.0	1.41 (1.15–1.75)	20
1.0–2.2	1.23 (0.99–1.53)	15
2.3–3.5	1.18 (0.94–1.47)	18
3.6–5.5	1.05 (0.82–1.34)	18
>5.5	1.0 (reference)	17
Body-mass index		
≥30.0	1.57 (1.30–1.91)	12
25.0–29.9	1.33 (1.12–1.57)	24
23.0–24.9	1.16 (0.95–1.41)	18
<23.0	1.0 (reference)	33
Smoking (cigarettes/day)		
≥15	5.48 (4.67–6.42)	15
1–14	3.12 (2.50–3.90)	7
Former smoker	1.55 (1.31–1.82)	34
Never smoked	1.0 (reference)	44
Alcohol consumption (g/day)		
0	1.65 (1.39–1.95)	34
0.1–5.0	1.41 (1.18–1.68)	33
5.1–10.0	1.26 (1.00–1.60)	11
>10.0	1.0 (reference)	22

*Relative risk was estimated from a multiple logistic-regression model and adjusted for age (in five-year categories), time periods (seven time periods), presence or absence of a parental history of myocardial infarction before the age of 60 years, menopausal status and use or nonuse of postmenopausal hormones, presence or absence of a history of hypertension, and presence or absence of a history of high cholesterol levels. CI denotes confidence interval.

†Percentages may not add to 100 because of rounding and missing values.

‡The intakes of trans fat, cereal fiber, marine n−3 fatty acids, and folate (including supplements), glycemic load, and the ratio of polyunsaturated fat to saturated fat were categorized in quintiles. For each participant, the quintile values for each nutrient were summed (a higher quintile score represented a lower risk), and the sum was recategorized into quintiles.

§Activities included vigorous sports, jogging, brisk walking, heavy gardening, heavy housework, and activities "strenuous enough to build up a sweat."

risk than those consuming 10 g or more a day. We included all women with dietary scores in the highest 40 percent as being at low risk, but within that group, those with higher scores had lower risk.

Table 2 provides estimates of the reduction in risk for women in the low-risk category for three, four, or five of the modifiable risk factors. Women in the low-risk category for all five factors considered together, as compared with all other women, had a relative risk of 0.17 (95 percent confidence interval, 0.07 to 0.41). The population attributable risk was 82 percent (95 percent confidence interval, 58 to 93), suggesting that 82 percent of the coronary events in this cohort might have been prevented if all women had been in the low-risk group.

TABLE 2. RISK OF CORONARY EVENTS IN LOW-RISK GROUPS DEFINED ACCORDING TO DIFFERENT
CONSTELLATIONS OF MODIFIABLE RISK FACTORS FOR CORONARY DISEASE
IN THE NURSES' HEALTH STUDY, 1980 TO 1994.*

GROUP	PERCENTAGE OF WOMEN IN GROUP	NO. OF CORONARY HEART DISEASE EVENTS	RELATIVE RISK (95% CI)†	POPULATION ATTRIBUTABLE RISK (95% CI)‡
				%
Three low-risk factors§	12.7	62	0.43 (0.33–0.55)	54 (42–64)
Diet score in upper 2 quintiles				
Nonsmoking				
Moderate-to-vigorous exercise ≥30 min/day				
Four low-risk factors¶	7.2	24	0.34 (0.23–0.52)	64 (46–76)
Diet score in upper 2 quintiles				
Nonsmoking				
Moderate-to-vigorous exercise ≥30 min/day				
Body-mass index <25				
Five low-risk factors	3.1	5	0.17 (0.07–0.41)	82 (58–93)
Diet score in upper 2 quintiles				
Nonsmoking				
Moderate-to-vigorous exercise ≥30 min/day				
Body-mass index <25				
Alcohol ≥5 g/day				

*CI denotes confidence interval.

†Relative risk was estimated from a multiple logistic-regression model and adjusted for age (in five-year categories), time periods (seven time periods), presence or absence of a parental history of myocardial infarction before the age of 60 years, menopausal status and use or nonuse of postmenopausal hormones, presence or absence of a history of hypertension, and presence or absence of a history of high cholesterol.

‡The population attributable risk is the percentage of coronary disease events in the population that are attributable to the nonadherence to the particular combination of lifestyle characteristics. Women with missing values were considered to be in the high-risk group.

§The model was also adjusted for body-mass index and alcohol use.

¶The model was also adjusted for alcohol use.

As shown in Table 3, we repeated this analysis with only the 78 percent of women who were not currently smoking. Women who were in the low-risk category for the remaining four risk factors, as compared with all other current nonsmokers, had a relative risk of 0.25 (95 percent confidence interval, 0.10 to 0.60). The population attributable risk was 74 percent (95 percent confidence interval, 39 to 90 percent), suggesting that among the nonsmokers, 74 percent of the coronary disease events might have been prevented by compliance with the remaining components of the low-risk index.

To adjust for possible confounding according to socioeconomic status, we conducted further analyses in which we controlled for the parents' occupation and husband's education. This had no substantial effect on the estimates (for example, the relative risk in the low-risk group went from 0.17 to 0.19).

Only about 3 percent of the population met the criteria for low risk. To address the possibility that these women represented a unique and peculiar subgroup, we performed further analyses, successively relaxing the criteria. We observed a graded effect on the population attributable risk. For example, if women at low risk were defined as those not currently smoking, having dietary scores among the highest 45 percent, exercising at least 25 minutes a day, having a body-mass index under 26, and drinking at least 4 g of alcohol a day (a group that constituted 5.1 percent of the population), the population attributable risk would be 72 percent (95 percent confidence interval, 47 to 83 percent). Further relaxation of the criteria to include 10 percent of the population (at least 15 minutes of exercise a day, consumption of more than 2 g of alcohol a day, and a body-mass index of less than 28) yielded a relative risk of 0.36 (95 percent confidence interval, 0.26 to 0.50) and a population attributable risk of 62 percent (95 percent confidence interval, 47 to 72 percent).

Table 4 shows the results for analyses of major cardiovascular disease (coronary events plus stroke). Women in the low-risk group had a relative risk of 0.25 (95 percent confidence interval, 0.14 to 0.44), with a population attributable risk of 74 percent (95 percent confidence interval, 55 to 86 percent).

DISCUSSION

In this population of middle-aged women, those who did not smoke cigarettes, were not overweight, maintained the healthful diet described above, exer-

TABLE 3. Risk of Coronary Events in Low-Risk Groups Defined According to Different Constellations of Modifiable Risk Factors for Coronary Disease among Current Nonsmokers in the Nurses' Health Study, 1980 to 1994.*

Group	Percentage of Women in Group	No. of Coronary Heart Disease Events	Relative Risk (95% CI)†	Population Attributable Risk (95% CI)‡
				%
Two low-risk factors§	16.4	62	0.68 (0.52–0.88)	28 (10–44)
Diet score in upper 2 quintiles				
Moderate-to-vigorous exercise ≥30 min/day				
Three low-risk factors¶	9.4	24	0.54 (0.36–0.82)	43 (17–62)
Diet score in upper 2 quintiles				
Moderate-to-vigorous exercise ≥30 min/day				
Body-mass index <25				
Four low-risk factors	4.0	5	0.25 (0.10–0.60)	74 (39–90)
Diet score in upper 2 quintiles				
Moderate-to-vigorous exercise ≥30 min/day				
Body-mass index <25				
Alcohol ≥5 g/day				

*CI denotes confidence interval.

†Relative risk was estimated from a multiple logistic-regression model and adjusted for age (in five-year categories), time periods (seven time periods), presence or absence of a parental history of myocardial infarction before the age of 60 years, menopausal status and use or nonuse of postmenopausal hormones, presence or absence of a history of hypertension, and presence or absence of a history of high cholesterol levels.

‡The population attributable risk is the percentage of coronary disease events in the population that are attributable to the nonadherence to the particular combination of lifestyle characteristics.

§The model was also adjusted for body-mass index and alcohol use.

¶The model was also adjusted for alcohol use.

cised moderately or vigorously for half an hour a day, and consumed alcohol moderately had an incidence of coronary events that was more than 80 percent lower than that in the rest of the population. Closer adherence to a more healthful lifestyle might reduce the risk of coronary heart disease still further.

This analysis has several important limitations. Despite the large numbers of subjects and the long follow-up, the estimates were somewhat imprecise, largely because there were few cases of coronary heart disease among women in the low-risk categories. Indeed, we could not provide reliable estimates on which to base more stringent recommendations because of the small number of cases. The fact that the incidence of coronary events increases in a graded fashion as the criteria for low risk are relaxed supports the robustness of the findings, and suggests that the results do not apply solely to a select group of peculiarly health-conscious persons. Some of the lifestyle characteristics (especially diet and physical activity) were measured with error, which undoubtedly caused some misclassification. However, with the prospective design, such misclassification would tend to lead to an underestimate of the true effect. Some factors we considered have not been tested in randomized trials with clinical end points. However, ample observational data support their use. For some variables, there probably will never be randomized trials of primary prevention, so we must make decisions on the basis of the best available information.

For simplicity, we considered only a limited set of variables. For example, we did not include consumption of nuts,[30,31] linolenic acid,[32] vitamin B$_6$,[23] or vitamin E[33-35] or the use of aspirin or postmenopausal hormones.[36,37] Larger reductions in risk might be possible with these added preventive factors. Some of these factors may be especially worthy of consideration for women who avoid alcohol to minimize the risk of breast cancer[38] or because of a personal or family history of alcoholism.

We also did not consider pharmacologic treatment of hypertension and of lipid levels, which has proved efficacious in the prevention of coronary heart disease. However, we did adjust for these factors in the analysis. Since part of the effect of diet and lifestyle is mediated through improvements in lipid levels and blood pressure, adjustment for those conditions might lead to an underestimate of the overall benefit of the factors we considered. Our nurse participants are more likely to receive treatment for these conditions than the general population. However, not all participants are receiving optimal therapy; there is thus a greater potential for prevention, if all treatments are considered. Our results complement those of Stamler et al.,[39] who found that the relative risk of death from coronary heart disease ranged from 0.08 to 0.23

TABLE 4. RISK OF CORONARY EVENTS OR STROKE (CARDIOVASCULAR EVENTS) IN LOW-RISK GROUPS DEFINED ACCORDING TO DIFFERENT CONSTELLATIONS OF MODIFIABLE RISK FACTORS FOR MAJOR CARDIOVASCULAR DISEASE IN THE NURSES' HEALTH STUDY, 1980 TO 1994.*

GROUP	PERCENTAGE OF WOMEN IN GROUP	NO. OF CARDIOVASCULAR EVENTS	RELATIVE RISK (95% CI)†	POPULATION ATTRIBUTABLE RISK (95% CI)‡
				%
Three low-risk factors§	12.7	106	0.46 (0.37–0.55)	51 (42–60)
Diet score in upper 2 quintiles				
Nonsmoking				
Moderate-to-vigorous exercise ≥30 min/day				
Four low-risk factors¶	7.2	44	0.38 (0.28–0.51)	60 (47–70)
Diet score in upper 2 quintiles				
Nonsmoking				
Moderate-to-vigorous exercise ≥30 min/day				
Body-mass index <25				
Five low-risk factors	3.1	12	0.25 (0.14–0.44)	74 (55–86)
Diet score in upper 2 quintiles				
Nonsmoking				
Moderate-to-vigorous exercise ≥30 min/day				
Body-mass index <25				
Alcohol ≥5 g/day				

*CI denotes confidence interval.

†Relative risk was estimated from a multiple logistic-regression model and adjusted for age (in five-year categories), time periods (seven time periods), presence or absence of a parental history of myocardial infarction before the age of 60 years, menopausal status and use or nonuse of postmenopausal hormones, presence or absence of a history of hypertension, and presence or absence of a history of high cholesterol.

‡The population attributable risk is the percentage of major cardiovascular events in the population that are attributable to the nonadherence to the particular combination of lifestyle characteristics.

§The model was also adjusted for body-mass index and alcohol use.

¶The model was also adjusted for alcohol use.

in low-risk persons, defined as nondiabetic subjects with no history of coronary disease who were not current smokers and who had cholesterol levels of less than 200 mg per deciliter (5.17 mmol per liter) and blood pressure of 120/80 mm Hg or less.

By simultaneously examining the effect of several lifestyle variables, we took into account the clustering of healthful types of behavior within individual women. In addition, we adjusted for many coronary risk factors. Nevertheless, confounding by other variables, particularly socioeconomic status, could have affected our results. However, all the participants were registered nurses with some college education. Analysis of home addresses according to census-tract data found substantial economic homogeneity (Laden F: personal communication). Furthermore, adjustment for parental occupation and the husband's education had little effect on the findings. Indeed, at least some of the health benefits of higher socioeconomic status are mediated through the lifestyle variables we studied.

Thus, although vigorous pharmacologic treatment of hypertension and lipid levels (when necessary) has been proved effective, these data support the hypothesis that adopting a more healthful lifestyle could prevent a substantial majority of coronary disease events in women.

REFERENCES

1. Willett W, Stampfer MJ, Bain C, et al. Cigarette smoking, relative weight, and menopause. Am J Epidemiol 1983;117:651-8.
2. Colditz GA, Martin P, Stampfer J, et al. Validation of questionnaire information on risk factors and disease outcomes in a prospective cohort study of women. Am J Epidemiol 1986;123:894-900.
3. Wolf AM, Hunter DJ, Colditz GA, et al. Reproducibility and validity of a self-administered physical activity questionnaire. Int J Epidemiol 1994;23:991-9.
4. Chasan-Taber S, Rimm EB, Stampfer MJ, et al. Reproducibility and validity of a self-administered physical activity questionnaire for male health professionals. Epidemiology 1996;7:81-6.
5. Manson JE, Hu FB, Rich-Edwards JW, et al. A prospective study of walking as compared with vigorous exercise in the prevention of coronary heart disease in women. N Engl J Med 1999;341:650-8.
6. Willett WC. Nutritional epidemiology. 2nd ed. Vol. 30 of Monographs in epidemiology and biostatistics. New York: Oxford University Press, 1998.
7. Willett WC, Green A, Stampfer MJ, et al. Relative and absolute excess risks of coronary heart disease among women who smoke cigarettes. N Engl J Med 1987;317:1303-9.
8. Colditz GA, Bonita R, Stampfer MJ, et al. Cigarette smoking and risk of stroke in middle-aged women. N Engl J Med 1988;318:937-41.
9. Kawachi I, Colditz GA, Stampfer MJ, et al. Smoking cessation in relation to total mortality rates in women: a prospective cohort study. Ann Intern Med 1993;119:992-1000.
10. Kawachi I, Colditz GA, Stampfer MJ, et al. Smoking cessation and

time course of decreased risks of coronary heart disease in middle-aged women. Arch Intern Med 1994;154:169-75.

11. Rosenberg L, Palmer JR, Shapiro S. Decline in the risk of myocardial infarction among women who stop smoking. N Engl J Med 1990;322: 213-7.

12. Stampfer MJ, Colditz GA, Willett WC, Speizer FE, Hennekens CH. A prospective study of moderate alcohol consumption and the risk of coronary disease and stroke in women. N Engl J Med 1988;319:267-73.

13. Rimm EB, Klatsky A, Grobbee D, Stampfer MJ. Review of moderate alcohol consumption and reduced risk of coronary heart disease: is the effect due to beer, wine, or spirits? BMJ 1996;312:731-6.

14. Thun MJ, Peto R, Lopez AD, et al. Alcohol consumption and mortality among middle-aged and elderly U.S. adults. N Engl J Med 1997;337: 1705-14.

15. Sacco RL, Elkind M, Boden-Albala B, et al. The protective effect of moderate alcohol consumption on ischemic stroke. JAMA 1999;281:53-60.

16. van Gijn J, Stampfer MJ, Wolfe C, Algra A. The association between alcohol and stroke. In: Verschuren PM, ed. Health issues related to alcohol consumption. Washington, D.C.: ILSI Press, 1993:43-79.

17. Pate RR, Pratt M, Blair SN, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA 1995;273:402-7.

18. National Center for Chronic Disease Prevention and Health Promotion, President's Council on Physical Fitness and Sports. Physical activity and health: a report of the Surgeon General. Atlanta: Centers for Disease Control and Prevention, 1996.

19. Willett WC, Manson JE, Stampfer MJ, et al. Weight, weight change, and coronary heart disease in women: risk within the 'normal' weight range. JAMA 1995;273:461-5.

20. Willett WC, Stampfer MJ, Manson JE, et al. Intake of trans fatty acids and risk of coronary heart disease among women. Lancet 1993;341:581-5.

21. Hu FB, Stampfer MJ, Manson JE, et al. Dietary fat intake and the risk of coronary heart disease in women. N Engl J Med 1997;337:1491-9.

22. Wolk AM, Manson JE, Stampfer MJ, et al. Long-term intake of dietary fiber and decreased risk of coronary heart disease among women. JAMA 1999;281:1998-2004.

23. Rimm EB, Willett WC, Hu FB, et al. Folate and vitamin B_6 from diet and supplements in relation to risk of coronary heart disease among women. JAMA 1998;279:359-64.

24. Albert CM, Hennekens CH, O'Donnell CJ, et al. Fish consumption and risk of sudden cardiac death. JAMA 1998;279:23-8.

25. Liu S, Stampfer M, Manson J, et al. A prospective study of dietary intake of carbohydrate, glycemic load and risk of myocardial infarction in US women. Am J Clin Nutr 2000;71:1455-61.

26. Stone PH, Sacks FM. Strategies for secondary prevention. In: Manson JE, Ridker PM, Gaziano JM, Hennekens CH, eds. Prevention of myocardial infarction. New York: Oxford University Press, 1996:463-510.

27. Walker AE, Robins M, Weinfeld FD. The National Survey of Stroke: clinical findings. Stroke 1981;12:Suppl 1:I13-I44.

28. Wacholder S, Benichou J, Heineman EF, Hartge P, Hoover RN. Attributable risk: advantages of a broad definition of exposure. Am J Epidemiol 1994;140:303-9. [Erratum, Am J Epidemiol 1994;140:668.]

29. Rothman KJ, Greenland S. Modern epidemiology. 2nd ed. Philadelphia: Lippincott–Raven, 1998.

30. Hu F, Stampfer M. Nut consumption and risk of coronary heart disease: a review of epidemiologic evidence. Curr Atheroscler Rep 1999;1: 204-9.

31. Hu FB, Stampfer MJ, Manson JE, et al. Frequent nut consumption and risk of coronary heart disease in women: prospective cohort study. BMJ 1998;317:1341-5.

32. Hu F, Stampfer M, Manson J, et al. Dietary intake of alpha-linolenic acid and risk of fatal ischemic heart disease among women. Am J Clin Nutr 1999;69:890-7.

33. Stampfer MJ, Hennekens CH, Manson JE, Colditz GA, Rosner B, Willett WC. Vitamin E consumption and the risk of coronary disease in women. N Engl J Med 1993;328:1444-9.

34. Stephens NG, Parsons A, Schofield PM, Kelly F, Chesseman K, Mitchinson MJ. Randomised controlled trial of vitamin E in patients with coronary disease: Cambridge Heart Antioxidant Study. Lancet 1996;347:781-6.

35. GISSI-Prevenzione Investigators (Gruppo Italiano per lo Studio della Sopravvivenza nell'Infarto Miocardico). Dietary supplementation with n-3 polyunsaturated fatty acids and vitamin E after myocardial infarction: results of the GISSI-Prevenzione trial. Lancet 1999;354:447-55.

36. Steering Committee of the Physicians' Health Study Research Group. Final report on the aspirin component of the ongoing Physicians' Health Study. N Engl J Med 1989;321:129-35.

37. Grodstein F, Stampfer MJ, Colditz GA, et al. Postmenopausal hormone therapy and mortality. N Engl J Med 1997;336:1769-75.

38. Smith-Warner SA, Spiegelman D, Yaun S-S, et al. Alcohol and breast cancer in women: a pooled analysis of cohort studies. JAMA 1998;279: 535-40.

39. Stamler J, Stamler R, Neaton JD, et al. Low risk-factor profile and long-term cardiovascular and noncardiovascular mortality and life expectancy: findings for 5 large cohorts of young adult and middle-aged men and women. JAMA 1999;282:2012-8.