Ten Years of Life

Is It a Matter of Choice?

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Background: Relative risk estimates suggest that effective implementation of behaviors commonly advocated in preventive medicine should increase life expectancy, although there is little direct evidence.

Objective: To test the hypothesis that choices regarding diet, exercise, and smoking influence life expectancy.

Methods: A total of 34 192 California Seventh-Day Adventists (75% of those eligible) were enrolled in a cohort and followed up from 1976 to 1988. A mailed questionnaire provided dietary and other exposure information at study baseline. Mortality for all subjects was ascertained by matching to state death tapes and the National Death Index.

Results: California Adventists have higher life expectancies at the age of 30 years than other white Californians by 7.28 years (95% confidence interval, 6.59-7.97 years) in men and by 4.42 years (95% confidence interval, 3.96-4.88 years) in women, giving them perhaps the highest life expectancy of any formally described population. Commonly observed combinations of diet, exercise, body mass index, past smoking habits, and hormone replacement therapy (in women) can account for differences of up to 10 years of life expectancy among Adventists. A comparison of life expectancy when these factors take high-risk compared with low-risk values shows independent effects that vary between 1.06 and 2.74 years for different variables. The effect of each variable is assessed with all others at either medium- or high-risk levels.

Conclusions: Choices regarding diet, exercise, cigarette smoking, body weight, and hormone replacement therapy, in combination, appear to change life expectancy by many years. The longevity experience of Adventists probably demonstrates the beneficial effects of more optimal behaviors.

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AN UNDERLYING goal of therapeutic and preventive medicine is to increase the number of productive and satisfying years of life experienced by the population. Achieving this by prevention has the advantage of reduced morbidity when disease does not develop or is delayed, and avoids the use of medications that are costly and will cause adverse effects in a proportion of patients. However, there is little direct evidence that life is extended by preventive strategies.

The implication that this is so has been strong, as many of these strategies are associated with lower relative risks of mortality, and many of these associations are reasonably assumed to be causal. Unfortunately, the mathematical relationship between a lower relative risk and extra years of life is complex. It is not easy to predict the number of years of life gained from a particular reduction in relative risk for all-cause mortality.[1]

Relative risks are an appropriate means of reporting results for research purposes. However, the general public and probably nonepidemiologic medical practitioners may find results expressed as predicted extra years of life, or delay in age at onset of a specific disease,[2,3] equally, if not more, useful.

A statistical method that we recently described[4] is applied to the Adventist Health Study cohort to predict the expected length of life in subjects who subscribe to different behaviors. If associations with mortality are causal, then the differences in expected age at death result from individual choices. An advantage of the Seventh-Day Adventist population is that there is a wide range of dietary and other health habits, enabling

SUBJECTS AND METHODS

The *Adventist Health Study cohort* was defined in 1976 as non-Hispanic white subjects, at least aged 30 years, who lived in California Adventist households and completed 2 mailed demographic and lifestyle questionnaires. The study enrolled 34 192 men and women who met these criteria and followed their cases until 1988. Further details of the study design have been published previously.[5]

Briefly, subjects were initially contacted from names and addresses in church directories. Of those then formally identified by a brief census questionnaire, 75.1% completed an extensive lifestyle questionnaire that included sections on demographics, medical history, diet, physical activity, and a few psychosocial variables. Having been enrolled in the cohort, subjects were contacted each year thereafter by mail to provide the name of any hospital where they had been hospitalized during that year. Study field staff visited these hospitals to photocopy data providing evidence of new myocardial infarctions (international diagnostic criteria[6]) or cancers (histological features required). Deaths during follow-up were found as further described.

The height and weight used to calculate body mass index were self-reported. The validity of body weight data was supported in a substudy[7] in which the correlation between self-reported and measured weight was 0.95. The dietary portion of the questionnaire was a food frequency instrument that included questions for each of 55 foods or food groups, plus 10 qualitative dietary questions. Most dietary questions had 8 frequency categories, ranging from "never consume" to "more than once each day."[8]

The meat index was determined from responses to 6 questionnaire items on the frequency of consumption of the following specific meats: beef (hamburger, steak, other beef, or veal), pork, poultry, and fish. *Vegetarians* are defined as those eating meats never or less than once per month; and *semivegetarians* as those eating meats more often than vegetarians, but less than once per week. All others are nonvegetarians. Few Adventist vegetarians are vegan. Nut consumption was included in these analyses because of previously published evidence[9,10] showing protective associations between nut consumption and deaths due to coronary heart disease. This variable was divided into consumption categories of 1 time per week (low), 1 to 4 times per week (medium), and 5 or more times per week (high).

A dietary validity study[11] enabled a comparison of food frequency results with the average of 5 unannounced 24-hour telephone recalls. Correlations between measurements of meat and nut consumption by the food frequency instrument and the 24-hour recalls are 0.83 and 0.46, respectively, when corrected for attenuation[12] in the recall data.

Physical activity was categorized as low, medium, or high, based on a cross-classification of 2 questions regarding occupational and leisure activities that incorporated intensity and duration. The first question provided a list of vigorous leisure activities that the subject must have undertaken at least 3 times each week for 15 minutes on each occasion. The second question asked for the frequency of vigorous activities during performance of "usual daily work or responsibilities." *High exercise* reflects a positive response to either or both of the vigorous occupational or leisure activity questions; and *low exercise*, low leisure and low occupational activities. Others scored at a *medium* level of exercise.

There were virtually no current cigarette smokers in this population, and past cigarette smoking was estimated by a simple question with 3 possible choices: (1) "yes, currently smoking some"; (2) "yes, smoked in the past but not now"; and (3) "no, never smoked cigarettes." The questions on hypertension and diabetes required that these be indicated only when diagnosed by a physician. The few (<1%) Adventist current smokers, being atypical, and

us to evaluate strong contrasts. The cohort had no upper age limit, and person-years of experience were obtained up to the age of 104 years.

RESULTS

The number of deaths at particular ages and the person-years available for analysis are shown for men and women in **Table 1**. Of the 5193 observed deaths, 1373 (26.4%) were ascribed to coronary heart disease, 1074 (20.7%) to cancer, and 531 (10.2%) to stroke. Risk factor values (**Table 2**) show that 28% to 31% of the subjects are vegetarian (they eat meat less often than monthly), that 23% eat nuts at least 5 times per week, and that about 40% exercise vigorously for 15 minutes at least 3 times per week. More men than women are past smokers (before joining the Adventist church), and 53% of postmenopausal women have ever used hormone replacement therapy (HRT). Values of the last 4 variables and body mass index are usually shifted further toward the "more healthful" direction in vegetarians.

The curves depicted in **Figure 1** and **Figure 2** compare California Adventists with other Californians, and show that Adventists have increased survival. The expected ages at death (95% confidence intervals) in Adventist men and women, given survival to the age of 30 years, are 81.2 (80.5-81.8) and 83.9 (83.5-84.4) years, respectively. This corresponds to an extra 7.3 (6.6-8.0) years of life expectancy for Adventist men and an extra 4.4 (4.0-4.9) years for Adventist women, when compared with other Californians. The lower curves in each figure demonstrate that at the age of 81 years, 28% more Adventist men survive, and at the age of 86 years, 19% more Adventist women survive. Vegetarian Adventist men and women have expected ages at death (95% confidence intervals) of 83.3 (82.4-84.3) and 85.7 (84.9-86.4) years, respectively.

The effect on life expectancy of changing a single variable will potentially differ according to the values of the other variables in the model. Thus, to estimate the effects of individual variables, we have first kept all covariates at intermediate values, and changed only the variable of interest.

Contrasts in life expectancy between high- and low-risk values of a particular exposure variable for covariates at medium risk (**Table 3**) range between 1.1 and 2.7 years, and in no case does the 95% confidence interval include zero. High physical activity, frequent

non-Adventists living in Adventist households are excluded from these analyses.

Follow-up to ascertain all deaths was completed for the years 1976 to 1988. Computer matching to California state death tapes[13] was augmented by similar matching to the National Death Index when this became available in 1979. These sources were supplemented by the use of church records and short mailed annual surveys between 1976 and 1983.

To compare survival (after the age of 30 years) between California Adventists and other Californians, data were used from the California non-Hispanic white population projections, and mortality statistics, for 1985.[14,15] This is approximately the midpoint of the Adventist Health Study follow-up, and these are the first California population data that accurately identify non-Hispanics. California State and other census data were known to overrepresent the number of subjects 95 years and older.[16] Corrected data became available in 1989, so we used 1989 hazards for these oldest ages only in non-Adventist Californians.

It is expected that during the early years of follow-up of a volunteer cohort an increasing proportion of subjects who were initially healthy will develop health problems, and the cohort will finally approximate the overall health status of the parent population. In the following analyses, the years from 1976 to 1979 of the Adventist Health Study were eliminated to avoid a healthy volunteer effect that was previously shown to disappear by follow-up year 4.[17] It was not possible to remove Adventists from the California data, as religion was not recorded. However, because Adventists constitute less than 1% of the California population, the conservative bias will be minimal.

A multivariate current life table method[4] used nonparametric estimates of age-specific baseline hazard rates. The method uses proportional hazards modeling to produce maximum likelihood estimates for the exposure coefficients, where the time variable is attained age. As the method is multivariate, the effects of particular variables are independent of others in the model. A product term with age accommodated differences in effects by age, where such coefficients were statistically significant. These were necessary for vegetarian status, exercise level, and nut consumption. Then the hazards, which are conditional on exposure values, are used to calculate age-specific probabilities for a life table.[18] Estimators of the variance, confidence intervals, and tests of significance for differences in the expected age at death have been described.[4] The expected age at death as used in this report is always conditional on survival to the age of 30 years.

Thus, the method produces estimates of life expectancy that depend on the values of exposure variables. In a similar way that a proportional hazard regression, for instance, produces relative risks, the method used herein produces life expectancies comparing exposed with unexposed status. Compared with the Kaplan-Meier method of survival analysis, the method used herein is multivariate, and hence allows control of confounding by covariates.

The exercise variable was handled differently from others to take into account the fact that low exercise is not always a choice. Individuals in the low exercise category can be grouped as follows: (1) those with known physical disabilities that may preclude the choice to exercise more vigorously; and (2) all others, who, as far as we know, chose to avoid exercise. The likelihood function contains 2 indicator variables for low exercisers, the first for those who indicated previous heart disease, stroke, rheumatoid arthritis, other arthritis, or rheumatism, at study baseline, and the second for other low exercisers. Because we wanted to focus on the effects of a choice not to exercise, the life table analyses used the coefficient for the second dummy variable to model the effects of low exercise. This was a conservative choice, because low exercisers with the nominated disorders at study baseline had a higher mortality on follow-up, no doubt due to their prevalent disease and the low physical activity.

consumption of nuts, vegetarian status, and medium body mass index each result in an approximate 1.5- to 2.5-years gain in life expectancy compared with the corresponding high-risk values. The sum of these independent effects (9.7 years in men and 10.4 years in women) is similar to those predicted in subjects who have contrasting values for all variables simultaneously. Results are not shown in the table, but hypertension accounts for the loss of 4.2 and 3.2 years and diabetes for the loss of 4.6 and 8.6 years in men and women, respectively, when behavioral covariates take medium-risk values. The effect of current cigarette smoking cannot be evaluated in this population as there are virtually no current smokers.

Setting covariates at values labeled medium in an Adventist population may not form a useful reference for many non-Adventists. In an effort to find results that may be more generally applicable, we set covariate values at the higher-risk values (lower part of Table 3). The effects seen are quite similar to those in the upper part of the table and are, thus, not strongly dependent on whether high- or low-risk covariate values are used.

As the model is multivariate, the joint effects of contrasting values of several variables on expected age at death are explored (**Figure 3** and **Figure 4**). The first bar shows life expectancy when all variables take medium-risk values. Then passing from left to right through the figures, additional variables are also set at either high- or low-risk values, those variables to the right of a particular bar being still at medium-risk values. In the final contrast, when all variables are at either low- or high-risk values, the differences in the expected ages at death are 10.8 years (men) and 9.8 years (women).

These variables are behavioral, and their values result from conscious choices by study subjects. Adding the pathophysiologic variables of hypertension and diabetes to the model markedly increases the contrasts to more than 20 years. Confidence intervals are generally narrow, and those for different risk factor combinations almost immediately become nonoverlapping. Those who subscribe to intermediate-risk behaviors for all variables (the first bar) achieve most of the increase in expected age at death found in the behaviorally more extreme low-risk groups.

The life expectancy of each subject in the Adventist cohort was then calculated, conditional on their risk factor values, and then compared with the life expectancy when all variables take low-risk values. The re-

Table 1. Number of Deaths and Person-years of Observation, 1976 to 1988: The Adventist Health Study*

	Men		Women	
Age, y	No. of Deaths	Person-years	No. of Deaths	Person-years
30-39	15	18 173	13	27 828
40-49	26	23 065	49	35 858
50-59	83	25 043	136	37 815
60-69	268	25 239	313	42 645
70-79	563	18 697	738	37 185
80-89	722	8359	1213	20 020
90-94	223	1236	495	3259
95-99	78	314	187	831
≥100	18	37	53	122
Total	**1996**	**120 163**	**3197**	**205 563**
Those aged ≥85 y	663	4557	1394	11 783

*Non-Adventists living in Adventist households are excluded.

Table 2. Values of Risk Factors in All Adventists and in Vegetarian Adventists*

	All Adventists		Vegetarian Adventists	
Variable	Men	Women	Men	Women
Vegetarian status				
Vegetarian	27.5	30.9	100.0	100.0
Semivegetarian	19.3	22.9	0	0
Nonvegetarian	53.2	46.2	0	0
Nut consumption, times/wk				
<1	35.8	37.6	20.2	23.7
1-4	41.4	39.7	44.9	42.6
≥5	22.8	22.7	34.9	33.7
Exercise†				
Low	32.3	46.5	28.6	45.1
Medium	22.5	17.2	22.0	16.1
High	45.3	36.3	49.4	38.8
Past smoking				
No	67.6	86.9	78.8	93.5
Yes	32.4	13.1	21.2	6.5
HRT use‡				
No	. . .	46.7	. . .	49.6
Yes	. . .	53.3	. . .	50.4
BMI, kg/m^2, mean (SD)	25.0 (3.54)	24.3 (4.76)	23.7 (3.22)	23.0 (4.06)

*Data are given as the percentage of subjects unless otherwise indicated. Percentages may not total 100 because of rounding. HRT indicates hormone replacement therapy; BMI, body mass index; and ellipses, data not applicable.
†In those not indicating a chronic disease at study baseline preventing exercise.
‡In postmenopausal women.

sults indicate that half of Adventist men and women are losing more than 4 years of life, apparently due to their suboptimal behavioral choices (**Table 4**).

COMMENT

These results strongly suggest that behavioral choices influence the expected age at death by several years, even as much as a decade. Recommendations to improve diet, increase physical activity, stop smoking, and reduce body weight are common themes of most preventive medicine practices. Evidence of the benefits associated with these behaviors can be used to motivate change.

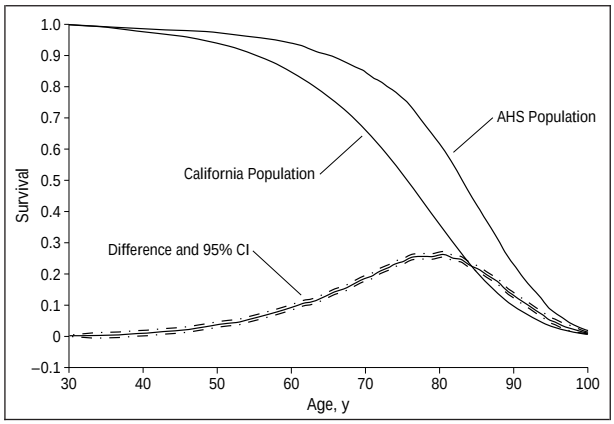

Figure 1. Survival of California Adventist men (1980-1988) and other California men (1985) beyond the age of 30 years. The difference between the 2 groups was significant ($P<.001$). These were non-Hispanic white subjects. Hazards for 1989 are used for non-Adventist Californians older than 94 years (see the "Subjects and Methods" section of the text). AHS indicates Adventist Health Study; CI, confidence interval.

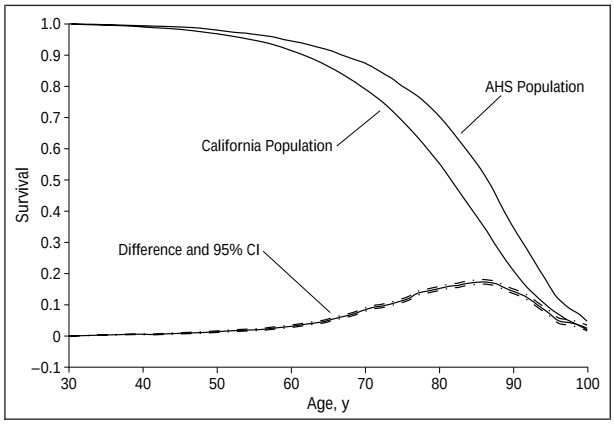

Figure 2. Survival of California Adventist women (1980-1988) and other California women (1985) beyond the age of 30 years. The difference between the 2 groups was significant ($P<.001$). These were non-Hispanic white subjects. Hazards for 1989 are used for non-Adventist Californians older than 94 years (see the "Subjects and Methods" section of the text). AHS indicates Adventist Health Study; CI, confidence interval.

It seems likely that the effects of these particular variables on life expectancy can be applied to Adventist and non-Adventist populations. There is no reason to suspect that Adventists are biologically different in their responses to environmental exposures. In support of this generalizability is the observation (Table 3) that changing covariates to high-risk values did not systematically change the estimated effects of the variables of interest. Analyses (not shown) on only the Adventist diabetic or the Adventist hypertensive subjects, both high-risk groups, also found contrasts of roughly similar magnitude to those reported for all subjects. All results, Adventist and non-Adventist, are for non-Hispanic whites and hence may not apply to other ethnic groups.

California Adventist men had a greater expected age at death by 7.3 years, and women by 4.4 years, when compared with non-Adventist Californians, but even this rela-

Table 3. Multivariate Estimates of the Effects of High- vs Low-Risk Values of Individual Behavioral Risk Factors*

Contrasts		Difference (Low Risk – High Risk) in Life Expectancy (95% Confidence Interval), y	
Low Risk	High Risk	Men	Women
Covariates at Medium Risk			
Vegetarian	Nonvegetarian	1.53 (0.41-2.65)	1.51 (0.53-2.50)
High exercise	Low exercise†	2.73 (1.41-4.06)	1.88 (0.86-2.90)
High nut consumption	Low nut consumption	2.74 (1.60-3.88)	1.87 (0.72-3.02)
Medium tertile BMI	High tertile BMI	1.41 (0.34-2.49)	2.25 (1.27-3.23)
Never smoker	Past smoker	1.25 (0.44-2.07)	1.80 (0.56-3.04)
HRT ever	HRT never	. . .	1.06 (0.27-1.86)
Covariates at High Risk			
Vegetarian	Nonvegetarian	2.38 (1.12-3.63)	1.65 (0.65-2.65)
High exercise	Low exercise†	2.14 (0.43-3.85)	2.19 (0.92-3.45)
High nut consumption	Low nut consumption	2.87 (1.64-4.11)	1.18 (0.06-2.29)
Medium tertile BMI	High tertile BMI	1.51 (0.35-2.68)	1.90 (1.03-2.76)
Never smoker	Past smoker	1.33 (0.44-2.22)	1.49 (0.40-2.58)
HRT ever	HRT never	. . .	0.82 (0.14-1.50)

*All variables are entered into the statistical model, but HRT switched on only after the age of 50 years, where appropriate. BMI indicates body mass index; HRT, hormone replacement therapy; and ellipses, data not applicable.

†Among individuals not limited in their ability to exercise by existing coronary heart disease, stroke, rheumatoid arthritis, rheumatism, or other arthritis.

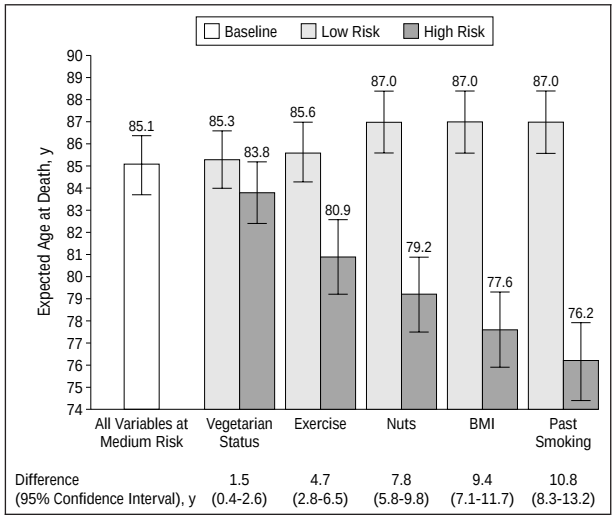

Figure 3. Expected ages at death (95% confidence intervals) in men with jointly high- or low-risk values for the risk factor in a particular column and those to its left (other variables at medium-risk values). BMI indicates body mass index.

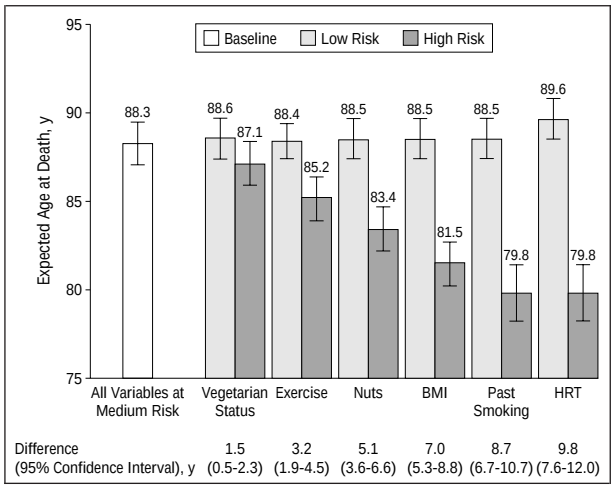

Figure 4. Expected ages at death (95% confidence intervals) in women with jointly high- or low-risk values for the risk factor in a particular column and those to its left (other variables at medium-risk values). BMI indicates body mass index; HRT, hormone replacement therapy.

Table 4. Proportion of the Adventist Study Population Who Lose the Specified Number of Years of Life Expectancy Apparently Due to Their Choices*

Years Lost	% of the Population	
	Men	Women
≥1	97.5	94.8
≥2	82.6	87.6
≥3	68.7	71.5
≥4	53.5	51.0
≥5	40.0	34.2
≥6	29.7	19.0
≥7	15.0	9.9
≥8	7.5	4.2
≥9	3.8	1.3
≥10	1.5	0.4

*Subjects possibly unable to exercise above low levels due to existing coronary heart disease, stroke, rheumatoid arthritis, other arthritis, or rheumatism are not penalized.

tively long-lived population is probably losing more than 4 years of life on average, due to suboptimal choices. The extra years of life predicted in these analyses are slightly greater than similar estimates from California Adventist and non-Adventist data collected between 1960 and 1965[19] and quite similar to comparisons between Adventists and others in Norway[20] and the Netherlands.[21] As expected, average California Adventists and non-Adventists are apparently less different than the theoretical extreme contrasts among Adventists. These latter contrasts are described by the right-hand bars of Figures 3 and 4 and account for a 10-year difference in life expectancy.

Adventist vegetarian men and women have expected ages at death of 83.3 and 85.7 years, respectively. These are 9.5 and 6.1 years, respectively, greater than those of the 1985 California population in a univariate analysis. When vegetarians are forced to take medium-risk values for all other covariates in the statistical model, the corresponding expected ages at death are 85.3 and 88.6 years, respectively (Figures 3 and 4). That these values are higher than those from the univariate vegetarian analyses indicates that sporadic high-risk covariate values have a greater effect on decreasing life expectancy than do sporadic low-risk values on increasing life expectancy, and the combined effects in a univariate analysis do not correspond to medium risk.

To our knowledge, the life expectancies of California Adventist men and women are higher than those of any other well-described natural population. Comparable data from several other populations around the same

Table 5. Expected Length of Life at Birth and at the Age of 65 Years: California Adventists Compared With International Populations

	Length of Life, y			
	Men		Women	
Country (Year)	At Birth	At Age 65 y	At Birth	At Age 65 y
Australia (1990)	73.9	15.2	80.0	19.0
Canada (1985-1987)	73.0	14.9	79.7	19.1
Denmark (1989-1990)	72.0	14.1	77.7	17.9
Finland (1989)	70.9	13.8	78.9	17.7
Iceland (1989-1990)	75.7	16.1	80.3	19.3
Japan (1990)	75.9	16.2	81.8	19.9
New Zealand (1987-1989)	71.6	14.1	77.6	17.8
Norway (1990)	73.4	14.6	79.8	18.6
United Kingdom (1985-1987)	71.9	13.4	77.6	17.3
United States (1990)	73.0	14.9	79.7	19.1
California Adventists (1980-1988)*	78.5	19.1	82.3	21.6
Vegetarians	80.2	20.3	84.8	22.6

*Hazards for those aged 0 to 29 years are those from California State data, as data for these ages are not available for Adventists. Non-Adventist data are taken from international longevity comparisons (1992).[22]

calendar period are shown in **Table 5** and support this conclusion. Japanese individuals have often been described as the longest-lived population,[23] but they do not survive as long as California Adventists.

The difference of only 2.8 years in the expected age at death of Adventist men and women is much less than that seen in most other populations. In lower-risk Adventists, this difference shrinks to less than 2 years. Compared with non-Adventists, the Adventist women gain fewer years than men. In other Californians, the expected ages at death of men and women differ by 5.7 years. Adventist women can anticipate fewer years of widowhood, assuming their husbands are also Adventist.

The volunteer status of the Adventist subjects may theoretically bias comparisons with all Californians if there was a tendency for Adventists with life-threatening diseases to not participate in the study. Indeed, such a healthy volunteer effect was previously documented in the cohort,[17] but this had largely disappeared by 1980, the first year that we allow data to contribute to the comparison with other Californians. Removing person-years from the analysis before 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, and 1986, in turn, resulted in estimated life expectancies (men and women combined) of 83.27, 83.22, 83.13, 83.18, 83.28, 83.30, 83.36, 83.29, and 83.46 years, respectively. The results were similar when men and women were analyzed separately. The all-cause mortality rate increased from 1977 to 1979, but from 1980 onward remained stable, and as can be seen, these differences trivially influenced the estimated life expectancies. By 1980, the population had apparently accumulated a stable proportion of unwell participants who were initially underrepresented due to self-selection.

The results previously discussed show that Adventists live longer but do not identify the factors that contribute to their increased longevity. Non-Adventists are usually nonvegetarian, eat nuts much less frequently,[24,25] exercise vigorously less frequently,[26] and are more likely to be current (or past) cigarette smokers than Adventists who for practical purposes do not smoke. Vegetarians also have lower body mass index values.[27-29] The magnitude of the longevity contrasts between California Adventists and non-Adventists can be readily accounted for by the combined effects of commonly seen differences in these behavioral variables. The analyses comparing Adventists with others, and those within the Adventist population, are broadly consistent. This suggests that we have been able to identify many of the important variables accounting for their higher expected age at death.

The independent effects described are those associated with adhering to the nominated behavioral patterns at all ages after the age of 30 years. This is not an unrealistic premise, as the rankings within a population of meat intake,[30] exercise habits,[31] and obesity status[32,33] remain reasonably stable for many individuals during adult life. However, diabetes and hypertension are often first manifest in middle age. The effects on life expectancies when these last disorders are modeled to begin at the age of 55 years, rather than the age of 30 years, compared with their lifelong absence are reductions of 3.8 and 2.8 years in male and female hypertensive subjects and of 4.2 and 7.0 years in male and female diabetic subjects (covariates set at medium-risk values), respectively. These values are only modestly less than the reductions observed when these disorders are modeled to begin at the age of 30 years.

Substantial gains in life expectancy would only be worthwhile if they were also accompanied by a longer period of good-quality life. Although our data cannot directly address quality of life, it was previously shown[34] that the vegetarian Adventists took less medication and had fewer overnight hospital stays, surgical procedures, and x-ray examinations during the previous year. Vegetarians also had a reduced prevalence of several chronic diseases[29] that may degrade the quality of life. The recent work of Vita et al[35] with non-Adventists provides strong evidence that persons who choose lower-risk health habits postpone disability.

If the associations that we have found with behavioral risk factors are confirmed by others and considered causal, the implications for public health are profound. It has been estimated that a gain in life expectancy in US women of 5 years, starting from 1980 levels (within the follow-up period of the Adventist cohort), will take until 2040, ie, 60 years.[36] Yet, our data suggest that an additional increment of similar magnitude could occur more rapidly if major shifts in dietary and exercise patterns could be induced.

The 6 variables that we chose for these analyses were those that significantly predicted mortality in this population when a multivariate analysis was used. Other variables, such as intake of fruit and vegetables and psychosocial and religious factors, may also be important, but they either were not measured or, as measured, did not predict mortality independent of the 6 chosen factors.

Although the variables that we used may in part be surrogates for other factors, it is worth recalling that it is quite uncommon to find strong estimated effects due

to confounding alone. The confounding factors would then need to be powerful determinants of risk and to be closely linked to the nominated variables.[37] The variables that we chose were strongly and significantly related to coronary heart disease and/or all-cause mortality.[38,39] Thus, it is likely that they do have important unconfounded independent associations with mortality, although our estimates of these effects may be modestly distorted by unknown confounding. Important determinants of mortality that are not included herein but are independent of the chosen variables will not have biased our results.

The effects ascribed to "nonvegetarian status" in Table 3 are probably related to the greater intake of foods high in saturated fat and the lower intake of foods higher in unsaturated fat, fiber, antioxidant vitamins, and other phytochemicals in nonvegetarian Adventists.[29] This may affect mortality due to cardiovascular causes and cancer.[40,41] Similarly, those who consume more nuts have been shown to have 35% to 50% lower rates of coronary events in 4 of the largest cohorts in nutritional epidemiologic studies.[9,42-44] This is probably due in part to the blood cholesterol–lowering effects of nuts,[10] and perhaps to their unusually high content of antioxidant vitamin E.[42] Increased physical activity is associated with important reductions in the relative risks of coronary events, stroke, and cancers of the breast and colon.[45-48] The mechanisms are not entirely understood, but probably include effects on blood lipid levels, sex hormones in women, blood insulin level, the immune system, and obesity and on the reduced risk of diabetes and hypertension.

The effect of HRT on all-cause mortality in women is controversial. The only large clinical trial[49] reported so far did not confirm observational work that had suggested that HRT protected against coronary heart disease, although this emphasizes the need for more research rather than disproving that HRT may be beneficial overall.[50] A possible explanation is that those using HRT are self-selected to be more health-conscious and seek medical attention earlier, and it is this that accounts for their lower risk. If so, such a bias could also be present in the Adventist data, but must depend on factors other than those already included in the model.

Other investigators have predicted the effects of different physiologic risk factors, such as hypercholesterolemia, hypertension, and diabetes, on life expectancy. These effects are often in the range of 1 to 4 years, similar to those we found for behavioral risk factors. Physiologic risk factors may be more directly damaging, but behavioral risk factors can affect total mortality by changing risks of several causes of mortality.

Tsevat et al[51] used a rather complicated combination of data from US Vital Statistics and the Framingham Heart Program and some assumptions and approximations about effects for those older than 85 years to predict changes in life expectancy. These were increases of between 0.5 and 5.7 years by either quitting smoking or changing blood pressure, blood cholesterol, or obesity status to optimal levels. Grover et al,[52] using Lipid Research Clinic cohort data, forecasted the benefits of antihypertensive therapy, or lipid-lowering medications, in these hyperlipidemic subjects as being between 0.85 and 4.74 extra years when the subjects were examined at the age of 40 years.

More recently, an analysis of 5 large cohorts[53] used the coefficients of a multivariate proportional hazards analysis to compare hypothetical low-risk individuals with others who did have 1 or more risk factors. Different studies in this group estimated that the low-risk groups had 5.8 to 9.5 more years of life expectancy, the largest values being where the baseline ages were lowest, as expected. No account was taken of the possibly quite different effects of individual risk factors at different ages.[39]

It was estimated that higher physical activity may extend life by at least 2.1 years[54] in a Finnish study. The College Alumni Study group[55] estimated an extra 2.51 years for more active 35- to 39-year-old men, before the age of 80 years. The Established Populations for Epidemiologic Studies of the Elderly found that nonsmokers with high physical activity had more than 5 years greater life expectancy at the age of 65 years when compared with those with low physical activity.[56] These results from univariate or bivariate analyses are similar to our multivariate findings.

In conclusion, California Adventists live longer than other Californians, and indeed longer than most, if not all, other formally described populations. This may be explained by common differences in behavioral risk factors between Adventists and others. Although it has been suspected that well-informed choices, particularly in combination, improve life expectancy, we have demonstrated herein the relatively large magnitude of such effects.

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