Secular trends in diet and risk factors for cardiovascular disease: The Framingham Study

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ABSTRACT

Objective In this study we examined changes in dietary intake and risk factors for cardiovascular disease that occurred over three decades in a US-population–based sample.
Design Secular trends in dietary profiles and risk factors were studied in cross-sectional samples of subjects from the Framingham Study in 1957-1960, 1966-1969, and 1984-1988.
Results Dietary levels of cholesterol appeared to have declined considerably, whereas macronutrient and fatty acid intakes appeared to change only slightly. Men appeared to increase their saturated fat intakes from 16.4% in 1966-1969 to 17.0% in 1984-1988 (P<.01). In spite of relatively stable mean total fat intake levels, 35% to 60% of Framingham Study men and women reported decreased consumption of higher-fat animal products over the 10-year period between 1974-1978 and 1984-1988. Framingham subjects who reported modifying their diets by substituting lower-fat foods for high-fat items between 1974-1978 and 1984-1988 were more likely to achieve the guidelines of the National Cholesterol Education Program and Healthy People 2000 for dietary fat and cholesterol intake and for serum total cholesterol level. Levels of systolic and diastolic blood pressure, total and low-density lipoprotein cholesterol, and cigarette smoking were also lower in 1984-1988 than in earlier times. Compared with 1957-1960, mean body mass index and prevalence rates of overweight and hypertension were higher in 1984-1988, despite higher levels of reported physical activity.
Conclusions The observed secular trends in diet and risk factor levels for cardiovascular disease in the Framingham population are important to guide the development and implementation of population-based strategies for promoting cardiovascular health, including nutrition interventions. *J Am Diet Assoc. 1995; 95:171-179.*

In spite of a decline of about 3% per year in mortality rates for coronary heart disease (CHD) since 1968, CHD remains the major cause of death in the United States (1). The search for causal factors has led to an examination of risk factors and lifestyle behaviors that may contribute to the development of the disease. The Adult Treatment Panel II of the National Cholesterol Education Program (NCEP) recognized the following as major risk factors for CHD: elevated serum total cholesterol level, particularly in combination with high levels of low-density lipoprotein (LDL) cholesterol, age (≥45 years for men and ≥55 years for women), low levels of high-density lipoprotein (HDL) cholesterol, hypertension, diabetes mellitus, cigarette smoking, and family history of premature CHD (2). In addition, obesity and physical inactivity were identified as important CHD risk factors that should be targeted for intervention activities.

In 1992, the Healthy People 2000 objectives for the nation (3) were published. These nutrition guidelines were consistent with NCEP recommendations for lowering CHD risk (2,4) and recommended dietary fat intakes of 30% of total energy or less and saturated fat intakes of less than 10% of total energy. The guidelines also suggested that complex carbohydrates and fiber-containing foods be increased and that sodium intake be decreased (3). In addition, the NCEP recommended a dietary cholesterol intake that does not exceed 300 mg/day (2,4).

Detection of secular trends in dietary intake patterns and risk factor status of the population, and assessment of potential associations between them, are useful in interpreting national changes in CHD risk and mortality rates. They also provide direction for the design of appropriate preventive interventions. This article examines these trends over three periods of the Framingham Study: 1957-1960, 1966-1969, 1984-1988. Data from the first two periods were gathered in two cross-sectional samples from the original Framingham Heart Study cohort; data from the third period were collected cross-sectionally from the Framingham Offspring-Spouse Study.

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METHODS

The Framingham Study

The Framingham Heart Study was initiated in 1948 with the examination of 5,209 subjects, 2,873 women and 2,336 men, aged 30 to 62 years (5). Survivors of this original cohort have been monitored every 2 years; during these biennial examinations, data concerning risk factor status were collected.

In 1971, 5,135 Framingham Study offspring and spouses, 12 to 60 years of age, were recruited to participate in the Framingham Offspring-Spouse Study, which was designed to assess genetic and familial disposition toward CHD and to examine secular trends in cardiovascular disease risk across generations. The design of this cohort was described by Kannel et al (6).

Assessment of Nutrient Intake

During exams 4 through 6 (1957-1960) of the Framingham Heart Study, data on usual dietary intake were collected from a sample of men and women (n=435 and 473, respectively, aged 37 to 70 years) using the diet history method of Burke (7). This technique consisted of an hour-long interview guided by open-ended questions that elicited the quantities of food eaten on a typical day. The data were coded and categorized using a precoded tally sheet with 133 food groups — the Framingham Composite Table (8). Food quantities were converted into estimates of nutrient intake using nutrient composition data from this time period (8).

The second dietary analysis was performed during exams 9 through 11 of the Framingham Heart Study (1966-1969) by means of the 24-hour recall method (8,9). The dietary data collection method was designed to be comparable with that used in the Honolulu and Puerto Rico heart studies (9-11). Only men (n=859, aged 47 to 65 years) were interviewed. Household measures were used to determine portion sizes; the reported food intakes were summed on the Framingham Composite Table according to standardized protocols (8). The nutrient content of the reported foods was estimated using food composition data published at that time (8).

A third collection of dietary data was conducted among all participants (n=3,873, aged 18 to 77 years) during exam 3 of the Framingham Offspring-Spouse Study (1984-1988). A comprehensive dietary behavior assessment consisted of a 24-hour recall, food habit questionnaire, semiquantitative food frequency questionnaire, and 3-day food record (12). The 24-hour recall was performed by a trained nutritionist; food portion sizes were determined using a validated two-dimensional visual aid to help respondents report portions of foods consumed (13,14).The Framingham exam clinic was open Mondays through Saturdays, and recalls were collected for the prior 24-hour period (Sundays through Fridays) for any given person. In a subsample, 24-hour recalls and 3-day food records yielded comparable estimates of group mean nutrient intake (12); thus, the 24-hour recall data for the 1984-1988 cohort are reported in this article. The 24-hour recall data were coded using an interactive, computerized Nutrition Data Management System (Boston University, Boston, Mass) according to formal coding procedures (12-14). Protocols of US Department of Agriculture (USDA) (15) and predetermined standards were used to estimate unknown food items and portion sizes. Nutrient composition of foods was determined using the computerized Michigan State database (16). We considered examining the extent to which the nutrient databases may have contributed to differences in intakes reported here. However, data from 1957-1960 and 1966-1969 are available only in summary file format, so such analyses were not possible.

Because different dietary assessment methods were used during three decades in the Framingham Study, and in light of the observation that the diet history overestimates nutrient intake (17), this article does not focus on energy intake differences between the study periods. We report macronutrient intake as density variables (expressed as percentage of total energy). This technique adjusts for energy intake and makes nutrient data more comparable across periods.

Risk Factor Assessment

Risk factor data presented here were collected at two Framingham Heart Study exams (in 1957-1960 at exams 4 through 6 in 435 men and 473 women, aged 37 to 70 years, and in 1966-1969 at exams 9 through 11 in 865 men, aged 47 to 65 years) and in one Framingham Offspring-Spouse Study exam (in 1984-1988 at exam 3 in 1,602 men and 1,704 women, aged 37 to 70 years). Approximately 200 men were included in both the 1957-1960 and 1966-1969 cohorts. The risk factors assessed were age, systolic and diastolic blood pressure, cigarette smoking, body mass index, physical activity, blood total cholesterol, and triglycerides. Levels of LDL, HDL, and very-low-density lipoprotein (VLDL) cholesterol were measured at cohort exams 9 through 11 and exam 3 of the Framingham Offspring-Spouse Study. Methods for determining risk factor status within the Framingham Study have been summarized by Cupples et al (5) and are highlighted here.

Blood pressure was determined by a single measurement on the subject's nondominant arm using a mercury sphygmomanometer. Treated hypertension was defined as the use of antihypertensive medication. Cigarette smoking was self-reported. Overweight and severe overweight were defined using the body mass index to evaluate body weight for height greater than the 85th and 95th percentiles, respectively, for US adults according to the 2nd National Health and Nutrition Examination Survey (NHANES II) population distribution (3,18). Physical activity was assessed by questionnaire to ascertain estimates of activity in a usual day based on a 24-hour history. A physical activity index was calculated from the numbers of hours per day spent in specific types of activities that were categorized (sedentary or slight, moderate, or heavy activity) and weighted according to the oxygen consumption required to perform such activities. Scores ranged from 24 (total bed rest) to 120. At exams 4 through 6 of the Framingham Heart Study cohort, serum cholesterol concentrations were determined by the method of Abell et al (19). At exams 9 through 11 and in the Framingham Offspring-Spouse Study, venous blood was drawn from subjects after a 12- to 24-hour fast and mixed with ethylenediaminetetraacetate to give a final concentration of 0.1%. Aliquots of plasma were obtained by centrifugation. Total and HDL cholesterol levels and triglyceride levels were determined using automated enzymatic methods (20,21); VLDL and LDL cholesterol levels were assessed using the method of Friedewald et al (22). Because plasma cholesterol concentrations have been shown to be 3% lower than serum values (23), we adjusted the 1957-1960 serum total cholesterol values to make them comparable with plasma levels from later times.

Analytic Techniques

Descriptive statistics, including means and percentages, were computed for each period: 1957-1960, 1966-1969, and 1984-1988. Analyses were performed to exclude from the 1966-1969 sample the 200 men who were in both cohorts (1957-1960 and 1966-1969), but results were not substantially different from analyses using the overlapping samples. Therefore, we included the men in both samples in the presentation of descriptive results. *P* values, however, represent tests of significance that were performed on the independent samples. For continuous measures such as blood pressure and total cholesterol level, age-adjusted means were computed according to analysis of covariance techniques. Categorical measures were adjusted by direct standardization using the combined age distribution over the study periods. In the latter

Table 1
Secular trends in age-adjusted[a] mean dietary factors: Framingham Study men (1957-1960, 1966-1969, 1984-1988) and women (1957-1960, 1984-1988)

Dietary factor	Men			Women	
	1957-1960 (aged 37-70 y, n=435)	1966-1969 (aged 47-65 y, n=865)	1984-1988 (aged 37-70 y, n=1,602)	1957-1960 (aged 37-70 y, n=473)	1984-1988 (aged 37-70 y, n=1,704)
Energy (kcal)	3,128.7	2,677.6	2,272.6****	2,138.7	1,536.2****
Protein (% kcal)	16.0	15.7	17.0****	16.9	17.5*
Carbohydrate (% kcal)	41.4	38.2	41.2****	42.6	43.0
Cholesterol (mg)	702.4	535.4	376.2****	490.8	253.6****
Cholesterol (mg/1,000 kcal)	228.0	205.9	165.4****	233.3	167.0****
Fat (% kcal)	38.7	39.4	38.4*	39.7	38.0***
P:S ratio[b]	0.39	0.34	0.34***	0.41	0.37*
Saturated fat (% kcal)[c,d]	NA[e]	16.4[c] (15.2)[d]	17.0**[c] (13.4)[d]	NA	16.7[c] (13.1)[d]
Monounsaturated fat (% kcal)[c,d]	NA	17.2 (15.9)[d]	15.1***[c] (12.0)[d]	NA	14.4[c] (11.3)[d]
Polyunsaturated fat (% kcal)[c,d]	NA	5.9[c] (5.5)[d]	6.2*[c] (4.9)[d]	NA	6.9[c] (5.4)[d]

[a]Age adjustment was performed using the combined age distribution over all periods for which data for the nutrient were available. Individual fatty acid components for women in 1984-1988 were not age adjusted because data from earlier time frames were not available.
[b]Medians were reported because of extreme skewness of the ratio of polyunsaturated fat to saturated fat (P:S ratio). Significant differences exist among men (P=.0001) and women (P=.0114) with respect to the P:S ratio using the Kruskal-Wallis test for differences among the medians. Mean values for the P:S ratio in men are 0.40, 0.39, and 0.44 for the 1957-1960, 1966-1969, and 1984-1988 periods, respectively. Mean values for women are 0.42 and 0.50 for the 1957-1960 and 1984-1988 periods, respectively. Age-adjusted analysis of variance showed significant differences among men (P=.0012) and women (P=.0001) with respect to the mean P:S ratio.
[c]Adjusted for missing values in nutrient data bank.
[d]Unadjusted for missing values in nutrient data bank.
[e]NA=not applicable.
****P<.0001; ***P<.001; **P<.01; *P<.05.

analyses, tests of significance for differences over time were conducted using a Mantel-Haenszel test of homogeneity.

All dietary differences over time were age adjusted and evaluated through analysis of covariance methods. Mean nutrient intake at each period was estimated using different nutrient databases that had varying levels of missing information on fatty acids. Thus, estimates were adjusted on the percentages of saturated, monounsaturated, and polyunsaturated fatty acids to the total level of fat consumed. This was done by dividing the respective percentages by the proportion of total fat with known fatty acid components. For example, if a subject consumed 70 g total fat but only 50 g came from foods that had complete data on monounsaturated, polyunsaturated, and saturated fatty acids in the database, then an observed saturated fat intake of 20 g was divided by 50/70 to produce an adjusted saturated fat intake level of 28 g. Use of this procedure allowed for the comparison of fatty acid intakes across periods, while adjusting for the different levels of nutrient information missing from databases.

Subjects of the Framingham Offspring-Spouse Study were also asked about changes in their diets during the 10 years before exam 3 (1984-1988). The percentage of subjects who indicated that they did not consume certain food items is reported as well as changes in consumption during the 10-year period (decreased, increased, or stayed the same). χ^2 Analyses were used to examine the relationships between these responses and exam 3 total cholesterol levels and dietary fat and cholesterol consumption. For this analysis, subjects were classified according to those with total cholesterol levels greater than 6.20 mmol/L[1] vs those at or less than this level. Dietary fat and cholesterol consumption were categorized according to Healthy People 2000 and NCEP criteria (2,4) (less than 30% of energy from total fat and less than 300 mg of cholesterol intake per day). Subjects were classified according to whether they met or did not meet these dietary criteria. In addition, subjects were divided into two groups according to self-reported changes in dietary consumption: those who decreased consumption or did not consume the item and those who consumed the same amount or increased their intake level. Relative risks comparing group 1 with group 2 were computed for the likelihood of satisfying NCEP and Healthy People 2000 guidelines.

RESULTS

Table 1 presents the age-adjusted mean nutrient intakes for Framingham men in 1957-1960, 1966-1969, and 1984-1988 and for Framingham women in 1957-1960 and 1984-1988. Because of the skewness of the ratio of polyunsaturated fat to saturated fat (P:S ratio), the median values are reported. In men, the proportions of energy derived from carbohydrate, protein, and fat were significantly different over the periods but varied only slightly in any clinically meaningful way. For example, fat intake as a percentage of energy was 38.7% in 1957-1960, 39.4% in 1966-1969, and 38.4% in 1984-1988 (P<.05). In contrast, mean dietary cholesterol intakes were progressively lower over the time frames: 702 mg/day in 1957-1960, 535 mg/day in 1966-1969, and 376 mg/day in 1984-1988 (P<.0001). Saturated and polyunsaturated fats, on the other hand, were higher in 1984-1988 than in 1966-1969 (17.0% vs 16.4% [P<.01], and 6.2% vs 5.9% [P.05], respectively), whereas monounsaturated fats were lower (15.1% vs 17.2%, respectively [P<.001]). The median P:S ratio remained stable between 1966-1969 and 1984-1988.

In women, dietary cholesterol intakes were considerably lower in 1984-1988 than in 1957-1960 (254 mg/day vs 491 mg/day, respectively [P<.0001]). Total fat intakes were slightly lower and

[1]To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.7. To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.026. Cholesterol of 5.00 mmol/L=193 mg/dL.

Table 2
Ten year self-reported change in food intake patterns among men and women 37 to 70 years old: Framingham Offspring-Spouse Study

Food Items	Decreased Intake		Same Intake		Increased Intake		Don't use	
	Men	Women	Men	Women	Men	Women	Men	Women
	%							
Meats and alternatives								
Red meat	45.6	60.0	51.0	37.5	2.2	1.2	1.2	1.3
Poultry	2.9	2.1	46.8	39.4	49.6	58.1	0.7	0.4
Fish	3.0	2.9	41.2	40.5	52.7	54.0	3.1	2.7
Eggs	52.7	48.4	39.7	44.5	4.4	3.9	3.2	3.2
Vegetarian products	9.6	9.5	22.2	15.7	3.2	4.0	64.9	70.7
Dairy foods								
Cheese	18.4	19.9	65.6	65.1	13.5	13.9	2.5	1.2
Whole milk	54.6	53.5	25.8	20.8	1.8	1.5	17.7	24.2
Low-fat or skim milk	9.2	8.0	21.4	20.8	37.0	45.3	32.3	25.9
Butter	44.3	45.3	29.6	25.1	3.2	3.1	23.0	26.4
Stick margarine	18.8	23.0	45.5	44.3	16.8	15.0	18.9	17.8
Soft margarine	13.3	13.6	31.6	24.4	16.3	18.8	38.8	43.2
Fruits	4.6	4.1	58.1	53.9	35.8	41.1	1.5	0.9
Vegetables	1.8	1.8	58.7	48.8	39.2	49.3	0.3	0.1
Breads and cereals								
Whole grains	8.9	7.4	52.2	48.1	22.9	31.5	16.0	13.0
Commercial-baked goods	38.1	44.0	46.8	36.9	5.3	6.2	9.8	12.9
Home-baked goods	35.1	46.1	50.6	42.6	5.4	5.3	8.9	6.0
Alcohol	27.6	26.1	48.8	44.9	11.4	9.8	12.2	19.3
Salt	47.3	52.5	35.4	30.9	1.9	1.2	15.3	15.4

protein intakes were higher in 1984-1988 in contrast to the late 1950s (38.0% vs 39.7% [$P<.001$] and 17.5% vs 16.9% [$P<.05$], respectively). The percentage of energy from carbohydrate was not significantly different. In 1984-1988, levels of saturated, monounsaturated, and polyunsaturated fat were 16.7%, 14.4%, and 6.9%, respectively. (Data from 1957-1960 were not available.)

Table 2 presents the respondents' self-reported changes in consumption of selected foods over the 10 years, 1974-1978 through 1984-1988. Thirty-five percent to 55% of men and slightly more women (44% to 60%) reported decreasing their consumption of red meat, eggs, whole milk, butter, home- and commercial-baked goods, and salt, whereas 26% to 51% of men and 20% to 45% of women reported eating the same amounts of these items over this time frame. Similar proportions of men (36 to 52%) and women (32% to 58%) reported increasing their consumption of poultry, fish, low-fat and skim milk, whole grains, and fruits and vegetables. Overall, 22% to 59% of men and 21% to 54% of women reported not altering their intakes of any of these items over the 10-year period. Cheese intakes appeared to change least, with about 65% of men and women reporting no change in cheese consumption from the late 1970s to 1980s. Commercial vegetarian products were the most infrequently consumed items among both men and women. In addition, 63% of women reported making a change in their eating habits "to be healthier," whereas only 56% of men reported making similar changes.

Table 3 presents the age-adjusted mean risk factor levels for Framingham men between 1957-1960, 1966-1969, and 1984-1988 and for women between 1957-1960 and 1984-1988. Mean systolic and diastolic blood pressure levels were analyzed separately for those persons receiving antihypertensive medication and for those who were untreated. The trends were consistent within the treatment subgroups, so the overall means are presented.

In men, mean levels of systolic blood pressure, prevalence of cigarette smoking, and levels of total cholesterol and LDL cholesterol were significantly lower in 1984-1988 in comparison with earlier times. For example, the mean total cholesterol was 5.57 mmol/L in 1984-1988 in contrast with 5.94 mmol/L in 1957-1960 and 5.71 mmol/L in 1966-1969 ($P<.0001$); LDL cholesterol levels were 3.71 mmol/L in 1966-1969 and 3.59 mmol/l in 1984-1988 ($P<.001$). Levels of HDL cholesterol and triglycerides were not significantly different between 1966-1969 and 1984-1988. The proportion of men with treated hypertension appeared to rise with the advent of antihypertensive medication in the early 1960s: 21.5% of men were treated for hypertension in 1984-1888 compared with 5.8% in 1966-1969 and 0.9% in 1957-1960 ($P<.0001$).

In women, systolic and diastolic blood pressure levels, prevalence of cigarette smoking, and total cholesterol levels were all significantly lower in 1984-1988 in comparison with earlier times. As in men, the proportion of women with treated hypertension rose in 1984-1988 to 19.1%, from 6.1% in 1957-1960 ($P<.0001$).

Despite higher reported levels of physical activity among both men and women, mean body mass index in 1984-1988 was significantly higher than in earlier periods. Prevalence rates of overweight (significant only for men [$P<.0001$]) and severe overweight ($P<.0001$) increased among Framingham men and women over the 30-year observation period.

Table 4 summarizes the relative risks in men and women of satisfying the NCEP criteria for total cholesterol (<6.20 mmol/L), dietary fat (30% of energy), and dietary cholesterol (300 mg/day) associated with decreased or nonconsumption of various food items vs the same or increased use over the "past 10 years."

The NCEP dietary cholesterol guidelines were more likely met in men and women who had *decreased* their intakes of red meat, poultry (in women only), eggs, cheese, whole milk, butter, and salt. For example, men who had decreased their consumption of eggs were 1.35 times more likely to consume less than 300 mg dietary cholesterol per day.

NCEP dietary fat recommendations were more likely met in persons who had decreased intake of red meat, eggs (in men only), cheese, whole milk, butter, soft margarine (in men only),

Table 3
Secular trends in age-adjusted mean risk factor status: Framingham Study men (1957-1960, 1966-1969, 1984-1988) and women (1957-1960, 1984-1988)

Risk factor	Men			Women	
	1957-1960 (aged 37-70 y, n=435)	1966-1969 (aged 47-65 y, n=865)	1984-1988 (aged 37-70 y, n=1,602)	1957-1960 (aged 37-70 y, n=473)	1984-1988 (aged 37-70 y, n=1,704)
Age (y)	50.7	55.9	50.7****	50.4	50.2
Systolic blood pressure (mm Hg)	131.2	134.2	129.3****	130.9	124.1****
Diastolic blood pressure (mm Hg)	82.1	82.3	82.3	80.6	78.3****
Treated hypertension[a] (%)	0.9	5.8	21.5****	6.1	19.1****
Cigarette smoking (% smoking)	57.1	40.7	27.3****	44.3	28.4****
Body mass index (weight[kg]/height[m]^2)	25.8	26.9	27.4****	24.9	25.7**
Overweight[b] (%)	25.3	33.7	40.2****	24.9	29.0
Severe overweight[c] (%)	5.4	10.3	14.8****	4.5	11.1****
Physical activity[d]	32.3	34.3	35.4***	30.9	33.7****
Blood total cholesterol (mmol/L)[e]	5.94	5.71	5.57****	6.18	5.49****
HDL cholesterol (mmol/L)	NA[g]	1.17	1.14	NA	1.47
LDL cholesterol (mmol/L)	NA	3.71	3.59***	NA	3.47
Triglyceride (mmol/L)[f]	NA	1.58	1.72	NA	1.32

[a]Treated hypertension is defined as the use of any antihypertensive medication.
[b]Overweight is defined as above the second National Health and Nutrition Examination Survey (NHANES II) 85th percentile: Men, body mass index ≥27.8; women, body mass index ≥27.3.
[c]Severe overweight is defined as above the NHANES II 95th percentile: men, body mass index ≥31.1; women, body mass index ≥32.2
[d]Total weighted average of hours spent per day in the following activities: rest=1.0; sedentary=1.1; slight=1.5; moderate=2.4; heavy=5.0; range=24 to 120.
[e]To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.7. To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.026. Cholesterol of 5.00 mmol/L=193 mg/dL. HDL=high-density lipoprotein cholesterol; LDL=low-density lipoprotein cholesterol.
[f]To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. To convert mg/dL triglyceride to mmol/L, multiply mg/dL by 0.0113. Triglyceride of 1.80 mmol/L=159 mg/dL.
[g]NA=not applicable.
****P<.0001; ***P<.001; **P<.01; *P<.05.

commercial- and home-baked goods, and salt. Persons consuming more low-fat or skim milk and whole grains (in women only) were more likely to meet NCEP dietary fat recommendations.

Men who had decreased their alcohol intake and women who had increased their consumption of fish and low-fat or skim milk were *more* likely to meet NCEP serum cholesterol recommendations. In contrast, men and women who had decreased their egg intake and women who had decreased consumption of cheese and baked goods were *less* likely to meet NCEP guidelines for serum total cholesterol.

DISCUSSION

The Framingham Study provides a unique opportunity to examine secular trends in nutrient intake and CHD risk factor status within a well-characterized, population-based sample. Evaluation of the three Framingham data sets (1957-1960, 1966-1969 [men only], and 1984-1988) revealed that dietary cholesterol levels fell substantially in both men and women, whereas total carbohydrate and protein intakes changed little. Total fat intakes fell slightly across the periods, but mean levels were well above published recommendations. The intake of saturated fat appeared to increase in men from 1966-1969 and 1984-1988 (similar trend data not available for women) and was higher than recommended in 1984-1988 in both men and women.

Consistency with National Estimates of Nutrient Intake

Trends in cholesterol intake in the Framingham population are largely consistent with the findings of national studies (18,24). The Nationwide Food Consumption Survey (1977), NHANES II (1976-1980), and the Continuing Survey of Food Intakes by Individuals (CSFII) (1985) demonstrated an apparent decline in mean dietary cholesterol intake between 1976 and 1985 within the US population (18,25). Only modest changes were noted in macronutrient intake, including total fat, in the national data sets. Each national study confirmed that mean total fat intake levels were well above recommended levels and that carbohydrate intakes were below recommendations. A meta-analysis of 171 studies of individual dietary intake conducted between 1920 and 1984 described a modest decline in total fat intake after the mid-1960s, from 40% to 42% of energy to 37% to 38%; this trend was observed for all age and sex groups (26).

Framingham Study and national trends in fat intake are somewhat different from those predicted by information on per capita food availability from food balance sheets. Food balance data indicate that consumption of total fat has remained relatively stable since the 1960s, with a slight increase from 1964 to the mid-1980s (27), and that there has been a decline in consumption of animal fat and a rise in consumption of vegetable fat (28). In contrast, the median P:S ratio of the Framingham diet appeared to decline between the 1950s and 1980s, although it remained stable after the mid-1960s in men. Findings from the Framingham Study revealed estimates of mean total fat intake (38% of total energy) that were slightly higher than recent NHANES II and CSFII levels (36% to 37%). Observed differences between Framingham Study findings and national estimates may reflect regional secular trends in population eating behavior and/or methodologic differences between these studies (ie, dietary data collection methods and nutrient data banks) (24).

The adjustment for missing fatty acid values in the nutrient database that we used in these analyses altered the interpretation of our data. For example, our estimates of saturated fat intake are similar to those of NHANES II men and women and CSFII women (13% of total energy) when missing fatty acid data are not considered. However, the national estimates are below the adjusted levels of Framingham men and women (17.0% and 16.7%, respectively). The same findings apply to the estimates of

Table 4
Relative risk of satisfying National Cholesterol Education Program (NCEP) serum cholesterol, dietary cholesterol, and dietary fat guidelines associated with decreased or nonconsumption of foods vs same or increased use over 10 years: Framingham Study men and women 37 to 70 years old[a]

Food items	Blood cholesterol level[b] (<6.20 mmol/L)		Fat intake[b] (<30% of energy)		Cholesterol intake[b] (<300 mg/day)	
	Men	Women	Men	Women	Men	Women
Meat and alternatives						
Red meat			1.65***	1.42***	1.14**	1.09**
Poultry						1.20*
Fish		0.71**				
Eggs	0.88*	0.86**	1.55***		1.35***	1.16***
Dairy foods						
Cheese		0.75***	1.80***	1.36**	1.28***	
Whole milk			1.90***	1.75***	1.13*	1.15***
Low-fat or skim milk		0.88*	0.78*	0.69***		
Butter			1.47***	1.47***	1.27***	1.12***
Stick margarine						
Soft margarine			1.30*			
Fruits						
Vegetables						
Breads and cereals						
Whole grains				0.77*		
Commercial-baked goods		0.89*	1.51***	1.30**		
Home-baked goods		0.84***	1.45***			
Alcohol	1.19***					
Salt			1.67***	1.46***	1.14*	1.08*

[a]Only significant results are presented.
[b]76.2% of men and 74.1% of women had blood cholesterol levels <6.20 mmol/L; 19.4% of men and 21.8% of women consumed <30% of energy from fat; 51.2% of men and 71.0% of women consumed <300 mg of cholesterol per day. These estimates of compliance with NCEP guidelines are for the subset of individuals aged 37 to 70 years included in these analyses and are comparable with those for the entire Framingham Offspring-Spouse cohort published elsewhere (41).
*$P<.05$; **$P<.01$; ***$P<.001$; $+ .05\leq P\leq .10$.

monounsaturated and polyunsaturated fat from national studies compared with adjusted estimates from the Framingham Study. Nonetheless, we found, as did NHANES II researchers (28), that the P:S ratio was higher among women than men.

We presented the median values for P:S ratio in this article because of the skewness of the P:S ratios in our data. Interpretation based on the *median* value is quite different from that based on the *mean* P:S ratio (noted at the bottom of Table 1). For this reason, we suggest that other investigators carefully examine P:S ratio data to assess whether the data are normally distributed. In the case of marked skewness, it appears more appropriate to perform nonparametric analyses using the median P:S ratio.

Our finding of an apparent increase in saturated fat intake among Framingham men between 1966-1969 and 1984-1988 has not been reported previously in a population-based data set and needs to be confirmed elsewhere. Differences between our estimates and the NHANES and USDA data sets may reflect methodologic differences as noted earlier. In addition, the higher estimated fatty acid intake levels in Framingham subjects are likely to be a function of the adjustments we made for missing nutrient information in the data bank on the fatty acid content of foods. This analytical approach is not typically applied to NHANES or USDA data and is generally not discussed by other researchers. Thus, the literature may underestimate the fatty acid content of the diet, and national estimates may not capture actual secular trends in intake. The availability of complete nutrient information and adjustment for missing values in nutrient databases are critical to obtaining a valid estimate of population consumption levels and to determining whether Americans are reaching recommended intake levels.

Challenges Specific to Dietary Fat

Our finding that fat intake is high in spite of self-reported changes in food intake over the "past 10-years" suggests that consumers' knowledge of appropriate dietary practices and their ability to sustain favorable nutrition patterns may be limited. Even though Framingham women report a somewhat greater likelihood of making healthful dietary changes, our data indicate that men and women may find it equally difficult to implement and sustain dietary behaviors recommended for prevention of chronic disease. Other researchers have noted discrepancies between published dietary guidelines and the actual diets of Americans (29-31), which suggests the need for extensive public education and intervention efforts.

Long-term compliance with reduction in intake of dietary saturated fat is most problematic, even in persons who receive intensive initial nutrition education from a registered dietitian (32), because of the many barriers to maintenance of permanent behavioral changes. In the Framingham population, lower rates of change in total and saturated fat intake, as opposed to intake of dietary cholesterol, may reflect confusion on the part of the public about nutrient recommendations and food sources of nutrients caused by inadequate nutrition labeling (31). Other authors (33) have suggested that public health messages focus too heavily on "foods to avoid" while not providing appropriate guidance on how to select and prepare foods for an eating pattern that is consistent with current dietary and health recommendations. Our findings suggest that there is a potentially unique and valuable role for trained dietitians and public health nutritionists in preventive nutrition interventions to lower the risk for cardiovascular disease.

Trends in Risk Factor Levels for Cardiovascular Disease

Data presented from three periods of the Framingham Study suggest that serum total cholesterol levels, systolic and diastolic blood pressures, and prevalence rates of cigarette smoking were generally lower among men and women in 1984-1988 than in earlier periods. In contrast, the percentages of subjects who were overweight and who had hypertension, and the mean body mass index, rose within the Framingham population during this period despite a self-reported increase in physical activity. The increase in treated hypertension likely reflects improved strategies for both detection and treatment during the 1970s and 1980s (34,35). The decline in serum total cholesterol level is unrelated to treatment with lipid-lowering medications, because less than 1% of the cohort were receiving such therapy during any of the three time frames. The increase in the rate of overweight is consistent with dietary lipid patterns that remain high in comparison with recommended guidelines. Physical activity was likely overreported in the Framingham Study, thus explaining the finding of increased overweight despite an apparent increase in energy expenditure.

A report of Framingham men, aged 50 to 59 years in 1950, 1960, and 1970, also documented significant improvements in cardiovascular risk factors such as lower serum cholesterol levels, lower systolic blood pressures, better management of hypertension, and reduction in cigarette smoking (36). Our colleagues proposed that these improvements in risk factors were important contributors to the decline in mortality from cardiovascular disease that was observed in that cohort. Among Framingham women aged 50 to 59 years in 1950, 1960, and 1970, similar trends in risk factors were apparent, albeit cigarette smoking appeared to be increasing in middle-aged women. The unfavorable trend in cigarette smoking in middle-aged Framingham women is thought to be an important contributor to increasing heart attack rates among this group (Sytkowski PA, D'Agostino RB, Kannel WB. Changes in risk factors and presentation of disease associated with the decline in cardiovascular disease mortality among women in the Framingham Heart Study; unpublished data; 1992.). Data from our study show a consistent decline in the overall prevalence of cigarette smoking among women and in every age category (30-39, 40-49, 50-59, and 60-70 years; data not shown). Our findings for women aged 50 to 59 years may differ from those of our colleagues because we used a later time frame as an endpoint in our study (1984-1988).

Our risk factor findings are similar to trends reported in other population-based studies (34,37). Results of national surveys conducted between 1960 and 1991 indicate that mean serum total cholesterol levels in US adults (aged 20 to 74 years) have consistently declined across the entire distribution of serum cholesterol levels and in all age-sex groups over three decades (37). Also, the prevalence of high blood cholesterol level has dropped from 26% among US adults in 1976-1988 to 20% in 1988-1991 (38).

Although total cholesterol levels have fallen in the US population, HDL cholesterol and VLDL cholesterol levels remain unchanged; this finding suggests that the decline in total cholesterol levels is attributable to a decline in LDL cholesterol (39). These findings are consistent with those reported among Framingham men. The age-adjusted HDL cholesterol level reported in NHANES II for white men (1.15 mmol/L) was similar to the mean HDL cholesterol level reported here for Framingham men.

National trends also suggest an increased prevalence of overweight within certain segments of the US population (25). Overall, most estimates indicate that at least 25% of the adult American population is overweight or obese. Although overall prevalence rates of overweight changed little over time, there were observed increases within specific age groups among the general US population. Among men aged 45 to 54 years, the prevalence of overweight increased from 28.1% in 1960-1962 to 31.0% in 1976-1980. Among women in this same age range, the prevalence of overweight increased from 30.9% in 1960-1962 to 32.5% in 1976-1980 (25). Similarly, the percentages of severely overweight people increased within this age group from 7.9% to 10.7% among men and from 11.4% to 12.9% among women. The observed trend in increased body mass index among Framingham men and women in 1984-1988 was also noted among participants of both sexes in the Minnesota Heart Survey during the 1980s (34).

Dietary Behavioral Change and Compliance with NCEP Guidelines

Reported changes in consumption of specific types of foods were associated with recommended levels of dietary lipids and total serum cholesterol in the Framingham population. Although men and women differed in the extent to which food consumption changed, those who had decreased consumption of red meat, butter, eggs, cheese, whole milk, and salt over the past 10 years were more likely to meet NCEP dietary fat and cholesterol guidelines. These changes in food intake patterns have been demonstrated in other population studies. An analysis of food consumption data collected during the 1977-1978 Nationwide Food Consumption Survey and the 1985 CSFII suggested that red meat and whole milk consumption was decreasing and use of low-fat milk, poultry, and fish was increasing (40). Consumption of other important sources of energy, fat (high-fat desserts, butter, and margarine), and fiber (fruits, vegetables, and high-fiber cereals) changed little between 1977 and 1987, at least among older Americans (33).

Favorable dietary changes were associated with a greater likelihood of achieving NCEP recommendations for dietary fat and cholesterol intake and for serum cholesterol level. Achievement of NCEP serum cholesterol guidelines was not more likely, however, among men and women who had decreased their intake of eggs and women who were consuming less cheese and baked goods. These findings may appear counterintuitive, but we believe that there are several plausible explanations. First, population-based preventive nutrition messages were not widespread during the 1970s, so it is probable that persons who were changing their diets had CHD and/or definite risk factors for the disease and were modifying their diets based on the advice of a physician. Second, because the likelihood of satisfying the NCEP guideline for serum cholesterol level is smaller for those with very high blood cholesterol levels, reported dietary changes among these higher-risk persons were likely insufficient to reduce serum cholesterol to recommended levels. Third, self-reported dietary changes may have overestimated actual dietary changes that occurred over the periods. Given the cross-sectional nature of these results, we cannot draw cause-and-effect conclusions regarding the impact of dietary changes on blood cholesterol levels.

APPLICATIONS

The secular trends observed in diet and risk factor levels in the Framingham population are important to consider in the design and implementation of population-based educational strategies for the promotion of cardiovascular health. In particular, these data suggest that we need to emphasize lowering total fat and saturated fat intake levels and gender differences as they relate to changing food patterns. Our findings provide important insights into areas where dietary change seems to occur most readily among the sexes and areas to target for preventive nutrition interventions for reduction of heart disease risk. For example, men were more likely to decrease their egg intake, but women were more likely to decrease their consumption of red meat, stick margarine, baked goods, and salt. Women were also more likely than men to increase their consumption of poultry, fish, low-fat or skim milk, whole grains, fruits, and vegetables. Comparably high proportions of both men and women reduced their intake levels of whole milk, cheese, butter, and alcohol.

This research also suggests that more complete nutrient databases are needed to estimate trends in population food and nutrient intake correctly. Methods to adjust for missing fatty acid data deserve attention. ■

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