Mortality in vegetarians and nonvegetarians: detailed findings from a collaborative analysis of 5 prospective studies[1-3]

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ABSTRACT   We combined data from 5 prospective studies to compare the death rates from common diseases of vegetarians with those of nonvegetarians with similar lifestyles. A summary of these results was reported previously; we report here more details of the findings. Data for 76 172 men and women were available. Vegetarians were those who did not eat any meat or fish ($n = 27 808$). Death rate ratios at ages 16–89 y were calculated by Poisson regression and all results were adjusted for age, sex, and smoking status. A random-effects model was used to calculate pooled estimates of effect for all studies combined. There were 8330 deaths after a mean of 10.6 y of follow-up. Mortality from ischemic heart disease was 24% lower in vegetarians than in nonvegetarians (death rate ratio: 0.76; 95% CI: 0.62, 0.94; $P < 0.01$). The lower mortality from ischemic heart disease among vegetarians was greater at younger ages and was restricted to those who had followed their current diet for >5 y. Further categorization of diets showed that, in comparison with regular meat eaters, mortality from ischemic heart disease was 20% lower in occasional meat eaters, 34% lower in people who ate fish but not meat, 34% lower in lactoovovegetarians, and 26% lower in vegans. There were no significant differences between vegetarians and nonvegetarians in mortality from cerebrovascular disease, stomach cancer, colorectal cancer, lung cancer, breast cancer, prostate cancer, or all other causes combined.   *Am J Clin Nutr* 1999;70(suppl):516S–24S.

KEY WORDS   Vegetarians, vegans, mortality, ischemic heart disease, colorectal cancer, breast cancer, prostate cancer

INTRODUCTION

Investigators in 5 prospective studies deliberately recruited a large proportion of vegetarians and, for comparison, nonvegetarians with lifestyles similar to the vegetarians (1–5). We analyzed the combined data from these 5 studies to provide overall estimates of the association of a vegetarian diet with the risk of death from specific causes. In particular, we sought to test the hypotheses that the vegetarians would have lower mortality rates than the nonvegetarians from ischemic heart disease and from colorectal, breast, and prostate cancers. A summary of the findings was published previously (6). We report here a more detailed description of the results.

SUBJECTS AND METHODS

Studies

Five prospective cohort studies recruited vegetarians or populations known to contain a large proportion of vegetarians (**Table 1**). The Adventist Mortality Study recruited members of the Seventh-day Adventist church from 198 congregations in California (1), with follow-up for mortality by record linkage and personal contact (follow-up through 1965 only was used in this analysis). The Health Food Shoppers Study recruited people in the United Kingdom via health food shops, vegetarian societies and magazines; follow-up was performed by linking records with the National Health Service Central Register (2). The Adventist Health Study recruited Seventh-day Adventists throughout California; follow-up was performed by linking records with the California death certificate file, the National Death Index, and church records (3). There is no overlap between the follow-up periods in this study and the Adventist Mortality Study. The Heidelberg Study cohort was recruited through vegetarian magazines in the former Federal Republic of Germany; follow-up was conducted through the registrar's office of the last place of residence (4). The Oxford Vegetarian Study cohort was recruited through the Vegetarian Society of the United Kingdom and the news media; nonvegetarians were recruited from friends and relatives of vegetarians (5). Follow-up in this study was the same as for the Health Food Shoppers Study, and 863 subjects who were members of both of these cohorts were excluded from the Health Food Shoppers Study

TABLE 1
Description of the studies selected for analysis

Study	Location	Median year of recruitment[1]	Number of subjects[2]	End of follow-up	Person-years at risk	Mean length of follow-up
		y	*n*		*y*	*y*
Adventist Mortality (1)	California	1960 (1959–1960)	24 538	December, 1965	138 304	5.6
Health Food Shoppers (2)	United Kingdom	1974 (1973–1979)	9878	December, 1995	182 156	18.4
Adventist Health (3)	California	1976 (1976–1980)	28 952	December, 1988	320 818	11.1
Heidelberg (4)	Germany	1978 (1978–1981)	1757	May, 1989	17 317	9.9
Oxford Vegetarian (5)	United Kingdom	1981 (1980–1984)	11 047	December, 1995	150 799	13.7

[1] Range in parentheses.
[2] Subjects aged 16–89 y at recruitment with data on smoking status and diet group available.

and retained in the Oxford Vegetarian Study because the latter collected more information on potential confounding variables.

Definitions and main analyses

Subjects were eligible for analysis if they were aged 16–89 y at recruitment, if they had not been diagnosed with cancer before recruitment [except for *International Classification of Diseases*, ninth revision (ICD-9) 173, nonmelanoma skin cancer (7)], and if they provided sufficient information for classifying diet group and smoking category. Information on existing cardiovascular disease and diabetes at recruitment was available in 4 of the studies, and the influence of prior disease on the results was examined in a subanalysis.

The main analysis compared mortality in vegetarians with that in nonvegetarians. In the Health Food Shoppers Study, vegetarians were people who replied "yes" to the question "Are you a vegetarian?," whereas in the 4 other studies vegetarians were defined as people who reported that they did not eat any meat or fish; all others were defined as nonvegetarians. In none of the studies did the questionnaire specifically ask how long subjects had followed a vegetarian diet, but some information was available concerning how long subjects had followed their current diet. Vegetarians were classified according to whether they had followed their current diet for ≤5 y or >5 y. In the 2 studies in Seventh-day Adventists, age at baptism was used as a surrogate for age at becoming vegetarian because Adventists who follow a vegetarian diet typically establish this behavior at the time of baptism.

Smokers were categorized as never smokers, former smokers, current light smokers (1–14 cigarettes/d, user of other tobacco, or both), and current heavy smokers (≥15 cigarettes/d). This information was available from all studies with the following exceptions: in the Adventist Mortality Study the cutpoint between light and heavy smoking was 20 cigarettes/d; in the Health Food Shoppers Study there was no information on past smoking, therefore all noncurrent smokers were categorized as never smokers; in the Adventist Health Study the information on number of cigarettes smoked was for the maximum ever smoked, which was assumed to be the number of cigarettes smoked by current smokers; and in the Heidelberg Study there was no information on the number of cigarettes smoked and all smokers were assumed to be light smokers because the prevalence of smoking was very low in this study.

Adjustment for potential confounders

The principal analyses were of all subjects for whom we had complete data on both diet group and smoking. We also explored the effects of adjusting the results for 4 potential confounders:

body mass index, alcohol use, education level, and exercise level. Men and women were categorized into thirds of the distribution of body mass index of all men and all women, respectively. Alcohol users were categorized as regular drinkers or nonregular drinkers, definitions varied between studies, but the guideline was that regular drinkers consumed ≥1 alcoholic drink/wk. Education was classified as high—equivalent to the completion of American high school or above—or low; in the Oxford Vegetarian Study only data on social class were available and social classes I and II (8) were considered to be equivalent to high education. Exercise was classified as high or low on the basis of criteria used to define the level of activity in each study, with the guideline of producing 2 approximately equal-sized groups in each study. For these 4 potential confounding variables there were some missing data in each study, and there was no information on any of the 4 variables in the Health Food Shoppers Study and no information on exercise for the women in the Adventist Mortality Study.

Causes of death and statistical methods

The endpoints examined were stomach cancer (ICD-9 151), colorectal cancer (ICD-9 153 and 154), lung cancer (ICD-9 162), female breast cancer (ICD-9 174), prostate cancer (ICD-9 185), ischemic heart disease (ICD-9 410–414), cerebrovascular disease (ICD-9 430–438), all other causes, and all causes combined (7).

Subjects were censored on reaching age 90 y. Person-years at risk were calculated using the PERSON-YEARS computer program (9), and death rate ratios in each study were calculated by Poisson regression using GLIM-4 (10). All death rate ratios were adjusted for age in 5-y increments, sex, and smoking (never, former, current light, and current heavy). Mortality ratios for the separate studies were then combined to give a pooled estimate of effect using the random-effects model of DerSimonian and Laird (11), which both tests and allows for heterogeneity between studies. The test for heterogeneity was also applied to the pooled all-studies results to test for heterogeneity of effect between sexes and age groups.

RESULTS

The characteristics of the vegetarians and nonvegetarians are compared in **Table 2**. Smoking rates varied between studies, but in all studies the proportion of smokers was lower among the vegetarians than the nonvegetarians. In all studies for which data were available, vegetarians had a lower mean body mass index, a lower percentage of vegetarians were current alcohol users, and

TABLE 2
Characteristics of subjects selected for analysis[1]

Study and reference	Median age	Current smokers	Mean BMI	Current alcohol users	High education level	High exercise level[2]
	y	*%*	*kg/m²*	*%*	*%*	*%*
Men						
Adventist Mortality (1)						
Nonvegetarian (*n* = 5023)	49	7.2	25.7	2.0	54.4[3]	77.9
Vegetarian (*n* = 3971)	51	2.9	24.6	0.7	63.3[3]	81.2
Health Food Shoppers (2)						
Nonvegetarian (*n* = 2462)	46	30.6	—	—	—	—
Vegetarian (*n* = 1519)	41	20.1	—	—	—	—
Adventist Health (3)						
Nonvegetarian (*n* = 9045)	52	8.5	25.4	14.0	78.7[3]	65.8
Vegetarian (*n* = 3169)	51	0.2	23.8	0.4	86.5[3]	71.3
Heidelberg (4)						
Nonvegetarian (*n* = 304)	45	9.9	22.1	29.4	62.8[3]	34.8
Vegetarian (*n* = 480)	43	4.2	21.3	14.1	56.4[3]	40.3
Oxford Vegetarian (5)						
Nonvegetarian (*n* = 2572)	34	29.1	23.0	86.0	67.9[4]	62.6
Vegetarian (*n* = 1603)	33	17.5	22.0	63.2	64.8[4]	67.4
Women						
Adventist Mortality (1)						
Nonvegetarian (*n* = 9257)	50	1.2	25.1	1.6	51.6[3]	—
Vegetarian (*n* = 6287)	54	0.1	24.0	0.7	59.7[3]	—
Health Food Shoppers (2)						
Nonvegetarian (*n* = 3626)	45	18.0	—	—	—	—
Vegetarian (*n* = 2271)	47	12.3	—	—	—	—
Adventist Health (3)						
Nonvegetarian (*n* = 11904)	52	2.7	24.8	4.8	78.4[3]	51.9
Vegetarian (*n* = 4834)	54	0.2	23.0	0.2	85.4[3]	54.9
Heidelberg (4)						
Nonvegetarian (*n* = 370)	49	3.2	21.3	24.9	46.6[3]	32.8
Vegetarian (*n* = 603)	53	2.2	20.9	7.3	43.7[3]	37.0
Oxford Vegetarian (5)						
Nonvegetarian (*n* = 3801)	34	18.5	22.1	76.3	59.9[4]	58.4
Vegetarian (*n* = 3071)	32	13.4	21.3	56.5	60.1[4]	65.4

[1] Subjects aged 16–89 y at recruitment for whom data on smoking status and diet group were available. Data on body mass index, alcohol use, education level, and exercise level were not available for the Health Food Shoppers study; data on exercise were missing for women in the Adventist Mortality study. Overall, data on body mass index, alcohol use, education level, and exercise level were available for 81.5%, 83.4%, 83.0%, and 66.1% of the subjects, respectively.

[2] Defined as high or low on the basis of criteria used to define physical activity level in each study.

[3] Completion of American high school or above, or equivalent.

[4] Data on education not available. Social classes I and II (8) were considered equivalent to high education.

a consistently higher percentage of vegetarians were high exercisers. Variations in level of education between the 2 groups were small and inconsistent.

After a mean of 10.6 y of follow-up there were 8330 deaths before age 90 y (3910 men and 4420 women). The numbers of deaths and the death rate ratios for vegetarians compared with those for nonvegetarians in each study after adjustment for age, sex, and smoking, and for all studies combined using a random-effects model are shown in **Table 3**. The death rate ratio for ischemic heart disease varied between studies from 0.45 to 0.97, and the all-studies ratio was 0.76 (95% CI: 0.62, 0.94; $P < 0.01$). There was significant heterogeneity between studies ($P < 0.01$). None of the death rate ratios for other causes of death was significant in all studies, although some of the individual study results were significant in different directions (eg, breast cancer in the Health Food Shoppers and Adventist Health studies, cerebrovascular disease in the Adventist Mortality Study, and other causes

in the Health Food Shoppers and Adventist Health studies). The death rate ratios for all-cause mortality varied between studies from 0.80 to 1.17, and the test for heterogeneity between studies was highly significant ($P < 0.0001$). The all-studies death rate ratio for all causes of death was 0.95 (95% CI: 0.82, 1.11).

The all-studies death rate ratios for causes of death affecting men and women for vegetarians compared with nonvegetarians are shown in **Table 4**. For each cause of death except "other causes" the death rate ratio was lower in men than in women, although there was no significant heterogeneity between men and women for any cause of death. The only death rate ratios that were significantly different from 1 were for ischemic heart disease: $P < 0.001$ for men and $P < 0.05$ for women. However, both the death rate ratios for cerebrovascular disease and for all causes of death in men were nearly significant.

The all-studies death rate ratios for vegetarians compared with nonvegetarians by age at death are shown in **Table 5**.

TABLE 3
Death rate ratios and 95% CIs and the number of deaths for vegetarians compared with nonvegetarians by study, adjusted for age, sex, and smoking status, and for all studies combined

	Cancer					Ischemic heart disease	Cerebrovascular disease	Other causes	All causes
	Stomach	Colorectal	Lung	Breast	Prostate				
Study									
Adventist Mortality (1)									
Death rate ratio	0.64 (0.30, 1.36)	1.37 (0.73, 2.56)	0.59 (0.10, 3.28)	0.65 (0.28, 1.52)	1.41 (0.49, 4.04)	0.74 (0.63, 0.88)	0.65 (0.48, 0.87)	0.96 (0.83, 1.11)	0.83 (0.76, 0.92)
Number of deaths	30	41	6	26	15	598	182	737	1635
Health Food Shoppers (2)									
Death rate ratio	1.23 (0.62, 2.47)	0.90 (0.58, 1.39)	1.13 (0.67, 1.92)	1.74 (1.11, 2.72)	1.31 (0.65, 2.66)	0.97 (0.81, 1.16)	0.99 (0.78, 1.26)	1.20 (1.06, 1.37)	1.11 (1.02, 1.21)
Number of deaths	34	90	66	79	32	521	292	1013	2127
Adventist Health (3)									
Death rate ratio	1.58 (0.68, 3.70)	1.01 (0.66, 1.56)	0.69 (0.37, 1.27)	0.52 (0.27, 0.97)	0.79 (0.44, 1.41)	0.62 (0.53, 0.73)	0.93 (0.73, 1.19)	0.88 (0.79, 0.97)	0.80 (0.74, 0.87)
Number of deaths	26	104	96	64	66	921	317	1970	3564
Heidelberg (4)									
Death rate ratio	2.66 (0.32, 21.7)	0.35 (0.06, 2.11)	—[1]	1.09 (0.18, 6.67)	1.67 (0.14, 19.6)	0.45 (0.22, 0.95)	1.69 (0.69, 4.15)	1.45 (0.92, 2.30)	1.17 (0.85, 1.63)
Number of deaths	8	5	2	5	3	29	31	102	185
Oxford Vegetarian (5)									
Death rate ratio	0.46 (0.11, 1.85)	0.94 (0.49, 1.80)	0.66 (0.31, 1.37)	1.10 (0.57, 2.12)	0.42 (0.16, 1.09)	0.90 (0.68, 1.20)	1.17 (0.76, 1.80)	1.12 (0.91, 1.36)	1.00 (0.87, 1.15)
Number of deaths	9	38	33	36	21	195	87	400	819
χ^2_4 For heterogeneity between studies	4.83	2.56	2.52	10.89 ($P < 0.05$)	4.71	15.98 ($P < 0.01$)	8.73	18.35 ($P < 0.01$)	36.09 ($P < 0.0001$)
All studies									
Death rate ratio[2]	1.02 (0.64, 1.62)	0.99 (0.77, 1.27)	0.84 (0.59, 1.18)	0.95 (0.55, 1.63)	0.91 (0.60, 1.39)	0.76 (0.62, 0.94)	0.93 (0.74, 1.17)	1.06 (0.90, 1.24)	0.95 (0.82, 1.11)
Number of deaths	107	278	203	210	137	2264	909	4222	8330

[1] Estimate unreliable because there were only 2 deaths.
[2] Obtained by combining the results of all studies with use of a random-effects model.

TABLE 4
All-studies death rate ratios and 95% CIs and the number of deaths for vegetarians compared with nonvegetarians in men and women[1]

Cause of death	Men ($n = 30\,148$)	Women ($n = 46\,024$)	χ^2_1 Heterogeneity between sexes[2]
Stomach cancer			0.73
Death rate ratio	0.88 (0.51, 1.53)	1.32 (0.62, 2.80)	
Deaths	55	52	
Colorectal cancer			0.02
Death rate ratio	0.99 (0.70, 1.41)	1.02 (0.78, 1.35)	
Deaths	116	162	
Lung cancer			2.51
Death rate ratio	0.62 (0.36, 1.06)	1.08 (0.70, 1.68)	
Deaths	132	71	
Ischemic heart disease			1.24
Death rate ratio	0.69 (0.56, 0.84)	0.80 (0.67, 0.95)	
Deaths	1193	1071	
Cerebrovascular disease			1.95
Death rate ratio	0.77 (0.57, 1.02)	0.98 (0.80, 1.20)	
Deaths	350	559	
Other causes			0.03
Death rate ratio	1.00 (0.84, 1.18)	0.98 (0.83, 1.15)	
Deaths	1927	2295	
All causes			0.65
Death rate ratio	0.86 (0.73, 1.01)	0.93 (0.82, 1.06)	
Deaths	3910	4420	

[1] Adjusted for age, smoking status, and study by using a random-effects model.
[2] There were no significant differences between sexes.

The association of vegetarianism with lower mortality from ischemic heart disease was greater for deaths at younger ages; death rate ratios for ischemic heart disease were 45% ($P < 0.01$), 31% ($P < 0.01$), and 8% (NS) lower in vegetarians than nonvegetarians at ages <65, 65–79, and 80–89 y, respectively ($P < 0.05$ for trend). No other death rate ratios or trends were significant.

To assess whether the duration of current diet was associated with mortality, we subdivided the vegetarians according to whether they had followed their current diet for ≤ 5 y or for >5 y (**Table 6**). Most vegetarians had followed their diet for >5 y. With nonvegetarians as the reference group, all but one of the death rate ratios for vegetarians who had followed their current diet for ≤ 5 y were >1.00, and these differences were significant for lung cancer (9 deaths), other causes (123 deaths), and all causes of death (218 deaths). Conversely, all but one of the death rate ratios for vegetarians who had followed their current diet for >5 y were <1.00, the difference being significant for ischemic heart disease. Further analyses were conducted to examine the increases in mortality in vegetarians who had followed their current diet for ≤ 5 y. These analyses showed that the increases in mortality from all other causes and from all causes of death were observed in all 5 studies and were not reduced by restricting the analysis to subjects who had never smoked or by excluding deaths during the first 3 y of follow-up (results not shown).

Mortality in 5 diet groups

Diet was categorized further into 5 groups. The nonvegetarians were subdivided into regular meat eaters [ate meat ≥ 1 time/wk (reference group)], occasional meat eaters (ate meat occasionally but <1 time/wk), and fish eaters (never ate meat but did eat fish). The vegetarians were subdivided into vegetarians (ate dairy products, eggs, or both) and vegans (did not eat any animal products).

In the Health Food Shoppers Study there was no information on the frequency of meat consumption or on the consumption of fish or eggs; therefore, this study was excluded from the analysis (**Table 7**). Compared with the regular meat eaters, death rate ratios were significantly <1.00 for lung cancer in the vegetarians ($P < 0.05$), for ischemic heart disease in the occasional meat eaters, fish eaters (both $P < 0.01$), and vegetarians ($P < 0.001$); for other causes of death in the occasional meat eaters ($P < 0.01$); and for all causes of death in the occasional meat eaters ($2P < 0.001$), fish eaters, and vegetarians (both $P < 0.05$). However, the exclusion of data from the Health Food Shoppers Study in this analysis tended to lower the death rate ratio in the vegetarian groups compared with the nonvegetarian groups.

The number of vegans was small ($n = 753$ subjects, 68 deaths), so the analyses in Table 7 were repeated with the inclusion of data from the Health Food Shoppers Study, making the assumptions that all nonvegetarians were regular meat eaters and that vegetarians who reported that they did not consume dairy products were vegans. This increased the number of vegans to 1146, of whom 165 died before age 90 y. However, the numbers of deaths from individual cancers among vegans remained small (range: 3–8). The death rate ratios for the vegans compared with the regular meat eaters from the other causes of death were: for ischemic heart disease, 0.89 (95% CI: 0.65, 1.24; NS); for cerebrovascular disease, 0.51 (95% CI: 0.26, 1.00; NS); for other causes, 1.39 (95% CI: 1.12, 1.72; $P < 0.01$); and for all causes, 1.06 (95% CI: 0.81, 1.38). However, these death rate ratios should be interpreted with caution because of the uncertainty of the dietary classification of subjects in the Health Food Shoppers Study.

Adjustment for potential confounding factors

Information on alcohol, education, exercise, and body mass index was available for 43 038 subjects, of whom 3889 died

TABLE 5
All-studies death rate ratios and 95% CIs and the number of deaths for vegetarians compared with nonvegetarians by age at death[1]

Cause of death	Age at death			χ^2_2 het	χ^2_1 trend
	<65 y	65–79 y	80–89 y		
Stomach cancer				1.37	1.10
Death rate ratio	0.82 (0.25, 2.69)	0.84 (0.47, 1.52)	1.41 (0.70, 2.82)		
Deaths	17	50	40		
Colorectal cancer				0.95	0.40
Death rate ratio	0.78 (0.43, 1.41)	1.09 (0.77, 1.55)	1.04 (0.64, 1.68)		
Deaths	58	144	76		
Lung cancer				0.19	0.06
Death rate ratio	0.99 (0.49, 1.99)	0.81 (0.50, 1.33)	0.87 (0.43, 1.75)		
Deaths	53	110	40		
Breast cancer				1.31	0.25
Death rate ratio	0.74 (0.31, 1.78)	1.30 (0.77, 2.18)	0.87 (0.26, 2.95)		
Deaths	111	63	36		
Prostate cancer				0.87	0.51
Death rate ratio	2.25 (0.32, 15.8)	0.95 (0.58, 1.55)	0.82 (0.34, 1.97)		
Deaths	10	77	50		
Ischemic heart disease				5.34	5.31[3]
Death rate ratio	0.55 (0.35, 0.85)	0.69 (0.53, 0.90)	0.92 (0.73, 1.16)		
Deaths	259	1086	919		
Cerebrovascular disease				1.74	1.49
Death rate ratio	0.64 (0.35, 1.17)	0.90 (0.62, 1.30)	0.97 (0.81, 1.17)		
Deaths	62	371	476		
Other causes				1.87	0.17
Death rate ratio	1.22 (0.80, 1.85)	0.95 (0.82, 1.10)	1.05 (0.94, 1.17)		
Deaths	921	1655	1646		
All causes				2.37	1.11
Death rate ratio	1.01 (0.68, 1.49)	0.87 (0.75, 1.01)	1.00 (0.90, 1.12)		
Deaths	1491	3556	3283		

[1] Adjusted for sex, smoking status, and age within the 3 age groups, and for study by using a random-effects model. Het, heterogeneity.

[2] There were no significant differences except where noted.

[3] $P < 0.05$.

before age 90 y. Shown in **Table 8** are the all-studies death rate ratios for ischemic heart disease and all causes of death for vegetarians compared with nonvegetarians in this subset of subjects. The data were adjusted in 3 ways: *1*) for age, sex, and smoking status; *2*) for the variables listed in *1* and for alcohol, education, and exercise; and *3*) for the variables listed in *1* and *2* and for body mass index. The death rate ratios after adjustment for age, sex, and smoking status were lower than the corresponding all-studies death rate ratios in Table 3, largely because of the exclusion of all subjects in the Health Food Shoppers Study. Further adjustments of these death rate ratios for the potential confounding variables had little effect. For example, the death rate ratio for ischemic heart disease only changed from 0.61 to 0.66 after adjustment for all 4 potential confounders.

Mortality from ischemic heart disease among subjects with and without a history of cardiovascular disease or diabetes at recruitment

Information on cardiovascular disease (heart disease, stroke, and high blood pressure) and diabetes at recruitment was not available for the Health Food Shoppers Study, but in the other 4 studies this information was complete for 96.0% of the participants. The prevalence of these diseases at recruitment was lower in vegetarians than in nonvegetarians in all 4 studies and, among subjects for whom this information was available, 16.5% and

24.1% of vegetarians and nonvegetarians, respectively, had a history of cardiovascular disease or diabetes.

The all-studies ischemic heart disease death rate ratio for vegetarians compared with nonvegetarians, adjusted for age, sex, and smoking was 0.80 (95% CI: 0.70, 0.92) in participants with a history of cardiovascular disease or diabetes and 0.76 (95% CI: 0.59, 0.97) in participants without a history of cardiovascular disease or diabetes (χ^2_1 for heterogeneity = 0.17; $P > 0.1$).

DISCUSSION

We believe that the 5 studies analyzed here are the only large, prospective studies that included a large proportion of subjects following a Western-style vegetarian diet. Therefore, the results presented represent most of the information available on comparisons of mortality between Western vegetarians and nonvegetarians with broadly similar lifestyles.

Note that for the comparisons of the mortality between vegetarians and nonvegetarians reported here, standardized mortality ratios (SMRs) for all causes of death were considerably <100% in the 4 studies that reported SMRs. Thus, overall SMRs for men and women combined were 49% in the Adventist Mortality Study (12), 56% in the Health Food Shoppers Study (13), 48% in the Heidelberg Study (4), and 46% in the Oxford Vegetarian Study (5); no SMRs have been published for the Adventist Health Study. There-

TABLE 6
All-studies death rate ratios and 95% CIs and the number of deaths by duration of vegetarian diet[1]

| | | Duration of vegetarian diet[3] | |
Cause of death	Nonvegetarian[2] (n = 48 364)	≤5 y (n = 3734)	>5 y (n = 22 289)
Stomach cancer			
Death rate ratio	1.00	2.51 (0.85, 7.44)	0.97 (0.63, 1.50)
Number of deaths	62	4	39
Colorectal cancer			
Death rate ratio	1.00	0.66 (0.24, 1.79)	0.98 (0.76, 1.28)
Number of deaths	173	4	92
Lung cancer			
Death rate ratio	1.00	2.21 (1.07, 4.58)	0.72 (0.49, 1.05)
Number of deaths	154	9	38
Breast cancer			
Death rate ratio	1.00	1.23 (0.60, 2.54)	0.98 (0.54, 1.78)
Number of deaths	130	9	68
Prostate cancer			
Death rate ratio	1.00	1.01 (0.24, 4.29)	0.87 (0.55, 1.38)
Number of deaths	90	2	41
Ischemic heart disease			
Death rate ratio	1.00	1.20 (0.90, 1.61)	0.74 (0.60, 0.90)
Number of deaths	1530	49	625
Cerebrovascular disease			
Death rate ratio	1.00	1.10 (0.68, 1.77)	0.92 (0.68, 1.24)
Number of deaths	548	18	321
Other causes			
Death rate ratio	1.00	1.34 (1.11, 1.62)	1.03 (0.88, 1.20)
Number of deaths	2645	123	1369
All causes			
Death rate ratio	1.00	1.20 (1.04, 1.38)	0.93 (0.79, 1.09)
Number of deaths	5332	218	2593

[1] Adjusted for age, sex, smoking status, and study using a random-effects model.

[2] Reference group.

[3] Duration of diet was unknown for 1785 vegetarians.

fore, certain lifestyle aspects shared by the vegetarians and nonvegetarians in these studies appear to confer a substantially lower mortality rate than national rates. This lower mortality was due largely to the relatively low prevalence of smoking in these cohorts, but some of it may have been due to differences in diet between the subjects studied and the general population in each country.

All 5 studies had previously reported that infrequent meat consumption or vegetarianism was associated with low mortality from ischemic heart disease (5, 14–17), and these observations were strongly confirmed in the collaborative analysis: vegetarians had a 24% lower mortality from ischemic heart disease than nonvegetarians. The lower mortality from ischemic heart disease was confined to subjects who had followed their current diet for >5 y and was altered little by adjustment for alcohol use, education level, exercise level, or body mass index, and was observed in people with and without a history of cardiovascular disease or diabetes at the time of recruitment. The lower mortality of vegetarians was more pronounced when the reference group was regular meat eaters, largely because the occasional meat eaters and the fish eaters within the nonvegetarian category also had lower mortality from ischemic heart disease than did the regular meat eaters. Mortality from ischemic heart disease among the vegans was slightly higher than among the fish eaters and the vegetarians, but the number of vegans was small.

The highly significant association observed, the consistency of the association among various subgroups, and the absence of evidence of confounding suggest that the lower mortality observed from ischemic heart disease was due to the dietary differences between vegetarians and nonvegetarians. One possible explanation for the lower mortality from ischemic heart disease among the vegetarians is that they have lower serum total cholesterol concentrations than nonvegetarians. Measurements of serum cholesterol concentrations in samples of participants in 3 of the studies showed lower total serum cholesterol concentrations in the vegetarians than in the nonvegetarians: 0.61 mmol/L lower in the Health Food Shoppers Study (18), 0.43 mmol/L lower in the Oxford Vegetarian Study (19), and 0.33 mmol/L lower in the Heidelberg Study (20). Similar differences were observed in other cross-sectional studies comparing vegetarians with nonvegetarians (21, 22). It has been predicted that a 0.6 mmol/L reduction in the total serum cholesterol concentration would cause a 27% difference in mortality from ischemic heart disease (23), which is close to our observations in the current analysis and suggests that the lower mortality from ischemic heart disease in the vegetarians could have been due largely to their lower total serum cholesterol concentrations. It is also possible that the lower mortality in vegetarians was due in part to other mechanisms such, as reduced oxidation of LDL cholesterol or changes in blood clotting (24).

There was no evidence in this analysis of any difference between vegetarians and nonvegetarians in mortality from colorectal cancer, suggesting that meat consumption may not have an important role in the etiology of this disease. A similar conclusion

TABLE 7
All-studies death rate ratios and 95% CIs and the number of deaths by diet category[1]

	Nonvegetarians			Vegetarians	
Cause of death	Regular meat eaters[2] (n = 31 766)	Occasional meat eaters[3] (n = 8135)	Fish eaters[4] (n = 2375)	Vegetarians[5] (n = 23 265)	Vegans[6] (n = 753)
Stomach cancer					
Death rate ratio	1.00	0.36 (0.11, 1.18)	0.86 (0.20, 3.74)	0.71 (0.42, 1.21)	2.18 (0.43, 11.2)
Number of deaths	38	3	2	28	2
Colorectal cancer					
Death rate ratio	1.00	1.14 (0.72, 1.82)	1.00 (0.42, 2.38)	1.10 (0.79, 1.54)	0.83 (0.11, 6.17)
Number of deaths	78	30	8	71	1
Lung cancer					
Death rate ratio	1.00	0.69 (0.39, 1.22)	1.04 (0.41, 2.64)	0.62 (0.38, 1.00)	2.79 (0.39, 20.0)
Number of deaths	89	15	5	26	2
Breast cancer					
Death rate ratio	1.00	0.97 (0.56, 1.71)	1.50 (0.74, 3.04)	0.75 (0.49, 1.14)	—
Number of deaths	61	19	10	41	0
Prostate cancer					
Death rate ratio	1.00	1.06 (0.60, 1.89)	1.25 (0.30, 5.22)	0.75 (0.47, 1.21)	—
Number of deaths	51	18	3	33	0
Ischemic heart disease					
Death rate ratio	1.00	0.80 (0.69, 0.93)	0.66 (0.48, 0.90)	0.66 (0.52, 0.83)	0.74 (0.46, 1.21)
Number of deaths	912	251	42	521	17
Cerebrovascular disease					
Death rate ratio	1.00	0.97 (0.75, 1.25)	1.04 (0.65, 1.64)	0.87 (0.66, 1.13)	0.70 (0.25, 1.98)
Number of deaths	267	92	20	234	4
Other causes					
Death rate ratio	1.00	0.84 (0.75, 0.93)	0.85 (0.68, 1.06)	0.95 (0.79, 1.15)	1.33 (0.92, 1.93)
Number of deaths	1521	472	87	1087	42
All causes					
Death rate ratio	1.00	0.84 (0.77, 0.90)	0.82 (0.77, 0.96)	0.84 (0.74, 0.96)	1.00 (0.70, 1.44)
Number of deaths	3017	900	177	2041	68

[1] Adjusted for age, sex, smoking status, and study using a random-effects model. Data from the Health Food Shoppers study (2) were excluded because information on fish, egg, and frequency of meat consumption was not collected.
[2] Reference group (ate meat ≥ 1 time/wk).
[3] Ate meat occasionally but < 1 time/wk.
[4] Never ate meat but did eat fish.
[5] Ate dairy products, eggs, or both.
[6] Did not eat any animal products.

was reached in a study of cancer mortality in 2 groups of nuns, one of which did not eat meat (25). Some large studies have found a direct relation between red meat consumption and incidence of colon cancer (26), but a large prospective study found no association between frequency of red meat consumption and mortality from colon cancer (27). It is possible that meat consumption may be associated more with the incidence of colorectal cancer than with mortality from this disease, or that it may only be an important risk factor in people with low intakes of dietary fiber or some other constituent of plant foods. These issues were raised by the results on the incidence of colorectal cancer from the Adventist Health Study, which is reported in this supplement (28).

The results for breast cancer should be interpreted cautiously. We did not attempt to adjust the results for established reproductive risk factors because such data were not available for all studies. However, the results are consistent with the negative results of a collaborative analysis of prospective studies of total fat and fat type (29), with other studies of breast cancer in women who ate no meat (25, 30), and with previous reports from 3 of the collaborating studies (13, 31, 32).

TABLE 8
All-studies death rate ratios and 95% CIs and the number of deaths from ischemic heart disease and all causes of death in vegetarians compared with nonvegetarians in the subset of subjects for whom data were available on all 4 potential confounders, by level of adjustment[1]

		Adjustments		
Cause of death	Number of deaths	1	2	3
Ischemic heart disease	1047	0.61 (0.53, 0.70)	0.64 (0.53, 0.77)	0.66 (0.55, 0.79)
All causes	3889	0.90 (0.72, 1.12)	0.93 (0.76, 1.13)	0.94 (0.76, 1.16)

[1] n = 43 038. Adjusted for the factors listed and for study by using a random-effects model. 1, Age, sex, and smoking status; 2, age, sex, smoking status, alcohol use, education level, and exercise level; 3, age sex, smoking status, alcohol use, education level, exercise level, and BMI.

A previous publication from the Adventist Mortality Study reported a weak association of prostate cancer mortality with meat intake and a stronger association with total consumption of meat, milk, cheese, and eggs (33). The absence of a significant association of vegetarianism with prostate cancer mortality in the current analysis does not support the hypothesis that meat may increase the risk for this cancer, but the CIs for this estimate are relatively wide. Some previous studies reported an increase in prostate cancer risk with increasing meat consumption, but this association has been more consistent in case-control studies than in prospective studies (34).

For the other causes of death examined (lung cancer, stomach cancer, cerebrovascular disease, and other causes) no overall association with vegetarianism was expected and none was observed. The all-studies estimate of all-cause mortality was 5% lower in vegetarians than in nonvegetarians, consistent with the reduction in mortality from ischemic heart disease; however, the CIs for this estimate were relatively wide because of the substantial heterogeneity between the studies.

Among vegetarians who had followed their current diet for <5 y, mortality was significantly higher than that in nonvegetarians from lung cancer, other causes, and all causes. The higher mortality from lung cancer was based on only 9 deaths, but that from all other causes and from all causes was based on 123 and 218 deaths, respectively, and was observed in all 5 studies. We thought that the higher mortality rate might have been due to residual confounding among former smokers or to a recent change in diet in an attempt to alleviate ill health, but neither restricting the analysis to subjects who had never smoked nor exclusion of deaths during the first 3 y of follow-up lowered the mortality. We are therefore unable to explain this finding.

In conclusion, vegetarians had a 24% lower mortality from ischemic heart disease than nonvegetarians, but no associations of a vegetarian diet with other major causes of death were established.

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