AMERICAN JOURNAL OF INDUSTRIAL MEDICINE 38:455–462 (2000)

Respiratory Symptoms: Associations With Pesticides, Silos, and Animal Confinement in the Iowa Farm Family Health and Hazard Surveillance Project

Nancy L. Sprince, MD, MPH,* **Mary Q. Lewis,** MS, **Paul S. Whitten,** MS, **Stephen J. Reynolds,** PhD, CIH, **and Craig Zwerling,** MD, PhD, MPH

Background *Farmers are at risk for airways diseases resulting from exposures which include organic agents and chemicals on the farm. Few data on airways disease and farm exposures are available from population-based studies. The Iowa Farm Family Health and Hazard Surveillance Project provided the opportunity to assess associations between symptoms of airway disease and several farm exposures, including pesticides, grain dust, animal confinement, and exposures from silos, in a population-based study.*

Methods *A stratified two-stage cluster sample was used to provide a representative farmer sample from the state. Participants provided questionnaire responses concerning demographic, respiratory symptoms, smoking, and exposure information. Associations between farm exposures and airways disease symptoms were assessed in the 385 farmer participants using χ^2 analysis and logistic regression analysis adjusting for age and smoking.*

Results *The most frequently reported respiratory symptoms were flu-like symptoms in connection with dusty work (22%), dyspnea (21%), and phlegm (15%). Current smoking was uncommon (13%). Among farmers, applying pesticides to livestock was associated with significantly increased odds of phlegm (OR = 1.91, 95% CI 1.02–3.57), chest ever wheezy (OR = 3.92, 95% CI 1.76–8.72), and flu-like symptoms (OR = 2.93, 95% CI 1.69–5.12) in models adjusting for age and smoking. Conventional vertical silos were significantly associated with increased odds of chest ever wheezy (OR = 2.75, 95% CI 1.23–6.12) and flu-like symptoms (OR = 2.40, 95% CI 1.31–4.37). There were also significant associations between several respiratory symptoms and the presence of animal confinement facilities on the farm.*

Conclusions *The association between insecticide application to livestock and symptoms of airways disease is a new finding that could lead to further study of specific airway responses and exposures associated with this practice. Results confirming associations between respiratory symptoms and conventional vertical silos may be important in future studies aimed at prevention and control of exposures in those farm buildings.* Am. J. Ind. Med. 38:455–462, 2000. *© 2000 Wiley-Liss, Inc.*

KEY WORDS: farmers; agricultural exposures; respiratory symptoms; pesticides; silos; animal confinement

Department of Occupational and Environmental Health, The University of Iowa, College of Public Health, Iowa City, Iowa 52242
Contract grant sponsor: National Institute for Occupational Safety and Health; Contract grant number: CCU706063

*Correspondence to: Nancy L. Sprince, The University of Iowa College of Public Health, 100 Oakdale Campus, 108 IREH, Iowa City, IA 52242-5000. E-mail: nancy-sprince@uiowa.edu

Accepted 27 April 2000

INTRODUCTION

Farmers are at increased risk for several airway diseases including chronic bronchitis, chronic airflow obstruction, asthma, and asthma-like syndromes. Both animal-derived and plant-derived organic materials have been associated with airways diseases in farmers. These agents include complex mixtures occurring in animal confinement operations and in the storage and handling of grain [American Thoracic Society, 1998].

In addition to organic agents, chemicals in the agricultural environment may also be associated with airways diseases. Results of several studies suggest a possible association between pesticide exposures and asthma. In one cross-sectional study conducted in Canada, the use of carbamate insecticides was significantly related to the prevalence of asthma in a population of male farmers [Senthilselvan et al., 1992]. A few case reports have documented asthma symptoms after exposure to organophosphate insecticides [Bryant, 1985; Deschamps et al., 1994] and fungicides [Honda et al., 1992; Royce et al., 1993].

There have been few population-based studies that examine agricultural work-related respiratory symptoms and possible risk factors associated with them. In 1990, the National Institute for Occupational Safety and Health (NIOSH) sponsored the Farm Family Health and Hazard Surveillance Project and provided funding for six states to conduct the study. NIOSH objectives for the study included the following: (1) to ascertain the health status of farm operators, their families, and those living and/or working on farms; and, (2) to determine work-related risk factors and circumstances of exposure to potentially hazardous agricultural substances and processes. The Iowa Farm Family Health and Hazard Surveillance Project (FFHHSP) collected data from a representative sample of Iowa farmers and their families. The Iowa FFHHSP provides a unique opportunity to assess relationships between several important agricultural exposures and airways disease in a population-based study. In 1994, the year of data collection in the Iowa FFHHSP, Iowa ranked first in the US for hog, corn, and soybean production (U.S. Department of Agriculture 1994a, 1994b). Pesticide use in Iowa also ranked high. In 1994, Iowa ranked first among corn-producing states in herbicide use, with applications totaling 38 million pounds, and third in insecticide use, with applications totaling 2.9 million pounds on corn that year (U.S. Department of Agriculture 1994a, 1994c).

This study had the following aims: (1) to calculate the prevalence of respiratory symptoms among farmers in a population-based study and (2) to assess relationships between agricultural work-related airways disease and agricultural exposures including pesticides, livestock, silos, and grain dust.

MATERIALS AND METHODS

Sample Selection

The farmers in this study were participants in the Iowa Farm Family Health and Hazard Surveillance Project (FFHHSP), a cross-sectional morbidity study sponsored by the National Institute for Occupational Safety and Health (NIOSH). The sample selection process is described in detail elsewhere [Lewis et al., 1998]. In brief, this was a stratified two-stage cluster sample in which 18 counties were randomly selected, two from each of Iowa's nine crop and livestock reporting districts. This first stage of stratification was done to ensure a sample that would be representative of the different soil types and farming practices in Iowa. At the second stage of sampling, the Iowa Agricultural Statistics Service (IASS), a branch of the U.S. Department of Agriculture, randomly selected 100 principal farm operators from within those 18 counties, drawn from their database which includes nearly all of the state's farm operators (Iowa Agricultural Statistics, 1995). A delay in the start-up of the project due to funding agency delays and extensive flooding in Iowa in 1993 resulted in a loss of participants. To make up for this loss, IASS randomly selected another group of principal operators whom they contacted by telephone to enlist participation.

In 1994, a comprehensive questionnaire was mailed to 989 principal farm operators who had agreed to participate. Efforts to increase the response rate included a follow-up reminder mailing 1 month after the initial mailing, followed by telephone contact 1 month after the reminder letter had been mailed. A total of 390 farm operators (response rate of 39%) returned questionnaires with information about their farms and family members or others living and working there. Questions included demographic, smoking and exposure information as well as questions on history and symptoms of respiratory diseases. History and symptoms of other diseases were also included, but are not relevant to the present paper. This report is based on responses from the 385 male farm operator participants; responses from the five female farm operator participants were not included because of the low number. All protocols and subject instructions were reviewed and approved by the Institutional Review Board on Human Studies of the University of Iowa. The implied consent procedure used (subject received instructions to fill out and mail back the questionnaire if they wished to participate in the study) was also approved.

Respiratory Outcome Variables

Questions from the Respiratory and Allergy Supplement of the National Health and Nutrition Examination Survey [NHANES III; National Center for Health Statistics, 1994] were used to assess respiratory health in the Iowa FFHHSP.

- *Cough* was defined as a "yes" response to "Do you usually cough on most days for 3 consecutive months or more during the year?"
- *Phlegm* was defined as a "yes" response to "Do you bring up phlegm on most days for 3 consecutive months or more during the year?"
- *Chronic bronchitis* was defined as a "yes" response to both "Do you usually cough on most days for 3 consecutive months or more during the year?" and "Do you bring up phlegm on most days for 3 consecutive months or more during the year?" *and* duration of symptoms exceeded 2 years.
- *Dyspnea* was defined as a "yes" response to "Are you troubled by shortness of breath when hurrying on the level or walking up a slight hill?"
- *Chest ever wheezy* was defined as a "yes" response to "Apart from when you had a cold, does your chest *ever* sound wheezy or whistling?"

We used two outcomes, work-related chest wheeze and chest tightness at work, to assess for work-related airways symptoms. Definitions for these two were as follows:

- *Work-related chest wheeze* was defined as a "yes" response to "Are any of the above symptoms of wheezing or whistling brought on by work environment (i.e., do you feel better on days off?)"
- *Chest tightness at work* was defined as a "yes" response to "Does your chest ever feel tight in connection with your work?"

Because of a priori interest in symptoms that could represent organic dust toxic syndrome occurring in the course of farm work [American Thoracic Society, 1998], we included the following outcome variable:

- *Flu-like symptoms* were defined as a "yes" response to the following: "Have you, during the last 12 months, had episodes of "flu"-like symptoms (fever, shivering, headache, feel ill, cough, tiredness, weakness, muscle and joint pains) in connection with dusty work?"

Exposure Variables

We used responses to the following questions to categorize types of pesticide applications/exposure:

- *Insecticides to crops*: "Yes" response (indicating the respondent personally applied the insecticide) to "Did you use insecticides on field crops during the last 12 months?"
- *Insecticides to livestock*: "Yes" response to "Did you personally apply insecticides to livestock during the last 12 months?"
- *Herbicides*: "Yes" response (indicating the respondent personally applied the herbicide) to "Did you use herbicides on this farm for normal application during the last 12 months?"
- *Hand/arm pesticides*: "Yes" response to "Did you get pesticides, insecticides, herbicides, fungicides, or fumigants on your hands or arms while at work on the farm during the past 12 months?"

We assessed respiratory exposure from animal confinement or grain dust indirectly by responses concerning presence on the farm of equipment and/or buildings related to the production of livestock or grain. A checklist of buildings and equipment followed the question "What fixed equipment or buildings are in use for the normal operations of this farm?" We defined respiratory exposure from *animal confinement* as positive checklist responses to animal confinement buildings with and without ventilation fans. We defined respiratory exposure to *grain production* as positive checklist responses to any one or more of the following: crop or feed storage bins, fixed grain augers, elevators, or conveyers, grain dryers, and fixed feed grinding/mixing facilities. Presence of *conventional vertical silos* was also considered an exposure variable of interest but was separate from the other two exposure variables because of differences in exposure composition. The silo is a structure distinct from buildings related to animal and grain production. Silos are usually filled with hay grasses or chopped corn. Microbial and chemical products from anaerobic fermentation of the silage are present in these structures. Exposure is episodic but the concentration of dust and mold can be extremely high.

Smoking Variables

Questions from the Adult Tobacco Use Section of the National Health and Nutrition Examination Survey [NHANES III; National Center for Health Statistics, 1994] were used to assess smoking status. Current smokers were those who responded "yes" to "Do you smoke cigarettes now?" Ex-smokers did not currently smoke but had smoked at least 100 cigarettes during their entire life (1 pack = 20 cigarettes).

Statistical Analysis

Data were double-entered for verification and analyzed using SAS 6.1 for Windows. First, we calculated means and standard deviations for age, years of farming, and pack-years of smoking. We also calculated frequencies for the respiratory symptoms. We used STATXACT 3 for Windows

(Cytel Software, Cambridge, MA) to perform Fisher's exact test, assessing whether respiratory symptoms differed across smoking categories.

We assessed relationships between respiratory symptoms and exposures among the 385 farmer participants. First, we performed bivariate analyses using χ^2 to assess relationships between the seven exposures of interest (insecticides to crops, insecticides to livestock, herbicides, hand/arm contact with pesticides, animal confinement, grain, and conventional vertical silos) and the six respiratory outcomes of interest (cough, phlegm, dyspnea, chest ever wheezy, chest tightness at work, and flu-like symptoms). From the eight respiratory outcomes listed in Table II, we had excluded from further analysis those respiratory outcome variables for which frequencies were below 10% (work-related wheeze and chronic bronchitis).

We assessed the relationship between the seven exposure variables and the six respiratory variables using logistic regression analysis adjusting for smoking and age. Each exposure variable was assessed in a model separate from all other exposure variables. We also assessed for interactions between independent variables in each of the multivariate models. We used a significance level of $P \leq 0.05$.

RESULTS

Description and Respiratory Symptom Frequency Among the Farmer Participants

Table I shows that these participants had worked on the farm for many years and smoked infrequently. Table II shows that the most common respiratory symptoms were flu-like symptoms in connection with dusty work, dyspnea, and phlegm. Most of the respiratory symptoms varied significantly by smoking category; however, those respiratory symptoms most closely related to work exposures did not vary significantly by smoking category.

TABLE I. Demographic Characteristics and Smoking in 385 Iowa Farmers

Variable	Result
Age (mean $\pm$ SD)	54 ± 12
Years of work on farm (mean $\pm$ SD)	32 ± 15
Smoking[a]	
Current smokers, no. (%)	51 (13)
Ex-smokers, no. (%)	129 (34)
Non-smokers, no. (%)	204 (53)
Pack-years for current smokers (mean $\pm$ SD)	34 ± 22
Pack-years for ex-smokers (mean $\pm$ SD)	22 ± 22

[a]For one individual, smoking category could not be determined.

Associations Between Respiratory Symptoms and Exposures Among Farmer Participants

Among the farmer participants, 42% personally applied crop insecticides, 28% applied livestock insecticides, and 50% personally applied herbicides; 36% had animal confinement buildings, 85% had structures or equipment related to grain production, and 18% had conventional vertical silos. Tables III and IV show the results of the bivariate analysis of these exposure variables and the six respiratory symptoms. Personal application of insecticides to livestock was significantly associated with four of the six respiratory symptoms. Hand or arm exposure to pesticides was significantly associated with four of the six respiratory symptoms. Personal application of crop insecticides or herbicides was not significantly associated with any of the respiratory symptoms. The exposures in animal confinement, grain production and conventional vertical silos were each associated with one or more of the respiratory symptoms shown.

Tables V–VIII show associations between exposures and respiratory symptoms using logistic regression analysis, adjusting for age and smoking. In general, the associations identified as significant before adjustment for age and smoking (Tables III and IV) remained significant after adjustment for age and smoking (Tables V–VIII). When we assessed for significant interactions among the independent variables, age, exposure, and smoking status, we found no significant interactions. To assess whether the association between livestock application of pesticides and respiratory symptoms could be due to other factors associated with raising livestock, we repeated the analysis shown in Table VI, but confined it only to those farmers who reported having livestock. The associations with respiratory symptoms remained unchanged (results not shown). We also assessed correlations between livestock insecticide application and the other livestock-related exposures, namely animal confinement and conventional vertical silos. We found that the latter two exposures were correlated to some extent with livestock pesticide application (Spearman correlation coefficients of 0.25 and 0.20, respectively). In a further multivariate model, flu-like symptoms were still significantly associated with livestock insecticide application (OR = 3.1, 95% CI 1.7–5.6) after sequential adjustment for age, smoking, presence of conventional vertical silos, and presence of animal confinement buildings.

DISCUSSION

The most important finding in this population-based study is that farmers who applied insecticides to livestock are more likely to have respiratory symptoms. The farmers

TABLE II. Respiratory Symptoms by Smoking Category in 384 Iowa Farmers

Variable	Current smoker n = 51	Ex-smoker n = 129	Non-smoker n = 204	Total n = 384	χ^2 *P* value*
Respiratory symptoms					
Cough, no. (%)	16 (32)	11 (9)	14 (7)	41 (11)	26.6, 0.000
Phlegm, no. (%)	11 (23)	17 (14)	27 (14)	55 (15)	2.5, 0.294
Chronic bronchitis, no. (%)	8 (20)	3 (3)	9 (5)	20 (6)	13.8, 0.0013
Dyspnea, no. (%)	18 (35)	35 (28)	25 (13)	78 (21)	19.0, 0.0001
Chest ever wheezy, no. (%)	11 (23)	12 (10)	13 (7)	36 (10)	11.0, 0.004
Work-related respiratory symptoms					
Work-related chest wheeze, no. (%)	4 (8)	5 (4)	8 (4)	17 (4)	1.6, 0.4685
Chest tightness at work, no. (%)	5 (10)	13 (10)	25 (13)	43 (12)	0.5, 0.809
Flu-like symptoms, no. (%)	16 (33)	24 (19)	42 (21)	82 (22)	3.7, 0.157

*Fisher's exact test, two degrees of freedom.

TABLE III. Results of Bivariate Analysis Assessing Associations Between Use of Pesticides by Class and Respiratory Symptoms

	Cough		Phlegm		Dyspnea		Chest ever wheezy		Chest tightness at work		Flu-like symptoms	
Applications	χ^2	*P*-value	χ^2	*P*-value	χ^2	*P*-value	χ^2	*P*-value	χ^2	*P*-value	χ^2	*P*-value
Insecticides to crops	0.002	0.968	0.045	0.831	0.674	0.412	0.170	0.680	0.197	0.657	0.019	0.890
Insecticides to livestock	0.810	0.368	4.019	0.045	0.011	0.916	7.795	0.005	4.139	0.042	12.803	0.001
Herbicides	0.035	0.851	0.849	0.357	0.729	0.393	0.774	0.379	0.510	0.475	0.191	0.662
Pesticides (Hand/arm)	2.808	0.094	10.07	0.002	3.97	0.046	9.36	0.002	6.767	0.009	3.129	0.077

who personally applied livestock insecticides are much more likely to report both wheezing apart from colds and episodes of flu-like symptoms in connection with dusty work than those who did not apply this type of insecticide. To our knowledge, no other studies have examined this particular farm practice. Our result regarding wheezing apart from colds, a possible symptom of airways disease, is consistent with results of other studies involving pesticide usage. In a cross-sectional study of farmers in Saskatchewan, the investigators found that the prevalence of asthma was highly correlated with use of carbamate insecticides [Senthilselvan et al., 1992]. Several case reports have been published linking insecticide and fungicide exposure to asthma [Royce et al., 1993; Deschamps et al., 1994]. Application of pesticide to livestock is typically done by hand, pouring the chemical over the animal. There is potential for exposure from both skin contact and inhalation. Possible mechanisms could include respiratory tract irritation, sensitization or pharmacologic effect of insecticides. Our result regarding increased episodes of flu-like illness in those who applied insecticides to livestock is more difficult to explain. In general, organic dust toxic syndrome (ODTS)

TABLE IV. Results of Bivariate Analysis Assessing Associations between Agricultural Exposures and Respiratory Symptoms

	Cough		Phlegm		Dyspnea		Chest ever wheezy		Chest tightness at work		Flu-like symptoms	
Exposures from:	χ^2	*P*-value	χ^2	*P*-value	χ^2	*P*-value	χ^2	*P*-value	χ^2	*P*-value	χ^2	*P*-value
Animal confinement	7.71	0.005	2.32	0.83	0.23	0.64	1.59	0.21	13.9	0.001	6.69	0.01
Grain Production	0.33	0.57	0.40	0.53	4.84	0.03	2.07	0.15	0.937	0.333	0.0	1.00
Conventional vertical silos	1.45	0.85	1.86	0.17	0.81	0.37	4.38	0.04	3.00	0.08	7.45	0.006

TABLE V. Associations Between Hand/Arm Exposure to Pesticides and Respiratory Symptoms Using Logistic Regression Analysis Adjusting for Age and Smoking

	Phlegm		Dyspnea		Chest ever wheezy		Chest tightness at work	
Independent variables	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Age	1.00	0.98–1.03	1.05	1.02–1.07	1.04	1.01–1.08	0.99	0.96–1.02
Current smoker[a]	1.72	0.77–3.83	3.82	1.83–7.96	4.75	1.87–12.1	0.72	0.26–2.02
Ex-smoker[b]	0.93	0.47–1.84	2.00	1.09–3.66	1.14	0.46–2.80	0.88	0.42–1.85
Hand/arm pesticides[c]	2.98	1.47–6.03	2.01	1.12–3.61	4.97	1.80–13.7	2.66	1.23–5.77

[a]Current smoker = 1; ex- or nonsmoker = 0.
[b]Ex-smoker = 1; current or non-smoker = 0.
[c]Questionnaire report of hand or arm contact with pesticides on farms in the last 12 months = 1; report of no such contact = 0.

TABLE VI. Associations Between Application of Insecticides to Livestock and Respiratory Symptoms Using Logistic Regression Analysis Adjusting for Age and Smoking

	Phlegm		Chest ever wheezy		Flu-like symptoms	
Independent variables	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Age	1.00	0.97–1.02	1.04	1.01–1.08	1.01	0.99–1.04
Current smoker[a]	2.09	0.94–4.69	4.53	1.76–11.7	2.17	1.05–4.48
Ex-smoker[b]	0.96	0.48–1.91	1.02	0.42–2.47	0.76	0.42–1.39
Insecticides to livestock[c]	1.91	1.02–3.57	3.92	1.76–8.72	2.93	1.69–5.12

[a]Current smoker = 1; ex- or nonsmoker = 0.
[b]Ex-smoker = 1; current or non-smoker = 0.
[c]Questionnaire report of personal application of livestock insecticides in the last 12 months = 1; report of no such application = 0.

gives rise to acute, self-limited febrile, flu-like illness in association with high concentration exposure to organic dust or components [American Thoracic Society, 1998]. Although the concentration of organic dust exposures generated during insecticide applications to livestock is not known, it is possible that animal activity during these applications could give rise to the elevated concentrations of dust associated with ODTS. Another possibility is that livestock insecticide application could have an effect on airways that would enhance later flu-like reactions to organic dusts.

The farmers who reported having gotten pesticides on their hands or arms were much more likely to report chronic phlegm, chest wheeze, and chest tightness in connection

TABLE VII. Associations between Animal Confinement Buildings and Respiratory Symptoms using Logistic Regression Analysis Adjusting for Age and Smoking

	Cough		Chest tightness at work		Flu-like symptoms	
Independent variables	**OR**	**95%CI**	**OR**	**95% CI**	**OR**	**95% CI**
Age	1.00	0.97–1.03	1.00	0.96–1.03	1.00	0.98–1.02
Current smoker[a]	6.44	2.74–15.2	1.03	0.36–3.00	2.01	0.97–4.16
Ex-smoker[b]	1.22	0.50–2.95	0.86	0.37–1.99	1.01	0.54–1.86
Animal confinement[c]	3.01	1.47–6.18	3.75	1.78–7.88	2.05	1.20–3.50

[a]Current smoker = 1; ex- or nonsmoker = 0.
[b]Ex-smoker = 1; current or non-smoker = 0.
[c]Questionnaire report of animal confinement building(s) on the farm = 1; report of no such building(s) = 0.

TABLE VIII. Associations Between Conventional Vertical Silos and Respiratory Symptoms Using Logistic Regression Analysis Adjusting for Age and Smoking

	Chest ever wheezy		Flu-like symptoms	
Independent variables	**OR**	**95% CI**	**OR**	**95% CI**
Age	1.03	1.00–1.07	1.00	0.97–1.02
Current smoker[a]	5.42	2.11–13.9	2.12	1.02–4.41
Ex-smoker[b]	1.53	0.65–3.64	1.03	0.56–1.91
Conventional vertical silos[c]	2.75	1.23–6.12	2.40	1.31–4.37

[a]Current smoker = 1; ex- or nonsmoker = 0.
[b]Ex-smoker = 1; current or non-smoker = 0.
[c]Questionnaire report of conventional vertical silo(s) on the farm = 1; report of no such silo(s) = 0.

with work than those who did not. We postulated that this type of exposure may be indicative of lack of attention to safety precautions, including use of personal protective equipment (PPE) to prevent pesticide exposure. However, we found no such correlation between use of PPE and having gotten pesticides on hands or arms (results not shown). In another population-based study in Ohio, the authors found a weak, non-significant association between personal involvement with pesticides and both chronic cough and chronic phlegm [Wilkins et al., 1999]. Researchers in Colorado found an inverse association between pesticide use and respiratory symptoms [Champney et al., 1996]. The definitions for respiratory symptoms used in the Iowa, Ohio, and Colorado reports are identical but the definition of pesticide use varies among the studies. A possible explanation for variable results among states is that application methods, types, and amounts of pesticides used in each state differ.

This study's findings of the presence of respiratory symptoms were similar to those of the Ohio population-based FFHHSP [Wilkins et al., 1999]. The Iowa FFHHSP farmers had slightly higher prevalence of cough, phlegm, dyspnea, and chest wheeze. Colorado's FFHHSP included both farmers and spouses and reported higher prevalences than Iowa for dyspnea, chest wheeze, and cough but prevalence of phlegm was lower for the Colorado sample [Champney et al., 1996]. We were unable to find data on respiratory symptoms in rural populations not exposed to agricultural occupational hazards.

Our findings that certain farm characteristics were related to the presence of respiratory symptoms are also of interest. The farmers in our sample who had animal confinement buildings on their farms were much more likely to report chest tightness while at work and episodes of flu-like symptoms in connection with dusty work than farmers without these structures. These results are consistent with previous studies. In a cross-sectional study of workers in swine confinement buildings, Donham et al. [1984] found that confinement workers had a four-fold increase in odds of cough, phlegm, and wheeze compared with non-confinement swine workers. Chest tightness upon return to work as well as flu-like illness consistent with ODTS have also been reported previously in swine confinement workers [Donham et al., 1990].

Farmers who had conventional vertical silos as part of their farming operation were more likely to have chest wheeze apart from colds and episodes of flu-like symptoms than farmers who did not have this type of silo on their farm. In a study of dairy silo uncapping in New York, May et al. [1989] reported ODTS symptoms among silo workers. They showed that uncapping of silos can lead to exposure to dust containing extremely high concentrations of microorganisms. This high concentration of dust is partly due to the structure itself and also to the practice of placing a plastic sheet over the silage after it is filled. After more silage is placed on top of the sheet to seal the fresh silage below, the silo is then capped. Because this protective layer is exposed to air, it becomes moldy. When the silo is uncapped and this layer is removed, the moldy dust becomes airborne [Emanuel et al., 1975].

Unlike results of most studies of grain elevator workers, our results in farmers did not show exposure to grain to be a risk factor for respiratory symptoms. It is likely that grain dust exposures to farmers differ from those of grain elevator workers. Few data are available concerning respiratory symptoms in grain farmers. Dosman et al. [1987] found increased prevalence of phlegm, wheeze, dyspnea and chronic bronchitis after adjusting for age and smoking among 1,824 male farmers compared with 556 male nonfarmers. Over 90% of farmers in that study grew wheat and other field crops. In the present study of Iowa farmers, the chief crop types were corn (39%) and soybeans (27%), while wheat (0.1%) was an infrequent crop [Lewis et al., 1998]. Among Ohio grain farmers, Wilkins et al. [1999] found a significant association between a respiratory symptom (chronic cough) and one crop variable (having at least one acre of corn for silage and green chop). Differences in grain dust composition, concentrations of exposure, and, perhaps farming practices may explain the differences among these results.

The major limitation of this study is the low response rate, which could affect generalizability of the results. The major potential effect of this limitation is on the generalizability of the prevalence of respiratory symptoms, which could be overestimates or underestimates of prevalence of respiratory symptoms in the Iowa farming population. We have no data on the comparability of responders and non-responders with respect to respiratory symptoms, smoking, or specific farm exposures. We do have information suggesting comparability in some demographic features and types of farming. Specifically, Lewis et al. [1998] compared responders with non-responders in the Iowa FFHHSP and found a difference only in the number of acres of soybeans raised. Responders and non-responders were the same in the following: corn and hay acres, bushels of grain stored on farm, and number of head of hogs, beef cattle, and milk cattle. Lewis et al. also compared the FFHHSP sample to all farmers in the state of Iowa using the IASS database. Both groups of farmers were almost identical with respect to age, race, and gender.

In summary, our finding of associations between respiratory symptoms and insecticide application to livestock is, to our knowledge, a novel result. The next step in future research would be assessment of airways responses associated with this specific practice. Measurement of air concentrations of components of organic dust generated by animal activity during this process would also be of interest. In addition, our confirmation of associations between respiratory symptoms and conventional vertical silos may be important in providing direction for future studies aimed at prevention and control of exposures in those farm buildings.

REFERENCES

American Thoracic Society. 1998. Respiratory health hazards in agriculture. Am J Respir Crit Care Med 158:S1–S76.

Bryant DH. 1985. Asthma due to insecticide sensitivity. Aust NZ J Med 15:66–68.

Champney MR, Stallones L, Blehm KD, Tucker A, Merchant D. 1996. A survey of respiratory symptoms in a farming population in northeastern Colorado. J Agromed 3:47–57.

Deschamps D, Questel F, Baud FJ, Gervais P, Dally S. 1994. Persistent asthma after acute inhalation of organophosphate insecticide. Lancet 344:1712.

Donham KJ, Merchant JA, Lassise D, Popendorf WJ, Burmeister LF. 1990. Preventing respiratory disease in swine confinement workers. Intervention through applied epidemiology, education, and consultation. Am J Ind Med 18:241–261.

Donham K, Zavala DC, Merchant JA. 1984. Respiratory symptoms and lung function among workers in swine confinement buildings: a cross-sectional epidemiological study. Arch Environ Health 39:96–101.

Dosman JA, Graham BL, Hall D, Van Loon P, Bhasin P, Froh F. 1987. Respiratory symptoms and pulmonary function in farmers. J Occ Med 29:38–43.

Emanuel DA, Wenzel FJ, Lawton BR. 1975. Pulmonary mycotoxicosis. Chest 67:293–297.

Honda I, Kohrogi H, Ando M, Araki S, Ueno T, Futatsuka M, Ueda A. 1992. Occupational asthma induced by the fungicide tetrachloroisophthalonitrile. Thorax 47:760–761.

Iowa Agricultural Statistics. 1995. U.S. Department of Agriculture Iowa Agricultural Statistics Service, 1995.

Lewis MQ, Sprince NL, Burmeister LF, Whitten PS, Torner JC, Zwerling C. 1998. Work-related injuries among Iowa farm operators: an analysis of the Iowa Farm Family Health and Hazard Surveillance Project. Am J Ind Med 33:510–517.

May JJ, Pratt DS, Stallones L, Morey PR, Olenchock SA, Deep IW, Bennett GA. 1989. A study of dust generated during silo opening and its physiologic effects on workers. In: Dosman JA, Cockcroft DW, editors. Principles of health and safety in agriculture. Boca Raton: CRC Press, p 76–79.

National Center for Health Statistics. 1994. Third National Health and Nutrition Examination Survey, 1988–94, US DHHS.

Royce S, Wald P, Sheppard D, Balmes J. 1993. Occupational asthma in a pesticides manufacturing worker. Chest. 103:295–296.

Senthilselvan A, McDuffie HH, Dosman JA. 1992. Association of asthma with use of pesticides. Results of a cross-sectional survey of farmers. Am Rev Respir Dis 146:884–887.

U.S. Department of Agriculture: National Agricultural Statistics Service. 1994a. Crop Production—1994 Summary.

U.S. Department of Agriculture: National Agricultural Statistics Service. 1994b. Hogs and Pigs—December 1, 1994.

U.S. Department of Agriculture: National Agricultural Statistics Service. 1994c. Agricultural Chemical Usage Survey.

Wilkins JR, Engelhardt HL, Rublaitus SM, Crawford JM, Fisher JL, Bean TL. 1999. Prevalence of chronic respiratory symptoms among Ohio cash grain farmers. Am J Ind Med 35:150–163.