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Associations of Occupational Exposures on Environmental Allergies Among Farmers and Ranchers in the Central United States

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ABSTRACT

Importance: Environmental allergies plague millions of adults every year. Farmers and ranchers are at a heightened risk of exposure to allergens due to their occupation.
Objective: Few studies have addressed the contribution of occupational exposures to environmental allergies and potential preventive strategies to reduce exposure. The objective of this study is to determine whether occupational exposures affect the risk of environmental allergies among farmers and ranchers in the central midwestern states.
Design: Surveillance data from the Central States Center for Agricultural Safety and Health Farm and Ranch Health and Safety Surveys from 2018, 2020, and 2023 were analyzed to investigate risk factors for environmental allergies. Logistic regression was used to evaluate associations.
Setting: The study was conducted across seven states, including Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. Surveys were mailed to randomly selected agricultural operations.
Participants: Eligible participants were farm and ranch operators with an email address and an estimated gross farm income of at least $5,000. The study was sent to "operators" defined as those who manage a farm or ranch business.
Main Outcome(s) and Measure(s): The primary outcome variable is the presence of environmental allergies, assessed through self-reported physician-diagnosed allergies. The primary variable of interest was air contaminant exposure. Additional predictor variables included skin exposures, musculoskeletalexposures, workstrain symptoms,musculoskeletal discomfort, sex, age, type of operation, primary occupation, percentage of worktime, and production variables.
Results: Beingfemale (OR = 1.84) and having a primary occupation other than farm/ranch work (OR = 1.47) were significantly associated with higher odds of environmental allergies. Surprisingly, participants without symptoms of work strain (OR = 1.72), musculoskeletal discomfort (OR = 1.93), and musculoskeletal exposures (OR = 1.48) were positivelyassociated with environmental allergies. Occupational exposures, including respiratory exposure to grain, feed, or hay dust (OR = 1.43), road dust (OR = 1.39), skin contact with pesticides or fertilizers (OR = 1.22), and detergents and disinfectants (OR = 1.22) increased theodds of having environmental allergies. Dairy (OR = 0.61) and grainproduction (OR = 0.75) decreased the odds.
Conclusionsand Relevance: These findings highlight the need for occupational health interventions aimed at reducing respiratory and skin exposures in farm and ranch environments.

KEYWORDS
Agriculture; Central States; environmental allergies; occupational exposure; respiratory exposure

Introduction

In the United States, 41.7% of adults have self-reported allergies.[1] Included in these allergies are environmental allergies, which are an immunoglobin E (IgE)-mediated hypersensitive reaction that occurs following an exposure to environmental factors, leading to symptoms ranging from mild to severe like allergic rhinitis, eczema, and wheezing.[2] The economic and health impacts of these allergies are not minor. Allergic rhinitis and associated treatment alone contribute to over three billion dollars in medical expenses each year.[3] Agricultural workers are frequently exposed to environmental allergens due to their work with occupational exposures such as dust, pesticides, airborne particles, and livestock.[4] These exposures contribute to an increased risk of respiratory conditions, which include environmental allergies.[5]

Well-described occupational exposures to allergies include skin exposures and air contaminants. Of the environmental exposures, the contribution of pesticides has been widely studied. For example, farmers were at risk for atopic diseases when using herbicides, insecticides, and other pesticides.[6] Research indicated that 30.8% of farmers had experienced allergic rhinitis,

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a symptom of environmental allergies, at some point in their lives, and those with allergic rhinitis were 1.38 times more likely to be exposed to pesticides.[7] Pesticides are not the only contributing factor to environmental allergies among agricultural workers. Farmers working with livestock have an increased risk of developing allergies and atopic disease due to exposure to other agents.[5] For example, biological aerosol and organic dust have been linked to adverse health effects, including allergies.[8] Despite the risks associated with these occupational exposures, susceptibility may be influenced by early-life exposure to farm environments, which can have protective effects against allergies, as suggested by the hygiene hypothesis.[9]

Other occupational exposures linked to allergies may be associated with other health conditions, such as musculoskeletal disorders. Agricultural workers perform physically demanding job tasks such as moving large animals, carrying heavy loads of feed, and performing manual labor. The extent to which these tasks occur regularly may vary by the type of farm production. Tasks with the highest postural load risks are collecting and moving manure, pouring milk into a bucket, filling feed bags, and manually feeding livestock.[10,11] Many of these tasks stir dust, animal dander, pollens, and/or fungal molds, which are linked to allergy risk exposures.[12] Although there is no literature that has explored the relationships between musculoskeletal disorders and allergies, the occupational tasks and exposures linked to musculoskeletal disorders may also contribute to allergy development.

Many studies have investigated asthma and allergies in pediatric and adult populations.[5,8,13,14] However, many of these studies have focused broadly on respiratory conditions, such as asthma. However, there remains a need to further investigate the relationship between occupational exposures and specifically environmental allergies in adult farm and ranch operators.[15–17]

Allergies are a well-known public health concern; previous research has not identified specific agricultural exposures that contribute to environmental allergy development in adult agricultural workers. This study aims to address these gaps by assessing the contribution of occupational exposures to environmental allergies in farmers and ranchers in the central midwestern states of the United States. Leveraging surveillance data, we aim to identify the association between occupational exposures and self-reported physician diagnosed environmental allergies. We hypothesize that certain occupational exposure affects the risk of environmental allergies among farmers and ranchers in the central midwestern states.

Methods

Study setting

The data for this study were collected through three cross-sectional surveys administered in 2018, 2020, and 2023. The surveys targeted farm and ranch operators across seven states, including Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. The sample was unique and unduplicated across all years, ensuring no operators received or participated in more than one survey year. The survey questionnaire is called the Farm and Ranch Health and Safety Survey (FRHSS), which was developed by the Central States Center for Agricultural Safety and Health (CS-CASH). It consists of 29 questions focusing on injuries, chronic health outcomes, work-related exposures, and the use of personal protective equipment. The questions remained the same over the years, although some questions were removed or added in 2023. The paper-based survey was distributed to a random sample of approximately 2,500 farm and ranch operations per state each survey year, totaling around 17,500 operations across all seven states annually. Responses were collected via mail and entered into the Research Electronic Data Capture (REDCap 14.9.6) software (in 2018) and Microsoft Access (in 2023). TeleForm software was used in 2020 for automated reading of scanned paper forms.

Population and sampling

The survey sampling frame was obtained from Farm Market iD (FMiD) for the 2018 and 2020 surveys and US Farm Data for the 2023 survey. FMiD and the US Farma Data used stratified random sampling techniques from compiled databases from the United States Department of Agriculture (USDA) annual surveys, remote sensing data, and other public and private sources, covering approximately 95% of agricultural operations in the United States. Eligible participants were farm and ranch operators with an email address and an estimated gross farm income of at least $5,000. The study was sent to "operators" defined as those who manage a farm or ranch business. The 2018 survey was distributed in May, with a follow-up request in June, yielding a response rate of 19% (3,268 farms and 4,423 operators). The 2020 survey was sent in March, followed by a June follow-up, resulting in a 16% response rate (2,736 farms and 3,492 operators). The 2023 survey was distributed to 17,497 farms, with one follow-up reminder, resulting in 1,770 responses, representing 2,367 operators and a response rate of 10.1%. This analysis included respondents aged 18 or older who identified as primary, secondary, or tertiary farm or ranch operators.

Outcome variable

The primary outcome variable is the presence of environmental allergies, assessed through self-reported physician-diagnosed allergies. Participants were asked: "Has the operator ever been diagnosed by a physician with any of the following respiratory conditions? (Mark all that apply)". Response options included "None, Chronic obstructive pulmonary dis. (COPD), Asthma, Farmer's lung, Sinus disease (Sinusitis), Nasal Inflammation, runny nose (Rhinitis), and Environ. Allergies". For the statistical analysis, the outcome variable, environmental allergies, was dichotomized into a binary variable (Yes = 1, No = 0). This questionnaire did not specify a difference between environmental allergies and other general allergies.

Potential risk factor variables

The following survey question identified the primary variables of interest: "Was the operator exposed to high levels of any of the following air contaminants during the past 12 months? (Mark all that apply.)" The response options were "None, Grain/feed/hay dust, animal confinem. dust, Field/road dust, Manure/silage gases, Anhydrous ammonia, fuels/solvents/paints, and other, specify (free response)." Participants were able to mark all applicable exposures. Each individual air contaminant exposure response option was treated as a separate binary variable (Yes = 1, No = 0).

Additional potential predictor variables at the operator level were examined. For skin exposures, the survey asked: "Was the operator exposed to any of the following chemicals or animal-based allergens while working during the past 12 months? (Mark all that apply.)" Response options for these skin exposures were "None, pesticides/fertilizers, animals/livestock, detergents/disinfectants, fuels/solvents/paints, and other, specify (free response)." Each response option was treated as a separate binary variable (Yes = 1, No = 0).

For musculoskeletal exposures, the survey asked: "Was the operator exposed to any of the following situations at work during the past 12 months? (Mark all that apply.)" Response options for these musculoskeletal exposures were "None, forceful exertion, repetitive tasks, awkward postures, frequent manual labor, vibrations, other, specify". Similarly, for work strain symptoms, the survey asked: "Did the operator experience extended work periods that resulted in any of the following during the past 12 months? (Mark all that apply.)" Response options were "None, High stress level, Exhaustion/fatigue, Sleep deprivation." For musculoskeletal discomfort, the survey asked: "Did the operator experience pain or discomfort that affected his/her work in any of the following body areas during the past 12 months? (Mark all that apply.)" Response options were "None, Neck, Shoulder, Upper back, Elbows, Knees, Ankle/feet, Hips/thighs, Low back, Wrists/hands," Responses for the categories musculoskeletal exposures, work strain symptoms, and musculoskeletal discomfort were categorized as "None" (coded as 0) vs. "Some" (one or more symptom or exposure, coded as 1).

Additional predictor variables at the operator level were analyzed, including sex (male or female), age (categorized as <50, 50–64, and 65–100), type of operation (farm, ranch, or both), primary occupation (farm/ranch work vs. other occupations), and the percentage of work time dedicated to farm or ranch activities (grouped as 0%–24%, 25%–49%, 50%–74%, 75%–99%, and 100%). These variables were considered for inclusion in multivariable regression models. Production-related factors were examined, including the types of crops and livestock raised. This encompassed commodities such as corn, hay, wheat, beef, dairy, cereal grains, livestock, pasture/rangeland, legumes, corn & soy, soybeans, cow-calf operations, and fed cattle. Participants were able to mark multiple products. Each production variable was categorized as a binary variable (Yes = 1, No = 0). If an individual marked a production exposure, it was coded as "Yes". If they did not mark the production allergen exposure, it was coded as "No", regardless of the other selections.

Statistical methods

Descriptive statistics were calculated to summarize the characteristics of the sample. Frequency tables were generated to examine the distribution of the risk factor variables among participants with and without environmental allergies. A logistic objective function was used to model the probability of having an allergy, with allergy (Yes = 1, No = 0) as the outcome variable. First, the outcome variable, environmental allergy diagnosis, was cross-tabulated with all the selected operator, production, and exposure variables. Next, bivariate analyses were conducted using the chi-square test to evaluate the individual relationships between each risk factor and the outcome variable. Variables that showed a significant association ($p < .05$) were selected for the multivariable model. Multivariable analysis was performed using logistic regression and adjusting for confounders. The adjusted odds ratio (ORs) with a 95% confidence interval (CI) was reported to support the multivariable results. All statistical analyses were done using SAS OnDemand for Academics.

IRB statement

The University of Nebraska Medical Center Institutional Review Board approved this study protocol as exempt (#452–11-EX).

Results

The final dataset included 10,151 operators with a mean age of 59 years. The sample contained 8,528 men and 1,542 women. Environmental allergies were reported by 9% of the operators. Demographic and farm characteristics between operators with environmental allergies ("Yes", 8.97%) and those without ("No", 91.03%) are presented in Table 1. All the characteristics listed show statically significant differences ($p < .05$), indicating differences between groups. The study consisted of mainly primary operators, although the secondary and tertiary operators were more common among those with environmental allergies. There were more men with environmental allergies than women (712, 78.16%). Women made up a larger portion of the allergy group (20.97%) compared to the group without allergies (13.31%). The majority of respondents identified farming/ranching as their primary occupation, with about half spending all of their work time on the business. More environmental allergy positive operators worked 25–49% of the time (15.48%) versus those without environmental allergies (12.48%). The majority of survey respondents were operators that work on farms, however operators with environmental allergies were more likely to work on both a farm and ranch (15.04% vs. 11.75%).

Environmental allergies were more common among operators working cattle (49.78%), corn (81.08%), grain (65.71%), livestock (53.76%), and sheep (5.20%). The frequency of environmental allergies was lower for those who reported producing dairy (3.76%) and goats (1.55%). Oats, alfalfa, barley, goats, grass, root vegetables, soybeans, and wheat show no statistical significance between those with and without environmental allergies (Table 2).

The prevalence of environmental allergies was lower among operators reporting work strain symptoms (33.6%) compared to those without work strain symptoms (56.1%). Musculoskeletal discomfort was lower among those with environmental allergies (15.8%) than those without environmental allergies (35.8%). Operators with respiratory exposures to grain, feed, or hay dust (68.1%), animal confinement dust (16.6%), road dust (59.1%), manure/silage gas (16.3%), and fuels/solvents/paints (35.9%), showed higher percentages of environmental allergies, as shown in Table 3. Similarly, environmental allergies were more frequent among operators that had skin exposure to pesticides or fertilizers (65.3%), animals/livestock (48.3%), detergents/disinfectants (34.0%) and solvents (64.0%), as shown in Table 3.

Table 1. Demographics and farm characteristics of study participants ($n = 10,153$).

Operator Characteristics	Environmental Allergy Present n (%)	Environmental Allergy Absent n (%)	*p*-value
Total	911 (8.97)	9242 (91.03)	
Sex	712 (78.2)	7816 (84.6)	<.001
Male	191 (21.0)	1351 (14.6)	
Female	8 (0.88)	75 (0.81)	
Missing			
Age group	190 (20.9)	1904 (20.6)	NS
18–49	392 (43.0)	3657 (39.6)	
50–64	329 (36.1)	3681 (39.8)	
65 and older			
Operator	602 (66.1)	6573 (71.1)	<.01
Primary	249 (27.3)	2121 (23.0)	
Secondary	60 (6.59)	548 (5.93)	
Tertiary			
Primary Occupation	677 (74.3)	7071 (76.5)	<.05
Farm/Ranch Work	226 (24.8)	1938 (21.0)	
Other	8 (0.88)	233 (2.52)	
Missing			
Time Spent Working on Operation	417 (45.8)	4343 (47.0)	.05
100%	161 (17.7)	1668 (18.1)	
75–99%	115 (12.6)	1024 (11.1)	
50–74%	141 (15.5)	1153 (12.5)	
25–49%	71 (7.79)	850 (9.20)	
0–24%	6 (0.66)	204 (2.21)	
Missing			
Type of Operation	610 (67.0)	6399 (69.2)	<.05
Farm	93 (10.2)	892 (9.65)	
Ranch	137 (15.0)	1086 (11.8)	
Both	71 (7.79)	865 (9.36)	
Missing			

Table 2. Farm product characteristics by environmental allergies among operators ($n = 10,070$).

Production	Environmental Allergies Present n (%)	Environmental Allergies Absent n (%)	*p*-value
Total	904 (8.97)	9166 (91.03)	
Oats	146 (16.2)	1722 (18.8)	.05
Yes	758 (83.9)	7444 (81.2)	
No			
Alfalfa	532 (58.9)	5562 (60.7)	NS
Yes	372 (41.2)	3604 (39.3)	
No			
Barley	110 (12.2)	1078 (11.8)	NS
Yes	794 (87.8)	8088 (88.2)	
No			
Cattle	450 (49.8)	4017 (43.8)	<.001
Yes	454 (50.2)	5149 (56.2)	
No			
Corn	733 (81.1)	7668 (83.7)	<.05
Yes	171 (18.9)	1498 (16.3)	
No			
Dairy	34 (3.76)	520 (5.67)	<.05
Yes	870 (96.2)	8646 (94.3)	
No			
Goats	14 (1.55)	92 (1.00)	NS
Yes	890 (98.5)	9074 (99.0)	
No			
Grain	594 (65.7)	6555 (71.5)	<.001
Yes	310 (34.3)	2611 (28.5)	
No			
Grass	780 (86.3)	7860 (85.8)	NS
Yes	124 (13.7)	1306 (14.2)	
No			

(*Continued*)

Table 2. (Continued).

Production	Environmental Allergies Present n (%)	Environmental Allergies Absent n (%)	*p*-value
Livestock	486 (53.8)	4437 (48.4)	<.01
Yes	418 (46.2)	4729 (51.6)	
No			
Root Vegetables	16 (1.77)	199 (2.17)	NS
Yes	888 (98.2)	8967 (97.8)	
No			
Sheep	47 (5.20)	308 (3.36)	<.01
Yes	857 (94.8)	8858 (96.6)	
No			
Soybean	702 (77.7)	7362 (80.3)	NS
Yes	202 (22.3)	1804 (19.7)	
No			
Wheat	350 (38.7)	3467 (37.8)	NS
Yes	554 (61.3)	5699 (62.2)	
No			

Table 3. Work environment exposures by environmental allergies among operators ($n = 10,153$).

Exposure Factors	Environmental Allergies Present n (%)	Environmental Allergies Absent n (%)	*p*-value
Total	917 (8.92)	9365 (91.08)	
Skin Exposures			
Skin Exposure to Pesticides/Fertilizers	595 (65.3)	4949 (53.5)	<.001
Yes	316 (34.7)	4293 (46.5)	
No			
Skin Exposure to Animals/Livestock	440 (48.3)	3386 (36.6)	<.001
Yes	471 (51.7)	5856 (63.4)	
No			
Skin Exposure to Detergents or Disinfectants	310 (34.0)	1988 (21.5)	<.001
Yes	601 (66.0)	7254 (78.5)	
No			
Skin Exposure to Solvents	583 (64.0)	4806 (52.0)	<.001
Yes	328 (36.0)	4436 (48.0)	
No			
Air Contaminants			
Respiratory Exposure to Grain, Feed, or Hay Dust	620 (68.1)	4623 (50.0)	<.001
Yes	291 (31.9)	4619 (50.0)	
No			
Respiratory Exposure to Animal Confinement Dust	151 (16.6)	1055 (11.4)	<.001
Yes	760 (83.4)	8187 (88.6)	
No			
Respiratory Exposure to Road Dust	538 (59.1)	3599 (38.9)	<.001
Yes	373 (40.9)	5643 (61.1)	
No			
Respiratory Exposure to Manure/Silage Gases	148 (16.3)	887 (9.60)	<.001
Yes	763 (83.7)	8355 (90.4)	
No			
Musculoskeletal Exposures			
Work Strain Symptoms	605 (66.4)	4059 (43.9)	<.001
Yes	306 (33.6)	5183 (56.1)	
No			
Musculoskeletal Discomfort	767 (84.2)	5931 (64.2)	<.001
Yes	144 (15.8)	3311 (35.8)	
No			
Noise Exposure	829 (91.0)	7588 (82.1)	<.001
Yes	82 (9.00)	1654 (17.9)	
No			
Musculoskeletal Exposure	824 (90.4)	7152 (77.4)	<.001
Yes	87 (9.55)	2090 (22.6)	
No			
Preventative Musculoskeletal Techniques	829 (91.00)	7565 (81.8)	<.001
Yes	82 (9.00)	1677 (18.2)	
No			

Table 4. Multivariable analysis of risk factors associated with environmental allergies in 9,760 operators.

Variable	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Demographic Variables		
Sex	reference	reference
Male	1.55 (1.31–1.84)	1.84 (1.52–2.23)
Female		
Primary Occupation	reference	reference
Farm/Ranch Work	1.22 (1.04–1.43)	1.47 (1.23–1.75)
Other		
Skin Exposures		
Skin Exposures Pesticides/Fertilizers	reference	reference
No	1.63 (1.42–1.88)	1.22 (1.03–1.44)
Yes		
Skin Exposure Detergents/Disinfectants	reference	reference
No	1.88 (1.63–2.18)	1.22 (1.04–1.44)
Yes		
Air Contaminants		
Respiratory Exposure Grain, Feed, or Hay Dust	reference	reference
No	2.13 (1.84–2.46)	1.43 (1.19–1.71)
Yes		
Respiratory Exposure Road Dust	reference	reference
No	2.26 (1.97–2.60)	1.39 (1.18–1.64)
Yes		
Production Products		
Dairy	Dairy	Dairy
No	No	No
Yes	Yes	Yes
Grain	Grain	Grain
No	No	No
Yes	Yes	Yes
Musculoskeletal Exposures		
Work Strain Symptoms	2.53 (2.19–2.91)	1.72 (1.47–2.02)
No	reference	reference
Yes		
Musculoskeletal Discomfort	2.97 (2.48–3.57)	1.93 (1.58–2.37)
No	reference	reference
Yes		
Musculoskeletal Exposure	2.77 (2.21–3.47)	1.48 (1.15–1.91)
No	reference	reference
Yes		

The final model of the multivariable analysis included the primary exposures of interest, which include respiratory exposure to grain, feed, or hay dust, respiratory exposure to road dust, skin exposure to pesticides or fertilizers, and skin exposure to detergents or disinfectants, as well as the covariates sex, primary occupation, work strain symptoms, musculoskeletal discomfort, musculoskeletal exposure, dairy, and grain (Table 4). Women have greater odds of environmental allergies than men (adjusted OR (aOR)=1.84, 95% CI: 1.52–2.23). Those whose primary occupation was off the farm or ranch were at an increased odds of environmental allergies (aOR = 1.47, 95% CI: 1.23–1.75). Skin exposure to pesticides or fertilizers (aOR = 1.22, 95% CI: 1.03–1.44) and detergents or disinfectants (aOR = 1.22, 95% CI: 1.04–1.44) were significantly associated with environmental allergies. The absence of work strain symptoms (aOR = 1.72, 95% CI: 1.47–2.02) and musculoskeletal discomfort (aOR = 1.93, 95% CI: 1.58–2.37) were both significantly associated with environmental allergies and (adjusted OR = 1.43, 95% CI: 1.19–1.71) and road dust (adjusted OR = 1.39, 95% CI: 1.18–1.64) were both linked to elevated odds of allergies. The absence of musculoskeletal exposures was associated with increased allergy odds (aOR = 1.48, 95% CI: 1.15–1.91). Production of dairy (aOR = 0.61, 95% CI: 0.42–0.88) and grain (aOR = 0.75, 95% CI: 0.64–0.87) was associated with significantly lower odds of environmental allergies. Figure 1 shows a forest plot of these results.

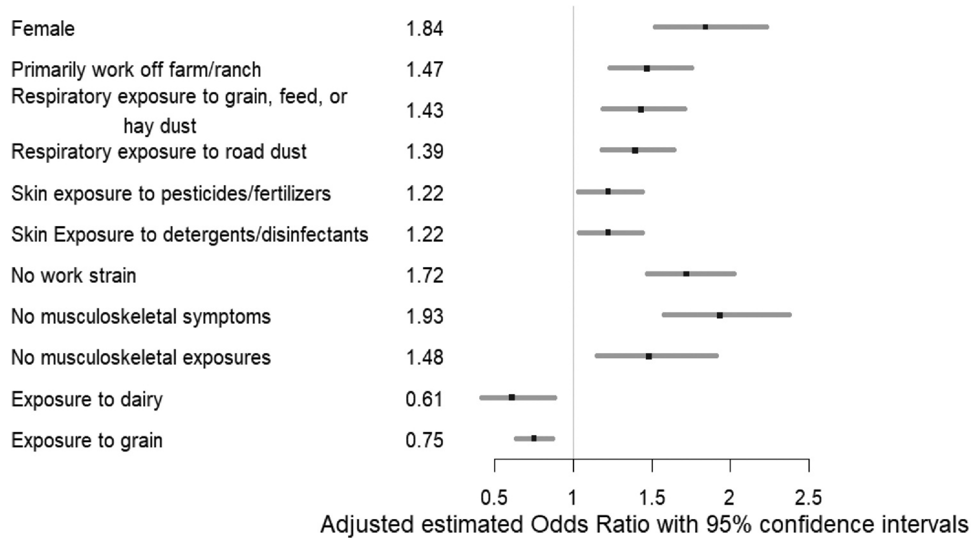

Figure 1. Farm and operator characteristics associated with environmental Allergies.

Discussion

The study identified several factors associated with environmental allergies among farmers and ranchers in the central states. The final multivariable model identified being female and having a non-farming primary occupation as having significantly higher odds of environmental allergies These factors reflect a reduced exposure to agricultural work. Significant associations were observed in the absence of self-reported work strain symptoms, musculoskeletal discomfort, and musculoskeletal exposures. Musculoskeletal discomfort, musculoskeletal exposures, and work strain have been shown previously to be significantly associated.[18] This result may reflect the lack of priority of allergies when agricultural operators are experiencing high work strain and experiencing musculoskeletal symptoms. Environmental exposures like respiratory exposure to grain, feed, or hay dust, respiratory exposure to road dust, and skin exposure to pesticides, fertilizers, detergents, or disinfectants, were all significant in the adjusted model. As expected, respiratory exposures showed a greater association than skin exposures on environmental allergies. Dairy and grain production were associated with significantly lower odds of environmental allergies, indicating a protective effect which may support the hygiene hypothesis.[13,14]

Environmental allergies are a major public health concern. Environmental allergies affect about one in five individuals in the United States.[19] Two in three individuals with asthma have environmental allergies.[19] Agricultural workers are at a heightened risk of environmental allergies because they are regularly exposed to irritants.[20] Prior studies have explored the role of exposures like pesticides, which have been shown to damage the bronchial mucosa making the airway sensitive to allergens.[21]

Many of these findings are consistent with previous research. Being female was associated with about twice the odds of environmental allergies, which aligns with prior literature indicating higher prevalence allergies among women.[22] Those whose primary occupation was not farming had elevated odds of environmental allergies, consistent with previous literature.[23] The findings may reflect the health worker effect, individuals with underlying conditions may be less likely to enter or remain in farming or ranching.[9] This pattern could also be explained by the hygiene hypothesis [13,14] or exposure to more environmental microorganisms when working outdoors.[24] Participants who answered "none" to the variables work strain symptoms, musculoskeletal discomfort, and musculoskeletal exposure were strongly associated with environmental allergies. The association between absence of work strain symptoms or musculoskeletal discomfort warrants further investigation. Previous research on asthma found that 17% of workers changed jobs, had accommodations or ceased working due to their symptoms.[25] Workers with allergic rhinitis experienced a 26.6% reduction in productivity while at work and 27.8% needed restrictions in their daily activities.[26] Individuals with environmental allergies (or other morbidities) may be less likely to engage in work that will increase their exposure to allergens, a concept known as the healthy worker effect.[9] The work-strain may function as a stress-amplifying factor with allergens exacerbating the issue.

Respiratory exposure to grain, feed, or hay dust and road dust was significantly associated with higher odds of environmental allergies. These exposures are well-documented allergens in agricultural environments.[27–29] Skin exposure to pesticides or fertilizers, and detergents or disinfectants was significantly associated with allergic outcomes, consistent with previous literature.[30,31] Dairy production was associated with lower odds of environmental allergies, which may be explained by previous research suggesting that exposure to cattle and cow-related allergens, such as bovine lipocalin (BLG), may have immune-modulating effects.[32] Grain production, being associated with lower odds of environmental allergies, may again support the hygiene hypothesis, which suggests that early and frequent exposure to microbial agents may have protective effects.

There are a few limitations in this study. First, the environmental allergy diagnosis was based on self-reported, physician-diagnosed allergies occurring at any point in the respondent's life. This can introduce response bias or recall bias. The data relied on self-reported exposures, which might not accurately capture true exposure levels compared to other measurement methods. Second, the cross-sectional nature of the study limits our ability to infer causality. Third, we adjusted for key variables, but confounders cannot be ruled out. Finally, while the dataset is large, there is a low response rate which could impact the generalizability of the findings. This could introduce selection bias as individuals who chose to respond may be more motivated by health concerns and the observed associated could result in an overestimation or underestimation. Given the effect sizes are generally small, the results may have false significance and limited clinical relevance.

These findings highlight the need for occupational health interventions aimed at reducing respiratory and skin exposures in farm and ranch environments. Risk of environmental allergies in agricultural workers is complex, some exposures could be protective, while others might increase risk. Given the nature of responses in this study, cross-sectional surveys, it is important that future research should include longitudinal approaches. Through such study designs, the associations between exposure intensity, the role of physical strain, and sex-associated differences in allergy risks will be evaluated more thoroughly.

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Disclosure statement

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Author contributions

Conceptualization, AW; Methodology, AW, CB, YD; Formal Analysis, AW, CB, YD; Resources, SC, RR; Data Curation, AW, RA; Writing – Original Draft Preparation, AW; Writing – Review & Editing, AW, CB, YD, SC, RR; Visualization, AW, CB; Supervision, SC, CB, RR; Project Administration, RR; Funding Acquisition, RR

Institutional and ethics approval and informed consent

University of Nebraska Medical Center Institutional Review Board approved this study protocol as exempt (#452–11-EX)

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References

1. Seité S, Kuo AMS, Taieb C, Strugar TL, Lio P. Self-reported prevalence of allergies in the USA and impact on skin—an epidemiological study on a representative sample of American adults. *Int J Environ Res Public Health*. 2020;17(10):3360. doi: 10.3390/ijerph17103360.
2. Murrison LB, Brandt EB, Myers JB, Hershey GKK. Environmental exposures and mechanisms in allergy and asthma development. *J Clin Invest*. 2019;129 (4):1504–1515. doi: 10.1172/JCI124612.
3. Tkacz JP, Rance K, Waddell D, Aagren M, Hammerby E. Real-world evidence costs of allergic rhinitis and allergy immunotherapy in the commercially insured United States population. *Curr Med Res Opin*. 2021;37 (6):957–965. doi: 10.1080/03007995.2021.1903848.
4. de B RM, de CDS, Chong-Silva DC, et al. Association between exposure to pesticides and allergic diseases in children and adolescents: a systematic review with meta-analysis. *J Pediatr (Rio J)*. 2022;98(6):551–564. doi: 10.1016/j.jped.2021.10.007.
5. Poole JA. Farming-associated environmental exposures and atopic diseases. *Ann Allergy Asthma Immunol*. 2012;109(2):93–98. doi: 10.1016/j.anai.2011.12.014.
6. Mazurek JM, Henneberger PK. Lifetime allergic rhinitis prevalence among U.S. primary farm operators: findings from the 2011 farm and ranch safety survey. *Int Arch Occup Environ Health*. 2017;90(6):507–515. doi: 10.1007/s00420-017-1217-z.
7. Peccia J, Hospodsky D, Bibby K. New directions: a revolution in DNA sequencing now allows for the meaningful integration of biology with aerosol science. *Atmos Environ*. 2011;45(10):1896–1897. doi: 10.1016/j.atmosenv.2010.11.037.
8. Strieker S, Weinmann T, Gerlich J, et al. Farm living and allergic rhinitis from childhood to young adulthood: prospective results of the GABRIEL study. *J Allergy Clin Immunol*. 2022;150(5):1209–1215.e2. doi: 10.1016/j.jaci.2022.05.027.
9. Chowdhury R, Shah D, Payal AR. Healthy worker effect phenomenon: revisited with emphasis on statistical methods - a review. *Indian J Occup Environ Med*. 2017;21(1):2–8. doi: 10.4103/ijoem.IJOEM_53_16.
10. Taghavi SM, Mokarami H, Ahmadi O, Stallones L, Abbaspour A, Marioryad H. Risk factors for developing work-related musculoskeletal disorders during dairy farming. *Int J Occup Environ Med*. 2017;8 (1):39–45. doi: 10.15171/ijoem.2017.861.
11. Mw N, Nonnenmann D, Anton F, Ger L, Merlino K, Donham MW. Musculoskeletal symptoms of the neck and upper extremities among Iowa dairy farmers. *Am J Ind Med*. 2008;51(6):443–451. doi: 10.1002/ajim.20582.
12. May S, Romberger DJ, Poole JA. Respiratory health effects of large animal farming environments. *J Tox Env Health Part B*. 2012;15(8):524–541. doi: 10.1080/10937404.2012.744288.
13. Frei R, Heye K, Roduit C. Environmental influences on childhood allergies and asthma - the farm effect. *Pediatr Allergy Immunol*. 2022;33(6):e13807. doi: 10.1111/pai.13807.
14. Von Mutius E, Vercelli D. Farm living: effects on childhood asthma and allergy. *Nat Rev Immunol*. 2010;10(12):861–868. doi: 10.1038/nri2871.
15. Sigsgaard T, Basinas I, Doekes G, et al. Respiratory diseases and allergy in farmers working with livestock: a EAACI position paper. *Clin Transl Allergy*. 2020;10 (1):29. doi: 10.1186/s13601-020-00334-x.
16. Hoppin JA, Umbach DM, London SJ, et al. Pesticides and atopic and nonatopic asthma among farm women in the Agricultural Health Study. *Am J Respir Crit Care Med*. 2008;177(1):11–18. doi: 10.1164/rccm.200706-821OC.
17. Wells AD, Poole JA, Romberger DJ. Influence of farming exposure on the development of asthma and asthma-like symptoms. *Int Immunopharmacol*. 2014;23(1):356–363. doi: 10.1016/j.intimp.2014.07.014.
18. Patel O, Syamlal G, Pk H, Wa A, Mazurek JM. Pesticide use, allergic rhinitis, and asthma among US farm operators. *J Agromed*. 2018;23(4):327–335. doi: 10.1080/1059924X.2018.1501451.
19. Chengane S, Beseler CL, Duysen EG, Rautiainen RH. Occupational stress among farm and ranch operators from a seven state surveillance system in the Midwestern United States. *BMC Public Health*. 2021;21(1):2076. doi: 10.1186/s12889-021-12053-4.
20. Ng A, Boersma P. *Diagnosed Allergic Conditions in Adults: United States, 2021*. National Center for Health Statistics (U.S.); 2023. doi: 10.15620/cdc:122809.
21. American Thoracic Society. Respiratory health hazards in agriculture. *Am J Respir Crit Care Med*. 1998;158(supplement_1):S1–S76.
22. Ahmad MF, Ahmad FA, Alsayegh AA, et al. Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures. *Heliyon*. 2024;10(7):e29128. doi: 10.1016/j.heliyon.2024.e29128.
23. Jensen-Jarolim E, Untersmayr E. Gender-medicine aspects in allergology. *Allergy*. 2008;63(5):610–615. doi: 10.1111/j.1398-9995.2008.01645.x.
24. Tizek L, Redlinger E, Ring J, Eyerich K, Biedermann T, Zink A. Urban vs rural – prevalence of self-reported allergies in various occupational and regional settings. *World Allergy Organ J*. 2022;15(1):100625. doi: 10.1016/j.waojou.2022.100625.
25. Ege MJ, Mayer M, Normand AC, et al. Exposure to environmental microorganisms and childhood asthma. *N Engl J Med*. 2011;364(8):701–709. doi: 10.1056/NEJMoa1007302.
26. Blanc PD, Cisternas M, Smith S, Yelin EH. Asthma, employment status, and disability among adults treated by pulmonary and allergy specialists. *Chest*. 1996;109 (3):688–696. doi: 10.1378/chest.109.3.688.
27. Caballer BDLH, Rodríguez M, Fraj J, Cerecedo I, Antolín-Amérigo D, Colas C. Allergic rhinitis and its

impact on work productivity in primary care practice and a comparison with other common diseases: the cross-sectional study to evaluate work productivity in allergic rhinitis compared with other common diseases (CAPRI) study. *Am J Rhinol? Allergy*. 2012;26 (5):390–394. doi: 10.2500/ajra.2012.26.3799.

28. Puvvula J, Baccaglini L, Johnson A, Du Y, Bell JE, Rautiainen RH. Prevalence and risk factors for pulmonary conditions among farmers and ranchers in the central United States. *J Agromed*. 2022;27 (4):378–390. doi: 10.1080/1059924X.2021.2025180.
29. Liebers V, Brüning T, Raulf M. Occupational endotoxin exposure and health effects. *Arch Toxicol*. 2020;94 (11):3629–3644. doi: 10.1007/s00204-020-02905-0.
30. SenGupta K, Karmakar B, Roy S, Kaur A, Gupta Bhattacharya S. Analyzing airborne fungal concentration in Kolkata, India: temporal distribution, the effect of atmospheric parameters and health impact. *Air Qual Atmos Health*. 2023;16(5):963–984. doi: 10.1007/s11869-023-01316-1.
31. Hong S, Kwon HJ, Choi WJ, Lim WR, Kim J, Kim K. Association between exposure to antimicrobial household products and allergic symptoms. *Environ Health Toxicol*. 2014;29:e2014017. doi: 10.5620/eht.e2014017.
32. Anderson SE, Meade BJ. Potential health effects associated with dermal exposure to occupational chemicals. *Environ Health Insights*. 2014;8s(1):EHI.S15258. doi: 10.4137/EHI.S15258.