



Published in final edited form as:

J Agromedicine. 2025 January ; 30(1): 38–48. doi:10.1080/1059924X.2024.2407983.

Factors Associated with Personal Protective Equipment Usage Rates in the Central States: Generalized Multilevel Multinomial Models

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Abstract

Objectives: This study examined the factors affecting the use of personal protective equipment (PPE) among US agriculture producers, specifically focusing on chemical, respiratory, and hearing protection. The primary goals were to identify demographic and farm-related factors linked to lower PPE usage and to explore the associations between PPE use and self-reported injuries or diseases in this occupational context.

Methods: We developed generalized multilevel multinomial logistic regressions for the agricultural safety and health survey data from 2018 and 2020. Our models aimed to explore associations between PPE use, covariates, and their impact on skin diseases, hearing loss, and respiratory diseases. The hierarchical structure of the data was accommodated by designating the survey year as the level-3 variable and the state of residence as the level-2 variable, further delineating the nested structure of the respondents. We proposed using Adaptive Quadrature methods to approximate marginal maximum likelihood function, along with Gauss-Hermite quadrature weights when estimating fixed-effects and random effects in the proposed models. Missing data in this hierarchical structure were addressed through a multiple imputation method.

Results: Our findings revealed older age is associated with lower PPE usage across all types. Males exhibited higher PPE use, particularly for chemical (OR: 1.26, 95% CI: 1.08, 1.47) and respiratory protection (OR: 1.33, 95% CI: 1.18, 1.52). Producers on grain-only farms showed increased chemical PPE use (OR: 1.26, 95% CI: 1.10, 1.43) compared to those on livestock-only farms. Additionally, individuals spending 0%–24% of their worktime on the farm/ranch demonstrated lower PPE use than those who spent more time engaged in farm-related activities.

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Conclusion: The study underscores the importance of addressing low PPE usage among agriculture producers. Interventions tailored to specific groups, such as female producers, livestock-only farms, older-aged producers, and part-time producers, can effectively improve PPE use. By identifying these high-risk groups, interventions can be better adapted and targeted to enhance the adoption of PPE, subsequently reducing the risk of health hazards in the agriculture sector.

Keywords

Agricultural health safety; generalized multilevel multinomial models; imputation; intervention strategies; odds ratio; personal protective equipment (PPE)

Introduction

Agriculture producers in the United States experience elevated rates of fatal and non-fatal injuries, evidenced by 2020 data showing 368 fatalities and an incidence rate of 18.0 deaths per 100,000 producers, contrasting sharply with the overall occupation rate of 3.4 deaths per 100,000 workers. Non-fatal injuries also present a significant concern, with 11,880 work-related injuries causing hired agriculture workers to miss work in 2020, excluding self-employed farmers and ranchers.¹ Beyond agriculture producers, those living on or visiting farms face substantial risks due to hazardous environments. In 2014, there were 7,469 youth injured on farms, with 60% of those injuries occurring outside of work conditions.² Agriculture workers encounter health hazards, including high noise levels, pesticide, and organic dust exposures.

Agriculture producers face an elevated risk of hearing loss compared to other occupations and the general population, presenting a significant occupational health concern.³ This heightened risk is attributed to prolonged exposure to high noise levels generated by tractors, electric tools, firearms, livestock, and various equipment.^{3,4} These findings underscore the pervasive nature of potential hearing threats in the agricultural setting, emphasizing the need for targeted interventions to mitigate these risks.

Exposure to hazardous chemicals through the application of pesticides also poses a risk. Those involved in applying and mixing pesticides or working in areas where these chemicals have been used may inhale or carry them on their clothes and skin. Such exposure affects the producers and poses risks to those in their vicinity and household, leading to the dissemination of toxic chemicals.³ A significant association between insecticides/herbicides and lifetime allergic rhinitis and asthma in farm producers in the United States has been reported.⁵ Pesticide exposure can manifest in neurological problems, headaches and dizziness, respiratory symptoms, alterations in sleep and mood, gastrointestinal symptoms, and irritation of the skin and eyes.⁶ Personal protective equipment (PPE), including protective gloves and respirators, are important modifiers of the association between pesticides and Parkinson's Disease. These protections may reduce the risk of Parkinson's associated with certain pesticides.⁷

Exposure to organic dust poses a significant concern for agriculture producers, mainly when working in confined spaces such as barns and grain bins and in livestock confinement.

Inhaling organic dust in these environments introduces microorganisms and toxic materials from animal waste, potentially causing respiratory damage.³ Exposure to organic dust triggers diverse immunological pathways, with repetitive exposure potentially inducing changes to immunity, fostering the development of chronic inflammation.⁸ This alteration in immune responses, particularly in the lungs, may lead to shifts in the population of immune cells, consequently predisposing individuals to lung inflammation and potential disease.⁹

In agriculture, where the potential for injury is notably high, adopting effective risk mitigation strategies is imperative for agriculture producers, and one such crucial measure is the proper utilization of PPE.¹⁰ While employing PPE occupies the lowest tier in the protection hierarchy of controls, its significance in reducing risks cannot be overstated.¹¹ It is incumbent upon agriculture producers to not rely on PPE alone, but to address and diminish risks proactively, including measures such as curtailing pesticide usage or opting for less hazardous alternatives. Despite these efforts, the pivotal role of PPE remains, particularly when encountering specific hazards in the agricultural environment.¹² The Occupational Safety and Health Administration (OSHA) mandates farms with 11 or more employees diligently assess existing hazards, provide functional and adequate PPE, and conduct comprehensive training on its proper use.^{3,13} However, most farms in the U.S. fall under the classification of family farms, employing fewer than 11 workers, and consequently, they are not obliged to establish a formal PPE program.¹⁴

Required PPE varies according to the specific risks present in the agricultural working environment. Chemical PPE is essential when handling pesticides to protect against these hazardous chemicals.¹³ Reference to the Safety Data Sheet (SDS) is crucial for obtaining recommendations regarding appropriate clothing, eye protection, and respiratory safeguards. Recommended PPE may include protective gear like hats, safety goggles, chemical-resistant gloves, and full-length shirts and pants, effectively shielding agriculture workers from direct contact with harmful chemicals. Respiratory hazards during agriculture work necessitate respirators to prevent inhalation of air-borne threats.¹³ Choosing the proper respirator is essential, particularly if toxic materials become airborne and pose an inhalation risk to producers.¹⁴ Protection from noise exposure is crucial when operating loud machinery generating noise levels exceeding 85 decibels. Employing hearing protection, such as earplugs, earmuffs, or noise-reducing earbuds, significantly reduces the risk of permanent hearing loss.¹⁵

Properly fitted and tested PPE is crucial for maintaining its effectiveness in controlled work environments; however, when misused, its efficacy can fall below-recommended standards.¹² While adequate training and education are essential to ensure proper PPE use, achieving consistent adherence among agriculture producers is a significant challenge in safeguarding their well-being.

Limited data exist on PPE usage rates among U.S. agriculture producers, but studies indicate potentially low rates. Farmers in midwestern states had low PPE usage rates despite satisfactory availability. Notably, 78% rarely or never wore earmuffs in conditions requiring elevated vocal effort, and 72% rarely or never used earplugs. Chemical-related tasks saw frequent glove use but infrequent utilization of other PPE. A survey of midwestern

farmers indicated a need for information regarding hazard sources, consequences, and proper PPE use.¹⁶ Factors contributing to lower PPE usage included a history of smoking and a diminished health assessment.¹⁷ A survey of California farmers revealed that, in dusty conditions, only 24.4% of producers used respiratory protection regularly, 22.8% used hearing protection in loud conditions, and 56.3% rarely or never used any hearing protection.¹⁸ Concerning gender and PPE use, a survey of women working in the dairy industry in Pennsylvania found infrequent use of PPE on a regular basis.¹⁹

Enhancing the effectiveness of interventions necessitates adaptation and a targeted educational focus on workers less inclined to use PPE. However, there needs to be more research on characteristics associated with PPE use among farmers and ranchers in the Midwestern region of the U.S. This study aimed to identify associations between demographic and farm characteristics with chemical, hearing, and respiratory PPE in Midwestern farmers. Data on PPE usage were collected from bi-annual surveillance surveys conducted by the Central States Center for Agricultural Safety and Health (CS-CASH) among agricultural producers in a seven-states region. The analysis explored relationships between worker age, gender, farm type, farm size, state of residence, and percentage of time working on the farm or ranch with the use of respiratory, hearing, and chemical PPE. Associations between PPE use and self-reported hearing loss, respiratory disease, and skin conditions were also explored. It was hypothesized that an association would be found between workers who self-reported lower rates of PPE use and higher rates of hearing loss, respiratory disease, and skin conditions.

Methods

Data collection

The current study analyzed data from the Farm and Ranch Health and Safety Survey (FRHSS), administered by CS-CASH researchers to randomly selected farms and ranches, stratified by state (2500 per state). Contact information with selected farm production variables was obtained from Farm Market iD, a commercial agricultural data service provider, currently part of DTN Industries (DTN LLC, Burnsville, MN).

The FRHSS surveys were administered by the University of Nebraska Medical Center's College of Public Health in the spring of 2018 and 2020 via postal service. Respondents were asked to provide information on work-related injuries, chronic health conditions, exposures, and preventive practices for up to three operators on the farm or ranch operation. In 2018, returned responses were entered by members of the CS-CASH team into University of Nebraska Medical Center's Research Electronic Data Capture secure web platform. In 2020, the returned forms were scanned into OpenText TeleForm OCR software (Waterloo, ON, Canada) and quality checked manually. Before mailing, paper surveys were coded with unique identification numbers to enable repeat mailings to nonrespondents and merging of agricultural production variables from Farm Market iD data set to survey data. To incentivize return of the survey, respondents are eligible to win several large monetary prizes.

Generalized multilevel regression models

To accurately accommodate the hierarchical structure of the data, we designated the survey year as the level-3 variable, encompassing the nested respondents. The state of residence was regarded as the level-2 variable, further delineating the nested structure of the respondents. Consequently, individual variables served as the level-1 variables utilized in this study to anticipate the extent of PPE utilization and their corresponding effects on skin diseases, hearing loss, and respiratory diseases. We proposed a generalized statistical formula for a three-level multinomial model with random effects at different levels that can be expressed using a generalized linear mixed model (GLMM) framework:

$$\text{Logit}(\Pr(Y_{ijk} = m)) = \alpha_{mj} + \beta_m X_{ijk} + \mu_{0jk} + \mu_{1k} \quad (1)$$

where Y_{ijk} is the dependent categorized PPE usage outcome for individual i in state j during survey year k , and m represents the outcome categories. We categorized the PPE usage into respiratory, chemical, and hearing protection, and stratified into three levels: low ($\leq 25\%$), medium ($26\% - 74\%$), and high ($\geq 75\%$) usage. The covariable X_{ijk} is a vector of individual-level predictor variables, for example, age, gender, farm type (livestock, grain, or both), occupation type (farm versus ranch), percent of worktime on the ranch/farm, and gross farm income. Age quartiles were established by using the distribution of age in the survey data.

The random effects μ_{0jk} is the study state site, a seven-state region in the US central states, comprising Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. The random effect μ_{1k} is the survey year level (2018 versus 2020). We specified the categorised outcomes Y_{ijk} as a multinomial distribution and a cumulative logit link function for our models. The analysis incorporated the states in which respondents worked as random effects, assessing odds for lower PPE usage in each state. Furthermore, we developed another three-level logistical model with random effects to determine the effect of PPE (Y_{ijk}) on skin injury/disease, hearing loss, or respiratory disease (Z_{ijk}):

$$\text{Logit}(\Pr(Z_{ijk} = 1)) = \xi_{mj} + \gamma Y_{ijk} + \psi_m X_{ijk} + \mu_{0jk} + \mu_{1k} \quad (2)$$

Adaptive quadrature methods

The marginal distribution of the data for individual subject i in our models (1) and (2) can be expressed as

$$f(y_i) = \int \dots \int p(y_i | \theta_1, \theta_2) p(\theta_2) d\theta_2 \quad (3)$$

, where y_i is the outcomes, such as the PPE outcome Y_{ijk} or the skin injury outcome Z_{ijk} , θ_1 is the vector of fixed-effects parameters and covariance parameters, and θ_2 is the vector of random-effects parameters with the density function $p(\theta_2)$. We employed adaptive quadrature methods to approximate the marginal maximum likelihood function (3), incorporating Gauss-Hermite quadrature weights. Missing data in multilevel datasets were handled using a multiple imputation method.²⁰ This involved generating diverse imputed datasets and consolidating the results to address potential issues posed by the absence of data. All statistical analyses were executed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

The 2018 and 2020 combined FRHSS response rate was approximately 16%. The survey response varied by state with the highest rate of respondents located in Nebraska (22.4%), followed by Iowa (17.0%), South Dakota (14.3%), Minnesota (13.4%), North Dakota (11.6%), Kansas (11.5%), and Missouri (9.8%). Ten observations were removed from the analysis due to having PPE usage percentages above 100%. Respondent demographics and farm/ranch information are presented in Table 1. Among the 7,905 operators included in the final analysis dataset, 1,208 were female (15.3%), 6,611 (83.6%) were male, and 86 (1.1%) were missing gender information. The quartile age groups showed that over 75% of operators were older than 50. Less than 1% of responses were missing age. Most responses were from Nebraska (22.3%), followed by Iowa (17.0%), and South Dakota (14.3%). About 39.1% of farms or ranches had both grain and livestock raised. Only 7.3% of farms or ranches had only livestock. Most of the responses were from the primary occupation type of farm (76.2%). Over 75% of operators spent more than 50% working on farms or ranches.

PPE usage is shown in Table 1, with 6,417 (81.2%) operators indicating they used at least one type of PPE. Fewer than 50% of respondents used either hearing PPE or respiratory PPE. However, more than 61% of operators used chemical PPE. As the ages of the operators increased, their likelihood of using any PPE diminished. Figure 1 illustrates a crosstabulation of the farm or ranch, highlighting its products and presenting the percentage of PPE usage across the three types. Operators exclusively engaged in livestock operation on farms or ranches exhibited notably low usage of all three types of PPE. The usage of chemical PPE is highest among the three types. The utilization of hearing PPE and respiratory PPE varied based on the type of operations and the products being produced.

A multilevel multinomial logistic analysis of factors associated with PPE usage is shown in Table 2. Males were more significantly likely to use Chemical PPE OR = 1.26, 95% CI :1.08–1.47 and Respiratory PPE OR = 1.34, 95% CI: 1.18–1.52. Farmers (grain only) were more significantly likely to use chemical, hearing and respiratory PPE compared to livestock type of operations OR = 1.60, 95% CI: 1.19–2.15; OR = 1.51, 95% CI: 1.28–1.79; and OR = 2.16, 95% CI: 1.81–2.57 respectively. Similarly, those characterizing themselves as farmers were more likely to use chemical and respiratory PPE compared to ranchers, except for hearing PPE (chemical PPE OR = 1.26, 95% CI: 1.10–1.43; hearing PPE OR = 0.97, 95% CI: 0.81–1.17; respiratory PPE OR = 1.19, 95% CI: 0.99–1.44). Operators who spent less time working on farm or ranch were less likely to use PPE (50%–74%) percent work

time group: chemical PPE OR = 1.52, 95% CI: 1.04–2.20; hearing PPE OR = 1.33, 95% CI: 1.06–1.65; respiratory PPE OR = 1.42, 95% CI: 1.13–1.79.

Producers were asked whether they had been diagnosed by a physician with respiratory disease, hearing loss, and skin disease. Results are shown in Table 3. Table 4 presents the multinomial logistic regression for self-reported skin disease, hearing loss, and respiratory disease. Medium usage of PPE resulted in 1.17 times the risk of respiratory disease (95% CI: 1.01–1.36) compared to those who reported high PPE use. However, the low PPE usage group showed a similar risk to those who reported high PPE use. Operators who spent 25%–49% of the time on the farm or ranch reported 1.41 times the risk of hearing loss (95% CI: 1.17–1.70) and 1.31 times the risk of respiratory disease (95% CI: 1.06–1.62).

Discussion

This study aimed to better understand the correlation between the use of PPE by agricultural workers in the Midwest U.S. and their personal demographics and farm/ranch status. Using surveillance and United States Department of Agriculture farm survey data from Midwestern farmers and ranchers, this study examined links between PPE use and age, gender, location (state), commodities raised, type of farm, and percentage of time working on the farm. In addition, associations between PPE use and self-reported skin disease, hearing loss, and respiratory disease were also examined.

PPE use by age

Age was a determinant in chemical and respiratory PPE use, with younger producers indicating more significant use of this equipment. Whether these results reflect a decrease in PPE use with age or if these older workers never adopted the use of these PPE cannot be determined by this analysis. Similar results were reported in a study of PPE use in Iowa farmers where increasing age was significantly associated with reduced use of hearing PPE.¹⁷ Variations in threat perception and educational opportunities across age groups may contribute to reduced adoption or continued use.²¹ Aging farmers may believe the “damage has already occurred” and using protection at this stage may not serve a purpose. Information should be provided to aging farmers and those who have hearing impediments regarding the importance of conserving their remaining hearing – “Save what you’ve got left”. Addressing the basis for lower use of PPE through targeted information and training may help to close this age gap in PPE use.

PPE use by gender

Differences in PPE use observed between male and female producers may be influenced by the division of work on the farm. Although shrinking, traditional differences exist where females may do more business management and livestock maintenance. In contrast, males do more machinery maintenance and operation, work with power tools, pesticide application work, and many other outdoor activities that may have high exposures and need for PPE. A Finnish study concluded gender indicates different work exposures in farming rather than a risk factor for injury.²² Additionally, women farm operators may need more role models for the use of hearing protective devices (e.g., in peers and advertising).²³ Training and

access to information may also play a role in explaining the gender difference. Previous findings suggest men may have more knowledge regarding the risks of pesticide use, thereby explaining the difference in PPE use between men and women.²⁴ Attempting to find PPE that fits properly and is sized for women presents another barrier for women.²⁵ A better understanding of the division of work, the corresponding risk of injuries, and the need for protection can help design PPE and interventions for males and females in agriculture.

PPE use by state

Of the seven states in the survey, participants from Missouri recorded the lowest rate of PPE use across all three categories (chemical, hearing, and respiratory), with a significant difference seen in chemical PPE use. Missouri also recorded the highest number of self-reported skin diseases, hearing loss, and respiratory diseases. Respondent distribution by age and state was not quantified, so this may have been a factor in this result. In 2023, Missouri had 87,000 farms, second in number only to Texas, with 90% classified as family farms.²⁶ Many of these family farms do not fall under OSHA oversight, which may explain the low use of PPE. Targeted training and outreach to farmers and ranchers in Missouri may increase awareness of the importance of donning PPE during specific tasks.

PPE use by type of farm

Livestock-only farms used chemical, hearing, and respiratory PPE significantly less than grain and grain/livestock farms. Livestock producers also self-reported significantly more hearing loss and respiratory disease. Although livestock farmers may not be exposed to the same level of pesticides as farmers, ranchers may be exposed to outdoor and confinement facility dust longer throughout the day. A California study found the more time spent in dust, the less likely producers were to use protection. They concluded mask or respirator use was most positively associated with respiratory concerns, so more effort should be concentrated on educating producers about long-term respiratory health risks and providing more user-friendly PPE.²⁷

Time working on the farm

Those spending over 50% of their time working on the farm or ranch were significantly more likely to wear respiratory PPE. This level may indicate the type of work that part-time farmers/ranchers undertake. Full-time farmers are more likely to apply pesticides.²⁸ They may also spend less time exposed to particulates such as in grain bins or confinement dust, therefore not recognizing the need for respiratory protection or not having PPE routinely available when needed. The finding that part time farmers (25%–49%) reported significantly greater hearing loss and respiratory conditions correlates with the lower use of PPE. These results highlight the need to address the importance of PPE use with part-time and hobby farmers and ranchers.

Need for life-long training, innovative outreach, and improved PPE

There is a general recognition that not all exposure hazards can ever be engineered from agricultural production. Therefore, work must continue to improve the acceptance and use of PPE. A systematic review in 2020 that examined PPE use by pesticide

applicators concluded there is a recognizable need for a life-long education program with training to change the perception and behavior of pesticide handlers sustainably.²⁹ Pesticide applicators are required to receive annual training. For other producers, the training could be incorporated into commodity meetings, events at farm shows, and community farm events. The finding by Kearney et.al that “In general, farmers are well aware of the risks associated with occupational hazards and recognize concern for health and safety protection in the workplace” begs the question of why producers do not wear PPE when they are aware of the hazards and health risks.³⁰ One explanation is that some producers may have risk-accepting personality traits.³¹ This trait, combined with other physical and time barriers, is likely a factor in keeping producers from adopting protection in situations where their health is at risk. Barriers include time required to don PPE, cost, accessibility, inconvenience, lack of comfort, and perception of weakness.¹² And for women, there are issues with size and fit. Working toward developing and promoting innovative PPE and calling for manufacturers to produce PPE designed for women will result in better acceptance and use rates.

Strengths and limitations

This study contributes valuable insights into some of the determinants for PPE use by midwestern farmers and ranchers. Utilizing a substantial dataset from seven central U.S. states, this study shed light on potential factors linked to lower PPE usage among agricultural producers. Using data imputation in SAS enhanced the reliability of the results by addressing missing data issues. The study’s focus on previously underexplored aspects of PPE use in different farm types adds to the existing body of knowledge.

Previous research examining nonresponse bias in the Farm and Ranch Health and Safety Survey found there was scant evidence of nonresponse bias. Farm and ranch characteristics of operations responding to the mailed survey were similar to those not responding.³² Therefore, those who responded to the survey (16%) were deemed to be representative of the region’s farm and ranch operators. The finding that there was a greater response to the survey in Nebraska compared to the other six states was not surprising, as the survey originated from a well-known Nebraska institution. Name recognition of the surveyor can significantly add to the trustworthiness of a survey. People are generally more likely to trust and respond to surveys conducted by organizations or individuals they recognize and perceive as credible.

The findings are not broadly generalizable, as they are specific to the states included in the survey. Additionally, the cross-sectional design and reliance on self-reported data introduce constraints in establishing causal relationships and may be susceptible to recall bias. The analysis provides a snapshot based on data from two-time points, but a longitudinal approach would offer a more dynamic understanding of PPE usage trends over time. Future studies should aim to expand the temporal scope and include additional states for a more comprehensive assessment of PPE practices in agriculture. To better understand why some states report significantly lower PPE use, age and farm size variables should be factored in the future analysis examining state PPE usage. To assess the protective effects of PPE, a longitudinal analysis focusing on the incidence of injury rather than the prevalence would help clarify if there is reverse causality involved.

Conclusion

This analysis underscores the importance of understanding the nuanced factors influencing PPE usage among agricultural producers. There needs to be an emphasis on tailored training programs, outreach, and research into innovative PPE for older producers, females, livestock-oriented operations, and individuals with minimal time spent on the farm. Additional research is needed to refine these insights and comprehensively address the multifaceted dynamics of PPE usage in agriculture. Research should include longitudinal analyses and an expanded geographical scope. As the agricultural landscape undergoes continuous evolution, ongoing research and adaptive strategies remain indispensable for enhancing the effectiveness of safety measures and ensuring the well-being of those involved in this vital industry.

Acknowledgments

The Central States Center for Agricultural Safety and Health at the University of Nebraska Medical Center funded this project through a National Institutes of Occupational Safety and Health (NIOSH) Agriculture, Forestry and Fishing Grant (U54 OH010162), and a National Institute of General Medical Sciences (U54 GM115458) that funds the Great Plains IDeA-CTR Network

Funding

The author(s) reported there is no funding associated with the work featured in this article.

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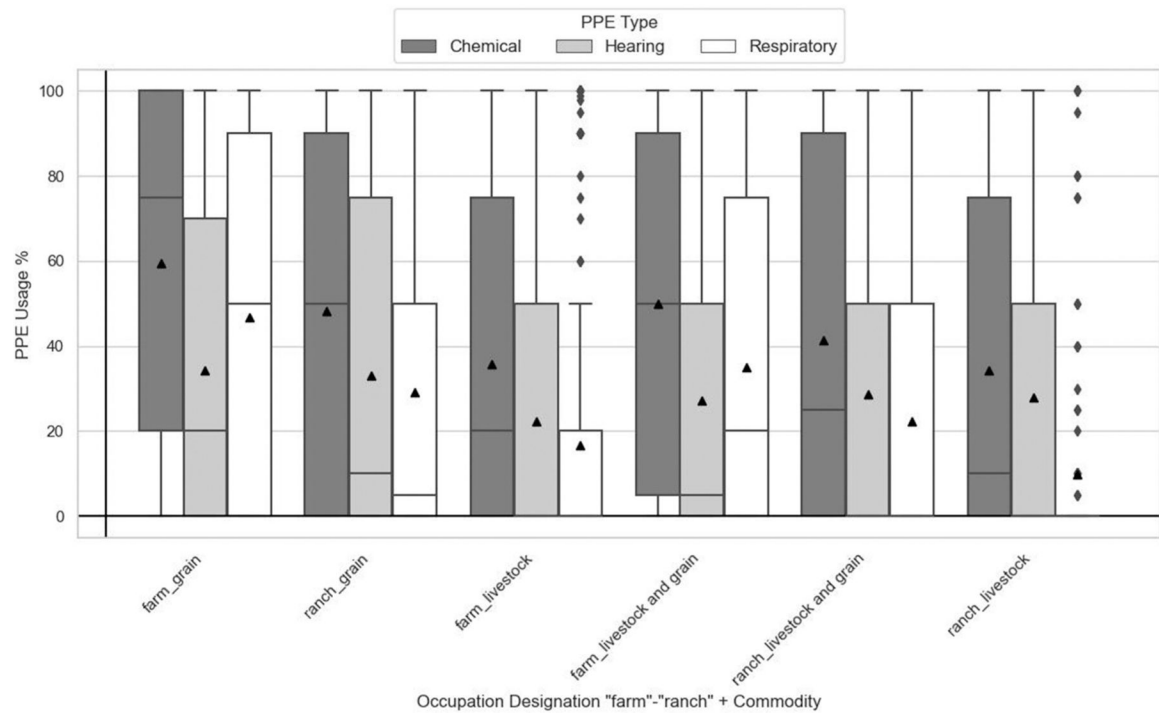


Figure 1.

Vertical boxplots of personal protective equipment (PPE) use percentage plotted by primary occupation type (farm or ranch) combined with farm type (grain, grain and livestock, or livestock) for all three types of PPE.

Table 1. Demographic and occupational characteristics by personal protective equipment (PPE) among operators.

Characteristics	All	PPE use (any types of PPE)*		Chemical PPE Yes	Hearing PPE Yes	Respiratory PPE Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Total	7,905 (100)	6,417 (81.2)	4,872 (61.6)	3,803 (48.1)	3,821 (48.3)	
Age						
19–50	1,948 (24.6)	1,665 (85.4)	1,336 (68.6)	1,076 (55.3)	1,110 (57.0)	
51–60	2,078 (26.3)	1,744 (83.9)	1,374 (66.1)	1,054 (50.7)	1,092 (52.6)	
61–67	1,863 (23.6)	1,542 (82.8)	1,186 (63.7)	918 (49.3)	917 (49.2)	
68–100	1,943 (24.6)	1,432 (73.7)	953 (49.0)	735 (37.8)	687 (35.4)	
Missing	73 (0.9)	34 (46.6)	23 (31.5)	20 (27.4)	15 (20.5)	
Gender						
Female	1,208 (15.3)	833 (69.0)	513 (42.5)	389 (32.2)	338 (28.0)	
Male	6,611 (83.6)	5,542 (83.8)	4,333 (65.5)	3,387 (51.2)	3,457 (52.3)	
Missing	86 (1.1)	42 (48.8)	26 (30.2)	27 (31.4)	26 (30.2)	
State						
Iowa	1,343 (17.0)	1,148 (85.5)	868 (64.6)	720 (53.6)	738 (55.0)	
Kansas	910 (11.5)	704 (77.4)	522 (57.4)	407 (44.7)	326 (35.8)	
Minnesota	1,082 (13.7)	916 (84.7)	702 (64.9)	618 (57.1)	586 (54.2)	
Missouri	759 (9.6)	558 (73.5)	374 (49.3)	328 (43.2)	267 (35.2)	
North Dakota	917 (11.6)	778 (84.8)	634 (69.1)	485 (52.9)	493 (53.8)	
Nebraska	1,766 (22.3)	1,414 (80.1)	1,097 (62.1)	774 (43.8)	878 (49.7)	
South Dakota	1,128 (14.3)	899 (79.7)	675 (59.8)	471 (41.8)	533 (47.3)	
Type of Farm						
Livestock	579 (7.3)	417 (72.0)	264 (45.6)	223 (38.5)	118 (20.4)	
Grain	4,014 (50.8)	3,362 (83.8)	2,642 (65.8)	2,107 (52.5)	2,209 (55.0)	
Grain/Livestock	3,073 (38.9)	2,455 (79.9)	1,836 (59.7)	1,349 (43.9)	1,427 (46.4)	
Missing	239 (3.0)	183 (76.6)	130 (54.4)	124 (51.9)	67 (28.0)	
Occupation Type						
Farm	6,022 (76.2)	5,074 (84.3)	3,982 (66.1)	3,032 (50.3)	3,236 (53.7)	
Ranch	1,737 (22.0)	1,286 (74.0)	856 (49.3)	744 (42.8)	562 (32.4)	

	All	PPE use (any types of PPE) *		Chemical PPE Yes	Hearing PPE Yes	Respiratory PPE Yes
		Yes				
Missing	146 (1.9)	57 (39.0)	34 (23.3)	27 (18.5)	23 (15.8)	
% Time Work on farm/ranch						
100%	3,654 (46.2)	3,120 (85.4)	2,462 (67.4)	1,836 (50.2)	2,045 (56.0)	
75–99%	1,426 (18.0)	1,217 (85.3)	974 (68.3)	748 (52.5)	781 (54.8)	
50–74%	897 (11.4)	725 (80.8)	550 (61.3)	442 (49.3)	399 (44.5)	
25–49%	1,052 (13.3)	834 (79.3)	585 (55.6)	496 (47.1)	421 (40.0)	
0–24%	739 (9.4)	470 (63.6)	273 (36.9)	257 (34.8)	152 (20.6)	
Missing	137 (1.7)	51 (37.2)	28 (20.4)	24 (17.5)	23 (16.8)	

* Any type of PPE: Operators reported used at least one of the three types of PPE for any percentage.

Table 2.

Multilevel multinomial logistic analysis of factors associated with by personal protective equipment (PPE) usage.

Effect	Chemical PPE OR (95% CI)	Hearing PPE OR (95% CI)	Respiratory PPE OR (95% CI)
Age Group (quartiles)			
19–50	Ref.	Ref.	Ref.
51–60	0.86 (0.86, 0.86)	0.92 (0.81, 1.05)	0.90 (0.79, 1.03)
61–67	0.79 (0.78, 0.80)	0.85 (0.74, 0.98)	0.84 (0.73, 0.96)
68–100	0.61 (0.61, 0.61)	0.71 (0.62, 0.82)	0.66 (0.57, 0.75)
Gender			
Female	Ref.	Ref.	Ref.
Male	1.26 (1.08, 1.47)	1.05 (0.93, 1.19)	1.34 (1.18, 1.52)
State			
South Dakota	Ref.	Ref.	Ref.
Iowa	1.43 (1.38, 1.48)	2.10 (1.32, 3.33)	1.53 (0.98, 2.39)
Kansas	1.13 (1.12, 1.14)	1.83 (1.12, 2.98)	1.17 (0.73, 1.88)
Minnesota	1.59 (1.57, 1.62)	1.89 (1.17, 3.04)	1.44 (0.91, 2.26)
Missouri	0.63 (0.63, 0.63)	0.96 (0.60, 1.53)	0.93 (0.59, 1.46)
North Dakota	1.37 (1.29, 1.44)	1.25 (0.71, 2.19)	1.46 (0.85, 2.52)
Nebraska	1.52 (1.51, 1.53)	1.32 (0.80, 2.17)	1.42 (0.88, 2.30)
Type of Farm			
Livestock	Ref.	Ref.	Ref.
Grain	1.60 (1.19, 2.15)	1.51 (1.28, 1.79)	2.16 (1.81, 2.57)
Grain/Livestock	1.14 (0.93, 1.40)	1.32 (1.11, 1.56)	1.37 (1.15, 1.64)
Occupation Type			
Ranch	Ref.	Ref.	Ref.
Farm	1.26 (1.10, 1.43)	0.97 (0.81, 1.17)	1.19 (0.99, 1.44)
% Work Time on Farm/Ranch			
0–24%	Ref.	Ref.	Ref.
25–49%	1.51 (0.97, 2.34)	1.15 (0.97, 1.38)	1.08 (0.90, 1.30)
50–74%	1.52 (1.04, 2.20)	1.33 (1.06, 1.65)	1.42 (1.13, 1.79)
75–99%	1.50 (0.72, 3.10)	1.27 (1.01, 1.60)	1.41 (1.11, 1.80)
100%	1.55 (0.78, 3.08)	1.19 (0.95, 1.49)	1.58 (1.26, 1.99)

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Table 3.
Percentage of producers diagnosed with respiratory, hearing or skin conditions.

Diagnosed Condition	(%)
Respiratory Disease	
None	75.0
COPD *	2.2
Asthma	4.6
Farmers Lung	2.3
Sinus Disease	5.4
Nasal Inflammation	5.8
Environ. Allergies	8.7
Hearing Loss	
None	47.0
Mild	33.2
Moderate	16.3
Severe	3.5
Skin Disease	
None	79.4
Irritant Dermatitis	2.8
Allergic Dermatitis	1.2
Skin Cancer	10.9
Other	1.7

* Chronic Obstructive Pulmonary Disease.

Table 4. Multilevel multinomial logistic analysis of by personal protective equipment (PPE) usage associated with self-reported injuries/diseases.

Effect	Reported Skin Disease OR (95% CI)	Reported Hearing Loss OR (95% CI)	Reported Respiratory Disease OR (95% CI)
Age Group (quartiles)			
19–50	Ref.	Ref.	Ref.
51–60	1.42 (1.14, 1.75)	3.17 (2.75, 3.66)	1.05 (0.89, 1.24)
61–67	2.21 (1.79, 2.74)	5.42 (4.66, 6.29)	1.27 (1.07, 1.50)
68–100	4.09 (3.32, 5.03)	9.26 (7.95, 10.78)	1.53 (1.29, 1.81)
Gender			
Female	Ref.	Ref.	Ref.
Male	1.17 (0.99, 1.39)	3.09 (2.69, 3.55)	0.84 (0.73, 0.98)
State			
South Dakota	Ref.	Ref.	Ref.
Iowa	0.62 (0.31, 1.25)	0.89 (0.53, 1.49)	0.68 (0.39, 1.21)
Kansas	0.79 (0.39, 1.62)	0.98 (0.57, 1.68)	1.04 (0.58, 1.85)
Minnesota	0.28 (0.12, 0.66)	0.86 (0.50, 1.48)	0.52 (0.28, 0.96)
Missouri	1.39 (0.73, 2.67)	1.28 (0.77, 2.14)	1.28 (0.74, 2.20)
North Dakota	0.39 (0.14, 1.08)	0.91 (0.48, 1.71)	0.99 (0.50, 1.94)
Nebraska	0.65 (0.30, 1.41)	0.69 (0.39, 1.23)	0.61 (0.32, 1.15)
Type of Farm			
Livestock	Ref.	Ref.	Ref.
Grain	0.84 (0.69, 1.03)	0.81 (0.69, 0.96)	0.81 (0.67, 0.98)
Grain/Livestock	0.89 (0.73, 1.10)	0.87 (0.74, 1.03)	0.94 (0.78, 1.14)
Occupation Type			
Ranch	Ref.	Ref.	Ref.
Farm	1.08 (0.86, 1.37)	1.34 (1.10, 1.62)	1.06 (0.86, 1.31)
Percent Work Time on Farm/Ranch			
0–24%	Ref.	Ref.	Ref.
25–49%	0.94 (0.74, 1.20)	1.41 (1.17, 1.70)	1.31 (1.06, 1.62)
50–74%	0.97 (0.73, 1.30)	1.16 (0.92, 1.47)	1.30 (1.00, 1.69)
75–99%	0.93 (0.69, 1.26)	1.06 (0.83, 1.36)	1.04 (0.79, 1.38)

Effect	Reported Skin Disease OR (95% CI)	Reported Hearing Loss OR (95% CI)	Reported Respiratory Disease OR (95% CI)
100% PPE Use	0.92 (0.70, 1.23)	1.11 (0.88, 1.40)	1.11 (0.85, 1.45)
High	Ref.	Ref.	Ref.
Medium	1.14 (0.98, 1.31)	1.07 (0.94, 1.22)	1.17 (1.01, 1.36)
Low	0.88 (0.77, 1.01)	0.93 (0.83, 1.04)	0.95 (0.83, 1.08)