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Asthma Prevalence and Risk Factors Among Farmers in the Midwestern United States: Analysis of Regional Surveillance Data

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Ethical Considerations: The University of Nebraska Medical Center (UNMC) Institutional Review Board determined that this study was exempt under 45 CFR 46:104(d), Category 2, research that only includes survey procedures (IRB reference numbers 452-11 and 0071-23-EX).

Data Availability: The Data used for this study was generated and maintained by the Central States Center for Agricultural Safety and Health (CS CASH) and is not readily available to the public. De-identifiable data can be made available upon request.

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AI Statement: Language-based and regenerative AI was employed for English language editing to enhance clarity and coherence, as well as for modifying and correcting errors in the SAS codes used for data analysis and interpretation. However, substantial aspects of the research, analysis, and conclusion remain the author's original work.

ABSTRACT

Objectives

This study examined the prevalence and risk factors for asthma among farm and ranch operators in seven Midwestern States, using surveillance data from 2018, 2020, and 2023.

Methods

Regression models were developed to identify predictors of asthma, including demographic factors, agricultural exposures, and physical activity.

Results

The overall prevalence of asthma was 4.7%. Asthma was significantly associated with respiratory exposures to grain, feed, or hay dust [Adjusted Odds Ratio (AOR): 2.14, 95% Confidence Interval (CI): 1.74-2.63] and animal confinement dust [AOR: 1.72, 95% CI: 1.35-2.21] after adjusting for demographics and worktime on farm/ranch.

Conclusion

The identified occupational risk factors highlight the importance of surveillance and targeted prevention among agricultural populations to further reduce the long-term respiratory exposures, particularly in animal confinement operations.

Keywords: Agriculture, Asthma, Demographics, Exercise, Exposures, Respirator

LEARNING OBJECTIVES

After completing this enduring educational activity, the learner will be better able to:

- Outline factors that may influence the low asthma prevalence among US farmers compared to the general population
- Identify agricultural exposures and their associations with asthma outcomes
- Apply epidemiological findings to guide targeted interventions and policy improvements aimed at reducing occupational respiratory health risks in agricultural settings

INTRODUCTION

Asthma is a long-term respiratory condition marked by recurring episodes of breathing difficulties, which may occasionally require hospitalization and, in rare instances, can be life-threatening. [1] This respiratory condition causes inflammation and narrowing of the airways, and may result in other symptoms, such as coughing, wheezing, and chest discomfort. According to the World Health Organization (WHO), asthma affected an estimated 262 million people worldwide, resulting in 455,000 deaths in 2019. [2] Asthma is one of the most common chronic health conditions in the United States (US) as well. [3] The Centers for Disease Control and Prevention (CDC) estimated that 24,963,874 individuals lived with asthma, resulting in 986,453 emergency visits and 3,517 deaths in 2021. [4] The estimated incremental cost of asthma per affected individual is between $4,677.94 and $5,704.80 annually in the US. [5]

The asthma prevalence in the US general population was 8.6% in 2024, a slight decrease from 8.9% in 2023 and 8.7% in 2022. [6] However, asthma prevalence is lower among agricultural workers, despite agricultural work exposures. [7-9] Licensed pesticide applicators (farmers and contractors) and their spouses in Iowa and North Carolina reported an asthma prevalence of 7.2%. [10] Meanwhile, Arroyo et al. (2018) reported a much lower asthma prevalence of 3.1% among US farm workers, consistent with similar study reports of 3.4% and 6% among US migrant farm workers. [11-13]

The healthy worker effect (HWE) may explain the lower asthma prevalence seen among agricultural workers. The HWE suggests that working populations tend to have better health outcomes than the general population because healthier individuals are more likely to enter and stay in the workforce. On the other hand, those with pre-existing respiratory conditions like asthma may be less likely to start or remain in physically demanding agricultural jobs. This self-selection bias can lead to an underestimation of the true impact of occupational exposures on respiratory health outcomes. [14,15] Meanwhile, physical activity (often experienced in agricultural operations) can have a protective effect on asthma symptoms and respiratory functions. [16,17]

Underreporting asthma cases may also contribute to low asthma prevalence. The Occupational Safety and Health Administration (OSHA) requires employers to record injuries and illnesses using the OSHA Form 300. [18] However, this mandate applies only to employers with more than ten employees, completely missing self-employed farmers and workers on small farms. The Bureau of Labor Statistics (BLS) collects these workplace injury and illness data through its Survey of Occupational Injuries and Illnesses (SOII). [19,20] However, occupational asthma, even if diagnosed, is combined with all other occupational respiratory conditions in SOII reports.

The National Institute for Occupational Safety and Health (NIOSH) has set guidelines for reporting and tracking work-related asthma through national and state surveillance systems. [21] These guidelines emphasize the difference between occupational asthma, which is new-onset asthma caused by workplace exposures, and work-aggravated asthma, where preexisting asthma worsens due to job-related conditions. This distinction is relevant in this study because asthma status was based only on self-reported physician diagnosis. In routine practice, clinicians may use the term "asthma" to refer to a wide range of respiratory illnesses, resulting in patients interpreting or recalling these diagnoses differently. As a result, some agricultural workers may report asthma when their symptoms are due to other respiratory conditions. Meanwhile, others with work-related asthma may not have recognized the occupational link. These factors could lead to outcome misclassification, potentially weakening or masking the true association between agricultural exposures and asthma, impacting overall prevalence.

Although available data indicate that asthma prevalence is relatively low among agricultural workers, it is still important to understand the role of agricultural work exposures as contributors to asthma outcomes. This study aims to assess the asthma prevalence, associated risk factors, and preventive techniques such as personal protective equipment (PPE) use among farmers and ranchers in seven Midwestern states. Recent Farm and Ranch Health and Safety Surveys (FRHSS) enable analyses of occupational predictors for asthma, information that is critical for the prevention of this condition, which is a threat to conducting agricultural work.

METHODS

This study used data from 2018, 2020, and 2023 Farm and Ranch Health and Safety Surveys (FRHSS) conducted by the Central States Center for Agricultural Safety and Health (CS-CASH). Data were collected from stratified random samples of farms and ranches across seven US States: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. The inclusion criteria included having an email address (for online surveys in 2018 only) and having an estimated Gross Farm Income (GFI) of at least $5,000 to focus on active (vs. retired, residential acreage, etc.) farm operations.

Farm/ranch operation data with addresses and production variables were purchased for 2018 and 2020 from Farm Market iD (FMiD), while 2023 data were purchased from US Farm Data. Both are private companies providing agricultural data services for marketing, research, and other organizations. Paper surveys were mailed to the farm/ranch operations during the spring and summer of 2018 (16,826 operations) and 2020 (17,328 operations), and summer and fall of 2023 (17,497 operations). A second survey form was mailed out to those who did not respond to the first mailing.

The surveys included questions for up to three individual farm or ranch operators (producers) (principal operator, operator 2, operator 3). The questions covered demographics (age, sex, work activity), acute injuries, work-related chronic health conditions, exposures, and preventive practices. A sample survey form is available online. [22] Chronic respiratory conditions were queried by a question: “Has the operator ever been diagnosed by a physician with any of the following respiratory conditions?”. The response options were Chronic Obstructive Pulmonary Disorder (COPD), Asthma, Farmers' Lung, Sinus disease (Sinusitis), Nasal inflammation (Rhinitis), and Environmental allergies. Each respondent (operators 1, 2, and 3) was asked to mark all options that apply, and the asthma outcome status (Yes/No) was determined from the response to the ‘asthma’ option.

Exposure variables included six specific types of agricultural airborne contaminants based on the survey question: “Was the operator exposed to high levels of any of the following air contaminants during the past 12 months?” The listed exposures were grain, feed, or hay dust, animal confinement dust, field or road dust, manure or silage gases, anhydrous ammonia, and solvents or paints. Each of these exposure options was a binary variable (Yes = 1, No = 0), analyzed separately to evaluate its link to asthma. One item assessed the use of personal protective equipment (PPE), specifically for respiratory protection. Participants were asked, “When exposed to high levels of air contaminants at work, what percent of that time did the operator use appropriate respiratory protection (incl. N95 dust mask, half mask with dust/gas filters)?” This variable was coded as binary (some of the time = 1, none of the time = 0) to examine its potential protective association with asthma.

The associations of preventive techniques for musculoskeletal health were explored from a question: “Was the operator using any of the following preventive techniques to maintain his/her musculoskeletal health during the past 12 months?”. Response options included regular breaks, stretching, exercise, good lifting techniques, mechanizing tasks, and others. These activities were recorded as binary variables (Yes/No) and analyzed for their association with asthma outcomes in the context of overall health-promoting behaviors.

Crop and animal-related data were merged with the survey data using a common farm or ranch identifier. Crop variables included the number of acres of specific crops grown (corn, soybeans, wheat, hay, etc.). Animal-related variables included numbers of heads of animal species (dairy, beef cattle, hogs, sheep, goats, poultry, etc.). Crop and animal variables were dichotomized into the presence or absence of each type of production. When multiple operators (e.g., Operators 1, 2, and 3) were reporting from the same farm or ranch, they were assigned the same crop and livestock exposure variables, reflecting a shared farm environment.

Data Analysis

Outcome and exposure variables were cross tabulated by state and operator level (primary, second, third). Exposure variables were also tabulated with asthma outcome and PPE use variables to examine relationships of categorical variables using the chi-square test. Univariable and multivariable logistic regression models were fitted using online SAS® Studio 9.4 (SAS Institute Inc., United States) software to evaluate the associations between asthma and exposures and preventive variables. A significant association was determined using a p-value of less than 0.05. Significant occupation-related predictor variables associated with asthma were selected for multivariable analysis. Odds ratios (OR) and their 95% confidence intervals (95% CI) were used to quantify the association of asthma and predictor variables. To assess potential selection and non-response biases, the percentages of farms that responded to growing various agricultural products were compared between respondents, non-respondents, and the national Census of Agriculture estimates (USDA, 2023).

The surveillance program conducted by CS-CASH was reviewed by the Institutional Review Board (IRB) of the University of Nebraska Medical Center (UNMC). The study was determined to be exempt under 45 CFR 46:104(d), Category 2, research that only includes survey procedures; IRB reference numbers 452-11 and 0071-23-EX.

RESULTS

A total of 51,654 different farm and ranch operations received mailed questionnaires in the three survey rounds, and 7,244 operations returned completed surveys, resulting in a combined response rate of 14%. Of the farm operations that responded, 76% identified as a farm, 11% as a ranch, and 13% as both.

Farm and ranch operations

Relatively small differences were found between respondents and non-respondents in growing corn, wheat, oats, barley, grass, and soybeans. No significant differences were found in rearing cattle, goats, sheep, and root tuber vegetables (Table 1). Respondent and non-respondent data were also fairly consistent with the national United States Department of Agriculture (USDA) Census of Agriculture data, except for corn, soybeans, small grains, and grass/forage that are prominently grown in the surveillance region, and less commonly in most other states.

Age and Sex

The total number of farm operators from the 7,244 returned surveys was 10,282 (Table 2). Overall, among those who responded to the questions about demographics and asthma diagnosis, 8,562 (85%) were male and 1,552 (15%) were female. On average, there were 1.4 operators per farm, with a breakdown of 7,174 (71%) principal operators, 2,364 (23%) second operators, and 630 (6%) third operators. The split between male vs. female operators was 97%/3% among principal operators, 48%/52% among second operators, and 82%/18% among third operators.

Principal operators had an average age of 64.1, which was 12 years older than the second operators at 52.2, and 20.4 years older than the third operators at 43.7.

Primary Occupation

The majority of survey participants reported farming or ranching as their main occupation (78%), while 22% specified "other" occupations (with 230 missing or unspecified). Farming/ranching was more prominent among principal operators (83%) compared to second operators (66%) and third operators (67%) (Table 2).

Work time spent on the farm

Among survey participants who responded (n=10,041; 73 missing), 82% reported spending 50-100% of their work time on the farm (vs. other job), while 18% reported 0-49%. The percentages of operators who worked on the farm/ranch 100% of their worktime were 78% among principal operators, 17% among second operators, and 5% among third operators. On the other hand, the percentages of those in the lowest 0-24% farm work time group were 7% among principal operators, 15% among second operators, and 85% among third operators.

Asthma cases reported

There were 479 self-reported cases of medically diagnosed asthma (Table 2). The highest asthma prevalence (8.6%) was observed among female third operators, while the lowest prevalence (3.3%) was reported among male third operators. The overall asthma prevalence was 4.7% with a higher prevalence observed among female operators (5.3%) compared to males (4.6%).

Asthma prevalence among farm operators exposed to the various respiratory hazards generally ranged from 6% to 7% across the seven states (Table 3). Operators exposed to animal confinement dust had the highest asthma prevalence at 7.1%, while those exposed to field/road dust had the lowest prevalence at 5.9%. Grain/feed/hay (5,221) and field/road dust (4,125) were the most common agricultural exposures among farm operators, resulting in the highest reported asthma cases (314 and 245). However, their overall asthma prevalence was lower than that associated with other respiratory exposures.

The highest overall prevalence of asthma by state was reported in Minnesota (7.6%), followed by North Dakota (7.3%), and then Nebraska (6.9%) and Missouri (6.3%). The lowest asthma prevalence was reported in South Dakota (4.7%). Anhydrous ammonia exposure among farm operators in Minnesota resulted in the overall highest asthma prevalence (12.0%) by state and respiratory exposures, while grain/feed/hay dust exposures among operators in South Dakota were associated with the lowest (4.1%).

Risk factors for asthma

Work strain symptoms, including high stress levels, sleep deprivation, and exhaustion/fatigue, were linked to higher odds of asthma after adjusting for age, sex, and the share of total work time spent on the farm (Table 4). All agricultural respiratory exposures were associated with asthma, where grain/feed/hay dust exhibited the strongest association. The odds of having asthma were consistently higher (OR 1.60-2.14) if exposure to these occupational factors occurred, even after adjusting for age, sex, and the percentage of time spent on the farm. Smaller but significant links to asthma were observed for skin exposures, including pesticide/fertilizer (AOR 1.29) and contact with animals/livestock (AOR 1.27). However, skin exposure to detergents/disinfectants was not significantly associated with asthma ($p = 0.0987$).

Higher PPE use (51% or more of the time when exposed) did not show a protective effect against asthma (AOR: 1.08) compared to those who used PPE less frequently. Routine exercise was linked to higher odds of asthma (OR: 1.45). However, these odds decreased slightly after adjusting for age, sex, and the percentage of work time spent on the farm (AOR: 1.43).

DISCUSSION

From our surveillance results, farmers and ranchers showed a lower asthma prevalence (4.7%) compared to the general US population (8.6%). [6] Our finding was lower than some previously reported prevalences of 7.2% and 6.0% in the Agricultural Health Study (AHS), which involved 43,548 pesticide applicators from Iowa and North Carolina. [10,23] Another study of 180 farm operators and their workers in North Carolina reported a 7% prevalence of physician-diagnosed asthma. [24] Lower prevalences similar to ours have also been reported in similar studies. [11-13]

Several factors can contribute to the low asthma prevalence among agricultural workers. Elevated standard of living and enhanced hygiene have been associated with an increased susceptibility to respiratory conditions such as allergies and asthma. [25] This concept, commonly referred to as the "hygiene hypothesis", suggests that overly sanitized environments may hinder exposure to microbes essential for training the immune system to recognize and respond to pathogens effectively. [26] Conversely, early life agricultural exposures may contribute to the development of a stronger immune system, sometimes described as the farm effect. [27]

Female farm operators had a higher prevalence of asthma (5.3%) than males (4.3%). This asthma prevalence was notably higher among female farm operators who were listed as the third operator (8.6%). Clinical studies suggest that higher prevalence among females may be due to several factors, such as estrogen levels, sex hormones, airway size, etc. [28,29] This finding is also consistent with a reported higher asthma prevalence among adult US female farmers and farm workers compared to males (7.8% vs 6.5%) in a previous study that assessed the prevalence of respiratory diseases in six continents. [30] Males dominate most high-risk jobs outside agriculture, which may explain their higher prevalence of asthma within the US general population. [31,32] Meanwhile, females are more likely to assume caretaking roles (e.g., animal husbandry) on livestock farms, [33] which generate dust and may expose them to respiratory illnesses such as asthma.

Preventable occupational exposures, including grain/feed/hay dust; animal confinement dust, field/road dust, manure/silage gas, anhydrous ammonia, and fuels/solvents/paints, were associated with having asthma among farmers. Grain and animal confinement operations pose a respiratory health risk in agriculture. [34] Even when possible confounding factors such as age, gender, and duration of farm work were adjusted in our models, these links to asthma persisted, suggesting that the elevated asthma risk may not be explained by basic demographics or duration of farm work exposure alone. This reinforces the finding that specific exposures in farming pose a significant risk for respiratory diseases. [35]

Exposure to grain, feed, and hay dust exhibited the strongest association with asthma. Farmers exposed to these organic dusts were more than twice as likely to have asthma compared to farmers without this exposure (AOR: 2.14). Multiple cross-sectional studies in North America and Europe have documented higher rates of asthma or asthma-like symptoms among farmers exposed to organic dust and livestock. [35,36] Although several studies supported our findings linking agricultural exposures with asthma and related symptoms, others suggested that early exposures may also be protective against asthma, consistent with the hygiene hypothesis. [37-41]

Using preventive measures, such as wearing a respirator when exposed to air contaminants, had no significant association with asthma in our study. Consistent respirator use is widely recommended to protect workers from work-related exposures such as dust and chemicals. [42] Although respirators can effectively reduce airborne exposures, some farmers may choose not to wear them because they feel healthy, and wearing a respirator feels uncomfortable, and having any respiratory condition may increase the difficulty of wearing a respirator. [42,43] However, when experiencing symptoms or being diagnosed with a respiratory disease such as asthma, there may be greater awareness of the importance of wearing respirators. Overall, using respiratory protection did not significantly affect the odds of having asthma even after adjusting for age, sex, and percentage of time spent on the farm (AOR: 1.08). This aligns with a previous finding that using respiratory protection more than 50% of the time during farm and ranch activities did not effectively prevent respiratory conditions, including asthma. [44]

Exercising (unspecified) was associated with an increased odds of asthma (AOR: 1.43). However, several studies have reported that routine physical activity, such as exercise, can improve lung function parameters and contribute to asthma prevention. [45,46] Farmers undertake rigorous physical activities during farm operations, which may contribute to the low prevalence of asthma despite consistent farm exposures. Exercise can also exacerbate asthma by constricting airways, posing significant health risks for individuals diagnosed with asthma. [47] It may be possible that farmers who have been diagnosed with asthma are using exercise-related activities to reduce asthma symptoms.

Reported respirator use, wearing it over 50% of the time when exposed, was 30% among all respondents and 42% among those who were exposed to the listed agricultural air contaminants. This finding is consistent with a previous survey study, where 36% of farmers reported using respirators. [42] Factors such as age, marital status, sex, smoking status, farm sales value, farm type, and geographic region significantly influenced ($p<0.05$) respirator use. In contrast, another study reported that only 15% of workers used respiratory protection 50% or more of the time when working in enclosed facilities, such as manure storage. [48] Avoidance of injury had the highest influence on the overall decision to use respirators, with personal appearance while wearing PPE having the least influence. Younger farmers were more likely to use respirators than older ones in one recent study. [49] However, age did not influence the use of respirators in the present study.

LIMITATIONS

This study does not represent the smallest farms where the estimated gross farm income is less than $5000. This limitation was used in sampling to focus on active farms with substantial crop or animal production and associated work exposures. Low response rate is a concern in this study. The potential effects of self-selection were analyzed by comparing pre-existing farm production data between those who responded and those who did not. We found fairly small differences in farm characteristics, presented in Table 1. An earlier study of Beseler and Rautiainen (2021) analyzed the 2017 survey dataset and also suggested that there was little evidence of nonresponse bias; however, it is not known if the injury and illness outcomes differ between respondents and non-respondents. [50]

This study was based on cross-sectional survey data, which cannot be used to infer causality. The outcome and exposure data were self-reported, meaning participants may have underestimated or overestimated their physician-diagnosed asthma and respiratory exposures, which can be difficult to recall and report accurately in a survey. Although an association with asthma was observed, the timing of exposure relative to disease onset cannot be confirmed because both were assessed at the same time. However, using physician-diagnosed asthma as the outcome improves the validity of the findings compared to self-diagnosed conditions, as it is based on prior medical assessments. These limitations, common in studies involving agricultural workers, emphasize the need for more prospective cohort studies that combine objective exposure monitoring with medical confirmation to better understand the causal relationships and temporal order between respiratory exposures and asthma.

The respondents were asked if they had ever been diagnosed with asthma, while the occupational exposures questions addressed exposures over the past 12 months. While year-to-year changes in farm production may be small in general, it is possible that, for instance, animal production was discontinued some years ago, and exposure to animal confinement dust triggered the asthma condition. In such a case, the connection between asthma outcome and potential animal confinement dust exposure could not be made. This may have led to a misclassification of exposures in some cases. Also, asthma may have developed due to prolonged exposures over earlier years, and the current exposures no longer fully represent the occupational conditions contributing to asthma. Future studies should consider longitudinal exposure and outcome data collection to enhance the accuracy of results.

We had no information on health insurance among participants. Many farmers may lack health insurance and access to healthcare, which may limit professional assessment and diagnosis of asthma. Many farmers may live with undiagnosed asthma knowingly or unknowingly, which may have contributed to the low asthma prevalence in this study.

As observed in other studies, we could not find clear evidence that wearing respirators provides a preventive effect. Our ability to accurately measure this effect was limited by several factors. First, we lacked information on temporality, such as whether respirator use started out of necessity when already ill. Second, our question about respirator use was on a percentage scale, which was then simplified for analysis. Reporting nearly perfect 100% respirator use was uncommon but may have been necessary for effective protection. Finally, even if respondents mentioned respirator use, we cannot be certain they were using the correct types (such as approved N95 masks or gas masks with filters for specific exposures), or that they had been adequately fit tested. Many agricultural exposures linked to asthma, including pesticides, fumigants, solvents, and anhydrous ammonia, contain hazardous substances that require the use of cartridge-based air-purifying respirators or gas/vapor cartridges with specific color-coded filters. Considering respirator type and fit for purpose is crucial when making PPE decisions, as it can influence how well it protects against respiratory hazards in agriculture. [51] On the other hand, particulate-only respirators, such as N95 filtering facepiece respirators, protect against dust but not against gases or vapors. Therefore, choosing the wrong type of respirator, such as relying solely on particulate respirators in environments with combined dust and chemical exposures, might not prevent the inhalation of chemical asthmagens and could weaken the protective benefits discussed in this study.

CONCLUSION

In a large, multi-state sample of U.S. farm and ranch operators, the overall asthma rate was low at 4.7%. However, having asthma was significantly associated with exposures to grain, feed, hay dust, and animal confinement dust, which had the most significant effects. Preventive techniques such as exercise and respiratory protection were not associated with asthma, indicating that current practices may not be enough to lower exposure risks in agriculture. These findings emphasize the need for targeted prevention efforts focused on dust control and safe pesticide handling during animal confinement, feed, or harvest operations. Further studies are needed to determine whether the low asthma rate is due to underreporting, the health worker effect, or early-life exposures.

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Table 1. Percentage of farms and ranches by crops and animals they grow/raise; CS-CASH surveys vs. national USDA Census of Agriculture data

Agricultural Products	CS-CASH respondents	CS-CASH non-respondents	USDA data
Cattle	42.9	40.3	35.0
Sheep	3.4	2.6	2.6
Goats	1.0	0.9	3.3
Corn	83.5	77.6	34.7
Wheat	36.9	42.0	8.8
Oats	17.8	17.1	1.5
Barley	11.2	16.1	0.6
Grass	85.1	77.2	0.1
Root/Tuber/Vegetables	2.0	2.1	1.7
Soybeans	80.8	75.0	31.2

a The percentages reflect the proportion of farm operators who responded and did not respond to producing the listed commodities
b The USDA percentages are based on national-level data and are included for comparative reference

Table 2. Operator demographics and reported asthma cases

Variable	Operator 1	Operator 2	Operator 3	Total
Population				
Male	6,925 (97.2)	1,125 (47.7)	512 (81.5)	8,562 (84.7)
Female	203 (2.8)	1,233 (52.3)	116 (18.5)	1,552 (15.3)
Total	7,128 (100)	2,358 (100)	628 (100)	10,114 (100)
Average age in years				
Male	62.8	45.0	37.6	59.0
Female	65.3	59.4	49.8	59.5
Average	64.1	52.2	43.7	59.3
Primary occupation				
Farm/ranch	5,823 (83.2)	1,499 (65.6)	402 (66.6)	7,724 (78.1)
Other	1,173 (16.8)	785 (34.4)	202 (33.4)	2,160 (21.9)
Total	6,996 (100)	2,284 (100)	604 (100)	9,884 (100)
Time spent on the farm				
0-24%	518 (7.3)	341 (14.7)	85 (13.9)	944 (9.4)
25-49%	756 (10.6)	438 (18.9)	121 (19.8)	1315 (13.1)
50-74%	759 (10.7)	314 (13.5)	75 (12.3)	1148 (11.4)
75-99%	1322 (18.6)	405 (17.5)	112 (18.3)	1839 (18.3)
100%	3755 (52.8)	821 (35.4)	219 (35.8)	4795 (47.8)
Total	7,110 (100)	2319 (100)	612 (100)	10,041 (100)
Asthma cases reported				
Male	332 (4.8)	44 (3.9)	17 (3.3)	393 (4.6)
Female	13 (6.4)	60 (4.9)	10 (8.6)	83 (5.3)
Total	345 (72.0)	107 (22.3)	27 (5.6)	479 (4.7)

[a] Percentages shown in parentheses are column percentages within each variable category across the operator types (essentially, they should add up to about 100% for each row across Operators 1, 2, and 3), except for the "Total" columns, which show counts
[b] The total column for age represents the mean age of each category by sex
[c] Totals might differ across sections due to missing data (for example, time spent on the farm had 73 missing)
[d] Any minor discrepancies can be attributed to rounding
[e] Age was categorized following the CDC's most recent national asthma data guidelines
[f] Percentages in asthma cases reported represent prevalence, with the count of operators per group (population) used as the denominator
[g] Three operators in the second category did not answer the sex question but were included in the total count of operators who reported having asthma in that category

Table 3. Asthma conditions by State and respiratory exposures

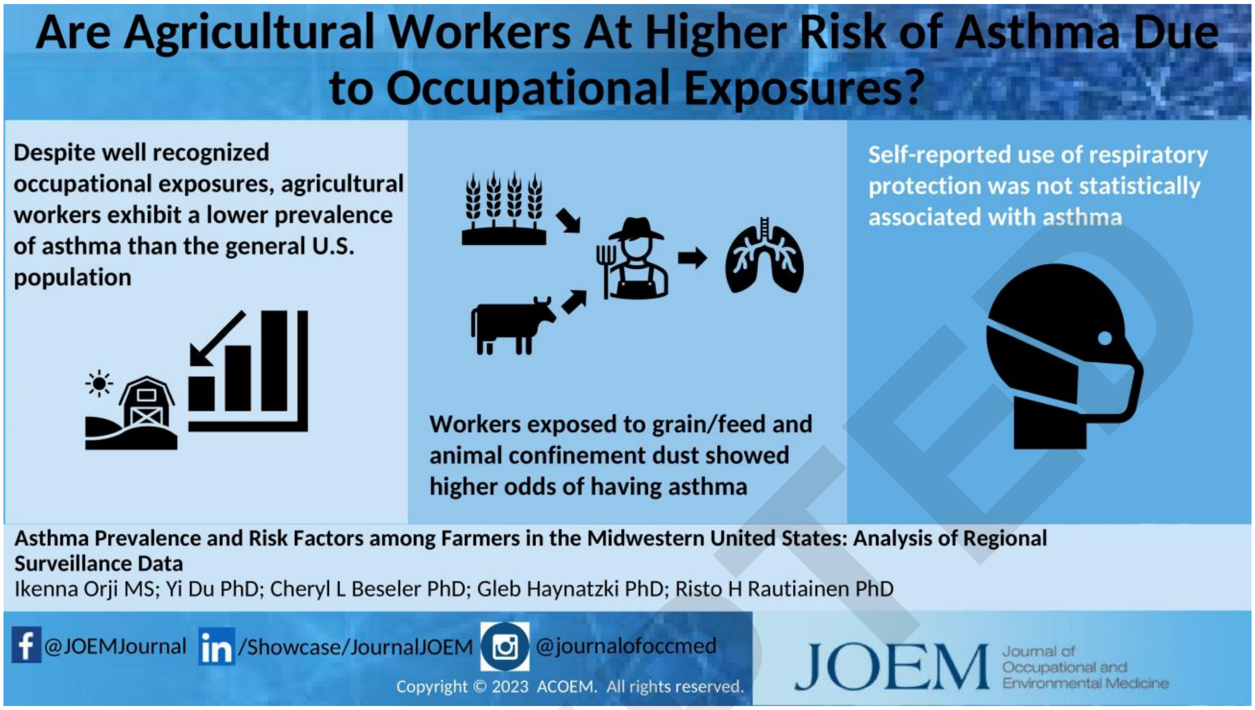
State	Asthma cases/Total exposed (% with asthma)						
	Grain/feed/hay	Animal confinement	Field/road dust	Manure/silage gas	Anhydrous ammonia	Fuel/solvent /paint	Total
Iowa	46/939 (4.9)	16/229 (7.0)	33/748 (4.4)	13/216 (6.3)	15/245 (6.1)	20/455 (4.4)	143/2,832 (5.0)
Kansas	38/534 (7.1)	7/126 (5.6)	27/454 (5.9)	5/102 (4.9)	5/100 (5.0)	14/248 (5.6)	96/1,564 (6.1)
Minnesota	50/741 (6.7)	19/235 (8.1)	36/559 (6.4)	14/167 (8.4)	9/75 (12.0)	26/330 (7.9)	154/2,107 (7.6)
Missouri	29/464 (6.3)	7/106 (6.6)	25/410 (6.1)	7/82 (8.5)	7/120 (5.8)	16/255 (6.3)	91/1,437 (6.3)
Nebraska	73/1,162 (6.3)	16/217 (7.4)	65/926 (7.0)	13/206 (6.3)	18/237 (7.6)	42/538 (7.8)	227/3,286 (6.9)
North Dakota	46/607 (7.6)	10/106 (9.4)	31/454 (6.8)	9/98 (9.2)	7/118 (5.9)	22/327 (6.7)	125/1,710 (7.3)
South Dakota	32/774 (4.1)	10/182 (5.5)	28/574 (4.9)	9/158 (5.7)	1/22 (4.5)	16/351 (4.6)	96/2,061 (4.7)
All States	314/5,221 (6.0)	85/1,201 (7.1)	245/4,125 (5.9)	70/1,029 (6.8)	62/917 (6.8)	156/2,504 (6.2)	

[a] Values indicate asthma cases as a percentage of total operators who reported exposure in the state. These percentages are just crude estimates
[b] Since operators can report multiple exposures, the numbers in the columns can vary, and the 'Total' column indicates the overall burden across all exposures rather than unique individuals or population rates
[c] The 'All States' row is a combined count from all states for each exposure, without adjusting for state populations
[d] Operators who did not respond to questions on their exposure or asthma status were excluded from the relevant counts
[e] Exposures are self-reported and include exposure to feed, grain, and hay dust, animal confinement dust, field and road dust, manure and silage gas, anhydrous ammonia, and various fuels, solvents, or paints involved in agricultural work

Table 4. Odds ratios for diagnosed asthma by occupational exposures and preventive measures

Predictor	Exposure status	n (%)	Odds ratio (95% CI) Crude OR	Adjusted OR
Work strain symptoms				
High stress level	No	7,751 (75.4)	Ref	
	Yes	2,531 (24.6)	1.42 (1.17-1.73)	1.45 (1.18-1.78)
Sleep deprivation	No	8,136 (79.1)	Ref	
	Yes	2,146 (20.9)	1.50 (1.22-1.85)	1.53 (1.24-1.89)
Exhaustion/fatigue	No	7,632 (74.2)	Ref	
	Yes	2,650 (25.8)	1.64 (1.35-1.99)	1.66 (1.36-2.02)
Respiratory exposures				
Grain/feed/hay dust	No	5,004 (49.7)	Ref	
	Yes	5,278 (51.3)	1.95 (1.60-2.36)	2.14 (1.74-2.63)
Animal confinement dust	No	9,065 (88.2)	Ref	
	Yes	1,217 (11.8)	1.70 (1.34-2.17)	1.72 (1.35-2.21)
Field/road dust	No	6,115 (59.5)	Ref	
	Yes	4,167 (40.5)	1.65 (1.38-1.99)	1.74 (1.44-2.10)
Manure/silage dust	No	9,241 (89.9)	Ref	
	Yes	1,041 (10.1)	1.58 (1.22-2.06)	1.62 (1.24-2.11)
Anhydrous ammonia	No	9,349 (90.9)	Ref	
	Yes	933 (9.1)	1.59 (1.21-2.08)	1.65 (1.24-2.18)
Fuels/solvents/paints	No	7,754 (75.4)	Ref	
	Yes	2,528 (24.6)	1.54 (1.27-1.88)	1.60 (1.31-1.96)
Skin exposures				
Pesticides/fertilizers	No	4,705 (45.8)	Ref	
	Yes	5,577 (54.2)	1.23 (1.02-1.48)	1.29 (1.06-1.58)
Animals/livestock	No	6,424 (62.5)	Ref	
	Yes	3,858 (37.5)	1.27 (1.06-1.53)	1.27 (1.05-1.54)
Detergents/disinfectants	No	7,976 (77.6)	Ref	
	Yes	2,306 (22.4)	1.21 (0.98-1.49)	1.20 (0.97-1.49)
Preventive techniques				
PPE use, time when exposed	0 - 50%	5,495 (70.2)	Ref	
	51% and above	2,333 (29.8)	1.07 (0.86-1.34)	1.08 (0.86-1.35)
Exercising	No	7,380 (71.8)	Ref	
	Yes	2,902 (28.2)	1.45 (1.20-1.76)	1.43 (1.18-1.74)

[a] All rows compare Yes vs No except PPE use (>50% vs ≤50%)
[b] n (%) represents the count and column percentage within the analytic sample for that predictor
[c] Outcome: self-reported physician diagnosis of asthma (dxresp_asthma), modeled as asthma="Yes."
[d] Each adjusted OR (95% CI) is from a separate logistic regression including the index predictor plus sex (Male vs Female), age category (0-34, 35-64, 65+), and percentage of time spent on the farm (0-50%, 51-100%). For the PPE use row, the model adjusted for sex and age only.


Are Agricultural Workers At Higher Risk of Asthma Due to Occupational Exposures?
Despite well recognized occupational exposures, agricultural workers exhibit a lower prevalence of asthma than the general U.S. population
Workers exposed to grain/feed and animal confinement dust showed higher odds of having asthma
Self-reported use of respiratory protection was not statistically associated with asthma
Asthma Prevalence and Risk Factors among Farmers in the Midwestern United States: Analysis of Regional Surveillance Data
Ikenna Orji MS; Yi Du PhD; Cheryl L Beseler PhD; Gleb Haynatzki PhD; Risto H Rautiainen PhD
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