Int Arch Occup Environ Health (2017) 90:507–515
DOI 10.1007/s00420-017-1217-z

ORIGINAL ARTICLE

Lifetime allergic rhinitis prevalence among US primary farm operators: findings from the 2011 Farm and Ranch Safety survey

Jacek M. Mazurek[1] · **Paul K. Henneberger**[1]

Received: 1 November 2016 / Accepted: 14 March 2017 / Published online: 24 March 2017

Abstract

Purpose Allergic rhinitis is associated with decreased quality of life, and reduced workplace performance and productivity. This study investigated the prevalence of lifetime allergic rhinitis and factors associated with allergic rhinitis among US primary farm operators.

Methods The 2011 Farm and Ranch Safety Survey data collected from 11,210 active farm operators were analyzed. Survey respondents were determined to have lifetime allergic rhinitis based on a "yes" response to the question: "Have you ever been told by a doctor, nurse, or other health professional that you had hay fever, seasonal allergies, or allergic rhinitis?" Data were weighted to produce nationally representative estimates.

Results An estimated 30.8% of the 2.1 million active farm operators had lifetime allergic rhinitis in 2011. The allergic rhinitis prevalence varied by demographic and farm characteristics. Farm operators with allergic rhinitis were 1.38 (95% CI 1.22–1.56) times more likely to be exposed to pesticides compared with operators with no allergic rhinitis. The association with pesticide exposure for allergic rhinitis and current asthma, and allergic rhinitis alone was statistically significant and greater than that for current asthma alone.

Conclusion Certain groups of farm operators may be at increased risk of allergic rhinitis. Studies should further investigate the association of allergic rhinitis with specific pesticide exposure.

Keywords Allergic rhinitis · Asthma · Agriculture · Farming · Occupational exposure · Pesticide · Surveys and questionnaire

Introduction

Agricultural workers have been shown to have increased rates of respiratory symptoms and diseases due to respiratory irritants and allergens (Greskevitch et al. 2007; ATS 1998). Rhinitis is an upper airway inflammatory disorder characterized by nasal itching, congestion, rhinorrhea, sneezing, and posterior nasal drainage (Stevens and Grammer 2015). Allergic rhinitis, the most common form of rhinitis, is a hypersensitivity reaction mediated by immunoglobulin-E (IgE) response to high molecular weight and some low molecular weight agents, which is categorized as seasonal (hay fever; occurring after exposure to outdoor aeroallergens, e.g., tree, grass, weed pollen) and perennial (occurring after exposure to indoor aeroallergens, e.g., dust mites, molds, animal allergens). Work-related rhinitis is characterized by intermittent or persistent symptoms caused by over 200 allergic or non-allergic factors in the workplace, and often coexists with work-related asthma (Cartier 2015; Stevens and Grammer 2015). Symptoms of work-related rhinitis improve when the patient is away from the work environment. Among farm workers, rhinitis has been associated with grain farming and handling, livestock breeding, feed manufacture and handling, dairy farming, and cotton, flax, and hemp processing. Agents from

Disclaimer The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

✉ Jacek M. Mazurek
JMazurek1@cdc.gov

[1] Respiratory Health Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Mailstop HG 900.2, 1095 Willowdale Road, Morgantown, WV 26505, USA

these agricultural processes associated with rhinitis include gram-negative bacterial endotoxins, thermophilic bacteria, fungi, arthropod parts, grain dust, silica and silicate dust, pollens, gases, and pesticides (Cartier 2015; Quirce and Bernstein 2011; ATS 1998).

Allergic rhinitis is associated with decreased quality of life, and reduced workplace performance and productivity (Meltzer et al. 2012). In 2006, an estimated 30% of working adults with allergic rhinitis missed work due to their nasal allergies (Blaiss et al. 2007). According to the 1998 American Academy of Allergy, Asthma and Immunology task force on allergic disorders report, allergic rhinitis results in 3.5 million lost workdays (Kay 2000). Based on a 2001–2002 survey of 8267 volunteer employees at 47 employer locations in the United States (US), Lamb et al. (2006) reported that 55% of employees had allergic rhinitis for an average of 52.5 days in the previous year. Moreover, allergic rhinitis was associated with an average 3.6 work days missed per year, and 2.3 h of productivity loss per workday resulting in $593 of total productivity losses per employee per year (the mean total productivity losses per employee for other conditions ranged from $518 for high stress to $40 for coronary heart disease) (Lamb et al. 2006). The 2005 medical spending in the US to treat allergic rhinitis was estimated at $11.2 billion (Soni 2008). Additional costs include diagnosing and treatment of comorbid conditions (e.g., asthma, chronic sinusitis, upper respiratory infection, otitis media, hearing impairment, and nasal polyposis) and emergency room visits (Blaiss et al. 2007; Meltzer et al. 2012; Schoenwetter et al. 2004). Finally, the use of sedating antihistamine medications to control allergy symptoms may increase risk of an acute, traumatic injury at work (Hanrahan and Paramore 2003). Hanrahan and Paramore (2003) found that similar proportions of individuals who self-diagnose allergic rhinitis and those with physician-diagnosed allergic rhinitis (despite the availability of prescription, non-sedating alternatives) rely on sedating antihistamine medications to control their disease symptoms.

The prevalence of allergic rhinitis in US adults is 14% on the basis of self-reported physician diagnoses and the presence of symptoms in the past year (Blaiss et al. 2007) and over 30% on the basis of self-reported nasal symptoms in the past year (Nathan et al. 2008). Although evidence suggests that farm workers may have reduced risk of asthma and allergy as a result of farming exposures in childhood (Braback et al. 2004; Kilpeläinen et al. 2000; Rennie et al. 2016) and continued exposure to the farming environment (Douwes et al. 2007), some studies indicated an elevated prevalence of allergic rhinitis among certain farm workers compared with that of the general population (Chatzi et al. 2005; Greskevitch et al. 2007; Heutelbeck et al. 2007; Rimac et al. 2010; Riu et al. 2008; Siracusa et al. 2000; Slager et al. 2009, 2010; Smit et al. 2007). Within these studies, allergic rhinitis prevalence among various agricultural workers ranges from 8 to 74%. To our knowledge, no studies examined the national prevalence of allergic rhinitis and factors associated with allergic rhinitis among US primary farm operators. To address this gap, we examined the 2011 US Farm and Ranch Safety Survey data (USDA 2016).

Methods

Data source

In 2011, to better understand the magnitude and scope of hazardous exposures related to agricultural operations, NIOSH sponsored the Farm and Ranch Safety Survey. The survey was conducted by the US Department of Agriculture's National Agricultural Statistics Service (NASS) (USDA 2016). Methods used to implement the survey have been published previously (Mazurek et al. 2015). Briefly, a sample of 25,000 farm operations was selected for a random telephone survey. Of these, 7497 (30.0%) could not be reached by telephone during the survey period and 1190 (4.8%) were non-active farms; operators managing 5103 (20.4%) operations refused to participate in the survey. A total of 11,210 (44.8%) active farm operations were surveyed. Data on agricultural exposures including crops, animal production exposures, farm maintenance activities, as well as demographic and medical information were provided by the primary farm operators (i.e., those who run the farm, making day-to-day management decisions) or their spouses. The adjusted survey response rate (calculated as a sum of completed interviews and non-active farms divided by the difference between total and the number of those who could not be reached by phone) was 70.8%.

Definitions

Survey respondents were determined to have lifetime allergic rhinitis based on a "yes" response to the question: "Have you ever been told by a doctor, nurse, or other health professional that you had hay fever, seasonal allergies, or allergic rhinitis?" Operators were determined to have current asthma if they had ever been told by a doctor, nurse, or other health professional that they had asthma and still have asthma. Information on respiratory symptoms was not collected.

Previously established definitions for classifying cigarette smoking were used. Respondents who reported smoking at least 100 cigarettes in their lifetimes and smoked cigarettes either every day or some days at the time of the survey were considered current smokers. Former smokers were those who smoked at least 100 cigarettes in their lifetime but are no longer smokers. Non-smokers included those who smoked fewer than 100 cigarettes in their lifetime.

Information on farm acreage and value of sales (i.e., the gross value of agricultural products sold from the operation for the year) was categorized by the NASS coders. Farms were classified based on the largest source of revenue for the farm. Farm exposures and hazards were identified using responses to questions asking about specific job duties or the presence or absence of a specific hazard on the farm. Operators were considered to have a second job if they answered "yes" to the question: "Do you have a second job in addition to your farming to supplement the farm income?" Questions used to categorize farm operations and to define exposures are listed in Table 1.

Statistical analysis

We used SAS® software version 9.3 for Windows (SAS Institute Inc., Cary, NC) survey procedures for analyses. Data were weighted to account for unequal selection probabilities, unit non-response, and post-stratification. Survey weights were calculated using farm counts published by NASS for calendar year 2011. To calculate the survey weights, farms were post-stratified within the nine US Census regions by the farm operation's gross value of sales (<\$10,000, \$10,000–\$99,999, and \$100,000+). Prevalence and proportions with corresponding 95% confidence intervals (CIs) were estimated. The Rao–Scott Chi-square test of independence was used to test the differences in the distribution of proportions. The multivariate logistic regression modeling to estimate prevalence odds ratios (PORs) for the associations between allergic rhinitis and age, sex, marital status, smoking status, second job, census region, farm acreage, value of sales, farm type, and farm exposures involved two steps. First, we developed a base model. Variables associated with allergic rhinitis in bivariable analyses at $P < 0.2$ (i.e., age, sex, second job, census region, farm acreage, and value of sales) were selected for the multivariable logistic regression model. The model was then reduced using a backward selection process. The least significant variable was removed and the model was refit until the resulting regression coefficients for remaining independent variables were significant at $P < 0.05$. The independent variables associated with allergic rhinitis in the base model included age (three categories: 16–39, 40–64, ≥65 years), sex, US census region (Midwest, Northeast, South, West), and value of sales (three categories: <\$10,000; \$10,000–\$99,000; and ≥\$100,000). Next, we assessed the associations between allergic rhinitis and exposures and asthma individually adjusting for base model covariates. Finally, we examined whether the association between allergic rhinitis and farm exposures differed by

Table 1 Definitions of farm type and exposures

Measure	Definition
Farm type	
Crops	Farm operations with the largest source of revenue from grains, tobacco, cotton, vegetables, fruits or nuts, nursery or greenhouse, cutting Christmas trees, and other crops or hay
Livestock	Farm operations with the largest source of revenue from swine, dairy, beef cattle, sheep or goats, equine, poultry, aquaculture, and other animals
Farm exposures and hazards	
Bale hay	Defined as a "yes" response to the question: "Do you/Does the farm operator bale hay or straw on the farm?"
Manure storage	Defined as a "yes" response to the question: "Do you/Does the farm operator have any manure storage facilities on the farm or ranch?"
Grain production	Defined as a "one or more" response to the questions: "How many PTO-driven feed mixers or forage grinders (do you/does the farm operator) have?", "How many silage blowers (do you/does the Farm Operator) have?", "How many PTO-driven portable grain augers (do you/does the Farm Operator) have?", "How many standalone grain bins with a capacity of 5000 bushel or more (do you/ does the Farm Operator) have on the farm or ranch?", or a "yes" response to the question "(Do you/Does the Farm Operator) use trenches on the farm or ranch for grain or animal feed storage?"
Animals	Defined as a "yes" response to any of these questions: "In the last 12 months (have you/has the farm operator) kept any large animals such as cattle, bison, horses, donkeys, ponies, mules or hogs?", "(Do you/does the farm operator have any beef cattle or bison on the farm or ranch?)", "(Do you/does the farm operator have any dairy cattle on the farm or ranch?)", "(Do you/does the farm operator have a dairy bull on the farm or ranch?)", "(Do you/ does the farm operator) have any horses or other equine such as ponies, mules, donkeys, or burros on the farm or ranch?", "(Do you/does the farm operator) have any hogs or pigs on the farm or ranch, whether owned by (you/ them) or by someone else?"
Pesticide	Defined as a "yes" response to the question: "In the past 12 months, (have you/has the farm operator) ever mixed, loaded, or applied pesticides on your farm?"

current asthma status using multivariate logistic regression analysis. For this analysis, we created a new variable with four distinct categories of allergic rhinitis and current asthma, i.e., (1) allergic rhinitis and current asthma, (2) allergic rhinitis alone, (3) current asthma alone, and (4) no allergic rhinitis and no current asthma (the referent group). All tests were two-sided with $P<0.05$ considered significant.

Results

Demographic characteristics of primary farm operators and current asthma prevalence have been previously reported (Mazurek et al. 2015). Briefly, of the estimated 2.2 million primary farm operators in 2011, most were over 40 years old (94.7%), males (83.7%), married or living with a partner (83.5%), and non-smokers (60.3%). An estimated 30.8% of farm operators had lifetime allergic rhinitis (Table 2) and 5.1% had current asthma. Current asthma was prevalent among 11.6% (95% CI 10.1–13.1%) of the operators with lifetime allergic rhinitis, and among 2.2% (95% CI 1.7–2.6%) of operators with no allergic rhinitis. Conversely, of those with current asthma, 70.6% (95% CI 65.4–75.7%) had lifetime allergic rhinitis (Table 3).

In bivariate analyses, lifetime allergic rhinitis was significantly ($P<0.05$) associated with age, sex, second job, farm value of sales, farm type, farm acreage and US census region (Table 2). After adjusting for other variables, the odds of allergic rhinitis were significantly higher among operators aged 16–39 years (32.6%; POR 1.37, 95% CI 1.05–1.79) and 40–64 years (32.3%; POR 1.25, 95% CI 1.10–1.42) than those aged ≥65 years (28.4%), among females than males (37.5 vs. 29.5%; POR 1.38, 95% CI 1.17–1.61), among those managing farms with value of sales <$10,000 (33.9%; POR 1.47, 95% CI 1.27–1.70) and $10,000–$99,000 (29.9%; POR 1.34; 95% CI 1.18–1.53) than those managing farms with value of sales ≥$100,000 (22.7%), and among operators living on farms located in the South compared to the West (38.2 vs. 29.0%; POR 1.50, 95% CI 1.32–1.70). Compared with operators with no allergic rhinitis, farm operators with lifetime allergic rhinitis were 6.03 times (95% CI 4.62–7.88) more likely to have declared current asthma, 1.74 times (95% CI 1.11–2.72) morel likely to have asthma diagnosed before the age of 18 years, and 1.38 times (95% CI 1.22–1.56) more likely to report pesticide exposure (Table 3).

Multivariate associations between lifetime allergic rhinitis, current asthma, and farm exposures among operators are shown in Table 4. The magnitude of associations of lifetime allergic rhinitis and current asthma with the farm exposures was similar to associations of allergic rhinitis alone/current asthma alone with the farm exposures. A notable exception was the pesticide use exposure—the association for lifetime allergic rhinitis and current asthma, and allergic rhinitis alone was statistically significant and much greater than that for current asthma alone.

Discussion

This study found that an estimated 30.8% of primary farm operators had a history of allergic rhinitis. A review of cross-sectional studies conducted in various working populations showed that the prevalence of current rhinitis among swine confinement workers, farm workers, and grain handlers ranged from 8 to 65% (occupational rhinitis prevalence in these groups ranged from 18 to 64%) (Siracusa et al. 2000). Slager et al. found that 67–74% of Iowa and North Carolina pesticide applicators had current rhinitis (Slager et al. 2009, 2010). In a study of poultry workers in Croatia, 39% of worker reported nasal allergies (Rimac et al. 2010). The prevalence of self-reported allergic rhinitis among grape farmers was 45.8% (Chatzi et al. 2005), and among European greenhouse flower and ornamental plant growers was 31% (Riu et al. 2008). Lower prevalence of rhinitis has been reported among farmers and farm workers in East North Carolina (1.1%), and Dutch (7.6%) or Italian swine breeders (13.9%) (Akpinar-Elci et al. 2016; Brouwer et al. 1986; Galli et al. 2015). These differences can be explained, in part, by differences in study methods, e.g., use of information on either self-reported symptoms or physician diagnosis of rhinitis (Akpinar-Elci et al. 2016), symptoms and physician diagnosis of hay fever (Slager et al. 2009, 2010), or combining questionnaire data with results of allergy test results or specific IgE blood levels (Chatzi et al. 2005; Galli et al. 2015; Rimac et al. 2010).

In this study, 34.5% of primary farm operators who applied pesticides in the 12 months prior to the interview had a history of allergic rhinitis. Although this is lower than the rhinitis prevalence reported among workers in other settings, the positive association between pesticide application and lifetime allergic rhinitis in this study corroborates the previous reports (Akpinar-Elci et al. 2016; Chatzi et al. 2007; Slager et al. 2009, 2010; Ye et al. 2013). Although we did not evaluate the association of rhinitis with the use of specific pesticides, Slager et al. previously reported that exposure to petroleum oil, herbicides 2,4-dichlorophenoxyacetic acid (2,4-D) and glyphosate, the insecticide diazinon, and the fungicide benomyl were positively associated with current rhinitis (Slager et al. 2009, 2010). Similarly, in a study of grape farmers, exposures to paraquat and other bipyridyl herbicides were found to increase the risk of allergic rhinitis (Chatzi et al. 2007). Moreover, we found a positive association between pesticide application and comorbid asthma and lifetime allergic rhinitis

Table 2 History of lifetime allergic rhinitis among farm operators, by select characteristic

Characteristics	Estimated population (in 1000 s)	Lifetime allergic rhinitis						
		Distribution		Prevalence		Association		
		%[a]	95% CI	%[a]	95% CI	POR[b]	95% CI	*P* value
Total	2181	100.0		30.8	29.6–32.0			
Demographics								
Age group (years; mean = 59.8)								
16–39	113	**5.6**	4.5–6.7	**32.6**	27.3–37.8	**1.37**	**1.05–1.79**	0.0198
40–64	1270	**62.5**	60.1–64.8	**32.3**	30.7–33.9	**1.25**	**1.10–1.42**	0.0005
≥65	749	**32.0**	29.7–34.2	**28.4**	26.4–30.4	Reference		
Sex								
Male	1823	**80.2**	78.2–82.2	**29.5**	28.2–30.8	Reference		
Female	354	**19.8**	17.8–21.8	**37.5**	34.2–40.8	**1.38**	**1.17–1.61**	0.0001
Marital status								
Married or living with partner	1802	83.5	81.7–85.2	30.8	29.5–32.1	1.10	0.93–1.29	0.26
Widowed, divorced, separated, single	355	16.5	14.8–18.3	30.9	27.9–33.9	Reference		
Smoking status								
Current	200	9.4	7.9–10.8	30.7	26.6–34.9	0.90	0.73–1.11	0.27
Former	645	30.6	28.4–32.9	31.2	28.9–33.4	1.03	0.90–1.17	0.32
Never	1281	60.0	57.6–62.4	30.8	29.2–32.3	Reference		
Second job								
Yes	1041	**52.6**	50.2–55.0	**33.4**	31.6–35.2	1.11	0.97–1.27	0.12
No	1114	**47.4**	45.0–49.8	**28.5**	26.9–30.1	Reference		
Farm characteristics								
Farm value of sales[c]								
<$10,000	1201	**60.5**	58.7–62.2	**33.9**	31.9–35.8	**1.47**	**1.27–1.70**	<0.0001
$10,000–$99,000	600	**26.6**	25.3–28.0	**29.9**	28.5–31.4	**1.34**	**1.18–1.53**	0.047
≥$100,000	380	**12.9**	11.9–13.9	**22.7**	20.9–24.5	Reference		
Region[d]								
Midwest	796	**28.4**	26.5–30.3	**24.1**	22.1–26.0	0.81	0.70–0.94	<0.0001
Northeast	142	**5.3**	4.9–5.7	**25.2**	23.3–27.1	0.81	0.71–0.93	<0.0001
South	916	**52.1**	50.2–54.1	**38.2**	36.0–40.4	**1.50**	**1.32–1.70**	<0.0001
West	327	**14.2**	13.2–15.1	**29.0**	27.2–30.8	Reference		
Farm type								
Crops	1068	**53.7**	51.3–56.1	**32.2**	30.5–33.9	0.96	0.85–1.08	0.51
Livestock	1113	**46.3**	43.9–48.7	**29.4**	27.7–31.1	Reference		
Farm size (acres)								
<101	1389	**67.5**	65.6–69.4	**32.7**	31.0–34.3	0.83	0.65–1.05	0.11
101–999	666	**27.7**	25.9–29.5	**28.1**	26.3–29.8	0.90	0.72–1.11	0.84
≥1000	126	**4.7**	4.0–5.4	**25.1**	21.8–28.3	Reference		
Farm exposures and hazards								
Bale hay								
Yes	856	**38.2**	35.9–40.5	**29.2**	27.4–31.0	0.95	0.84–1.08	0.43
No	1273	**61.8**	59.5–64.1	**32.0**	30.3–33.6	Reference		
Manure storage								
Yes	98	**3.3**	2.6–4.1	**22.2**	17.8–26.6	0.78	0.59–1.02	0.07
No	2017	**96.7**	95.9–97.4	**31.3**	30.1–32.6	Reference		
Grain production								
Yes	426	**17.3**	15.6–19.0	**26.4**	24.1–28.8	0.95	0.81–1.10	0.49
No	1689	**82.7**	81.0–84.4	**32.1**	30.7–33.5	Reference		

Table 2 (continued)

Characteristics	Estimated population (in 1000 s)	Lifetime allergic rhinitis						
		Distribution		Prevalence		Association		
		%[a]	95% CI	%[a]	95% CI	POR[b]	95% CI	*P* value
Animals								
Yes	1426	**69.7**	67.5–72.0	**31.9**	30.5–33.4	1.04	0.92–1.19	0.53
No	689	**30.3**	28.0–32.5	**28.9**	26.7–31.0	Reference		
Pesticides								
Yes	843	**44.8**	42.3–47.2	**34.5**	32.6–36.5	**1.38**	**1.22–1.56**	<0.0001
No	1263	**55.2**	52.8–57.7	**28.6**	27.0–30.1	Reference		

Numbers in bold show a statistically significant difference across levels of demographic or a statistically significant association

[a]Weighted to produce unbiased national estimates

[b]*POR* prevalence odds ratio; POR adjusted for age, sex, region, and value of sales

[c]Defined by the USDA Census of Agriculture and reflects the gross value of agricultural products sold from the operation for the year

[d]Midwest: Illinois, Indiana, Michigan, Ohio, Wisconsin, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota; Northeast: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Jersey, New York, Pennsylvania; South: Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia, Alabama, Kentucky, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, Texas, West: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming, Alaska, California, Hawaii, Oregon, Washington

Table 3 Estimated number and prevalence of farm operators with lifetime allergic rhinitis by asthma characteristics

Characteristics	Estimated population (in 1000 s)	Lifetime allergic rhinitis						
		Distribution		Proportion		Association		
		%[a]	95% CI	%[a]	95% CI	POR[b]	95% CI	*P* value
Current asthma[c]								
Yes	108	**11.6**	10.1–13.1	**70.6**	65.4–75.7	**6.03**	**4.62–7.88**	<0.0001
No	2019	**88.4**	86.9–89.9	**28.7**	27.5–29.9	Reference		
Farm work-related asthma								
Yes	16	15.5	11.1–20.0	70.9	57.9–83.9	1.01	0.50–2.05	0.98
No	90	84.5	80.0–88.9	70.0	64.3–75.8	Reference		
Age of asthma diagnosis[d]								
<18 years	59	**46.7**	40.7–52.6	**74.8**	68.8–80.9	**1.74**	**1.11–2.72**	0.02
≥18 years	81	**53.3**	47.4–59.3	**62.0**	55.6–68.5	Reference		
Asthma attack in the past 12 months[e]								
Yes	55	51.2	44.5–58.0	70.9	63.4–78.4	0.97	0.59–1.59	0.90
No	53	48.8	42.0–55.5	70.2	63.1–77.3	Reference		
Asthma attack at work[f]								
Yes	20	39.1	29.9–48.4	75.4	63.8–87.1	1.39	0.62–3.10	0.42
No	35	60.9	51.6–70.1	68.6	58.8–78.4	Reference		

Numbers in bold show a statistically significant difference across groups or a statistically significant association

CI confidence interval, *POR* prevalence odds ratio

[a]Weighted to produce unbiased national estimates

[b]POR adjusted for age, sex, region, and value of sales

[c]Missing information on current asthma for 280 respondents

[d]Includes individuals who do not have current asthma, but were diagnosed with asthma in the past

[e]For operators with current asthma

[f]For operators who reported an asthma attack in the past 12 months

Table 4 Logistic regression

Dependent variable	Allergic rhinitis and current asthma		Allergic rhinitis alone		Current asthma alone	
	POR[a]	95% CI	POR[a]	95% CI	POR[a]	95% CI
Bale hay	0.89	0.65–1.21	0.96	0.84–1.09	0.85	0.55–1.33
Manure storage	1.28	0.72–2.26	**0.71**	**0.53–0.96**	0.91	0.46–1.80
Grain production	0.95	0.67–1.35	0.95	0.81–1.11	1.03	0.63–1.70
Animals	1.03	0.75–1.42	1.04	0.91–1.19	0.96	0.60–1.54
Pesticides	**1.90**	**1.42–2.54**	**1.33**	**1.17–1.51**	1.16	0.73–1.84

Models with independent variables lifetime allergic rhinitis and current asthma, lifetime allergic rhinitis alone, or current asthma alone

Numbers in bold show a statistically significant association

[a]Prevalence ratios adjusted for age, sex, US census region, and value of sales. Prevalence ratios from the multivariable logistic regression model examining four disjoint categories of allergic rhinitis and current asthma (i.e., allergic rhinitis and current asthma, allergic rhinitis alone, current asthma alone, and no allergic rhinitis or current asthma as a referent category)

(Table 4). The association was not significant for operators with current asthma alone. The combination of current asthma and lifetime allergic rhinitis and the findings in our study are similar to the combination of adult-onset asthma and allergy in a study by Hoppin et al. (2009).

This study showed that operators with lifetime allergic rhinitis have higher prevalence of current asthma than those with no allergic rhinitis. These results are corroborated by the previous reports on risk of asthma among patients with occupational rhinitis (Ameille et al. 2013; Karjalainen et al. 2003). For example, Karjalainen et al. (2003) followed patients with occupational rhinitis for asthma incidence and found that the relative risk (RR) of asthma was 4.8 (95% CI 4.3–5.4) compared with those with other occupational disease. The risk was highest among farmers (RR 6.8) and wood workers (RR 7.0).

This study is subject to limitations. First, we examined the prevalence of self-reported lifetime history of physician-diagnosed allergic rhinitis. The diagnosis was not validated with medical records. In addition, no information on rhinitis symptoms, skin prick test results, and laboratory test results for total serum IgE or allergen-specific IgE antibodies were available. Thus, it is possible that our results are overestimates because of potential inclusion of operators with non-allergic rhinitis. Validity of self-reported allergic rhinitis remains unknown. Moreover, because Farm and Ranch Safety Survey is a cross-sectional survey, causality or the temporal relationship between allergic rhinitis and pesticide application could not be assessed. It is also possible that we underestimate the allergic rhinitis prevalence, because the survey asked about lifetime rhinitis diagnosis and some operators might not recall it if it has been established in a distant past. Furthermore, it is not clear what proportion of operators with an allergic rhinitis diagnosis established in the past may no longer have any symptoms. However, a longitudinal prospective population-based study of children followed from birth to 26 years of age by Nissen et al. (2013) showed an increasing rate of sensitization to aeroallergens with increasing age and suggested the persistence of allergic diseases. In addition, our findings might be affected by the healthy worker survivor effect, i.e., when some workers with respiratory symptoms might avoid or leave certain jobs with work-related exposures that trigger their symptoms (Mounchetrou et al. 2012; Slager et al. 2009). For example, operators with allergies might avoid active participation in haying, manure store, grain, or animal production implying potential reverse causation. Finally, our outcome and exposure results are based solely on questionnaire report by farm operator or operator's spouse and required recall of certain variables such as farming exposure and past history of rhinitis diagnosis. Although proxy responses, particularly by spouses, have shown good agreement with self-reported responses (Weinfurt et al. 2002), no data were available to the investigators to assess potential bias.

This study is one of the few to investigate lifetime allergic rhinitis prevalence and associated pesticide exposure in a nationally representative population of farmer operators. Results showed a high prevalence of lifetime allergic rhinitis among farm operators relative to the general population and identified groups of farm operators at increased risk of allergic rhinitis. Work-related allergic rhinitis and asthma have common risk factors and agents associated with work-related respiratory diseases are continuously revised and new ones are reported. A table with a list of agents causing work-related asthma with key references is available on the Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNESST) Web site at http://www.asthme.csst.qc.ca/document/Info_Med/IdCauses/Bernstein/AgentsAnglais.pdf. The US Association of Occupational and Environmental Clinics publishes a list of substances that meet criteria for causing work-related asthma by sensitization or acute irritant-induced asthma (http://www.aoecdata.org/ExpCodeLookup.aspx). Additional data are needed to evaluate rhinitis-associated socio-economic adverse effects in farm operators including quality of life reduction, number of work days lost, and reduced productivity. In addition, researchers should further investigate the association of allergic rhinitis with specific pesticide exposure.

Acknowledgements The authors thank Drs. Toni A. Bledsoe and Geoffrey Calvert for helpful comments.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Funding National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

References

Akpinar-Elci M, Pasquale DK, Abrokwah M, Nguyen M, Elci OC (2016) United airways disease among crop farmers. J Agromed 21:217–223. doi:10.1080/1059924X.2016.1179239

Ameille J, Hamelin K, Andujar P et al (2013) Occupational asthma and occupational rhinitis: the united airways disease model revisited. Occup Environ Med 70:471–475. doi:10.1136/oemed-2012-101048

American Thoracic Society (ATS) (1998) Respiratory health hazards in agriculture. Am J Respir Crit Care Med 158:S1–S76. doi:10.1164/ajrccm.158.supplement_1.rccm1585s1

Blaiss MS, Meltzer EO, Derebery MJ, Boyle JM (2007) Patient and healthcare-provider perspectives on the burden of allergic rhinitis. Allergy Asthma Proc 28(Suppl 1):S4–S10. doi:10.2500/aap.2007.28.2991

Braback L, Hjern A, Rasmussen F (2004) Trends in asthma, allergic rhinitis and eczema among Swedish conscripts from farming and non-farming environments. A nationwide study over three decades. Clin Exp Allergy 34:38–43. doi:10.1111/j.1365-2222.2004.01841.x

Brouwer R, Biersteker K, Bongers P, Remijn B, Houthuijs D (1986) Respiratory symptoms, lung function, and IgG4 levels against pig antigens in a sample of Dutch pig farmers. Am J Ind Med 10:283–285

Cartier A (2015) New causes of immunologic occupational asthma, 2012–2014. Curr Opin Allergy Clin Immunol 15:117–123. doi:10.1097/ACI.0000000000000145

Chatzi L, Prokopakis E, Tzanakis N, Alegakis A, Bizakis I, Siafakas N, Lionis C (2005) Allergic rhinitis, asthma, and atopy among grape farmers in a rural population in Crete, Greece. Chest 127:372–378. doi:10.1378/chest.127.1.372

Chatzi L, Alegakis A, Tzanakis N, Siafakas N, Kogevinas M, Lionis C (2007) Association of allergic rhinitis with pesticide use among grape farmers in Crete, Greece. Occup Environ Med 64:417–421. doi:10.1136/oem.2006.029835

Douwes J, Travier N, Huang K et al (2007) Lifelong farm exposure may strongly reduce the risk of asthma in adults. Allergy 62:1158–1165. doi:10.1111/j.1398-9995.2007.01490.x

Galli L, Facchetti S, Raffetti E, Donato F, D'Anna M (2015) Respiratory diseases and allergic sensitization in swine breeders: a population-based cross-sectional study. Ann Allergy Asthma Immunol 115:402–407. doi:10.1016/j.anai.2015.08.006

Greskevitch M, Kullman G, Bang KM, Mazurek JM (2007) Respiratory disease in agricultural workers: mortality and morbidity statistics. J Agromedicine 12:5–10. doi:10.1080/10599240701881482

Hanrahan LP, Paramore LC (2003) Aeroallergens, allergic rhinitis, and sedating antihistamines: risk factors for traumatic occupational injury and economic impact. Am J Ind Med 44:438–446. doi:10.1002/ajim.10285

Heutelbeck AR, Janicke N, Hilgers R, Kutting B, Drexler H, Hallier E, Bickeboller H (2007) German cattle allergy study (CAS): public health relevance of cattle-allergic farmers. Int Arch Occup Environ Health 81:201–208. doi:10.1007/s00420-007-0207-y

Hoppin JA, Umbach DM, London SJ et al (2009) Pesticide use and adult-onset asthma among male farmers in the Agricultural Health Study. Eur Respir J 34:1296–1303. doi:10.1183/09031936.00005509

Karjalainen A, Martikainen R, Klaukka T, Saarinen K, Uitti J (2003) Risk of asthma among Finnish patients with occupational rhinitis. Chest 123:283–288. doi:10.1378/chest.123.1.283

Kay GG (2000) The effects of antihistamines on cognition and performance. J Allergy Clin Immunol 105:S622–S627. doi:10.1067/mai.2000.106153

Kilpeläinen M, Terho EO, Helenius H, Koskenvuo M (2000) Farm environment in childhood prevents the development of allergies. Clin Exp Allergy 30:201–208. doi:10.1046/j.1365-2222.2000.00800.x

Lamb CE, Ratner PH, Johnson CE et al (2006) Economic impact of workplace productivity losses due to allergic rhinitis compared with select medical conditions in the United States from an employer perspective. Curr Med Res Opin 22:1203–1210. doi:10.1185/030079906X112552

Mazurek JM, White GE, Rodman C, Schleiff PL (2015) Farm work-related asthma among US primary farm operators. J Agromed 20:31–42. doi:10.1080/1059924X.2014.976729

Meltzer EO, Blaiss MS, Naclerio RM et al (2012) Burden of allergic rhinitis: allergies in America, Latin America, and Asia-Pacific adult surveys. Allergy Asthma Proc 33(Suppl 1):S113–S141. doi:10.2500/aap.2012.33.3603

Mounchetrou IN, Monnet E, Laplante JJ, Dalphin JC, Thaon I (2012) Predictors of early cessation of dairy farming in the French Doubs province: 12-year follow-up. Am J Ind Med 55:136–142. doi:10.1002/ajim.21031

Nathan RA, Meltzer EO, Derebery J et al (2008) The prevalence of nasal symptoms attributed to allergies in the United States: findings from the burden of rhinitis in an America survey. Allergy Asthma Proc 29:600–608. doi:10.2500/aap.2008.29.3179

Nissen SP, Kjaer HF, Host A, Nielsen J, Halken S (2013) The natural course of sensitization and allergic diseases from childhood to adulthood. Pediatr Allergy Immunol 24:549–555. doi:10.1111/pai.12108

Quirce S, Bernstein JA (2011) Old and new causes of occupational asthma. Immunol Allergy Clin N Am 31:677–698. doi:10.1016/j.iac.2011.07.001

Rennie DC, Karunanayake CP, Chen Y et al (2016) Early farm residency and prevalence of asthma and hay fever in adults. J Asthma 53:2–10. doi:10.3109/02770903.2015.1058394

Rimac D, Macan J, Varnai VM et al (2010) Exposure to poultry dust and health effects in poultry workers: impact of mould and mite allergens. Int Arch Occup Environ Health 83:9–19. doi:10.1007/s00420-009-0487-5

Riu E, Monso E, Marin A et al (2008) Occupational risk factors for rhinitis in greenhouse flower and ornamental plant growers. Am J Rhinol 22:361–364. doi:10.2500/ajr.2008.22.3186

Schoenwetter WF, Dupclay L Jr, Appajosyula S, Botteman MF, Pashos CL (2004) Economic impact and quality-of-life burden of allergic rhinitis. Curr Med Res Opin 20:305–317. doi:10.1185/030079903125003053

Siracusa A, Desrosiers M, Marabini A (2000) Epidemiology of occupational rhinitis: prevalence, aetiology and determinants. Clin Exp Allergy 30:1519–1534. doi:10.1046/j.1365-2222.2000.00946.x

Slager RE, Poole JA, Levan TD, Sandler DP, Alavanja MC, Hoppin JA (2009) Rhinitis associated with pesticide exposure among commercial pesticide applicators in the Agricultural Health Study. Occup Environ Med 66:718–724. doi:10.1136/oem.2008.041798

Slager RE, Simpson SL, Levan TD, Poole JA, Sandler DP, Hoppin JA (2010) Rhinitis associated with pesticide use among private pesticide applicators in the Agricultural Health Study. J Toxicol Environ Health A 73:1382–1393. doi:10.1080/15287394.2010.497443

Smit LA, Zuurbier M, Doekes G, Wouters IM, Heederik D, Douwes J (2007) Hay fever and asthma symptoms in conventional and organic farmers in The Netherlands. Occup Environ Med 64:101–107. doi:10.1136/oem.2006.028167

Soni A (2008) Allergic rhinitis: trends in use and expenditures, 2000 to 2005. Agency for Healthcare Research and Quality, Rockville. Statistical brief 204. http://ftp.cdc.gov/pub/Health_Statistics/NCHS/NHIS/SHS/2014_SHS_Table_A-2.pdf. Accessed 26 Aug 2016

Stevens WW, Grammer LC III (2015) Occupational rhinitis: an update. Curr Allergy Asthma Rep 15:487. doi:10.1007/s11882-014-0487-8

US Department of Agriculture (2016) Economics, statistics and market information system. National Agricultural Statistic Service. Farm and Ranch Safety Survey Report. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1764. Accessed 1 March 2016

Weinfurt KP, Trucco SM, Willke RJ, Schulman KA (2002) Measuring agreement between patient and proxy responses to multidimensional health-related quality-of-life measures in clinical trials. An application of psychometric profile analysis. J Clin Epidemiol 55:608–618. doi:10.1016/S0895-4356(02)00392-X

Ye M, Beach J, Martin JW, Senthilselvan A (2013) Occupational pesticide exposures and respiratory health. Int J Environ Res Public Health 10:6442–6471. doi:10.3390/ijerph10126442