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Characteristics of Persons Who Self-Reported a High Pesticide Exposure Event in the Agricultural Health Study[1]

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Characteristics of persons who report high pesticide exposure events (HPEE) were studied in a large cohort of licensed pesticide applicators from Iowa and North Carolina who enrolled in the Agricultural Health Study between December 1993 and December 1995. Fourteen percent reported having "an incident or experience while using *any* pesticide which caused an *unusually* high personal exposure." After taking into account total number of applications made and education, females (OR = 0.76), applicators from NC (OR = 0.65), and privately licensed applicators (OR = 0.65) were less likely to have reported an HPEE. Work practices more common among both private and commercial applicators with an HPEE included delay in changing clothing or washing after pesticide application, mixing pesticide application clothing with the family wash, washing up inside the house after application, applying pesticides within 50 yards of their well, and storing pesticides in the home. Job characteristics more common among those with an HPEE included self-repair of application equipment and first pesticide use more than 10 years in the past. These job characteristics explained much of the difference in reported HPEE between males and females, but not between IA and NC subjects or between commercial or private applicators. © 1999 Academic Press

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INTRODUCTION

A relatively high dose of pesticides can result from exposure events that may result from spills, equipment maintenance accidents, or certain spot spraying operations. For example, in one report of an Iowa farmer spraying without implementation of effective safety procedures, the dose of 2,4-D received during an 8-h period (delivered dose of 2.5 mg), equaled the dose received from 17 years of drinking water from rural Iowa well water contaminated with 2,4-D (mean concentration 0.2 μg/L) (Olgivie *et al.*, 1990; Grover *et al.*, 1986; Kross *et al.*, 1992). The acute pesticide poisoning that may result from these high exposure events may lead to long-term adverse health effects (O'Malley, 1997).

Data on pesticide application practices and health were obtained from licensed pesticide applicators from Iowa and North Carolina who enrolled in the Agricultural Health Study (AHS), a prospective study of morbidity and mortality associated with pesticides and other agricultural exposures. In an earlier report, the occurrence of health care visits resulting from pesticide exposure was described for the AHS cohort (Alavanja *et al.*, 1998). Pesticide-related visits to health care facilities can result from both chronic and acute exposure. Although not all high exposure events result in a health care visit, and not all health care visits associated with pesticide exposure are the result of an acute exposure, we would expect a higher proportion of health care visits among those who experienced a high exposure event. It is therefore important to identify factors associated with such visits and also to identify factors or activities associated with unusually high pesticide exposure.

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In this investigation, we extend our initial observations by assessing factors associated with high exposure events using information provided by the subgroup of the AHS who completed a supplemental take-home questionnaire. We have previously demonstrated little difference between those who did and did not complete this supplemental questionnaire (Tarone *et al.*, 1997).

METHODS

A detailed description of the methods used in the Agricultural Health Study has been previously provided (Alavanja *et al.*, 1996). A total of 52,629 pesticide applicators were enrolled in the Agricultural Health Study between December 1993 and December 1996 (which were the first two years of enrollment) when they completed a 22 page "enrollment questionnaire." Of those who completed the enrollment questionnaire, 43% ($n = 22{,}884$) also completed a more detailed "applicator questionnaire." We have previously shown that applicators who also completed the more detailed applicator questionnaire were older than those who did not, and tended to have smaller farms, but differences in demographics and farm characteristics were small, and unlikely to introduce a bias in the current study (Tarone *et al.*, 1997). This analysis includes participants who completed both the enrollment and applicator questionnaire. To mitigate potential confounding, age and farm size, as well as a number of other variables were included in the statistical model we used to compute risk (odds ratio).

Cases are restricted-use pesticide applicators who reported they had an "… incident or experience while using *any* type of pesticide which caused you *unusually high* personal exposure." Controls are applicators who answered that they did not have such an exposure. Independent variables considered in this analysis were categorized into three groups—demographic characteristics of the pesticide applicator, work practices related to pesticides, and job characteristics. Demographic characteristics included gender, education, age, state of residence, race, and pesticide license type. The total number of days pesticides were applied in a study subject's working lifetime was previously found to be associated with pesticide-related health care visits and it was also used to adjust risk estimates (Alavanja *et al.*, 1998). The total number of days pesticides were applied was computed by multiplying the reported frequency of the number of years pesticides were applied in a working life by the average number of days pesticides were applied in a typical year.

Information collected about work practices and job factors in the AHS study relate to general practices and conditions employed during pesticide application over a working lifetime. These data do not relate to specific work practices and job characteristics at the time of the high pesticide exposure event (HPEE). They, therefore, cannot necessarily be viewed as proximal causal factors, but they may provide an indication of factors associated with such events.

Job characteristics are factors inherent to the farm operation or commercial pesticide application task. The job factors considered here included the following: Did the pesticide applicator repair their own pesticide application equipment? Were pesticides used on this job or by this farmer 10 or more years ago? Did the tractor used for pesticide applications have an enclosed cab, and if yes, was a charcoal filter used on the air purification system?

Pesticide-related work practices are defined as those activities and actions generally performed by the pesticide applicator while mixing, handling, applying, or storing pesticides that could be modified to prevent excessive pesticide exposure. Characteristics of persons or behaviors of persons evaluated include use of personal protective equipment and protective practices. Care in handling pesticides was assessed by the following set of questions: How long after pesticide use was clothing changed and shower or washing performed? Where were pesticides stored? How was pesticide application clothing laundered? What was the distance of the family well and the family home from fields where pesticides were applied, and from the area where pesticides were mixed? Were outside shower facilities available after pesticide application?

We were also interested in determining if there was a relationship between self-reports of pesticide-related health care visits (obtained from the enrollment questionnaire) and high exposure pesticide events, and if there was a difference in the proportion of such events by gender, state of residence, or license type. Since the data on health care visits were not directly related to the occurrence of an HPEE, the analyses will simply contrast our cases (those experiencing an HPEE) with controls (those not experiencing an HPEE) on the number of pesticide-related health care visits made in both groups.

Logistic regression methods were used to estimate odds ratios (OR) and the 95% confidence intervals (CI) in multivariate analysis (Breslow and Day, 1980). The dependent variable used was the dichotomous variable "yes" or "no" response to the question “Have you ever had an incident or experience while using *any* type of PESTICIDE which caused you *unusually high* personal exposure?” The independent variables demographic characteristics, job characteristics, and work practices listed above were used as categorical variables in the logistic regression.

RESULTS

Table 1 describes the 22,884 pesticide applicators included in this analysis. Approximately 11% are commercial applicators ($n = 2467$, all from Iowa) and 89% private (primarily farmers) applicators ($n = 20{,}417$; 12,495 from Iowa and 7,922 from North Carolina). Males represent 97% of this cohort ($n = 22{,}212$), while females are 3% of the cohort ($n = 672$); 98.6% of the cohort is white. The 1.4% nonwhites are predominately African–American farmers living in North Carolina. Approximately 7.2 million pesticide applications were made by subjects in this analysis, i.e., about 3.3 million by Iowa private applicators, over 1.1 million by Iowa commercial applicators, and over 2.7 million by North Carolina private applicators. During their working lifetime, 14% of the cohort ($n = 3231$) had at least one HPEE, as defined in the methods.

TABLE 1

Demographic Characteristics of Applicators Who Completed an Enrollment and Supplemental Questionnaire

	IA private	IA commercial	NC private	Total
Mean age	48.4	40.7	51.1	48.4
Gender				
Male	12,304	2.345	7,563	22,212
Female	191	122	359	672
Race				
White	12,491	1,894	7,619	22,374
Nonwhite	4	3	303	310
Median application days/year	15	30	15	21
Median years of application	16	8	16	15
Total number of applications	3,385,212	1,144,065	2,737,078	7,266,354
Percent with a high pesticide exposure event (HPEE)	(15%)	(22%)	(10%)	(14%)
Number of subjects with a pesticide-associated health care visit	834	209	449	1,497

Table 2 shows the demographic factors characterizing the applicators experiencing an HPEE. Women have only three-quarters of the risk of an HPEE compared to men, after controlling for education, state of residence, license type, farm size, and total number of days of pesticide application. Age was dropped from our logistic regression model in this and all subsequent analyses because it did not modify risk estimates once total number of days of pesticide application was included. North Carolina applicators were at a lower risk of an exposure event than Iowa applicators (OR = 0.65) and private applicators experienced significantly fewer HPEEs than commercial applicators (OR = 0.70). Farm size was not strongly associated with a high exposure event, but a small and marginally significant excess

TABLE 2

Demographic Characteristics Associated with Workers Experiencing a High Exposure Event

		Odds ratio of an HPEE	
Variable	No. with an HPEE	Odds ratio[a]	95% confidence interval
Gender			
Female	64	0.76	0.58–1.00
Male	3167	1.00 (ref)	
State of residence			
NC	802	0.65	0.59–0.72
IA	2429	1.00 (ref)	
License type			
Private	2696	0.70	0.62–0.81
Commercial	535	1.00 (ref)	
Education			
At least some college	1152	1.32	1.16–1.50
High school graduate	1712	0.80	0.70–0.91
Less than 12 years	367	1.00 (ref)	
Farm size in acres			
1000 acres or more	462	1.14	1.00–1.30
500–999 acres	692	1.07	0.95–1.20
200–499 acres	731	0.95	0.85–1.06
Not farming	129	0.95	0.77–1.16
Less than 200 acres	1217	1.00 (ref)	
Lifetime pesticide application (days)			
1500–4500	224	4.06	3.34–4.93
525–1499	569	3.27	2.82–3.79
450–524	452	2.88	2.47–3.36
367.5–449	320	2.38	2.01–2.81
210–366	512	2.07	1.78–2.40
150–209	166	1.75	1.43–2.14
108.5–149	286	1.52	1.29–1.80
56–107	181	1.26	1.04–1.52
24.5–55	150	0.94	0.76–1.14
<24	371	1.00 (ref)	

[a] Adjusted for gender, state, license type, education, farm size, and application days.

frequency of high exposure events (OR = 1.14) was seen among applicators who lived or worked on farms of 1000 or more acres. A monotonically increasing risk of an HPEE was seen with the number of days spent applying pesticides, with greater than a fourfold excess risk observed for those applying pesticides on 1500 days or more compared to those applying less than 24 days.

The general work practices used over a working lifetime of those who had an HPEE were compared to those who did not have a high exposure event (Tables 3 and 4). The overall disparity in the odds ratio between male and female applicators shown in Table 2 is not meaningfully altered (OR = 0.78) after controlling for the effect of work practices. There was no association with reported use of protective equipment (OR = 0.96). Pesticide applicators with an HPEE were more likely to delay changing their work clothing for several hours/days after a pesticide application (OR = 1.32) and were more likely to mix their work clothing with the family wash (OR = 1.22) compared to those who did not have an HPEE. HPEE cases were significantly more likely to wait until the end of the work day before washing (OR = 1.13) compared to controls, but were less likely (OR = 0.82) to have wash-up areas outside the home. Cases were more likely to store pesticides in their home (OR = 1.82), basement (OR = 1.44), or garage (OR = 1.24) than controls, who were more likely to stored chemicals in an attached outside building.

Cases were significantly more likely to apply pesticides closer (within 50 yards) to their drinking water well and closer to their homes than controls. A small, nonsignificant difference between cases and controls was seen for the distance between the home and the

TABLE 3

Work Practices, Gender, State of Residence, and License Type Associated (Odds Ratio) with Applicators Self-Reporting a High Exposure Event

	Odds ratio of an HPEE	
Work practice	Odds ratio[a]	95% confidence interval
Gender		
Female	0.78	0.60–1.02
Male	1.00 (ref)	
State of residence		
NC	0.72	0.64–0.80
IA	1.00 (ref)	
License type		
Private	0.52	0.44–0.62
Commercial	1.00 (ref)	
Used protective equipment		
Yes	0.96	0.85–1.07
No	1.00 (ref)	
Changed clothes after mixing/applying		
Change later	1.32	1.17–1.50
Always use disposable clothing	0.93	0.56–1.55
Change right away	1.00 (ref)	
How washed clothes after pesticide use		
Mixed with family wash	1.22	1.00–1.48
Soaked separately, then mixed	0.99	0.76–1.29
Washed separately	1.06	0.90–1.25
Sent out/separate machine	0.98	0.76–1.26
Always wear disposable clothing	1.00 (ref)	
Washed up in		
Outside area	0.82	0.74–0.91
Bathroom in home	1.00 (ref)	
Stored pesticides		
In home	1.82	1.43–2.31
In basement	1.44	1.29–1.60
In garage	1.24	1.03–1.49
In attached outbuilding	0.92	0.77–1.10
Don't store pesticides	1.00 (ref)	

[a] Adjusted for gender, state, license type, education, farm size, application days, protective equipment, changing clothes, washing clothes, washing area, and storing pesticides.

TABLE 4

Work Practices, Gender, State of Residence, and License Type Associated (Odds Ratio) with Private Applicators Self-Reporting a High Exposure Event

Work practice[a]	Odds ratio[b]	95% confidence interval
When washed after applying		
At lunch	0.77	0.55–1.04
At end of day	1.13	1.01–1.28
Right away	1.00 (ref)	
Distance of home from pesticide mixing		
$<$50 yards	1.21	0.94–1.56
50–100 yards	1.06	0.83–1.36
$>$100 yards	1.14	0.90–1.45
None mixed on farm	1.00 (ref)	
Distance of home from pesticide application		
$\geq$ 300 yards	0.69	0.60–0.78
200–299 yards	0.76	0.64–0.90
100–199 yards	0.76	0.68–0.85
$<$100 yards	1.00 (ref)	
Well (drinking water) distance		
$<$50 yards	1.33	1.02–1.72
51–100 yards	1.25	0.97–1.61
$>$100 yards	1.16	0.91–1.49
No pesticides mixed	1.00 (ref)	

[a] Questions only asked of private applicators.

[b] Adjusted for gender, state, license type, education, farm size, application days, protective equipment, changing clothes, washing clothes, washing area, storing pesticides, when washed, distance from mixing, distance from applying, and well water distance.

area typically used to mix pesticides, with cases (OR = 1.21) more likely to mix chemicals within 50 yards of the home.

The relationship between job characteristics and the occurrence of an HPEE is shown in Table 5. Applicators with an HPEE were more likely than controls to have been applying pesticides 10 or more years ago, after adjusting for the total number of lifetime pesticide applications (OR = 1.82). Personal repair of pesticide application equipment was also significantly more frequent among cases (OR = 1.47). No significant differences between cases and controls were observed with regard to the characteristics of the type of tractor cab on the pesticide application equipment used, although cases had a nonsignificant lower use of enclosed cabs with charcoal filters (OR = 0.88) and a slight excess use of closed cabs without a charcoal filter (OR = 1.09). After these job characteristics were entered into the logistic model along with the demographic characteristics of the study subjects, no difference was found between male and female applicators. Our data suggest that job characteristic are more important than gender as a factor resulting in an HPEE because the difference in risk disappears when job characteristics are taken into account. There were no meaningful differences in these findings when the job characteristics and work practices were considered jointly. (Data not shown).

TABLE 5

Job Characteristics, Gender, State of Residence, and License Type Associated (Odds Ratio) with Applicators Self-Reporting a High Exposure Event

	Odds ratio of an HPEE	
Job factor	Odds ratio[a]	95% confidence interval
Gender		
Female	1.00	0.76–1.32
Male	1.00 (ref)	
State of residence		
NC	0.69	0.62–0.77
IA	1.00 (ref)	
Licence type		
Private	0.40	0.33–0.47
Commercial	1.00 (ref)	
Applied pesticides 10 years ago		
Yes	1.82	1.57–2.10
No	1.00 (ref)	
Tractor cab used		
With charcoal filter	0.88	0.77–1.01
Closed cab	1.09	0.99–1.20
Open/no cab	1.00 (ref)	
Repair own pesticide equipment		
Yes	1.47	1.26–1.72
No	1.00 (ref)	

[a] Adjusted for total days of application, farm size, education, gender, state, license type, application 10 years ago, tractor cab, and equipment repair.

TABLE 6

Risk of a Health Care Visit by High Exposure Event and Other Factors

	Odds ratio of a health care visit	
Variable	Odds ratio[a]	95% confidence interval
High-exposure event		
Yes	3.60	3.20–4.06
No	1.00 (ref)	
Risk of a health care visit for a subcohort with an HPEE Only[a]		
Gender		
Female	1.42	0.74–2.75
Male	1.00 (ref)	
State of residence		
NC	1.07	0.83–1.37
IA	1.00 (ref)	
License type		
Private	1.03	0.75–1.40
Commercial	1.00 (ref)	

[a] Adjusted for total days of application, farm size, education, gender state, and license type.

The OR for a health care visit was significantly elevated for those who had experienced an HPEE (OR = 3.60) (Table 6). Among those who experienced at least one HPEE, female applicators were more likely to report a health care visit (OR = 1.42, 95% CI = 0.74–2.75).

DISCUSSION

The large size and high participation rate in the AHS makes it possible to characterize applicators with and without an HPEE. Over a working lifetime, at least one HPEE was reported by 22% of all commercial applicators in Iowa, 15% of Iowa private applicators, and 10% of North Carlonia private applicators. Because there is a significantly increased proportion of health care visits associated with these acute events, it is important to identify factors associated with these events so that preventive actions can be implemented.

Our data show that for the applicator population as a whole, the probability of an HPEE increases as the number of pesticide applications increases and that some quantifiable increase in risk is associated with every pesticide application (Table 2). It may, therefore, be overly optimistic to assume that all high exposure events can be prevented, but it may be possible to lower the frequency of occurrence. As a first step, it was possible for us to identify demographic subgroups in the population that have significantly lower frequencies of high exposure events, namely, women, private applicators, and residents of North Carolina. We also identified some work practices and job characteristics that are more frequent among persons with high exposure events.

The difference in risk between male and female applicators is not greatly affected by controlling for differences in work practices, but the difference in risk between the genders disappears when job characteristics are taken into consideration. Differences in risk by license type and or state of residence could not be explained by either the work practices or job characteristics studied here. Additional efforts to understand these differences may result in the identification of other factors that could be used in prevention programs.

It should be noted that there are several weaknesses inherent in this study. Although the Agricultural Health Study is prospective in design, the case–control type analysis reported here is actually cross sectional, making it impossible to ascertain time order of presumed independent and dependent variables. Thus, the factors identified in this investigation relate to the general practices and conditions that applicators experienced in their working lifetime and factors related to high exposure events may simply identify more or less careful people at differing risks of high exposure events, rather than causal factors in the HPEE.

Of the nine specific tasks or pesticide practices we investigated, seven were significantly more likely to be found among those applicators experiencing a high exposure event. Storing chemicals in or near the home and applying pesticides close to the home or well are more common among HPEE applicators. Locating pesticide storage areas away from the living area of the home and demarcating larger distances from the home as "no application zones" (e.g., 100 or more yards from the home or 50 or more yards from the family well) are not in and of themselves likely to prevent an HPEE; however, these factors may identify persons who are more likely to use care when handling pesticides. Other activities we identified may more directly increase the likelihood of an event, such as repairing pesticide application equipment. Repairing pesticide application equipment is a task that is prone to accidental exposures. In addition, repairing your own pesticide application equipment may be a surrogate index of how activity involved a farmer is in the "hands-on" operation of his/her farm. Risk may increase as the active involvement increases.

Wearing disposable work clothing during pesticide applications, changing work clothing soon after applications, and washing up before the end of the work day were work practices characterizing applicators who did not experience a high exposure event. To a lesser extent, washing/shower facilities outside the home, and separating pesticide applicator's work clothing from the family wash characterized applicators who did not experience a high exposure event. The press of time during the planting and pesticide application season and working on fields distant from home can make washing and changing clothing difficult; however, a substantial benefit was observed for these work practices. The practices described above could not be proximal causes of an HPEE because they occur after the pesticide application, but they suggest that there are a constellation of safe work practices that distinguish cases and controls.

The general practice of wearing personal protective equipment or clothing did not distinguish among those with or without an HPEE, but in our data we were unable to assess whether the protective equipment was worn appropriately or was worn at the time of the HPEE. More detailed obsservations on protective equipment use at the time of an HPEE should be made.

Among applicators who started to apply pesticides ten or more years ago, we observed a significant excess risk that was not explained by the total number of pesticide applications made. An explanation for this observation is not clear and will need further exploration. In the past 10 years there have been improvements in pesticide application machinery (Lunchick *et al.*, 1988) and the training of pesticide applicators (Rucker, 1994) which may in part be responsible for the reduced risk to applicators who first began applying pesticides more recently.

Although high exposure events are associated with an increased frequency of health care visits, the majority of high exposure events do not result in a health care visit. Women with a high exposure incident are more likely to visit a doctor or hospital than men but a similar difference is not seen by state of residence or license type. These results indicate that it will be necessary for us to control for the differences in gender to mitigate the difference between genders in the propensity to use these facilities when we are interpreting data based on health care visits.

The cross-sectional data generated here is our first attempt within the Agricultural Health Study to identify demographic, work practice, and job characteristics that distinguish pesticide applicators with and without a history of a high exposure event. Following up these initial observations with prospectively collected data that more directly document the time order of the events should make it possible to refine our conclusions and to suggest corrective action. In addition, it will be of interest to explore the potential health consequences of pesticide exposure among this potentially highly exposed group.

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