Acute and Chronic Disability Among U.S. Farmers and Pesticide Applicators: The National Health Interview Survey (NHIS)

O. Gómez−Marín, L. E. Fleming, D. J. Lee, W. LeBlanc, D. Zheng, F. Ma, D. Jané, T. Pitman, A. Caban Jr.

ABSTRACT. *The National Health Interview Survey (NHIS) is a multipurpose household survey of the U.S. civilian non−institutionalized population conducted annually since 1957. From 1986 to 1994, over 450,000 U.S. workers, age 18 years and older, participated in a probability sampling of the entire non−institutionalized U.S. population; variables collected included a range of measures of acute and chronic disability. The objective of the present study was to assess predictors of health status, and acute and chronic disability for farmers and pesticide applicators (pesticide−exposed workers) compared to all other U.S. workers using the 1986−1994 NHIS. After adjustment for sample weights and design effects using SUDAAN, several measures of acute and chronic disability and health status were modeled with multiple logistic regression. Farmers (n = 9576) were significantly older compared to all other U.S. workers (n = 453,219) and pesticide applicators (n = 180). Farmers and pesticide applicators had a higher proportion of males, whites, and Hispanics and were less educated. After adjusting for age, gender, race−ethnicity, and education, compared to all other workers, farmers were significantly less likely to report acute and chronic disability and health conditions, while pesticide applicators were more likely to report chronic disability, health conditions, and poor health. Given the cross−sectional nature of the data and the significant job demands of farming, both leading to a relative healthy worker effect, the present results indicate that at any point in time, farmers report less acute and chronic disability, compared to other U.S. workers, whereas pesticide applicators report similar or poorer health.*

Keywords. *Acute disability, Chronic disability, Health status, Farmers, Pesticide applicators, National Health Interview Survey.*

Although nationwide research has been performed in other countries (Kagamimori et al., 1998; Drever, 1995), very little health status and disability related research has been performed on the U.S. workforce as a whole, due to the lack of large and appropriately selected samples. Therefore, when studying the health status of the U.S. worker, particular industry/worker group and/or geographic constraints have applied. In addition, there has been relatively little research on different age, race−ethnicity,

Article was submitted for review in January 2004; approved for publication by the Journal of Agricultural Safety and Health of ASAE in April 2004.

The authors are **Orlando Gómez−Marín,** MSc, PhD, Associate Professor, Departments of Epidemiology & Public Health, and Pediatrics; **Lora E. Fleming,** MD, PhD, Professor, **David J. Lee,** PhD, Associate Professor, **William LeBlanc,** PhD, Statistical Analyst, **Diane Zheng,** MS, Data Analyst, **Dulce Jané,** MA, Research Associate, **Terry Pitman,** BSc, WebMaster, and **Alberto Caban, Jr.,** MPH, Research Associate, Department of Epidemiology and Public Health; and **Fangchao Ma,** MD, PhD, Research Assistant Professor, Department of Dermatology and Cutaneous Surgery, University of Miami School of Medicine, Miami, Florida. **Corresponding author:** Orlando Gómez−Marín, Department of Epidemiology and Public Health, University of Miami School of Medicine, 1801 NW 9th Avenue, Suite 200L, Highland Professional Building, Miami, FL 33136; phone: 305−243−6863; fax: 305−243−5544; e−mail: ogomez@med.miami.edu.

  ISSN 1074-7583

and female subpopulations, as well as socio−economic class, of the U.S. workforce as a whole. Recent research from different sources has shown that older age, racial−ethnic group, lower socio−economic class, and even some female subpopulations are at increased risk for disability compared to their white male counterparts (Austin et al., 1995; Landen and Hendricks, 1992; Zwerling et al., 1996; Bollini and Siem, 1995; Oman et al., 1999; Zwerling et al., 1995; Zwerling et al., 1998). Large databases with appropriate sampling methodology have not been available to examine and control for these many subpopulations among the U.S. workforce.

The National Health Interview Survey (NHIS) is a multipurpose household survey of the U.S. civilian non−institutionalized population conducted annually since 1957. From 1986 to 1994, over 450,000 U.S. workers, age 18 years and older, participated in a probability sampling of the entire non−institutionalized U.S. population. Data included a range of measures of acute and chronic disability collected for all participants. The NHIS database allows for cross−sectional and trend analysis of the aggregate morbidity data; thus, it represents a unique opportunity to explore new research hypotheses and to use the data as a surveillance tool to evaluate time trends and occupational disease in the U.S. for the past two decades in both genders and in a variety of racial−ethnic subpopulations.

As would be expected among workers exposed to neurotoxins, previous work with farmers and other pesticide−exposed workers has shown higher rates of acute and chronic neurologic diseases (McConnell, 1994; Maroni and Fait, 1993). In addition, the risks of fatal and non−fatal accidents are increased in pesticide−exposed occupational populations, possibly related in some cases to the concomitant exposure to neurotoxic chemicals in dangerous workplaces (Fleming et al., 2003; Wesseling et al., 2001; Zwerling et al., 1995; Cantor and Silberman, 1999). Additional acute and chronic health effects of pesticide exposure include dermatoses (both allergic and irritant contact dermatitis) and respiratory problems such as asthma and upper respiratory tract irritation (Brackbill et al., 1994; Mark et al., 1999; Beaumont et al., 1995; O'Malley, 1997; Hoppin et al., 2003). Other chronic health effects include cancer, lung disease, possible immunotoxicity, reproductive problems, aplastic anemia, and chronic skin diseases (Fleming et al., 1999a; Maroni and Fait, 1993; Fleming and Herzstein, 1997; Acquavella et al., 1998; Repetto and Baliga, 1997; Dich et al., 1997).

There have been almost no studies using large databases of pesticide−exposed workers such as farmers and pesticide applicators on a national or even regional scale in the U.S. (Blair et al., 1993; Fleming et al., 1999b; Brackbill et al., 1994; Beaumont et al., 1995; Alavanja et al., 1994; NIOSH, 1997; Pesatori et al., 1994; U.S. DHHS, 1998; Cantor and Silberman 1999; Kross et al., 1996); the majority of these studies have focused on occupational mortality, rather than the extent of morbidity and disability. The primary objective of the present study was to assess health status as well as acute and chronic disability indicators for farmers and pesticide applicators compared to all other U.S. workers using the NHIS database.

Materials and Methods

The National Health Interview Survey (NHIS) is a continuous multipurpose and multistage probability area survey of the U.S. civilian non−institutionalized population living at addressed dwellings (Kaminski and Spirtas, 1980; Botman and Jack, 1995; NCHS, 2000). Each week, a probability sample of households is interviewed by trained personnel to obtain information about the characteristics of each member of the household (Liao et al., 1998).

This dataset is anonymous and publicly available through the National Center for Health Statistics (NCHS). Although there are no human subject considerations in the use of this dataset per the NCHS, an official waiver was obtained from the University of Miami School of Medicine Human Subjects Committee.

During the 1986−1994 study period, annual NHIS survey response rates reportedly ranged from 95% to 98% (Massey et al., 1989). In the majority of cases (63%), the participants themselves answered all the questions, and for the remaining participants the responses were obtained from their relatives or other proxies. For simplicity, in the present study both self−reported and proxy−reported data are referred to as "reported."

Information on employment during the two weeks prior to the interview was collected for all persons 18 years of age or older in order to determine the person's employment status. As utilized by other investigators, all subjects age 18 years and older who had worked or reported having jobs, both paid and unpaid, during the two weeks prior to the NHIS survey were considered "currently employed" (Kaminski and Spirtas, 1980; Zwerling et al., 1997; Brackbill et al., 1988). "Farmer" and "pesticide applicator" were defined using Standardized Occupational Codes (SOC codes) provided in the NHIS database: SOC 455 for pesticide applicators and SOC 473−7, 479, 484−5, 488−9, 517 for farmers (NCHS, 1989). For the purpose of this study, both farmers and pesticide applicators were identified as "pesticide−exposed workers" and compared to "other occupations." Age was used either as a continuous or as a discrete variable based on tertiles of its frequency distribution in the study data set. Educational level was included as a measure of socio−economic class (Keller, 2001) and was grouped into three categories based on the highest grade completed: less than 12th grade, 12th grade, and more than 12th grade.

In the NHIS, a chronic condition was recorded if the respondent had a health problem that was detected at least three months before the interview or if it was a condition that would normally last at least three months. Acute conditions were defined as illnesses or injuries lasting less than three months and involving either seeking medical attention or one or more days of restricted activity.

Information for the prior two weeks and for the prior 12 months was collected on restricted−activity days, bed days, doctor visits, and hospital stays. Study−generated variables of the number of days, doctor visits, and hospital episodes were also included. Restricted−activity days were defined as those days during which the respondent reduced usual activities for all or most of the day due to illness; bed days were counted in the restricted−activity days as well as separately recorded as days during which all or most of the day was spent in bed. Health status indicators included a general question rating health status as excellent, very good, good, fair, or poor.

In the NHIS, disability was defined as any reported temporary or long−term reduction of a person's activity as a result of an acute or chronic condition. Restricted activity, bed disability, and work loss all denote varying degrees of disability and are not independent variables. As Kaminski and Spirtas (1980) noted using earlier NHIS data for occupational disability evaluation, a day of bed disability or work loss would also be considered a day of restricted activity, but the converse is not necessarily true. For example, a person's activity may be restricted in the sense that s/he may not be able to do heavy lifting, but this may not necessarily keep her/him in bed or away from work.

For the present analyses, measures of acute and chronic disability and health status were defined by NHIS variables adapted by the investigators. Acute disability was defined in terms of restricted−activity days in the prior two weeks (0 vs. $\geq$ 1), bed days in the prior two weeks (0 vs. $\geq$ 1), and lost work days in the prior two weeks due to illness or injury (0 vs. $\geq$ 1). Chronic disability was defined in terms of doctor visits in the prior 12 months (0 to 3 vs. $\geq$ 4) and hospitalizations in the prior 12 months (0 vs. $\geq$ 1). Health status was defined in terms of health self−rated as excellent, very good, or good vs. fair or poor (0 vs. 1) and the number of reported health conditions (0 vs. ≥ 1). Analyses were performed to compare the different industry/occupation groups with respect to each of the above health and disability indicators in two different ways: without and with adjustment for potential confounders (i.e., age, gender, race/ethnicity, and level of education).

Statistical Methods

Because of the multistage sampling design, all analyses were performed with adjustment for sample weights and design effects using the SUDAAN statistical package (RTI, 2001). The sample weights used were those required for the analysis of data from combined survey years and were calculated as specified by Botman and Jack (1995). The statistical techniques used included t−tests and one−way analysis of variance (ANOVA) for comparison of means of variables with normal or approximately normal distributions; and chi−squared analyses for comparisons of proportions or assessment of associations between discrete variables.

Multiple logistic regression analyses were used for the assessment of predictors of acute and chronic disability indicators, poor or fair health status, and presence of health conditions. Since all the health indicators used in the present analyses could have been reported by a proxy (family member), all initial logistic regression models included a variable indicating responder status (proxy vs. self−report). Also included in the initial models were terms corresponding to the interaction between the main independent variable, occupation, and responder status. None of the regression coefficients for the interaction terms or the responder status variable were statistically significant in any of the models analyzed. Therefore, the multiple logistic regression results included hereinafter (results section and table 3) correspond to seven independent models: one for each of the three acute disability indicators, one for each of the two chronic disability indicators, and one for each of the two health status indicators. Each of these seven models included occupation (farmers, pesticide applicators vs. all other workers) as the main independent variable, and the following covariates: age (45−64 years and 65+ years vs. 18−44 years), gender (female vs. male), race−ethnicity (white Hispanic, black non−Hispanic, all other vs. white non−Hispanic), and education (12th grade and >12th grade vs. <12th grade). Of note, for this study, “other race” included other, Aleutian Eskimo/American Indian, Asian/Pacific Islander, and unknown race; “white non−Hispanic” included non−Hispanic and unknown ethnicity; and there were 4179 (0.9%) persons without educational status information whose data were not used in the multivariate analyses.

Results

There were a total of 462,975 persons age 18 years and older who reported working within the two weeks prior to their participation in the 1986−1994 NHIS surveys (table 1). Among these U.S. workers, 215,842 (46.6%) were women. The overall mean age ±SD was 38.9 ±12.9 years.

Within the NHIS worker cohort, there were 9576 farmers and 180 pesticide applicators. There were 7 (3.9%) female pesticide applicators, and 1772 (18.5%) female farmers. At the time of the NHIS interview, farmers were significantly older than pesticide applicators (44.1 ±16.2 vs. 38.6 ±12.7 years; $p < 0.001$) and than the “other occupations” cohort (44.1 ±16.2 vs. 38.8 ±12.8 years; $p < 0.001$). As a pesticide−exposed occupational group, farmers plus pesticide applicators were significantly older compared to the “other occupations” cohort (43.9 ±16.2 vs. 38.8 ±12.8 years; $p < 0.001$).

Table 1. Sociodemographic characteristics of farmers, pesticide applicators, and other workers: The 1986−1994 National Health Interview Surveys (NHIS).

Demographic Variable	Pesticide−Exposed Workers (*n* = 9756) Farmers (*n* = 9576)	Pesticide Applicators (*n* = 180)	Total[a] (*n* = 9756)	All Other Workers (*n* = 453219)
Age, years (mean ±SD)	44.1 ±16.2	38.6 ±12.7	43.9 ±16.2	38.8 ±12.8
Gender				
Female, *n* (%)	1772 (18.5)	7 (3.9)	1779 (18.2)	214063 (47.2)
Race				
White, *n* (%)	8727 (91.1)	149 (82.8)	8876 (90.9)	372363 (82.2)
Black, *n* (%)	376 (3.9)	27 (15.0)	403 (4.1)	56157 (12.4)
Other, *n* (%)	473 (4.9)	4 (2.2)	477 (4.9)	24699 (5.4)
Hispanic, *n* (%)	1175 (12.3)	21 (11.7)	1196 (12.3)	33066 (7.3)
Education				
<12 grade, *n* (%)	3019 (31.9)	38 (21.2)	3057 (31.3)	61146 (13.6)
12 grade, *n* (%)	4135 (43.6)	82 (45.8)	4217 (43.2)	176620 (39.3)
>12 grade, *n* (%)	2322 (24.5)	59 (32.9)	2381 (24.4)	211384 (47.1)

[a] Total = pesticide−exposed workers, i.e., farmers plus pesticide applicators.
Note: For all discrete variables, all comparisons between farmers vs. pesticide applicators, farmers vs. all other workers, pesticide applicators vs. all other workers, and pesticide−exposed workers vs. all other workers are statistically significant (chi squared p−value <0.001).

The proportion of females was significantly lower ($p < 0.001$) among farmers (18.5%) and among pesticide applicators (3.9%) than among all other U.S. workers (47.2%). Compared to pesticide applicators, farmers were significantly more likely to be white race (91.1% vs. 82.8%; $p < 0.001$) and of Hispanic ethnicity (12.3% vs. 11.7%; $p < 0.001$); however, farmers were significantly less likely to have completed greater than a 12 grade education (24.5% vs. 32.9%; $p < 0.001$). Compared to other U.S. workers, pesticide−exposed workers (i.e., farmers plus pesticide applicators) were significantly more likely to be white race (90.9% vs. 82.2%; $p < 0.001$) and of Hispanic ethnicity (12.3% vs. 7.3%; $p < 0.001$), but they were significantly less likely to have completed greater than a 12th grade education (24.4% vs. 47.1%; $p < 0.001$).

Given the significant differences found in the preceding bivariate analyses, occupation was assessed as a predictor of each of the seven health indicators of interest after adjusting for age, gender, race−ethnicity, and education. The results of the multivariate regression analyses are presented in table 3, which shows the effect of each of the independent variables on disability. These results are briefly summarized in the following paragraphs, which focus on the role of the main independent variable, occupation, as an independent predictor of disability.

Acute Disability

As defined above, acute disability indicators associated with an acute condition were measured over the two−week period prior to the interview based on restricted−activity days, bed days, and lost work days, each ultimately defined as a summary dichotomous measure. Table 2 shows that, in general, the pesticide−exposed workers reported significantly less acute disability compared to all other U.S. workers. As shown in table 3, after controlling for age, gender, race−ethnicity, and educational level, compared to all other workers, farmers were significantly less likely and pesticide applicators were apparently less likely to experience any of the measures of acute disability.

Table 2. Acute and chronic disability measures and health status indicators for farmers, pesticide applicators, and other workers: The 1986−1994 National Health Interview Surveys (NHIS).

Disability and Health Status Variable	Pesticide−Exposed Workers (*n* = 9756) Farmers (*n* = 9576) *n* (%)	Pesticide Applicators (*n* = 180) *n*(%)	Total[a] (*n* = 9756) *n* (%)	All Other Workers (*n* = 453219) *n* (%)
Acute disability (prior two weeks)				
≥1 restricted−activity days	588 (6.1)	12 (6.7)	600 (6.2)	39356 (8.7)*
≥1 bed days	273 (2.9)	6 (3.3)	279 (2.9)	21807 (4.8)*
≥1 lost work days	376 (3.9)	9 (5.0)	385 (3.9)	27502 (6.1)*
Chronic disability (prior 12 months)				
≥4 doctor visits	1659 (17.3)	33 (18.3)	1692 (17.3)	103491 (22.8)*
≥1 hospitalizations	592 (6.2)	8 (4.4)	600 (6.2)	23003 (5.1)*
Health status				
Self−rated fair or poor health	841 (8.8)	17 (9.4)	858 (8.8)	27249 (6.0)*
≥1 health condition reported	3528 (36.8)	73 (40.6)	3601 (36.9)	172036 (37.9)**

[a] Total = pesticide−exposed workers, i.e., farmers plus pesticide applicators.

* Comparisons between farmers vs. pesticide applicators, farmers vs. all other workers, pesticide applicators vs. all other workers, and pesticide−exposed workers vs. all other worker are statistically significant (chi squared p−value < 0.001).

** Comparisons between farmers vs. pesticide applicators vs. all other workers (chi squared p−value = 0.06), and pesticide−exposed workers vs. all other worker (chi squared p−value = 0.03).

Chronic Disability

Chronic disability indicators associated with a chronic condition were measured by evaluating reports over the prior 12 months of doctor visits and hospitalizations, each ultimately defined as a summary dichotomous measure. In general, the pesticide−exposed workers reported significantly fewer doctor visits than all other workers, but the results were reversed for hospitalizations (table 2). As shown in table 3, after controlling for age, gender, race−ethnicity, and educational level, compared to all other U.S. workers, farmers were significantly less likely to report a high number (4 or more) of doctor visits, and slightly more likely to report one or more hospitalizations in the 12 months preceding the interview. The results for pesticide applicators were the reverse of those for farmers but were not statistically significant.

Health Status

Health status was measured by reported health status and by the report of health conditions, each ultimately defined as a summary dichotomous measure. The proportion of those reporting fair or poor health was significantly higher among pesticide−exposed workers than among all other workers. However, these two groups were comparable with respect to the proportion reporting a health condition (table 2). After controlling for age, gender, race−ethnicity, and educational level (table 3), farmers were significantly less likely to report a health condition, although they rated their health as worse compared to all other U.S. workers. Although not significant, pesticide applicators were more likely to rate their health as fair or poor, and also more likely to report at least one health condition.

Discussion

The present study evaluated acute and chronic disability indicators and reported health status of farmers, pesticide applicators, and all other U.S. workers during 1986−1994

Table 3. Results of multiple logistic regression analyses of disability and health measures among workers: The 1986−1994 National Health Interview Surveys (NHIS).

	Acute Disability Measures[a]			Chronic Disability Measures[b]		Health Status	
Independent Variable Categories	Restricted Activity Days OR (95% CI)	Bed Days OR (95% CI)	Lost Work Days OR (95% CI)	Doctor Visits OR (95% CI)	Hospitali−zations OR (95% CI)	Self−Rated Poor Health OR (95% CI)	Health Conditions OR (95% CI)
Occupation							
All other workers	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Farmers	0.78 (0.70−0.87)	0.71 (0.61−0.82)	0.73 (0.65−0.83)	0.82 (0.76−0.88)	1.04 (0.92−1.16)	1.08 (0.96−1.23)	0.92 (0.86−0.98)
Pesticide applic'rs	0.83 (0.45−1.53)	0.81 (0.35−1.85)	0.90 (0.45−1.80)	1.21 (0.80−1.83)	0.88 (0.42−1.86)	1.35 (0.80−2.30)	1.34 (0.97−1.86)
Age							
18−44	1.00	1.00	1.00	1.00	1.00	1.00	1.00
45−64	0.88 (0.86−0.91)	0.78 (0.76−0.81)	0.85 (0.83−0.88)	1.29 (1.26−1.31)	1.55 (1.50−1.60)	2.21 (2.15−2.28)	1.56 (1.53−1.58)
65+	0.88 (0.82−0.95)	0.66 (0.60−0.73)	0.70 (0.64−0.76)	2.14 (2.04−2.24)	2.72 (2.57−2.88)	3.01 (2.81−3.23)	2.57 (2.47−2.68)
Gender							
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.48 (1.45−1.52)	1.68 (1.63−1.73)	1.51 (1.47−1.55)	2.09 (2.06−2.13)	1.14 (1.11−1.17)	1.24 (1.21−1.27)	1.68 (1.63−1.73)
Race−ethnicity							
White, non−Hisp.	1.00	1.00	1.00	1.00	1.00	1.00	1.00
White, Hispanic	0.85 (0.79−0.92)	0.90 (0.82−0.98)	0.92 (0.84−0.99)	0.78 (0.74−0.82)	0.80 (0.73−0.88)	1.24 (1.14−1.35)	0.67 (0.63−0.71)
Black, non−Hisp.	0.97 (0.92−1.02)	1.00 (0.94−1.07)	1.06 (1.00−1.12)	0.83 (0.80−0.86)	0.95 (0.91−1.00)	1.85 (1.74−1.98)	0.75 (0.72−0.78)
All other	1.00 (0.96−1.03)	0.99 (0.95−1.03)	0.98 (0.95−1.01)	0.96 (0.93−0.98)	0.83 (0.80−0.86)	1.27 (1.22−1.32)	0.91 (0.89−0.94)
Education							
<12th grade	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12th grade	0.84 (0.81−0.87)	0.87 (0.83−0.91)	0.84 (0.80−0.87)	0.99 (0.96−1.02)	0.87 (0.83−0.90)	0.46 (0.45−0.48)	0.91 (0.89−0.94)
>12th grade	0.88 (0.84−0.91)	0.91 (0.86−0.95)	0.78 (0.74−0.81)	1.16 (1.13−1.20)	0.75 (0.72−0.79)	0.25 (0.24−0.26)	1.00 (0.98−1.03)

[a] Prior two weeks.
[b] Prior 12 months.
Note: Each of the seven logistic regression models includes as independent variables: occupation, age, gender, race−ethnicity, and education. Dependent variables are as follows: model 1 = restricted−activity days (0 vs. $\geq$ 1), model 2 = bed days (0 vs. $\geq$ 1), model 3 = lost work days (0 vs. $\geq$ 1), model 4 = doctor visits (0−3 vs. $\geq$ 4), model 5 = hospitalizations (0 vs. $\geq$ 1), model 6 = health self−rated as excellent or good vs. fair or poor (0 vs. 1), and model 7 = health conditions reported (0 vs. $\geq$ 1).

using a sample representative of the entire adult U.S. population. As seen in previous studies, farmers were found to be significantly older, on average, than the rest of the U.S. workforce. This nationwide trend of an aging agricultural workforce has been confirmed by other sources (U.S. Bureau of Census, 1998). Compared to all other U.S. workers, pesticide−exposed workers (i.e., farmers plus pesticide applicators) had a higher proportion of males, whites, and Hispanics and were less well educated. However, after controlling for age, gender, race−ethnicity, and educational level, farmers in general were significantly less likely to report acute and chronic disability and health conditions, while pesticide applicators were more likely to report chronic disability, health conditions, and poor health.

In a prior study using the NHIS mortality follow−up data, Fleming et al. (2003) found that pesticide applicators and farmers, in general, were at lower risk of death compared to other U.S. workers, and farmers were at lower risk of death than pesticide applicators. Compared to all other U.S. workers, pesticide−exposed workers were generally less likely to die from a variety of site−specific chronic diseases, including cardiovascular diseases and tobacco−associated chronic diseases (i.e., respiratory disease and respiratory cancers). However, these workers were at greater risk for accidental mortality, as well as hematopoietic and nervous system cancers.

Brackbill et al. (1994), using NHIS data, found an increased estimated prevalence of cardiovascular diseases, arthritis, amputations, and hearing loss among farmers compared to all other U.S. workers. In the present analyses, after controlling for age, gender, race−ethnicity, and education, farmers reported significantly less acute and chronic disability, and their reported health status was comparable to all other U.S. workers. This may represent an access to health care issue apparently common among farmers, given the NHIS disability indicators available (Emanuel et al., 1990). However, given the cross−sectional nature of the data and of the analyses, as well as the significant job demands of farming, both leading to a relative healthy worker effect, this more likely signifies that at any point in time (rather than longitudinally) farmers are, in general, healthier than other U.S. workers. Despite the small numbers, pesticide applicators reported worse or similar chronic and acute disability and health status compared to all other U.S. workers.

Data Limitations

These analyses suffer from some of the data limitations seen in previous epidemiologic studies of pesticide−exposed workers. Limitations include: the self−reported and cross−sectional nature of the data, which might lead to underestimation of the true health situation since really sick people leave the work force (part of the healthy worker effect), possible farmer under−reporting bias, lack of individual exposure measures, and occupational misclassification in general, as well as misclassification of occupation−related pesticide exposures. However, self−rated health has been shown in numerous national and international studies to be a significant independent predictor of morbidity and mortality (Markides and Lee, 1991; Idler and Benyamini, 1997). The use of the U.S. worker population as the major comparison population is appropriate for controlling for the healthy worker effect and other biases (Cooper et al., 1993; Breslow and Day, 1980; Checkoway et al., 1989; Monson, 1990; Burnett and Crouse, 1989). Previous work using the NHIS database has shown that farmers smoke less than many other worker groups (15% to 29% prevalence), which may explain some but not all of the study findings (Brackbill et al., 1988; Nelson et al., 1994; Sterling and Weinkam, 1990; Lee et al., 2004). These data were based entirely on self−report (by the individual or proxy) without objective confirmation. Access to care issues, particularly among farmers, may be reflected in some of the reporting of the disability indicators. The lack of these data is an important limitation on any conclusions that can be drawn from these analyses.

Conclusions

Researchers in occupational health are urged to seek out this important and publicly available resource. The NHIS database and mortality follow−up represent a probability sample of the entire U.S. population, with the ability to compare both morbidity and mortality among U.S. workers. Furthermore, as noted by NIOSH (1997) and the British Registrar General's decennial reports (Drever, 1995), databases such as the NHIS surveys and mortality follow−up can be used not only to target studies of work−related conditions and to add to the body of evidence generated from epidemiologic studies, but also to provide surveillance data for establishing priorities and for tracking progress towards the elimination of preventable diseases.

Acknowledgements

The data used in this article were made available in part by the Inter−University Consortium for Political and Social Research. The data for the National Health Interview Survey (NHIS) were originally collected and prepared by the U.S. Department of Health and Human Services and the National Center for Health Statistics. Neither the collector of the original data nor the Consortium bears any responsibility for the analyses or interpretations presented in this article. Funding was provided in part by NIOSH Grant No. 1 R01 0H03915−01 and the NIOSH Deep South Agricultural Center, University of South Florida, Tampa, Florida. Additional information on this study can be found at: www.rsmas.miami.edu/groups/niehs/niosh/.

References

Acquavella, J., G. Olsen, P. Cole, B. Ireland, J. Kaneene, S. Schuman, and L. Holden. 1998. Cancer among farmers: A meta−analysis. *Ann. Epidemiology* 8(1): 64−74.

Alavanja, M. C., G. Akland, and D. Baird. 1994. Cancer and non−cancer risk to women in agriculture and pest control: The Agricultural Health Study. *JOEM* 36(11): 1247−1250.

Austin, S. G., N. Huang, and C. W. Wornle. 1995. PMR study of mortality among Alabama workers and farmers. *American J. Ind. Med.* 27(1): 29−36.

Beaumont, J. J., D. F. Goldsmith, L. A. Morrin, and M. B. Schenker. 1995. Mortality in agricultural workers after compensation claims for respiratory disease, pesticide illness, and injury. *JOEM* 37(2): 160−169.

Blair, A., M. Dosemeci, and E. Heineman. 1993. Cancer and other causes of death among male and female farmers from 23 states. *American J. Ind.* Med. 23(5): 729−742.

Bollini, P., and H. Siem. 1995. No real progress towards equity: Health of migrants and ethnic minorities on the eve of the year 2000. *Soc. Sci. Med.* 41(6): 819−828.

Botman, S. L., and S. S. Jack. 1995. Combining national health interview survey data sets: Issues and approaches. *Stats. Med.* 14(5−7): 669−677.

Brackbill, R., T. Frazier, and S. Shilling. 1988. Smoking characteristics of U.S. workers, 1978−1980. *American J. Ind. Med.* 13(1): 5−41.

Brackbill, R. M., L. L. Cameron, and V. Behrens. 1994. Prevalence of chronic diseases and impairments among U.S. farmers, 1986−1990. *American J. Epid.* 139(11): 1055−1065.

Breslow, N. E., and N. E. Day. 1980. Statistical Methods in Cancer Research: Vol. I. The Analysis of Cohort Studies. Lyon, France: IARC.

Burnett, C. A., and W. E. Crouse. 1989. Agreement of latest and longest occupation and industry as reported by 1980 National Health Interview Survey. *JOEM* 31(4): 339−346.

Cantor, K., and W. Silberman. 1999. Mortality among aerial pesticide applicators and flight instructors: Follow−up from 1965−1988. *American J. Ind. Med.* 36(2): 239−247.

Checkoway, H., N. E. Pearce, and D. J. Crawford−Brown. 1989. Research Methods in Occupational Epidemiology. New York, N.Y.: Oxford University Press.

Cooper, S. P., P. A. Buffler, E. S. Lee, and C. J. Cooper. 1993. Health characteristics by longest held occupation and industry of employment: U.S. *American J. Ind. Med.* 24(1): 25−39.

Dich, J., S. H. Zahm, A. Hanberg, and A. Hans−Olov. 1997. Pesticides and cancer. *Cancer Causes Control* 8(3): 420−443.
Drever, F., ed. 1995. The Registrar General's decennial supplement for England and Wales: Occupational health. Series DS No. 10. London, U.K.: Office of Population Censuses and Surveys, Health and Safety Executive.
Emanuel, D. A., D. L. Draves, and G. R. Nycz. 1990. Occupational health services for farmers. *American J. Ind. Med.* 18(2): 149−162.
Fleming, L. E., and J. A. Herzstein. 1997. Emerging issues in pesticide health studies. *Occup. Med. State of the Art Reviews* 12(2): 387−397.
Fleming, L. E., J. A. Bean, M. Rudolph, and K. Hamilton. 1999a. Cancer incidence in Florida pesticide applicators. *JOEM* 41(4): 279−288.
Fleming, L. E., J. A. Bean, M. Rudolph, and K. Hamilton. 1999b. Mortality in a cohort of licensed pesticide applicators in Florida. *Occup. and Environ. Med.* 56(1): 14−21.
Fleming, L. E., O. Gómez−Marín, D. Zheng, F. Ma, and D. Lee. 2003. National Health Interview Survey (NHIS): Mortality among U.S. farmers and pesticide applicators. *American J. Ind. Med.* 43(2): 227−233.
Hoppin, J. A., D. M. Umbach, S. J. London, M. C. Alavanja, and D. P. Sandler. 2003. Animal production and wheeze in the Agricultural Health Study: Interaction with atopy, asthma, and smoking. *Occup. and Environ. Med.* 60(8): e3.
Idler, E. L., and Y. Benyamini. 1997. Self−rated health and mortality: A review of twenty−seven community studies. *J. Health and Social Behavior* 38(1): 21−37.
Kagamimori, S., I. Matusbara, and S. Sokejima. 1998. The comparative study of occupational mortality between Japan and Great Britain. *Ind. Health* 36(3): 252−257.
Kaminski, R., and R. Spirtas. 1980. Industrial characteristics of persons reporting morbidity during the health interview surveys conducted in 1969−1974. Cincinnati, Ohio: National Institute of Occupational Safety and Health.
Keller, S. D. 2001. Quantifying social consequences of occupational injuries and illnesses: State of the art and research agenda. *American J. Ind. Med.* 40(4): 438−451.
Kross, B. C., L. F. Burmeister, L. K. Ogilvie, L. J. Fuortes, and C. M. Fu. 1996. Proportionate mortality study of golf course superintendents. *American J. Ind. Med.* 29(5): 501−506.
Landen, D. D., and S. Hendricks. 1992. Estimates from the National Health Interview Survey on occupational injury among older workers in the United States. *Scand. J. Work Environ. Health* 18(supp. 2): 18−20.
Lee, D. J., W. LeBlanc, L. E. Fleming, O. Gómez−Marín, and T. Pitman. 2004. Trends in U.S. smoking rates in occupational groups: The National Health Interview Survey, 1987−1994. *JOEM* 46(6): 538−548.
Liao, Y., R. S. Cooper, G. Cao, R. Durazo−Arvizu, J. S. Kaufman, A. Luke, and D. L. McGee. 1998. Mortality patterns among adult Hispanics: Findings from the NHIS, 1986−1990. *American J. Public Health* 88(2): 227−232.
Mark, K. A., R. R. Brancaccio, N. A. Soter, and D. E. Cohen. 1999. Allergic contact and photoallergic contact dermatitis to plant and pesticide allergens. *Arch. Dermatology* 135(1): 67−70.
Markides, K. S., and D. J. Lee. 1991. Predictors of health status in middle−aged and older Mexican Americans. *J. Gerontology* 46(5): S243−S249.
Maroni, M., and A. Fait. 1993. Health effects in man from long−term exposure to pesticides. *Toxicology* 78(1−3): 1−180.
Massey, J. T., T. F. Morre, V. L. Parson, and W. Tadros. 1989. Design and estimation for the NHIS 1985−1994. Vital and Health Statistics Series 2 No. 110. DHHS Pub. No. PHS89−1384. Washington, D.C.: U.S. Department of Health and Human Services, National Center for Health Statistics.
McConnell, R. 1994. Pesticides and related compounds. In *Textbook of Clinical Occupational and Environmental Medicine,* 847−865.1st ed. L. Rosenstock and M. Cullen, eds. Orlando, Fla.: Saunders.
Monson, R. R. 1990. *Occupational Epidemiology.* 2nd ed. Boca Raton, Fla.: CRC Press.
NCHS. 1989. Classified index of industries and occupations, 1989. Washington, D.C.: U.S. Department of Health and Human Services, National Center for Health Statistics.

NCHS. 2000. Documentation for the NHIS multiple cause of death public−use data file, 1986−1994 survey years: Dates of death 1986−1997. Washington, D.C.: U.S. Department of Health and Human Services, National Center for Health Statistics.
Nelson, D. E., S. L. Emont, R. M. Brackbill, L. L. Cameron, J. Peddicord, and M. C. Fiore. 1994. Cigarette smoking prevalence by occupation in the U.S. *JOEM* 36(5): 516−525.
NIOSH. 1997. Mortality by occupation, industry, and cause of death: 24 reporting states (1984−1988). NIOSH Pub. No. 1997−114. Cincinnati, Ohio: National Institute of Occupational Safety and Health.
O'Malley, M. A. 1997. Skin reactions to pesticides. *Occup. Med.* 12(2): 327−345.
Oman, D., D. Reed, and A. Ferrara. 1999. Do elderly women have more physical disability than men do? *American J. Epidemiol.* 150(8): 834−842.
Pesatori, A. C., J. M. Sontag, J. H. Lubin, D. Consonni, and A. Blair. 1994. Cohort mortality and nested case control study of lung cancer among structural pesticide control workers in Florida (United States). *Cancer Causes Control* 5(4): 310−318.
Repetto, R., and S. S. Baliga. 1997. Pesticides and immunosuppression: The risks to public health. *Health Policy and Planning* 12(2): 97−106.
RTI. 2001. Software for Survey Data Analysis (SUDAAN), Version 8.0.0. Research Triangle Park, N.C.: Research Triangle Institute.
Sterling, T., and J. Weinkam. 1990. The confounding of occupation and smoking and its consequences. *Soc. Sci. Med.* 30(4): 457−467.
U.S. Bureau of Census. 1998. 1998 Census of Agriculture. Washington D.C.: Department of Commerce.
U.S. DHHS. 1998. Injuries among farm workers in the United States. NIOSH Pub. No. 98−153. Washington, D.C.: U.S. Government Printing Office.
Wesseling, C., C. Hogstedt, P. Fernandez, and A. Ahlbom. 2001. Time trends of occupational pesticide−related injuries in Costa Rica, 1982−1992. *International J. Occup. Environ. Health* 7(1): 1−6.
Zwerling, C., N. L. Sprince, and R. B. Wallace. 1995. Occupational injuries among agricultural workers 51 to 61 years old: A national study. *J. Agric. Safety and Health*1(4): 273−281.
Zwerling, C., N. L. Sprince, R. B. Wallace, C. S. Davis, P. S. Whitten, and S. G. Geering. 1996. Risk factors for occupational injuries among older workers: An analysis of the health and retirement study. *American J. Public Health* 86(9): 1306−1309.
Zwerling, C., P. S. Whitten, C. S. Davis, and N. L. Sprince. 1997. Occupational injuries among workers with disabilities: The NHIS 1985−1994. *JAMA* 278(24): 2163−2166.
Zwerling, C., P. S. Whitten, C. S. Davis, and N. L. Sprince. 1998. Occupational injuries among older workers with visual, auditory, and other impairments: A validation study. *JOEM* 40(8): 720−723.