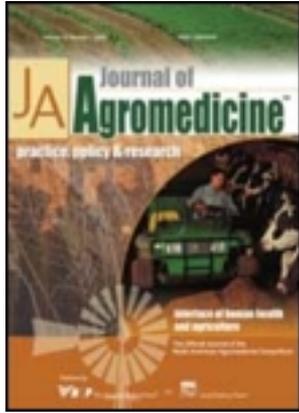


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Mortality in the California Farmer Health Study Cohort

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ABSTRACT. Western agriculture, in comparison with Midwestern and Eastern, is more diverse, with a drier climate, mild winters, and different exposures. This randomly selected cohort of 1947 Californian farmers confirmed the usual finding: a lower mortality rate than general population (by 50%). A low smoking prevalence and healthy worker effect are likely contributors. Although farmers were more likely to die from injuries and skin cancer, death was less likely from Alzheimer's and cerebrovascular diseases. Within the cohort, disability and persistent wheeze were associated with increased mortality. The 200 deaths were insufficient to determine the significance of rare diseases.

KEYWORDS. Farmer, mortality, cohort, California

INTRODUCTION

Although farmers are known to face increased risk of injury and accidental death,^{1,2} historically farming has been associated with lower overall mortality rates than the general population^{3–5} or other occupations.^{6,7} This suggests that despite the high fatal injury rate, due to work with heavy equipment, livestock, and other agricultural hazards,^{8–11} farming may not increase the overall risk of mortality. Alternatively, long-term farmers may belong to a subgroup of already healthier individuals (healthy worker effect).

Studies of cause-specific mortality in farmer populations have shown reduced rates of cardiac disease, diabetes, and lung cancer.^{12–17} Strenuous activity levels historically associated

with farming may have contributed to the lower incidence of cardiac disease and diabetes.^{13,15} However, the low prevalence of smoking (farmers experience lower lung cancer mortality associated with lower smoking prevalence)^{13,18} and the healthy worker effect are likely more important factors in the reduced overall mortality.

Farmers have exhibited an increased risk of some cancers, such as those of the lymphatic system, prostate, and colon, and this has been attributed to environmental toxicants, such as pesticides and herbicides. However, lifestyle or dietary factors may be related to these increases.^{19–22} In addition, farmers have higher rates of skin cancer than the general population due to the increased amount of solar exposure from time spent outside.^{22,23}

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Very few previous studies of agriculture and mortality have followed a cohort of farmers to examine individual exposures and deaths; instead, most have relied on more aggregate data studied retrospectively. The Agricultural Health Study of private pesticide operators (largely farmers) and their spouses in Iowa and North Carolina has followed a large cohort for an average of 13 years.⁵ However, the types of agriculture in those two states are very different and much less diverse than in California. This analysis was motivated by the aims of the University of California, Davis, Farmer Health Study (FHS), which are to identify the prevalence and risk factors for acute and chronic disease in this representative cohort of Californian farmers and farm managers followed for over 10 years.

Our aims were to compare the following: (1) the overall mortality rate of farm owners/managers to the general California population; (2) cause-specific mortality rates between farmers and the general California population; and (3) the characteristics of the decedents with their survivors within the cohort to discover any exposures associated with mortality. We were able to evaluate many covariates that are usually not collected in retrospective cohort studies or other noncohort designs.

METHODS

Sample Selection and Questionnaire Data Collection

A random sample of 4500 farms was selected from the California Agricultural Statistics Service (CASS) list of approximately 57,000 farms. More details of the FHS's sampling strategy have been previously described.^{10,24} A farm is defined by CASS as a location that produced, or normally would have produced, \$1000 or more in sales of agricultural products during the previous year. The primary operator of the farm (the individual who is responsible for making the day-to-day decisions) was interviewed. We were able to contact 3773 of 4500 farm operations (84%),

and of those, 2422 (64%) were eligible (the most frequent reason for ineligibility was that the individual was no longer farming). Of the eligible contacts, 1947 (80%) completed a computer-assisted telephone interview (CATI) in 1993. Respondents were surveyed on demographics, farm characteristics, and their health in an interview lasting approximately 40 minutes that was administered by trained interviewers. Repeat interviews were completed in 1998 and 2004.

Collection of Death Records

Data on the farmer cohort were collected from the National Death Index (NDI)²⁵ covering years 1993–2004. The NDI is a computerized database of death records that receives information from state vital statistics offices and is maintained by the National Center for Health Statistics (NCHS). The NDI computes a probabilistic matching score created from matching various variables. This study used decedent name (including middle names), social security number, birth date, age (integer year), sex, race, state of residence, and marital status. NCHS then sent a listing of probable matches. We compared date of death and state where death occurred to study participants' last contact to confirm NCHS matches. Where matches were found, NDI provided death certificate information, including underlying cause of death.

Comparison of Deaths Within the Farmer Health Study With Those in the California Population

In the original 1993 farmer cohort, 10% of respondents were female (of various races) and another 11% were non-Caucasian males (of various races). Due to these low percentages and the wide discrepancies in mortality rates for various races, only Caucasian males were used for this analysis.

Data on the mortality of the California Caucasian male population were collected from the Centers for Disease Control and Prevention's Wonder database covering years 1993–2004.²⁶ The information included mortality rates and underlying causes of death.

Life tables were created using the methods of Chiang,²⁷ as used by the California Department of Health Services. Age groups were defined in the farmer cohort to match those in the California database.

Crude Mortality Rate

Using the farmer and California populations of male Caucasians and adjusting for age by indirect standardization, the overall death rate was compared between the cohort and reference populations. The rate of Caucasian California deaths among males was calculated by dividing number of deaths by the total population; this was done for each age group. Farmer data were then broken down into age groups to match the California data. The expected number of farmer deaths was then calculated for each age group and each year by multiplying the Caucasian California death rate by the farmer population. The number of expected deaths is distributed as a Poisson variable with the mean equal to the total expected deaths, which allows for calculation of the probability of observing the actual number of farmer deaths under this distribution. Since death rates changed significantly over the time period of this study, separate comparisons were made for each year. Observed and expected deaths were also averaged over the years to create an overall summary comparison. Mortality ratios were calculated by dividing the observed number of deaths by expected number of deaths.

To estimate deaths attributable to smoking, we multiplied the proportion of lung cancers caused by smoking by the actual number of lung cancer deaths and divided by the proportion of smoking deaths that are lung cancer. The proportion of lung cancers caused by smoking was calculated using the number of lung cancer deaths among smokers versus nonsmokers; the proportion of smoking deaths that are lung cancer is estimated by the Centers for Disease Control and Prevention to be 0.32.²⁸

Cause-Specific Mortality Rate

For cause-specific deaths, the expected number of deaths was calculated for male farmers

each year by age group. The death rate for a specific cause was calculated by dividing the number of Caucasian male deaths due to that specific cause in California by the total number of California Caucasian male deaths. This rate multiplied by the number of male farmer deaths for that year and age group revealed the expected number of farmer deaths due to the specific cause. For each cause, the expected and observed deaths were summed over age groups and time. The observed deaths were hypothesized to follow a Poisson distribution with mean equal to the total expected deaths, and the probability of seeing the number of observed farmer deaths with this distribution was calculated. Mortality methods followed the procedures used by NIOSH.²⁹

Comparing Characteristics of Decedents and Survivors of the Farmer Health Study Cohort Associations With Mortality

The surviving cohort was compared with those who died during the 1993–2004 period. Variables considered were age, marital status, total family income, education, region of California, whether or not the farmer lived on a farm, weekly work hours, farm acres, farm type, smoking status (current or former vs. never smoker; and pack years), and various health problems, including permanent disability, various respiratory problems, cancer, diabetes, and high blood pressure. Logistic regressions were run individually for each variable. All models were adjusted for age, and health-related variables were also adjusted for smoking status. Variables that were significant at $p \leq .05$ were included in a multiple logistic regression model; using these variables, a backward selection procedure option was performed to define those variables most significant. A stepwise logistic regression procedure was also run, resulting in the same multivariate model. Possible interactions were then added to the model, but none were found to be significant at $p \leq .05$.

All analyses were conducted with Statistical Analysis Software version 9.1 (SAS Institute, Cary, NC).

RESULTS

Overall Mortality

There were 196 female and 218 non-Caucasian males in the 1947 subjects of the original cohort. Of the remaining 1533, 1428 had sufficient identifying information to allow them to be tracked through 2004. Of these, 200 (14%) were deceased by the end of December 2004, and 1228 (86%) remained alive at that date.

Comparison With the California Population

There were significantly ($p < .05$) fewer deaths than expected (allowing for age) in the male population for each year from 1993 to 2004, except for 1998 ($p = .094$) and 2004 ($p = .642$). Averaging over the years, there were 17 observed (O) deaths per year compared with

30 expected (E) ($O/E = 0.567$, $p = .007$), or a little over one half the expected deaths in the cohort (Figure 1).

Comparison Within Cohort

We compared the 200 deceased male Caucasian farm operators with those FHS farm operators still alive at the end of December 2004 ($N = 1228$) (Table 1a). Various demographic and health variables from the 1993 baseline survey were compared between these two groups. As expected, those who had died were older than those alive in 1993 (average age 68 vs. 52 years) (Table 1a). Subsequent comparisons were adjusted for age. There was no significant difference between the decedents and survivors in household income, education level, or region of California. Cigarette smoking was associated with mortality; 19.3% of current smokers were deceased, 17.6% of former smokers, and 10.6% of never smokers. Permanent

FIGURE 1. Observed versus expected mortality in the California Farmer Health Study Cohort. Significance values for overall mortality rates. Principal farm operator versus California population (Caucasian males only) adjusted for age. The observed rates were significantly different from expected, with $p \leq .01$ except for the following: 1998 ($p = .094$), 2000 ($p = .015$), and 2004 ($p = .642$) (color figure available online).

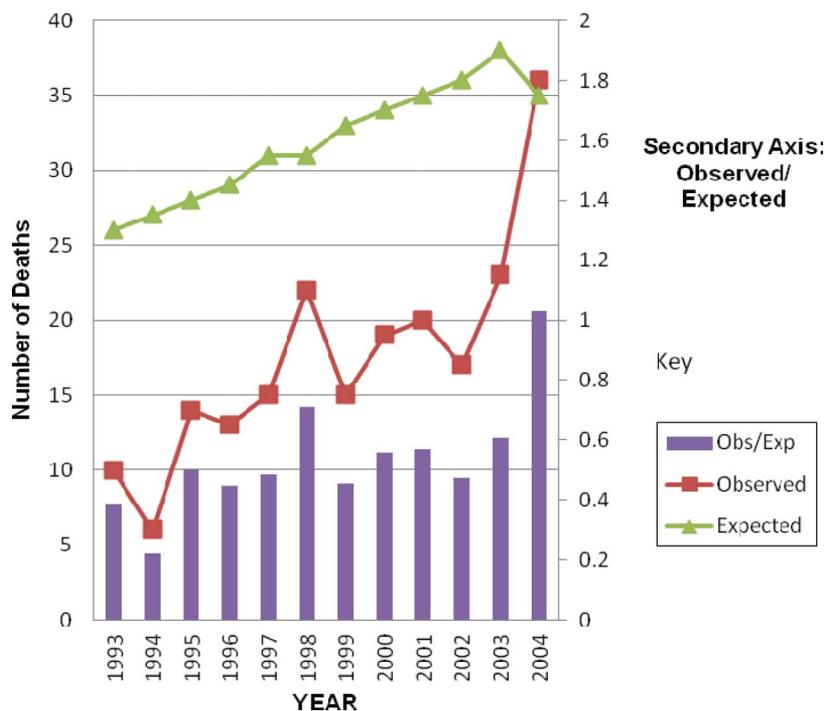


TABLE 1a. Demographic Comparison of Those Who Died to Surviving Participants

Characteristic	Mortality subjects (N = 200)	Surviving subjects (N = 1228)	p value
Age in 1993			<.0001
Mean (SD)	68 (10.2)	52 (12.3)	
[min-max]	[37-88]	[21-82]	
	n (%)	n (%)	
Married	174 (87%)	1084 (88%)	NS
Total family income			
<25,000	35 (18%)	96 (8%)	NS
25-50,000	61 (31%)	335 (28%)	
50-100,000	50 (26%)	446 (37%)	
>100,000	48 (25%)	332 (27%)	
Education less than a high school graduate	34 (17%)	78 (6%)	NS
CA region			NS
North Coast	20 (10%)	132 (11%)	
Central Coast	13 (7%)	90 (7%)	
Sacramento Valley	29 (15%)	197 (16%)	
San Joaquin Valley	78 (39%)	552 (45%)	
Mountains	16 (8%)	75 (6%)	
Southern CA	44 (22%)	182 (15%)	
Lived on a farm	152 (76%)	881 (72%)	NS
Years spent farming			NS
Mean (SD)	33.2 (18.4)	24.0 (13.9)	
IQR	19-47.75	13-32.5	
Weekly work hours			NS
<20	80 (42%)	451 (37%)	
20-40	52 (27%)	267 (22%)	
>40	60 (31%)	491 (41%)	
Acres farmed			NS
Mean (SD)	703.8 (2223.6)	1217.1 (7369.48)	
IQR	15-295	20-373	
Raised livestock	73 (37%)	432 (35%)	NS
Raised			NS
Animals	11 (6%)	62 (5%)	
Plants	125 (63%)	760 (64%)	
Animals and plants	62 (31%)	370 (31%)	
Had a permanent disability	19 (10%)	63 (5%)	.019
Smoking status			<.0001
Never smokers	82 (41%)	691 (56%)	
Former smokers	85 (43%)	398 (32%)	
Current smokers	33 (17%)	138 (11%)	
*Pack-years smoked			<.0001
Mean (SD)	48 (30.2)	28 (23.6)	
IQR	26-63	11-39	

Note. IQR = interquartile range; SD = standard deviation; NS = not significant, $p \geq .05$.
Logistic regression models all controlled for age.

*Pack-years smoked only calculated for those who had ever smoked.

disability in 1993 was associated with increased mortality. Mortality was not associated with farm variables, such as whether the subject lived on the farm, average weekly work hours, years

of farming, farm acreage, farm type, or whether or not livestock was kept.

We created models comparing health statistics controlled for both age and smoking status

TABLE 1b. Comparison of the Health Conditions of Those Who Died to Surviving Participants

Health condition	Mortality subjects (N = 200)	Surviving subjects (N = 1228)	p value
Limited amt of farm work due to health	50 (25%)	152 (12%)	.042
Ever had asthma	17 (9%)	92 (9%)	NS
Currently have asthma [†]	14 (7%)	53 (4%)	.0146
Chronic bronchitis diagnosis [†]	17 (9%)	44 (4%)	.038
Chronic cough diagnosis [†]	15 (8%)	49 (4%)	NS
Persistent wheeze diagnosis ^{*†}	26 (13%)	101 (8%)	NS
Ever had diagnosis of cancer [†]	39 (20%)	96 (8%)	NS
Ever had diagnosis of diabetes [†]	23 (12%)	57 (5%)	.034
Ever had diagnosis of high blood pressure [†]	71 (36%)	226 (18%)	.010

Note. All logistic regression models controlled for age and smoking status. NS = not significant, $p \geq .05$.

*Model also controls for "still has asthma."

[†]Doctor-diagnosed condition.

(Table 1b). Those who died during the study period were more likely to report health problems in 1993; there were increased levels of current asthma, chronic bronchitis, diabetes, and high blood pressure in the group that died. Also, by 1993, a higher percentage of subjects who died during the study period had limited the amount of farm work they did due to health (25% vs. 12%).

A multivariate analysis was conducted to compare differences in mortality in the farmer cohort. Variables found to be independently associated with mortality included age, smoking status, permanent disability, and persistent wheeze in 1993 (Table 2). Current smokers were 2.7 times as likely to die as never smokers, and the risk ratio for ex-smokers was 1.25 times greater than for never smokers. The association of respiratory symptoms with overall mortality (persistent wheeze in multivariate model) may reflect uncontrolled smoking dose in the smoking variable, severity of the respiratory disease, or other contributing factors, such as occupational exposures.

TABLE 2. Multivariate Model Associations With Mortality

Variable description	Odds ratio	95% CI for odds ratio	p value
Age	1.134	1.114–1.155	<.0001
Smoking status			
Current vs. Never	2.697	1.592–4.569	.001
Former vs. Never	1.252	0.861–1.819	
Permanent disability	1.996	1.058–3.769	.033
Persistent wheeze in 1993	1.957	1.120–3.421	.018

Note. All variables were contained in the same multivariate logistic model.

CI = 95% confidence interval.

Specific Causes of Death in the Farmer Cohort

The most common cause of death was heart disease (81/200), accounting for 41.5% of deaths. Almost a quarter of deaths were due to cancer (45/200), of which respiratory cancer was the most common (5%). An additional 9% ($n = 18$) died of chronic obstructive pulmonary disease (COPD) or respiratory disease. Deaths from accident or injury accounted for 5% ($n = 10$) of the total (Table 3).

Comparison With the California Population

The 200 Caucasian males from the farmer cohort who died between 1993 and 2004 were compared with male deaths in the general California population, age and year adjusted (Table 3). Deaths from cardiac disease were equal to the number expected ($O/E = 81/84 = 0.96$), but cerebrovascular mortality was significantly less than expected ($O/E = 4/13 = 0.31$), as was Alzheimer's disease ($O/E = 0/3$). Overall cancer, respiratory cancer, and respiratory disease mortalities were slightly but not significantly decreased in the cohort.

Deaths due to injuries were significantly increased, occurring more than twice as often as expected ($O/E = 9/4$, $p = .016$). Of the nine accidental deaths from injury, three were associated with agricultural machinery and two were by exposure to an unspecified gas, vapor,

TABLE 3. Significance Values for Specific Causes of Death: Comparison of Caucasian Male Farm-Operators and Their California Male General Population Equivalents

Cause of death	No. observed	No. expected	<i>p</i> value difference	Mortality ratio
Heart disease	81	84	NS	0.96
Cerebrovascular only	4	13	.004	0.31
Diabetes	3	5	NS	0.60
Respiratory disease/COPD	18	23	NS	0.78
Accident and injury	9	4	.016	2.25
Suicide	2	2	NS	1.00
Alzheimer's	0	3	.0493	0.00
Influenza and pneumonia	4	8	NS	0.50
Liver and cirrhosis	4	3	NS	1.33
Cancer	45	53	NS	0.85
Respiratory cancer	10	15	NS	0.67
Skin cancer	3	1	.045	3.00

Note. All models were adjusted for age and year. NS = not significant at $p \geq .05$.

or other factor. Another death was from being struck with or against an object. The remaining three deaths were due to motor vehicle (2) and bicycling (1) accidents.

Skin cancer mortality was significantly increased in the farmer cohort compared with male deaths in the general California population ($O/E = 3/1$, $p = .045$). Subjects who died of skin cancer spent an average of 75% of their time outdoors ($n = 3$, $SD = 25$), as opposed to an average of 66% of time of those in the study who died of other causes ($n = 197$, $SD = 29.7$). For those who died of skin cancer, the minimum time spent outdoors was 50% (range 50–100%). No difference was seen with respect to self-reported protective measures against sun exposure.

DISCUSSION

Overall Death Rates

U.S. farmers suffer a higher than average fatal injury rate; in 2009, full-time farmers and ranchers had a fatal injury rate of 38.5/1,000,000 workers compared with an average of 3.3/1,000,000 for all workers combined.³⁰ Despite the high injury fatality rate, most studies have found a lower overall risk of mortality for farmers than their non-farming counterparts.^{4,5,17,31,32} The University

of California, Davis, Farmer Health Study (FHS) mortality rate was about half the level expected and similar to that found in the recent Agricultural Health Study of commercial pesticide applicators in North Carolina and Iowa⁵ and in other studies.^{14,33} There are various theories for this, the most common being the “healthy worker effect,” meaning that subjects who are not healthy would leave or avoid a strenuous occupation, such as farming. Thelin and colleagues³⁴ suggested that farmers “retire” due to economic factors and they actually leave farming at a lower rate than other workers leave their occupations. In contrast, a more recent study questioned this accepted viewpoint, suggesting that, in fact, farming may increase the age-adjusted risk of all-cause mortality.³⁵ Although many of the FHS cohort had retired by 2004 (25%), only a small proportion retired under age 70, and the remainder continued to perform farming chores well into their 80s (data not shown). Other studies^{7,32} have looked at the difference between rural (including farmers) and urban residents and found lower mortality in rural communities, irrespective of occupation. Stiernstrom and colleagues⁴ have suggested that farming has a benefit in lowering mortality in addition to rural living.

The lower overall mortality of rural residents, and of farmers, is due in part to lower cigarette-smoking rates. We were unable to adjust for smoking in specific cause of death

comparisons, as certain necessary information was not available in the California mortality data. However, we were able to estimate the proportion of both total California deaths and our farmer deaths due to smoking. We employed a new method²⁸ to estimate the percentage of deaths attributable to smoking. It uses the number of smokers versus nonsmokers among lung cancer deaths to statistically predict the ratios. Of the 200 FHS deaths, 22 (11%) were likely associated with smoking, but of the total California male deaths, an estimated 19% were associated with smoking. This indicates that the lower mortality rate among our farmers (about 1/2 the rate expected) is in part due to a lower smoking rate.

We did not find evidence to suggest that farm type, location, size; the percentage of farming time spent working in the fields or on tractors; or whether livestock was raised were associated with mortality. In addition, the following farm-related variables were not associated with mortality in this cohort: whether the farm operator lived on a farm, the number of years in farming (adjusted for age), use of pesticides, accidental injury, or income.

It is possible that we undercounted the deaths of the FHS cohort population. We believe that this is unlikely, as the NDI probabilistic match score system is highly respected and very thorough.^{36,37} However, some subjects gave little identifying information; also, if they died outside of the country, their information may not have been in the NDI database. Although we do not know the number of deaths that may have been missed, we believe that it was relatively low and would not affect the overall conclusions of this analysis.

Association of FHS Cohort Exposures With Mortality

The exposures assessed in 1993 that were associated with death included, as expected, age and smoking status. Two other conditions were also associated with subsequent mortality: persistent wheeze and permanent disability. Although persistent wheeze can be a symptom of asthma, COPD, or other causes of airflow obstruction, asthma was not associated with

mortality. Persistent wheeze was found to be independently associated with exposure to dust in this cohort.³⁸ We examined both smoking status and number of pack years in the mortality analyses, and attempted to include smoking interactions in the models. The interaction variables were not significant, so for this reason we do not believe the observed association of persistent wheeze and mortality is explained by uncontrolled cigarette smoking. As far as we know, this association has not been recorded in other studies and may reflect the specific climate and geologic conditions in California where dusty conditions predominate over much of the growing season.

Permanent disability has been found previously to be associated with mortality for those suffering arthritis⁶, men with coronary heart disease,³⁹ and older subjects⁴⁰. In 1993, the farm operators had a rate of permanent disability from injury of 5.74%. The agriculture industry consistently has a higher rate of occupational injury and illness than the general working population.⁴¹ There is no equivalent statistic in the general population surveys used for this comparison. A substudy of the FHS cohort in 2004 revealed that 47.3% of the 412 nonretired farmers aged 50 to 90 reported a physical limitation that affected the type or amount of work farmers could perform. This is much higher than a similarly aged population in California asked in 2001 whether their physical health limited the kind of work or other activities that they could do; only 27% indicated such a limitation (95% confidence interval [CI] 25.7–28.3%).⁴² Although persistent wheeze and permanent disability may be connected to exposure to agricultural dust and injury in this cohort, their association with mortality cannot be directly attributed to farming.

Deaths From Specific Causes

Due to the small numbers, we were unable to investigate many specific causes of deaths, especially those that are less common. Although death certificates may misclassify cause of death, the validity with respect to underlying causes is quite high, particularly for specific causes, such as cancer.^{43,44} This said, the

results of this study agree with the observation that farmers in California are more likely to die from accident or injury than the general population.^{8,9,31} Although the risk of injury-related death was doubled for this cohort, it was still lower than other parts of the country, where mortality ratios from injury may be 4-fold or higher.^{45,46} Despite concerted safety campaigns by National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), and affiliates, our findings suggest a need for further education, training, and engineering interventions to decrease injury deaths in this population.

This study also found higher rates of death due to skin cancer in the farmer cohort, most likely due to the increased time spent outdoors. This agrees with studies already published.^{5,17} Clearly, people in outdoor jobs (such as farming) should be aware and vigilant in protecting themselves from the sun, including using sunscreens and covering up with clothing. We have previously observed that California farmers commonly do not exercise measures to prevent excess sun exposure.⁴⁷

Deaths from cerebrovascular disease were significantly lower in the farmers, but there was no observed decrease in overall cardiovascular deaths, possibly due to small numbers. Nevertheless, this finding has been observed in other studies.^{13,15,16} Although not statistically significant, there were lower mortality rates due to both respiratory disease, including COPD, and respiratory cancer in the FHS cohort. The literature shows mixed findings with respect to respiratory diseases; some studies have found lower rates of respiratory disease mortality among farmers,^{5,16,17} whereas others have found higher rates.^{9,48} Interestingly, some studies showing lower rates of lung cancer mortality have observed an increase in respiratory disease mortality, suggesting that the increase is not due to cigarette smoking.⁴⁹ Differences in rates of respiratory disease may also be dependent on the type of farming. For example, Sahlander et al.⁵⁰ found higher rates of respiratory disease in pig farmers, whereas Mastrangelo et al.⁵¹ found lower rates of lung cancer among dairy cattle farmers. Recent studies have confirmed the association of COPD with occupational exposures

in addition to smoking. However, to date, there is mixed evidence with regard to farming and COPD.^{5,33,52}

Smoking has been associated with death from many different cancers and other non-respiratory diseases. For example, laryngeal, stomach, urinary and pancreatic cancers; ischemic heart disease; cerebrovascular disease; and atherosclerosis are all increased among smokers.⁵³ As stated earlier, the smoking rate for this farmer population in 1993 was 11% overall, approximately 50% lower than in the general population of similar aged males.⁵⁴ Estimates of respiratory cancer due to smoking, however, are clearer. As with the general population, the lower lung cancer mortality closely tracked the lower smoking rate in the population.⁵³

Realistically, our sample size proved to be too small to detect any significant differences in death rates for less frequent specific causes of death. Although three cases of death due to Alzheimer's disease were expected, none were found ($p = .0493$). Farming has not been generally associated with Alzheimer's disease, although there are some suggestions that long-term exposure to pesticides may reduce cognitive function⁵⁵ and be associated with Alzheimer's among other neurodegenerative diseases.⁵⁶ However, smoking has been positively associated with Alzheimer's disease, as reviewed by Barnes et al.⁵⁷ and Williams et al.⁵⁸

The FHS cohort may have had a lower intensity of farm exposures than farmers in other parts of the country. Subjects surveyed were the primary operator (the manager, farm owner, or the person who made the day-to-day decisions). Although 76% of the farm operators lived on the farm, these individuals may have been less involved in physical activities of farming than the farm laborers, who do the majority of farm work in states with labor-intensive farming, such as California. Thirty-eight percent of the farmer population worked less than 20 hours per week in 1993, and an average of 20% of that time was spent indoors at administrative duties (median = 10%), reducing their actual time doing the physical activities of "farming" and, consequently, the effects of that farming on their mortality. Overall, only 50% of the

farm operators worked at least 40 hours a week (year round average) on their farm(s). As such, our “farming” population may be closer in mortality risk to the general California population than other farmworker populations. Therefore, the 50% lower mortality rate compared with the general population, in line with other recent studies,^{5,14,33} is suggestive of the main observation of the low smoking prevalence in the FHS cohort. However, the mean years of full-time farming for this cohort at the baseline in 1993 was 19, indicating that there was significant lifetime exposure to farming risks among the population.

Unlike the majority of previous studies on farming and mortality, a strong point of this study was its creation from a randomly selected representative sample of California farmers who worked in a wide variety of agricultural practices. The study area was the whole of California, which produces more than half of the nation’s fruits, vegetables, and nuts, and leads the country in the production of 60 different agricultural commodities. Farming exposures have changed markedly over the last 50 years, and farming practices in California differ in many ways from the rest of the country. Nevertheless, we found many similarities in overall and cause-specific farmer mortality between California and the U.S. farming communities.

Conclusions

Historically farming has been associated with lower overall mortality rates than the general population, despite a worryingly high risk of death from work-related injuries. This farming cohort smoked at a rate approximately 50% lower than the general population, providing a key contributor to the cohort’s lower mortality rate, in addition to a possible healthy worker effect. Nevertheless, increased mortality from work-related injuries and disability was observed and this provides a specific target for intervention efforts. Such efforts should include engineering changes, educational efforts, and regulations where appropriate. The finding that persistent wheeze independent of smoking status and asthma was associated with increased

mortality reflects an earlier determination in this cohort that persistent wheeze was independently associated with exposure to agricultural dust, a finding that deserves further exploration. Future studies on mortality in farming populations should assess personal lifestyle factors as well as working exposures. Data collected through such a strategy will allow assessment of the relative contributions of the healthy worker effect, genetic and cultural factors, and changing environmental, management, and work practices.

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