Does low meat consumption increase life expectancy in humans?[1–3]

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ABSTRACT

Background: Since meat products represent a major source of protein in the Western diet, findings on whether meat intake significantly contributes to the burden of fatal disease have important clinical and public health implications.

Objective: The objective was to examine whether a very low meat intake (less than weekly) contributes to greater longevity.

Design: We reviewed data from 6 prospective cohort studies and report new findings on the life expectancy of long-term vegetarians from the Adventist Health Study.

Results: Our review of the 6 studies found the following trends: *1*) a very low meat intake was associated with a significant decrease in risk of death in 4 studies, a nonsignificant decrease in risk of death in the fifth study, and virtually no association in the sixth study; *2*) 2 of the studies in which a low meat intake significantly decreased mortality risk also indicated that a longer duration (≥2 decades) of adherence to this diet contributed to a significant decrease in mortality risk and a significant 3.6-y (95% CI: 1.4, 5.8 y) increase in life expectancy; and *3*) the protective effect of a very low meat intake seems to attenuate after the ninth decade. Some of the variation in the survival advantage in vegetarians may have been due to marked differences between studies in adjustment for confounders, the definition of *vegetarian*, measurement error, age distribution, the healthy volunteer effect, and intake of specific plant foods by the vegetarians.

Conclusion: Current prospective cohort data from adults in North America and Europe raise the possibility that a lifestyle pattern that includes a very low meat intake is associated with greater longevity. *Am J Clin Nutr* 2003;78(suppl):526S–32S.

KEY WORDS Vegetarians, aging, epidemiology

INTRODUCTION

Historical accounts of populations that have purportedly experienced greater longevity because of the low meat content of their diet are often cited in literature promoting the health benefits of the vegetarian diet (1). Specifically, certain geographically isolated, agrarian peoples (ie, Hunzakuts, Vilcabambas, mountain dwellers of Turkey, Russian Caucasus) who follow primarily plant-based diets have reported ages that raise the possibility that their life expectancy may far exceed 70 y (2–6). During World Wars I and II, wartime food restrictions that virtually eliminated meat consumption in Scandinavian countries were followed by a decline in the mortality rate (by ≈2 deaths/1000) that returned to prewar levels after the restriction was lifted (7–12). Also, Nestle (13) cites data indicating that the life expectancy of adults in Japan and certain Mediterranean countries is up to 2 y longer than their peers in Western nations in which the per capita meat intake has, over the past few decades, been substantially higher.

Does lower meat intake improve survival among humans? It is noteworthy that the apparently supportive historical accounts do not constitute a formal study of the association. Of particular concern are the problems of accurate determination of attained age in rural areas and of interpreting a causal effect of meat from ecologic data. Presently, the strongest methodology available for testing whether low meat intake (as a long-term diet pattern) affects survival is the prospective cohort study in which meat intake is related to the subsequent risk of mortality. Therefore, in this report, we addressed this question by closely examining the current epidemiologic findings from prospective studies that related meat intake to all-cause mortality.

It is noteworthy that prospective studies relating diet to mortality tend to be conducted in affluent nations in which there is a low prevalence of meatless diets [≈6% follow meatless diets in the United States (14)]—a design feature that can substantially limit the statistical power to detect a relation between meatless diets and survival. In the studies we considered in this report (1, 15–23), the problem of a low prevalence of meatless diets was addressed by *1*) oversampling the vegetarians (15, 16), *2*) studying populations with a high prevalence of low meat consumers (1, 20–23), or *3*) studying a vegetarian population and focusing on the duration of adherence to a very-low meat intake diet as the exposure of interest (1, 18, 19).

In this report, our conclusions about whether very low meat intake contributes to greater longevity will be based on the published findings from prospective cohort studies and on new findings on the life expectancy of long-term vegetarians in the California Seventh-day Adventist cohorts (24).

METHODS

Selection of studies

We conducted a search of the MEDLINE (National Library of Medicine, Bethesda, MD) to identify prospective cohort studies

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in which dietary intake was measured at baseline in a population that was then enrolled in mortality surveillance. Among those published studies that had collected these data, we selected studies in which the authors had published an analysis in which very low meat intake was directly related to all-cause mortality. For the purpose of this report, we define "very low meat intake" as being either zero meat intake or the lowest meat intake category defined by the authors of the study.

On the basis of our review of the literature and the criteria described above, we identified 6 studies that examined the relation between very low meat intake and all-cause mortality. These studies are summarized in **Table 1**, and their design is discussed below.

Design of the selected studies

Oxford Vegetarian Study

In the Oxford Vegetarian Study (15, 16), 6000 vegetarians, defined as those who never eat meat or fish, were recruited through the Vegetarian Society of the United Kingdom and announcements in the media. Five thousand nonvegetarians were identified using a method whereby investigators asked the vegetarians to identify friends and relatives who were "of similar lifestyle and social class but who ate meat." These 11 000 subjects completed a food-frequency questionnaire at baseline (1980–1984) with items on meat intake and were then enrolled in a follow-up study with findings reported at 12 y (15) and 22 y (16). In a validation substudy conducted 2–4 y after baseline, it was found that the non–meat eaters had significantly lower total cholesterol and LDL-cholesterol concentrations.

Health Food Shoppers Study (United Kingdom)

In this study, a cohort of 10 771 adults was identified that consisted of customers of health food shops and clinics, subscribers to health food magazines, subscribers to Seventh-day Adventist publications, or members of vegetarian societies (17). Of the total study population, 4627 (43%) indicated that they were vegetarian (not defined further on the questionnaire). In a validity substudy in which a detailed dietary assessment was conducted 1.5–6 y after baseline, it was found that among those classified as "vegetarian" at baseline, 66% consumed meat or fish less than once per week. Key et al (17) have examined the relation between baseline "vegetarian" status and 17-y risk of all-cause mortality in this study population.

German vegetarians

In this study, the investigators identified a cohort of 1904 German vegetarians (zero or low intake of meat or fish) from the readership of vegetarian magazines (18, 19). The baseline questionnaire used in this study classified all of these subjects as either "strict vegetarian" (zero intake of meat or fish) or "moderate vegetarian" (low intake of meat or fish) and, in addition, by measured duration of adherence to these meat intake patterns. Among these vegetarians, Chang-Claude and Frentzel-Beyme (18) examined the relation between duration of very low meat intake and 11-y all-cause mortality. Chang-Claude et al (19) computed standardized mortality ratios comparing the mortality of these vegetarians to the mortality of the German population.

California Seventh-day Adventists

Over the past 4 decades, dietary data collected among US members of the Seventh-day Adventist church indicate that about one third to one half of the membership in California consumes no meat (24). For the purpose of 2 prospective cohort studies (1, 20–22), the population of California Seventh-day Adventists was identified by a census taken from church membership rosters in 1958 and in 1974. The population identified in the 1958 census was used to enroll the Adventist Mortality Study, in which 27 530 non-Hispanic whites completed a baseline questionnaire (Hammond's American Cancer Questionnaire) in 1960 and were followed prospectively for 26 y. The population identified in the 1976 census was used to enroll the Adventist Health Study, in which 34 198 non-Hispanic whites completed a baseline questionnaire (including a 55-item semiquantitative food-frequency questionnaire) in 1976 and were followed prospectively for 12 y. Validation studies of the Adventist Health Study cohort members indicated that the correlation between meat intake reported on the questionnaire and on 24-h recalls was 0.83 and that 93% of those classified as weekly meat eaters on the recalls were also classified as weekly meat eaters on the baseline questionnaire items (25).

The data from both cohort studies allowed the following previously unpublished analyses: *1*) the relation between very low intake of all meats and 26-y risk of all-cause mortality among adults of the Adventist Mortality Study, *2*) the relation between very low intake of all meats and specific meats and 12-y risk of all-cause mortality among adults of the Adventist Health Study, and *3*) the relation between change in meat intake over a 17-y interval and the subsequent 17–29-y risk of all-cause mortality among adults who were cohort members of both the Adventist Mortality Study and the Adventist Health Study. Fraser has recently reported that among California Seventh-day Adventists, vegetarians were substantially more likely to have never smoked cigarettes, to not use alcohol, and to have no prevalent chronic disease (20). To account for potential confounding by these factors, ever-smokers, alcohol users, and subjects with history of coronary artery disease, stroke, and cancer were excluded from the analysis of Seventh-day Adventists given in this report.

Populations following a Mediterranean diet pattern

A number of prospective studies have been conducted in populations of elderly subjects (at or beyond the seventh decade at baseline) with a high prevalence of adherence to a Mediterranean diet pattern (Greeks, Spaniards, Italians) (1). In the study of Italians (23), data from an extensive food-frequency questionnaire were used to measure intakes of all meats, and this exposure was related to risk of all-cause mortality.

RESULTS

A summary of the findings from the 6 studies that directly related very low intake of all meats to all-cause mortality is shown in Table 1. Five of the 6 studies indicated a decrease (from a 25% decrease up to almost a 2-fold decrease) in risk for very low meat intake relative to higher meat consumption. The remaining study, the Health Food Shoppers Study (17), reported no strong association for a "vegetarian" status variable that did not specifically measure meat intake (Table 1). Another notable exception was that in the Oxford Vegetarian Study, in which a significant 25% decrease in risk for zero meat intake was reported at 12 y of follow-up (15), the mortality ratio attenuated to a weak association after an additional 10 y of follow-up (16).

In **Table 2**, we provide the data from 2 studies of vegetarians [German vegetarians (18), Adventist vegetarians (1)] that related

TABLE 1
Studies that related very low intake of all meats to all-cause mortality[1]

Cohort	Reference	Length of follow-up	Description of very-low-meat-intake group	Description of high-meat-intake group	Adjusted mortality ratio (95% CI)[2]	Method of control for confounding
		y				
Oxford Vegetarian Study (UK)	Appleby et al (15, 16)	12	Zero meat intake (n = 6000)	Meateater (n = 5000)	0.80 (0.65, 0.99)	Age, smoking, BMI, social class
		22	Zero meat intake (n = 6000)	Meateater (n = 5000)	1.01 (0.89, 1.14)	Age, smoking, BMI, social class
Health Food Shoppers Study (UK)	Key et al (17)	17	Vegetarian (n = 4627)[3]	Nonvegetarian (n = 6144)	1.04 (0.93, 1.16)	Age, sex, smoking
Germans	Chang-Claude et al (18, 19)	11	Vegetarian (1904)[4]	General population	0.44 (0.36, 0.53) for men; 0.53 (0.44, 0.64) for women	Age
Adventist Mortality Study (US)	Kahn et al (22), Singh (1)	26	Zero meat intake (n = 7918)	Meat eaten once or more per wk (n = 6958)	0.88 (0.82, 0.93)	Age, sex, education, and BMI by multivariate adjustment; ever-smokers, alcohol users, and those with baseline chronic disease excluded from analysis
Adventist Health Study (US)	Fraser (20), Singh (1), Fraser and Shavlik (21)	12	Zero meat intake (n = 7191)	Meat eaten once or more per wk (n = 7463)	0.85 (0.76, 0.94)	Age, sex, education, BMI, physical activity by multivariate adjustment; ever-smokers, alcohol users, and those with baseline chronic illness excluded from analysis
Italians	Fortes et al (23)	5	Meat eaten less than once per wk (NR)	Meat eaten more than once per wk (NR)	0.55 (0.28, 1.10)	Age, sex, education, BMI, smoking, cognitive function, chronic diseases

[1] NR, not given in the published report.
[2] Very-low-meat-intake group compared with high-meat-intake group.
[3] *Vegetarian* was not defined further on the questionnaire for this study. Subsequent validity studies indicated that 66% of those indicating themselves as vegetarian consumed no meat or fish.
[4] *Vegetarian* was defined as zero or occasional intake of meat or fish as reported on a food-frequency questionnaire for this study.

TABLE 2
Studies that examined the relation between duration of very low intake of all meats and subsequent risk of all-cause mortality among vegetarians

Cohort	Long-duration group	Short-duration group	Length of subsequent follow-up	Age-adjusted mortality ratio (95% CI)[1]	Multivariate mortality ratio (95% CI)[1]
			y		
German vegetarians (18,19)	Very low meat intake for ≥20 y (n = 1259)	Very low meat intake for <20 y (n = 645)	11	0.69 (0.49, 0.98)	0.71 (0.49, 1.02)[2]
Seventh-day Adventist vegetarians (1)	Zero meat intake for 17 y (n = 1906)	Zero meat intake for <17 y (n = 265)	12	0.64 (0.48, 0.85)	0.70 (0.51, 0.96)[3]

[1] Long-duration group compared with short-duration group.
[2] Adjusted for age, sex, physical activity, BMI, and adherence to vegetarianism.
[3] Adjusted for age, sex, physical activity, BMI by multivariate adjustment; ever-smokers, alcohol users, and those with chronic diseases at baseline were excluded.

duration of very low meat intake to all-cause mortality. In both studies, decreases in risk were found for those indicating long-term (17 y and ≥20 y, respectively) adherence to a very-low-meat-intake diet relative to those indicating short-term (<17 y and <20 y, respectively) adherence to a very-low-meat-intake diet. In both studies, the protective effect of long-term vegetarianism was slightly attenuated by adjustment for variables (ie, body mass index, activity). Some of this attenuation may be attributable to adjustment for intermediate effects, such as the effect of vegetarian diet on maintaining a healthy weight that causally contributes to longevity.

In **Figure 1**, we provide survival and smoothed instantaneous hazard plots (26) from an attained age survival analysis (left truncation of age attained before entry) from the Adventist cohorts comparing long-term vegetarians (zero meat intake for 17 y) to short-term vegetarians (zero meat intake for <17 y). Life expectancies were computed using a life table method by Fraser that is based on proportional hazards modeling and has been previously described (27). The survival plots and data in Figure 1 indicate that long-term vegetarians (estimated life expectancy = 86.5 y) do experience a significant 3.6-y (95% CI: 1.4, 5.8, from model) survival advantage over short-term vegetarians (estimate life expectancy = 82.9). The instantaneous hazard plot does, however, raise the possibility that the survival advantage may attenuate in the oldest old (after the ninth decade). Taken together, these data (Tables 1 and 2; Figure 1) support a survival advantage for decreased meat consumption and further raise the possibility that long-term maintenance of this diet pattern over ≈2 decades further reduces risk.

DISCUSSION

Our summary of the prospective cohort data from 6 studies revealed the following major trends: *1*) very low meat intake was associated with a significant decrease in risk of death in 4 studies, a nonsignificant decrease in risk of death in the fifth study, and virtually no association in the sixth study (Table 1); *2*) 2 studies in which very low meat intake significantly decreased mortality risk provided the additional insight that among those who adhere to a very-low-meat-intake diet, longer duration (<2 decades or more) of adherence further contributed to a significant decrease in mortality risk and a significant 3.6-y increase in life expectancy (Figure 1); and *3*) the apparent protective effect of very low meat intake seems to attenuate after the ninth decade (Figure 1). Taken together, these data raise the possibility that a low-meat-intake diet does contribute to greater longevity.

Is a causative role of higher meat intake in fatal disease biologically plausible? When considering this question, it is important

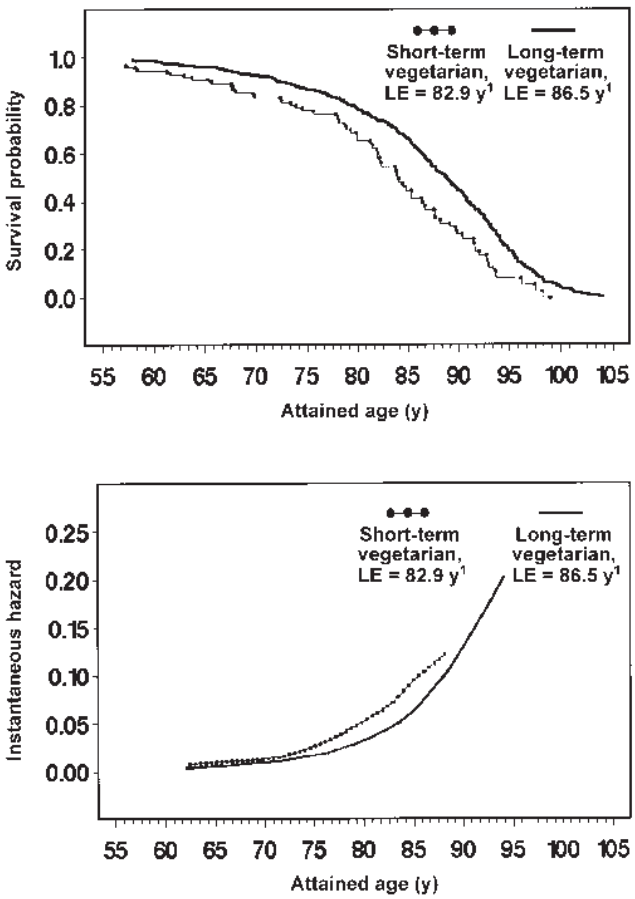

FIGURE 1. Cumulative survival, smoothed instantaneous hazards (26), and life expectancies (LE; reference 27) for long-term vegetarians (zero intake of all meats) and short-term vegetarians in the Adventist Studies. Long-term vegetarians reported zero meat intake for 17 y of the follow-up; short-term vegetarians reported zero meat intake for <17 y of the follow-up. [1]Significant 3.6-y difference (Z test given in reference 27) in life expectancy between long-term and short-term vegetarians (95% CI: 1.4, 5.8).

to note the extensive data implicating nutritional (macronutrients, micronutrients) and other components of ingested meat products (commercial feedlot additives, substances added or produced in preservation, processing, and cooking) as risk factors for fatal disease (1). These associations include but are not limited to the following: *1*) the contribution of saturated fat in meats (particularly red meats) to atherogenic (28) or perhaps hyperinsulinemic pathologies (29–32), *2*) the contribution of ingested meat protein to the endogenous formation of carcinogenic or mutagenic *n*-nitroso compounds (33) and heterocyclic amines (34, 35), *3*) the contribution of the increased caloric and heme iron content of meat products to higher oxidative stress (36, 37) and tissue damage [ie, myocardium (38–40)], *4*) the contribution of antibiotics administered to poultry and livestock in the feedlots to infectious human disease (through antibiotic resistance) in those consuming meat from these lots (41, 42), *5*) the contribution of transmissible prion diseases in cattle feed supplemented with rendered animal tissue to the development of variant Creutzfeldt-Jakob disease (43), and *6*) the contribution of certain cooking methods (ie, smoking, grilling) to the formation of biologically important amounts of carcinogens (benzo[a]pyrene and other polycyclic aromatic hydrocarbons) (44).

We found evidence in a new analysis of the Adventist studies (Figure 1) that the protective effect of very low meat intake seems to attenuate after about the ninth decade.

These data are quite similar to the findings by Lasheras et al (45) indicating that the protective effect of a low-meat diet pattern among 65–80-y-old adults [0.69 (0.43, 0.93)] was not evident among 80–95-y-old adults [1.24 (0.60, 2.53)]. Additionally, longer duration of follow-up (22 y compared with 12 y) in the Oxford Vegetarian Study (16) produced a time-dependent attenuation of the protective association for very low meat intake that was seen at 12 y of follow-up but not at 22 y (Table 1).

When the attenuation of the protective effect of low meat consumption is considered, it is important to note that the attenuation of hazards for individual risk factors (particularly modifiable factors such as diet, physical activity, and adiposity) with age has been reported in a number of studies and is seldom given an entirely causal interpretation (46, 47). Some of the noncausal interpretations include a survivor effect whereby the proportion of adults susceptible to death due to dietary intake would decrease over time, therefore decreasing the magnitude of risk estimates. This resonates with an argument that the increasing contribution of genetics to the longevity of an aging population would also decrease the magnitude of associations with other risk factors. Last, the elderly may have changed their diet in response to age-related pathologies (ie, dysphagia), to an increasing burden of comorbid disease, or both. If these changes involved reducing or even eliminating meat intake, then such changes would attenuate associations indicating a beneficial effect of meatless diets (47).

When the trends indicating a possible protective effect of very low meat intake reported in Tables 1 and 2 are interpreted, a number of limitations in study methodology need to be considered because they may contribute to differences in the magnitude of the estimates. A common criticism of a causal interpretation of observational data linking the vegetarian diet to better health outcome is that vegetarians are likely to exhibit a number of other positive prognostic factors (ie, avoidance of cigarettes and alcohol, higher levels of physical activity, higher socioeconomic status, greater awareness of personal health) (1, 21, 48). In this context, it is noteworthy that the data in Tables 1 and 2 indicate that most studies have controlled for confounding by some but certainly not all of these prognostic factors. For example, the 2-fold decrease in mortality risk for German vegetarians that was adjusted for only confounding by age should be interpreted with caution because there are undoubtedly many other confounding factors that would contribute to greater longevity among the German vegetarians compared with the total German population. In contrast, the findings from the Adventist studies that are reported here (Tables 1 and 2) provide a unique opportunity to evaluate the causal effects of meat because both the very-low-meat-intake subjects and the higher-meat-intake subjects were never-smokers, did not drink alcohol, and had no baseline history of major chronic diseases. Additionally, mortality risk for the Adventists (Tables 1 and 2) was adjusted for education, body mass, and physical activity.

Another possible methodologic limitation that may contribute to the variation in the observed relation between vegetarian status and mortality in Tables 1 and 2 is the criteria used to define and select vegetarians and nonvegetarians for a survival analysis. In Tables 1 and 2, it is noteworthy that some of the studies showing strong protective effects (ie, Adventist Studies) compared vegetarians who consumed no meat to nonvegetarians who were weekly meat eaters. These findings contrast with the null findings from some of the UK studies where "nonvegetarians" included occasional meat eaters (meat eaten less than once per week)—a feature that decreases the difference in dietary intake between vegetarians and nonvegetarians, thus biasing the mortality ratio toward unity. Similarly, a "healthy volunteer" bias in which vegetarian or nonvegetarian subjects responding to questionnaires or health interviews tend to be more health conscious than the general population can also serve to decrease the difference in survival between vegetarians and nonvegetarians if the bias is differential across exposure.

These factors are particularly noteworthy when considering the preliminary, 5-y findings from the European Prospective Investigation of Cancer (EPIC)–Oxford cohort (published in this supplement) indicating an apparently small difference in survival between vegetarians and nonvegetarians. That a sizable proportion of the nonvegetarians in the EPIC-Oxford cohort were *1*) occasional meat users, *2*) previous survey respondents who were affiliated with vegetarians, or *3*) people affiliated with vegetarian societies could detract from the insight gained by comparing their survival with vegetarians' survival.

Measurement error of usual dietary intake of meat is another limitation of the studies cited here. The validity studies conducted on food-frequency questionnaires used by some of these prospective studies did indicate, however, that these semiquantitative instruments were good estimators of meat intake as measured by 24-h recall or biochemical indicators of diet (1). Moreover, Willett has reported that measurement error in dietary assessment tends to bias the effect estimate toward the null (49), implying that *1*) the protective associations with very low meat intake reported here may in fact be stronger, and *2*) the null findings from crude, nonquantitative measures of meat intake may not be conclusive. In this context, it is noteworthy that the absence of a strong meat-mortality association in the Health Food Shoppers Study came from a design where meat intake was estimated from a nonquantitative item on whether a subject was vegetarian. A validity assessment of the survey used in this study indicated that self-reported vegetarian status on a questionnaire was a poor marker (ie, 34% of those indicating vegetarianism on a questionnaire did consume meats) of actual meat intake (17).

When interpreting the apparently protective associations for very low meat intake given in Table 1, it is noteworthy that many

of the foods that would replace meat in the vegetarian diet pattern (ie, legumes, soy products, nuts, and vegetables) may be causally protective against fatal disease (50–52). For example, among vegetarian Adventists, Kahn et al (22) reported a decreased mortality risk for higher consumption of green salads, and Fraser et al (52) reported a decreased coronary artery disease mortality risk for higher consumption of nuts. This raises the possibility that a low-meat, high plant-food dietary pattern may be the true causal protective factor rather than simply elimination of meat from the diet. In a recent review of studies relating low-meat diet patterns to all-cause mortality, Singh (1; page 165) noted that "5 out of 5 studies indicated that adults who followed a low meat, high plant-food diet pattern experienced significant or marginally significant decreases in mortality risk relative to other patterns of intake."

That only a subset of vegetarians experience a survival advantage that is largely attributable to the preventive effect of specific plant foods in abundance in their diet may further explain variations in the magnitude or presence of a protective effect of the various groups of vegetarians in Tables 1 and 2. Further studies are needed to identify specific plant foods among vegetarians that may be contributing to a putative survival advantage.

CONCLUSION

Current data from prospective cohort studies of adults raise the possibility that a lifestyle pattern that includes a very low meat intake is associated with greater longevity. The findings from one cohort of healthy adults raises the possibility that long-term (≥ 2 decades) adherence to a vegetarian diet can further produce a significant 3.6-y increase in life expectancy.

Because meat products represent a major source of protein in the Western diet, investigating whether meat intake significantly contributes to the burden of fatal disease has important clinical and public health implications. Further investigation of meat intake in relation to survival in other cohorts is needed because the published studies summarized herein represent only a subset of the available cohort data. More work is also needed to identify the causative roles of specific plant foods in the longevity observed among vegetarians.

The authors had no conflicts of interest related to the research areas discussed in this report.

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