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The Risk Factors Associated with Personal Protective Equipment Usage Rates in the Central States by Generalized Multilevel Models

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Abstract

Background: Agriculture producers in the United States face some of the highest rates of fatal and non-fatal injuries among all occupations. This includes a high risk of respiratory damage when working in dusty environments, chemical and health hazards when working with pesticides or other dangerous chemicals, and hearing damage when working in noisy environments. These risks can be reduced using personal protective equipment (PPE). While some workplaces are required by the Occupational Safety and Health Administration (OSHA) to provide necessary PPE and monitoring according to the risks of a job, many small farms are not required by OSHA to provide a PPE program for their employees even though hazards exist. PPE use by agriculture producers has been found to be low.

Methods: Several studies have identified multi-level interventions to promote PPE usage in producers. Determining characteristics of farms and producers significantly associated with lower PPE use can help target interventions to increase the number of producers who adopt PPE. Data from the Central States Center for Agricultural Safety and Health's 2018-2020 seven-states survey on injuries in agriculture producers was analyzed to identify demographic and farm information significantly associated with PPE usage rates for chemical, respiratory, and hearing PPE. Multinomial logistic regression was used to identify associations between PPE use and variables of age, gender, gross farm income, type of farm, percent of work time spent on the farm/ranch, and occupation type. Multinomial logistic regression was also used to identify associations between PPE use and injuries/diseases.

Results: Older age was associated with lower PPE use for all PPE types. Males had higher PPE use than females for chemical (OR = 1.26, 95% CI [1.08, 1.47]) and respiratory PPE (OR = 1.33, 95% CI [1.18, 1.52]). Producers on grain-only farms had higher chemical PPE use (OR = 1.26, 95% CI [1.10, 1.43]) than those on livestock-only farms. Producers that spent only 0-24% of their worktime on the farm/ranch had lower PPE use than those that spent more work time on the farm/ranch.

Discussion/Conclusion: Using this information, interventions can be better adapted and targeted to groups at highest risk of health hazards due to low PPE usage. Female producers, producers on livestock-only farms, older-aged producers, and part-time producers may be beneficial groups to adapt interventions to improve PPE use.

Chapter 1: Background and Introduction

Agriculture producers have some of the highest rates of fatal and non-fatal injuries among occupations in the United States¹. In 2020, agriculture producers experienced 368 occupational fatalities, which is 18.0 deaths per 100,000 producers compared to 3.4 deaths for all occupations¹. For non-fatal injuries, 11,880 work-related injuries that caused hired agriculture workers to miss work occurred in 2020 (this data excluded self-employed farmers and ranchers)¹. Beyond the producers, those living or visiting farms face high risks due to hazardous environments. In 2014, 7,469 youth were injured on farms with 60% of those injuries occurring outside of work conditions². Some of the hazards examined in this project include the following:

Noise levels. Agriculture producers have some of the highest risks for hearing loss compared to other occupations³. People living on farms have a higher risk of hearing loss compared to the general population³. High noise levels from things like tractors, electric tools, guns, livestock, and other equipment can cause permanent hearing loss in people exposed for long periods of time³. Depczynski et al. (2005) determined that some of the most common auditory hazards on farms are firearms, cab-less tractors, tools, small motors, handling pigs, shearing sheds, older tractors, and heavy machinery⁴.

Pesticide Exposure. Agriculture producers can be exposed to toxic chemicals through pesticide use. Producers who apply and mix pesticides or work where pesticides have been applied can inhale the toxic chemicals or carry them on their clothes or skin. Producers contaminated with pesticides can expose themselves and those around them to the toxic chemicals³. Patel et al. (2018) found significant association between insecticide/herbicide use and lifetime allergic rhinitis and asthma in farm producers in the United States⁵. Use of 2,4-dichlorophenoxyacetic acid (OR = 1.5, 95% CI [1.2, 1.9]) and carbaryl (OR = 2.3, 95% CI [1.4, 3.7]) were associated with developing lifetime allergic rhinitis⁵. Exposure to pesticides can also cause neurological

problems such as headache and dizziness, respiratory symptoms, sleep and mood changes, gastrointestinal symptoms, and skin and eye irritation⁶.

Organic Dust Exposure. When working in locations such as barns and silos, agriculture producers can inhale organic dusts containing microorganisms and toxic materials from animal waste that can cause respiratory damage³. Exposure to organic dust can stimulate various immunological pathways that, when repeatedly elicited, can result in a change to immunity leading to chronic inflammation⁷. Organic dust exposure can likely alter the population of immune cells in the lungs, possibly leading to lung inflammation and disease⁸.

While the risks for injury can be high when working on a farm, agriculture producers can reduce their risk through the proper use of personal protective equipment (PPE)⁹. PPE use is considered the lowest consideration in the protection hierarchy of controls¹⁰. So, while agriculture producers should take steps to eliminate or reduce risks aside from just wearing PPE such as limiting pesticide use or using less dangerous pesticides, PPE use is recommended when hazards will be encountered¹¹. OSHA requires employers on farms that employ eleven or more employees to assess present hazards for the need for PPE, provide any necessary PPE that is functional and effective, and train employees on proper use¹². But most farms in the U.S. are considered family farms, employing less than 11 producers, and therefore are not required to have a PPE program¹³.

The type of PPE needed depends on the risks encountered in the working environment.

Pesticides and Hazardous Chemicals Protection. Chemical PPE should be used when encountering and using pesticides or other potentially dangerous chemicals¹². When dealing with pesticides or hazardous chemicals, the MSDS should be consulted for the recommended

clothing, eye protection, and respiratory protection¹². This would include protective clothing such as protective hats, safety goggles, chemical resistant gloves, and long-sleeved shirts and pants that can prevent the chemicals from contacting the body of the agriculture worker

Respiratory Hazard Protection. Respirators can prevent inhalation of airborne hazards that are commonly encountered during agriculture work¹². Disposable respirator masks can protect from dusts¹². When encountering hazards such as toxic vapors, gases, and high concentrations of harmful particulates, air purifying half-masks and full masks are more suitable¹². If toxic material may be airborne and able to be inhaled by producers, the proper respirators should be used¹³.

Noise Exposure Protection. When operating loud machinery such as tractors or tools that create noise levels greater than 85 dB, the use of hearing protection will reduce the risk for permanent hearing loss¹⁴. Hearing protection can include ear plugs, earmuffs or other noise reducing ear buds.

When used improperly or in uncontrolled work environments, PPE effectiveness can drop below recommended standards. Properly fitted and tested PPE, training and education is crucial to ensure effectiveness of this equipment¹¹. While proper PPE use is important, getting producers to use PPE consistently is another major part of protecting agriculture producers.

Little data exists on the usage rates of PPE among agriculture producers throughout the United States, but a few studies indicate that the rates may be low. Farmers from midwestern states were recruited to take a survey about PPE usage. The various PPE usage rates were low even though the producers were generally satisfied with the availability of PPE. When working in conditions where producers needed to shout to be heard, 78% of respondents reported rarely or

never wearing earmuffs and 72% reported rarely or never wearing ear plugs. When working with chemicals, gloves were often used, but other types of PPE were rarely used¹⁵. Among midwestern farmers, producers seem to lack the proper knowledge in areas of sources of hazards, consequences of hazard exposure, and proper PPE use¹⁶. Factors that seem to affect lower PPE usage are smoking history and lower assessment of health¹⁷. A study examining PPE usage among agriculture producers in California found that when working in dusty conditions, only 24.4% of producers used respiratory protection more than half the time. When working in loud conditions, only 22.8% used hearing protection over half the time and 56.3% of respondents rarely or never used any hearing protection. When using pesticides, fifty-nine out of 885 producers rarely or never used PPE¹⁸.

Targeting farmers with low rates of PPE usage would be likely to increase the overall safety and health of agriculture producers. Research examining personal opinions and outside factors affecting PPE use found that the factors having the greatest influence on PPE usage were a desire to prevent any injuries or detrimental exposures and to manage pre-existing conditions, comfort, and influence from a spouse¹⁵. Factors associated with higher PPE use in California agriculture producers included being of a younger age, a concern over specific health issues (i.e., respiratory damage, hearing loss, cancer), and viewing farming as a more dangerous occupation than others¹⁸. Producers that experience more anger and anxiety may have lower PPE use, and increased knowledge of proper PPE use may increase the comfort and effectiveness when using PPE¹⁹. Knowing what factors have a strong influence on PPE usage can be useful to create effective interventions to increase PPE usage.

A review of studies examining interventions to increase respiratory protection use in producers found some evidence showing that education and training did not improve respiratory

protection use in producers. Motivational interviewing did lead to higher scores measuring PPE use compared to typical educational sessions²⁰. Another review found that providing education on hazards present in the workplace and proper use of the protective equipment promoted better knowledge and use of respiratory protection in the short-term, but long-term changes need a multi-dimensional approach²¹. A review focusing on pesticide use safety found that multi-faceted interventions were typically most effective among the studies reviewed in changing or improving the adherence to safety recommendations when using pesticides. Most of the reviewed interventions targeted individuals rather than multiple level approaches. Targeting multiple levels of the ecological model (such as interpersonal, organizational, public policy, and community) may be the best approach to cause lasting and significant benefits to the safety precautions that agriculture producers take while on the job²².

To increase the overall effectiveness of programs and interventions to promote PPE use, it would be beneficial to adapt them and focus on workers less likely to use PPE. However, no research exists on what characteristics of agriculture producers are associated with PPE use. Through analyzing survey data collected from agriculture workers, this study looks to find the demographic and farm characteristics associated with lower PPE and define workers that may be less likely to use PPE.

Chapter 2: Specific Aims

The mission of the Central States Center for Agricultural Safety and Health (CS-CASH) is to decrease the prevalence of fatalities, injuries, and illnesses in agriculture producers in their seven-state region and beyond throughout the United States. CS-CASH turns research and evidence into practical applications (research, outreach, and education) to promote the health and safety of agriculture producers. Every two years, as part of a surveillance research project CS-

CASH sends out a survey to agriculture producers (owners of farms) across the seven states focusing on injuries, fatalities, PPE use, exposures, and other injury and health related information. The survey data is merged with the United States Department of Agriculture's classification survey thereby providing further data on the farmers and ranchers that respond.

Aim 1: Identify which demographic and farm characteristic variables are significantly associated with lower PPE usage in the CS-CASH survey.

Hypothesis for Aim 1: It is hypothesized that age will be significantly negatively associated with PPE use. Also, those farms that work with grain versus livestock will be significantly positively associated with PPE usage. Additionally, it is hypothesized that states with the largest average farm size will have the highest PPE usage.

Approach for Aim 1: A multinomial logistic regression will be used to find significant associations between the PPE usage of the three different types (chemical, respiratory, and hearing) and the demographic and farm variables (age, gender, gross farm income (GFI), occupation type, percent of worktime spent on the worksite, and type of farm product of grain versus livestock).

Aim 2: Evaluate the relationship between PPE use and self-reported injuries and disease to provide insight into the possible protective effects of PPE in agriculture work.

Hypothesis for Aim 2: I hypothesize that higher chemical PPE use will be associated with significantly lower odds of having a self-reported skin disease or injury, higher hearing PPE use will be associated with significantly lower odds of having self-reported hearing loss, and higher respiratory PPE use will be associated with significantly lower odds of having a self-reported respiratory disease.

Approach for Aim 2: A multinomial logistic regression will be used to evaluate the relationship between the different levels of PPE use and the odds of having different kinds of injuries and diseases that are likely protected by each PPE type. Chemical PPE will be evaluated with skin diseases and injuries. Hearing PPE will be evaluated with levels of hearing loss. Respiratory PPE will be evaluated with respiratory diseases.

Chapter 3: Significance and Methods

Very little research has been undertaken to examine the demographics that are significantly associated with PPE use in the CS-CASH seven-states region. Understanding locations and characteristics of people who are less likely to use PPE can improve the Center's effectiveness in creating interventions and programs that promote the use of PPE. Focused interventions can produce a larger impact on people who are likely to have lower PPE usage rates and are at greater risk for health hazards while on the job.

Methods

Data Resource: Every two years, CS-CASH sends out an agricultural injury and health survey to farm owners across the seven-states region that they serve. The twenty-nine-question survey focuses on injuries, fatalities, PPE use, as well as demographics for the primary producer and two other producers on the farm. Information for up to three people can be collected on each survey. The primary owner and the two other possible survey respondents in this analysis will be referred to as "producers". The survey data is merged with the United States Department of Agriculture's classification survey thereby increasing the amount of data that is known for each respondent.

Data design: Using CS-CASH survey data gathered in 2018 and 2020, a summary table including frequencies and averages of all collected demographic data and farm statistics on the survey respondents was created. The three categories of PPE usage (respiratory, chemical, and hearing) were categorized so that $\leq 25\%$ is low usage, 26%-74% is medium usage, and $\geq 75\%$ is high usage. Missing data was accounted for using a multiple imputation method. This method creates many different imputed data sets and combines the results to account for the possible issues that the missing data could present²³.

The age variable was divided into four quartiles of ages using SAS (ages 0-50, 51-60, 61-67, and 68-100). A dummy variable was created for the farm type variable with “0” being a livestock farm, “1” being a cereal/grain farm, and “2” being a farm that produces both grain and livestock. The state variable had seven categories, one for each state. The occupation type variable had two groups of either farm or ranch. The percentage of work time spent on the farm/ranch was divided into five groups: 100%, 75-99%, 50-74%, 25-49%, and 0-24%. GFI was included in the models, but the results were not meaningful.

Skin disease options on the survey included none, irritant dermatitis, allergic dermatitis, skin cancer, or other. Respiratory disease options on the survey included none, chronic obstructive pulmonary disease (COPD), asthma, farmers lung, sinus disease (sinusitis), nasal inflammation/runny nose (rhinitis), and environmental allergies. Hearing loss options on the survey included none, mild, moderate, and severe.

Statistical models: Multinomial logistic regression was used to model the relationship between the category levels of PPE usage and the demographic and farm variables of age, gender, farm type (livestock, grain, or both), type of occupation (farm versus ranch), percent of worktime spent on the ranch/farm, and gross farm income. Models were created for chemical PPE,

respiratory PPE, and hearing PPE. Specifically, a cumulative logit model was used to assess the odds of having a lower PPE usage category for each of the variables in the model. The multinomial logistic regression was also used to model the relationship between the category levels of PPE usage and the states that the survey respondents work for each type of PPE. The state that the survey respondents worked in was added to the model as a random effect. The model assessed the odds of having a lower PPE usage category for each state included in the survey. Additionally, the year of the survey (2018 versus 2020) will be included in the model as a random effect to create a three-level multinomial logistic regression.

For the second aim, three logistic regressions modeled the relationship between the presence of a skin injury/disease, hearing loss, or the presence of a respiratory disease and the level of chemical, hearing, and respiratory PPE use respectively. A logistic regression was used to model the binary variables of having a skin injury/disease or not and having a respiratory disease or not. A multinomial regression was used to model the four hearing loss categories. Additionally, all variables included in the previous models (age, gender, farm type, type of occupation, percent of work time spent on the ranch/farm, gross farm income) were included in each model as well as covariates. The models for the presence of a respiratory or skin disease/injury were a binary logit model with respondents either having a disease/injury or not. The level of hearing loss model was a cumulative logit model modeling the odds of having a lower level of hearing loss across four levels.

Chapter 4: Results

Descriptive Statistics

Ten observations were removed from the analysis due to having PPE usage percents above 100% in the data set.

Table 1. Summary Statistics of all variables. Total counts are not equal across variables as some responses are missing.

Demographic and Farm Variables	Overall
Age (Years)	
0-25	350 (4.43%)
26-50	1671 (21.14%)
51-75	5194 (65.70%)
76-110	690 (8.73%)
Gender	
Male	6621 (84.57%)
Female	1208 (15.43%)
State	
Iowa	1344 (16.98%)
Kansas	910 (11.50%)
Minnesota	1084 (13.70%)
Missouri	760 (9.60%)
North Dakota	919 (11.61%)
Nebraska	1770 (22.36%)
South Dakota	1128 (14.25%)
Occupation Type	
Farm	6022 (77.61%)
Ranch	1737 (22.39%)
Percent Time Farming	
100%	3654 (47.04%)
75-99%	1426 (18.36%)
50-74%	897 (11.55%)
25-49%	1052 (13.54%)

0-24%	739 (9.51%)
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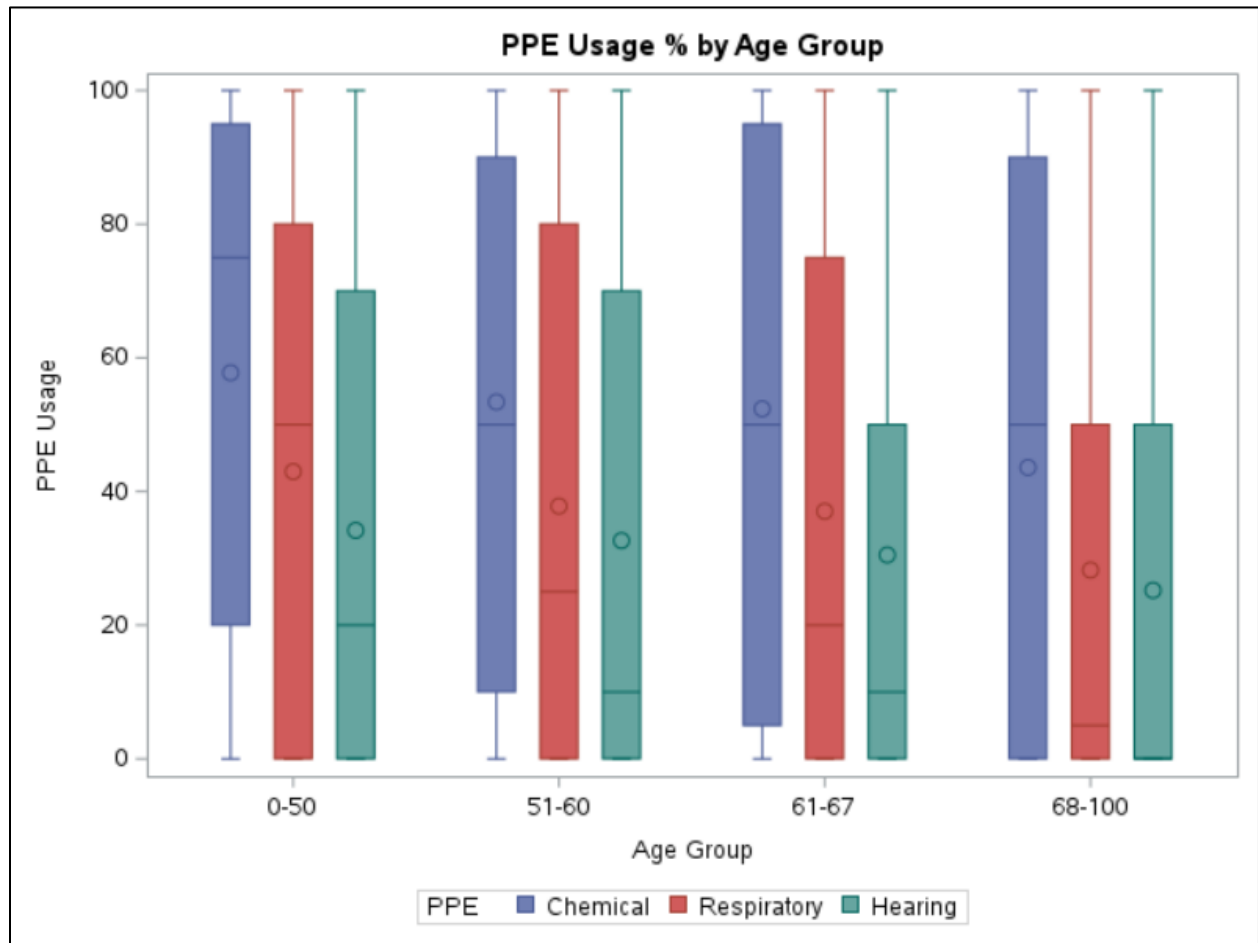


Figure 1. Vertical boxplots of PPE use percentage plotted by age groups (0-50, 51-60, 61-67, 68-100) for all PPE types.

In Figure 1, all PPE types have the highest mean and median percentage of PPE usage in the 0-50 age group and the lowest mean and median percentage of PPE usage in the 68-100 age group.

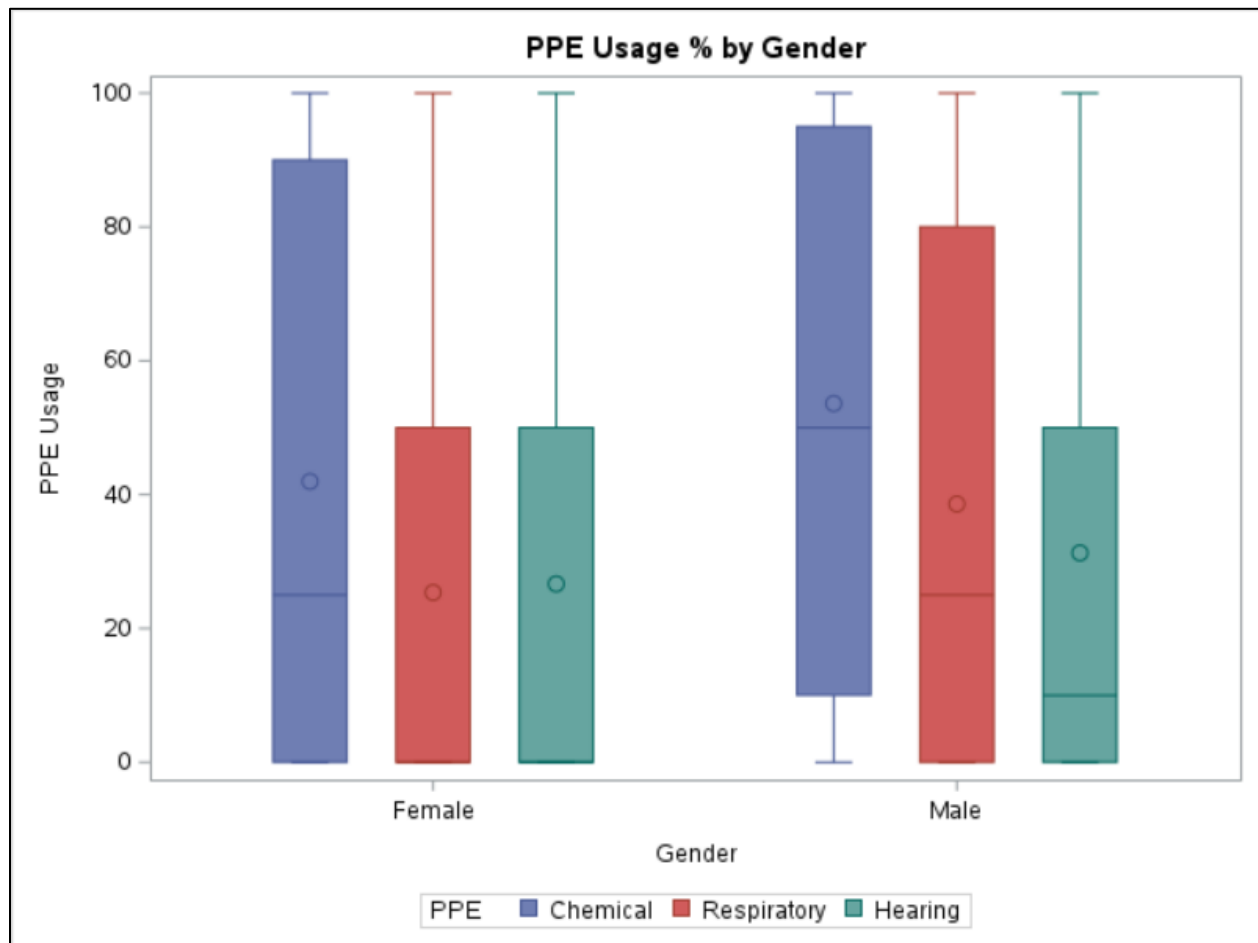


Figure 2. Vertical boxplots of PPE use percentage plotted by gender (female and male) for all PPE types.

In Figure 2, all PPE types share a similar trend that females have lower median and mean PPE usage percentages compared to males. Hearing PPE usage is closer between males and females compared to usage of chemical and respiratory PPE.

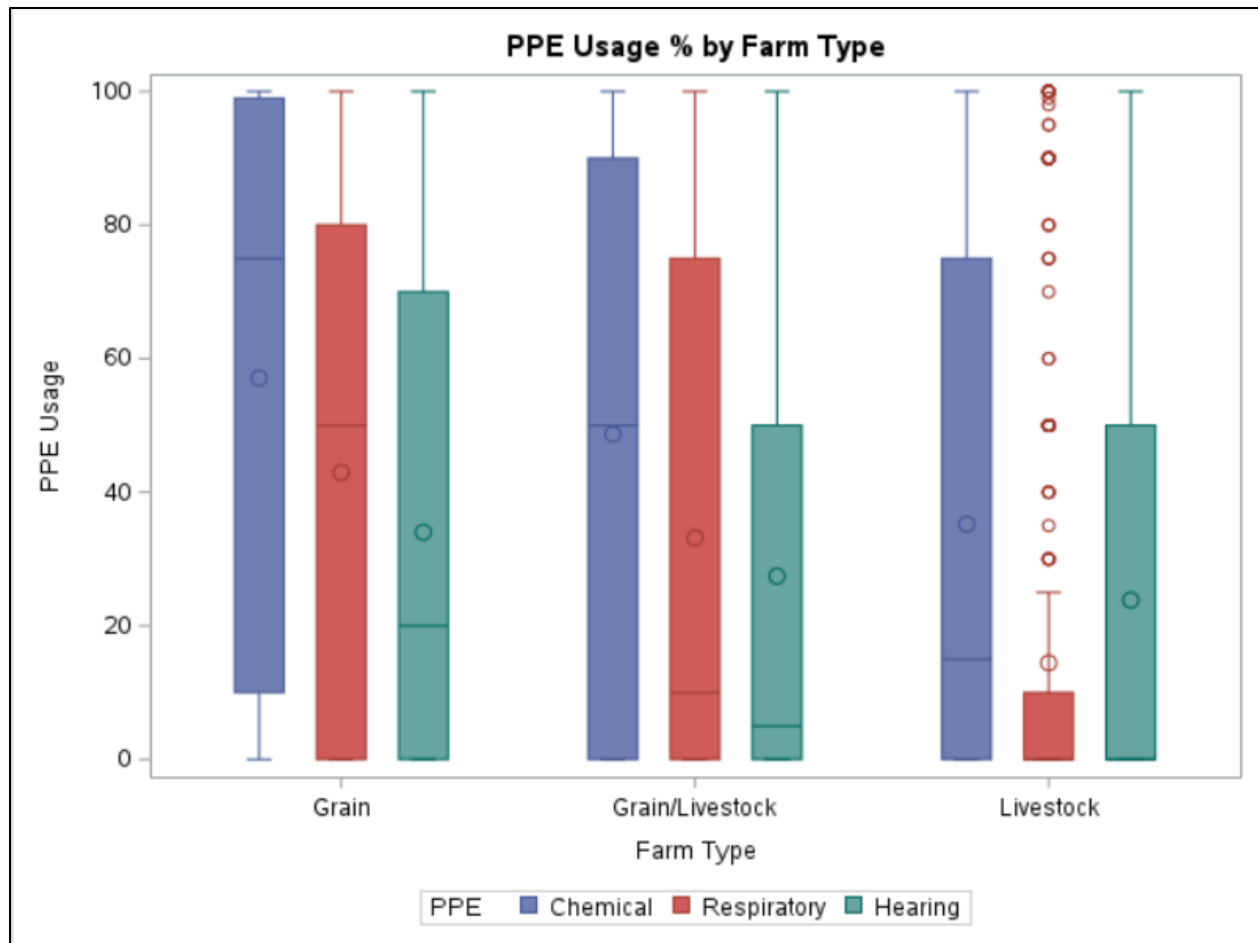


Figure 3. Vertical boxplots of PPE use percentage plotted by farm type (grain, grain and livestock, livestock) for all PPE types.

In Figure 3, all PPE types follow a similar trend of grain farms having the highest PPE usage followed by grain and livestock farms and, lastly, by only livestock farms. Respiratory PPE usage is noticeably lower in the livestock farm type compared to the other farm types.

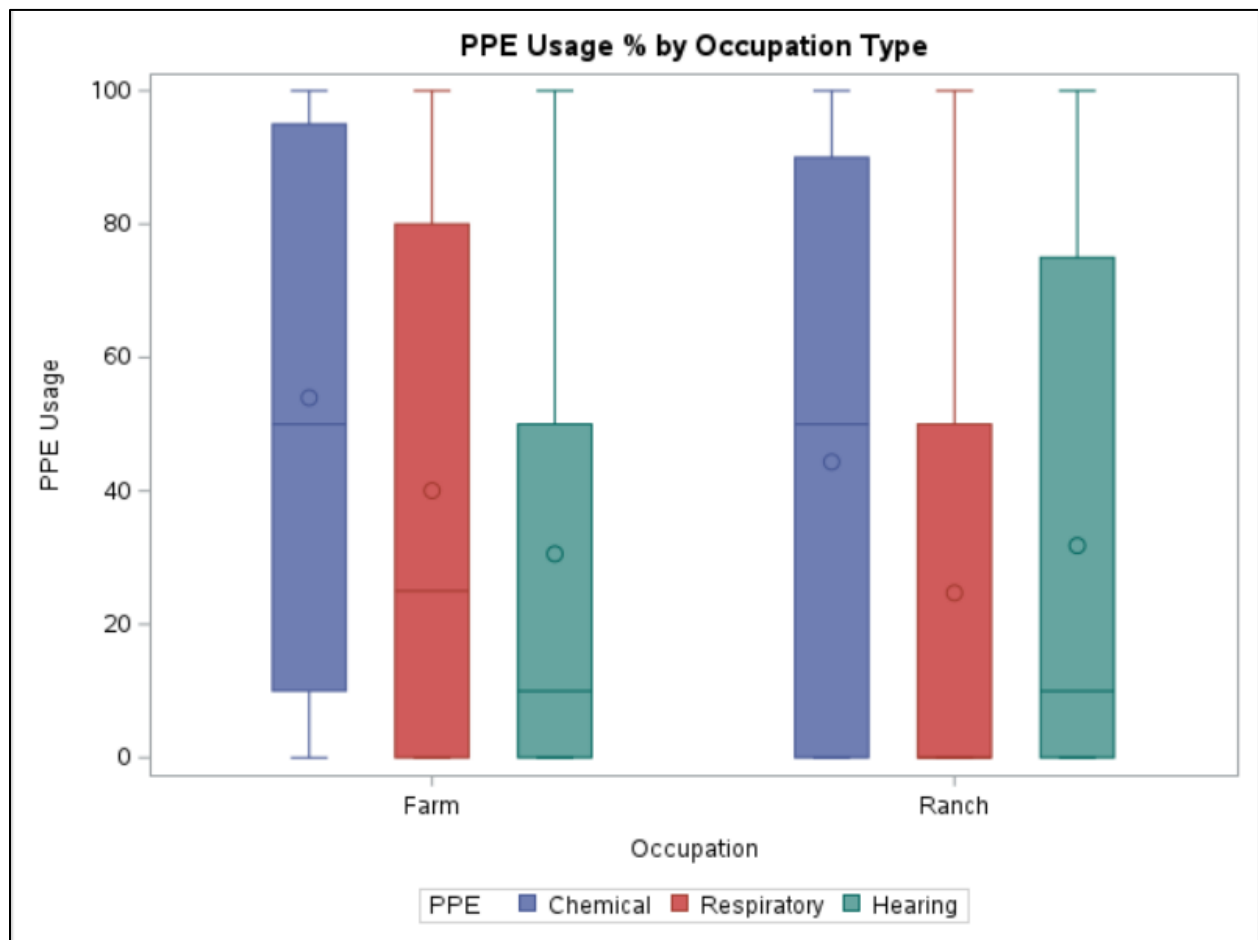


Figure 4. Vertical boxplots of PPE use percentage plotted by farm type primary occupation type (farm versus ranch) for all PPE types.

In Figure 4, Chemical and Hearing PPE usage are similar between those working on ranches compared to farms. Respiratory PPE usage is noticeably higher in those identifying as farmers compared to ranchers.

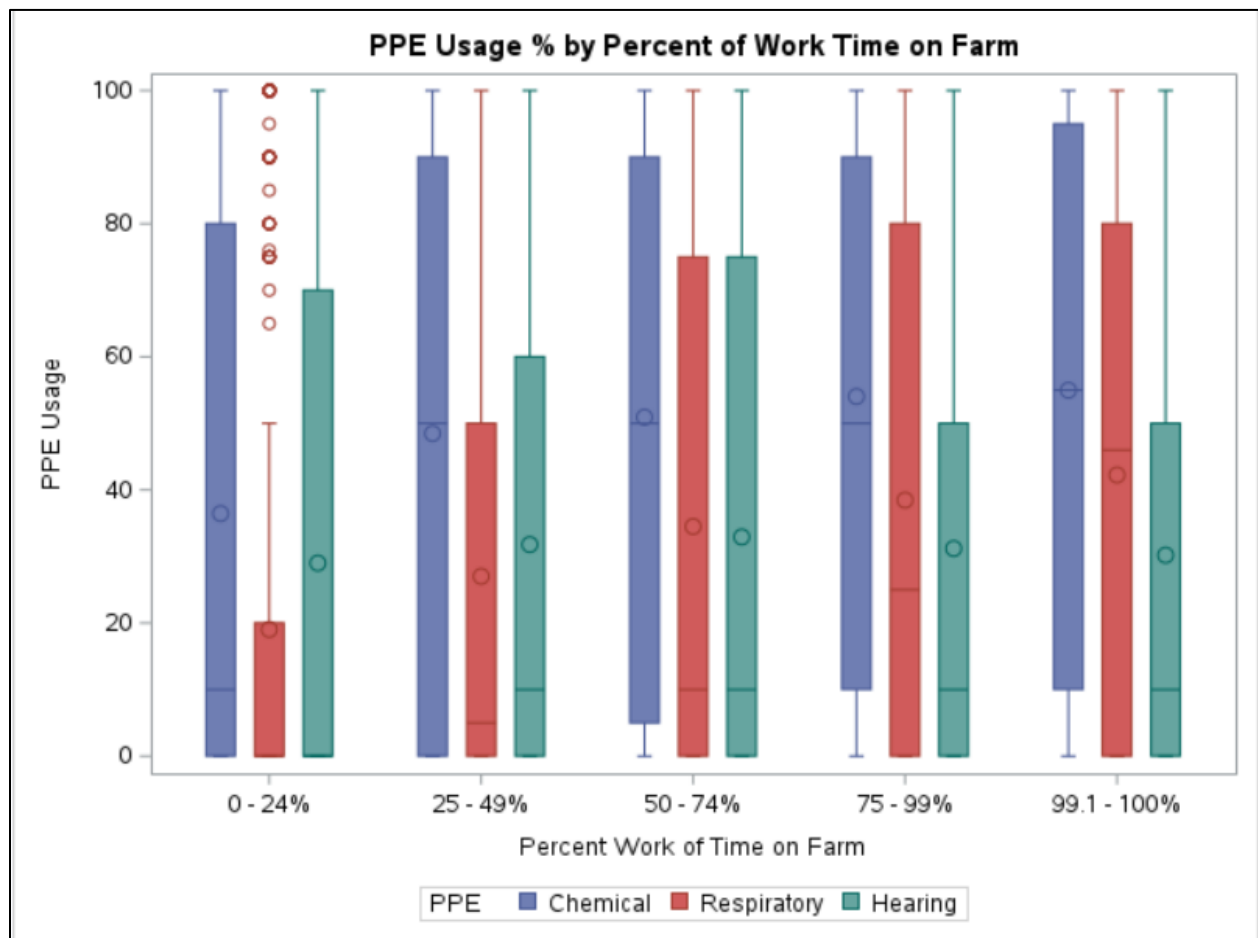


Figure 5. Vertical boxplots of PPE use percentage plotted by work time spent on the farm/ranch for all PPE types.

In Figure 5, all PPE types have noticeably lower percent-usage in the producers spending 0-24% of their work time on the ranch/farm. Chemical and Respiratory PPE both show a general trend that as work time spent on the farm/ranch increases, PPE usage also appears to increase. Hearing PPE does not have a general trend across the groups, but the 0-24% group is lower in PPE usage than the four groups.

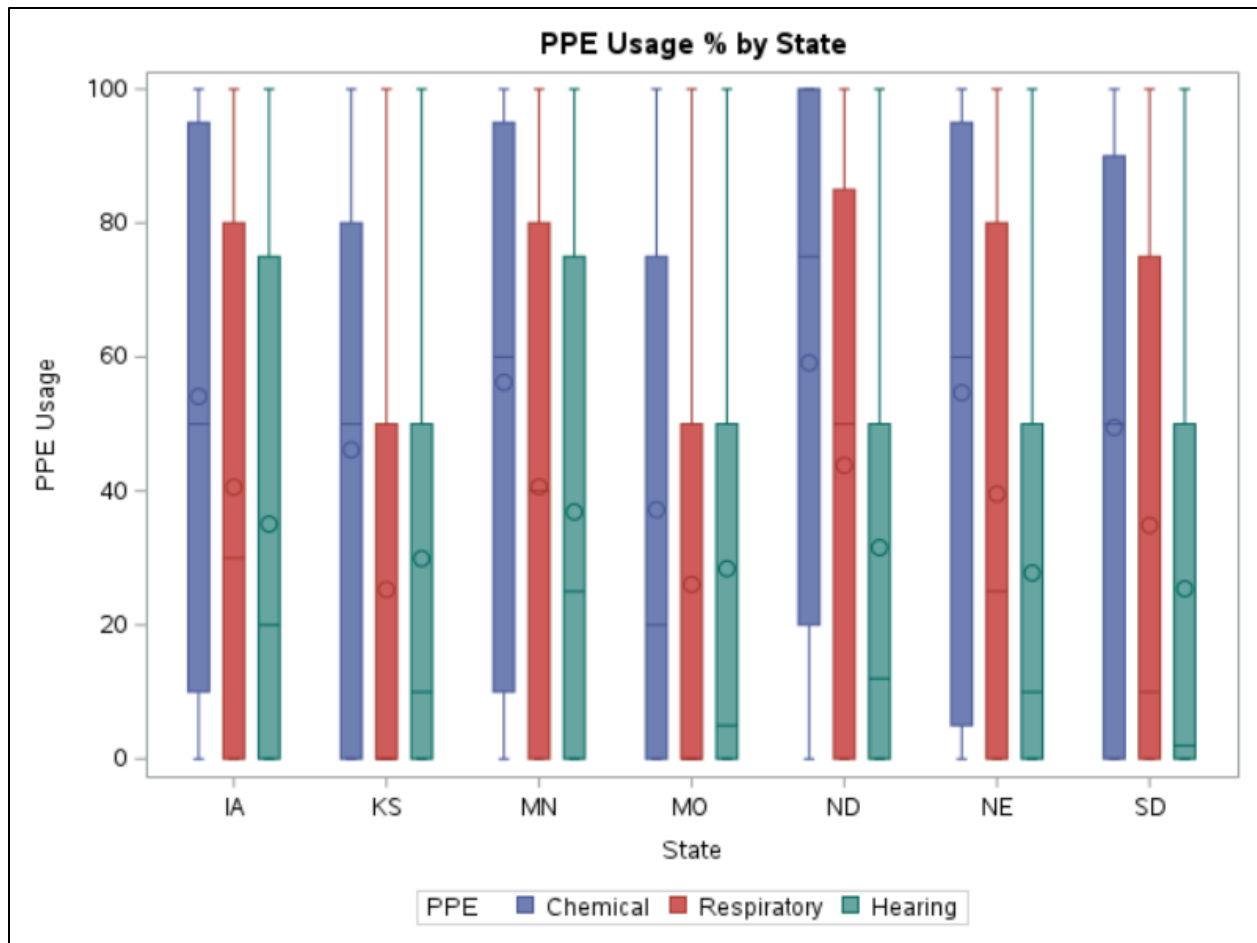


Figure 6. Vertical boxplots of PPE use percentage plotted by State for all PPE types.

In Figure 7, chemical PPE usage appears equal across all states, average respiratory PPE usage is lower in KS, MO, and use of hearing PPE is equivalently low in all states.

Results for Demographic and Farm Variable Analysis

Table 3. Chemical PPE usage. Multinomial logistic regression, OR, 95% confidence intervals and p-values.

Effect	Chemical PPE Usage Odds Ratio (95% CI)	P-value
Year of Survey		
2018	Ref.	
2020	1.17 (1.15, 1.18)	<0.05
State		

South Dakota	Ref.	
Iowa	1.43 (1.38, 1.48)	<0.05
Kansas	1.13 (1.12, 1.14)	<0.05
Minnesota	1.59 (1.57, 1.62)	<0.05
Missouri	0.63 (0.62, 0.63)	<0.05
North Dakota	1.37 (1.29, 1.44)	<0.05
Nebraska	1.52 (1.51, 1.53)	<0.05
Age Group (quartiles)		<0.0001
0-50	Ref.	
51-60	0.86 (0.86, 0.86)	<0.05
61-67	0.79 (0.78, 0.80)	<0.05
68-100	0.61 (0.61, 0.61)	<0.05
Gender		
Female	Ref.	
Male	1.26 (1.08, 1.47)	0.0032
Type of Farm		<0.0001
Livestock	Ref.	
Grain	1.60 (1.19, 2.15)	0.0019
Grain/Livestock	1.14 (0.93, 1.40)	0.2071
Percent Work Time on Farm/Ranch		<0.0001
0-24%	Ref.	
25-49%	1.51 (0.97, 2.34)	0.0659
50-74%	1.52 (1.04, 2.20)	0.0291
75-99%	1.50 (0.72, 3.10)	0.2783
100%	1.55 (0.78, 3.08)	0.2146
Occupation Type		
Ranch	Ref.	
Farm	1.26 (1.10, 1.43)	<0.0006

For the random effects, the odds of using chemical PPE for producers responding in 2020 were significantly higher (OR = 1.17, 95% CI [1.15, 1.18]) than those responding in 2018. The odds of using chemical PPE for producers in Iowa (OR = 1.43, CI [1.38, 1.48]), Kansas (OR = 1.13, 95% CI [1.12, 1.14]), Minnesota (OR = 1.59, 95% CI [1.57, 1.62]), North Dakota (OR = 1.37, 95% CI [1.29, 1.44]), and Nebraska (OR = 1.52, 95% CI [1.51, 1.53]) were significantly higher than producers in South Dakota. The odds of using chemical PPE for producers in

Missouri were significantly lower (OR = 0.63, 95% CI [0.62, 0.63]) than producers in South Dakota.

The age of the producers was significantly associated with the outcome of chemical PPE usage across all groups. The odds of using chemical PPE for those aged 51-60 were significantly lower (OR = 0.86, 95% CI [0.86, 0.86]) than those aged 0-50. The odds of using chemical PPE for those aged 61-67 were significantly lower (OR = 0.79, 95% CI [0.78, 0.80]) than those aged 0-50. The odds of using chemical PPE for those aged 68-100 were significantly lower (OR = 0.61, 95% CI [0.61, 0.61]) than those aged 0-50.

The odds of using chemical PPE for producers who were male were significantly higher (OR = 1.26, 95% CI [1.08, 1.47]) than those who were female.

The type of farm was significantly associated with the outcome of chemical PPE usage across all groups. The odds of using chemical PPE for producers on grain-only farms were significantly higher (OR = 1.60, 95% CI [1.19, 2.15]) than those on livestock-only farms.

The percent of work time spent on the farm/ranch was significantly associated with the outcome of chemical PPE usage across all groups. The odds of using chemical PPE for producers that spent 50-74% of their work time on the farm/ranch were significantly higher (OR = 1.52, CI [1.04, 2.20]) than those that spent 0-24% of their work time on the farm/ranch.

The odds of using chemical PPE for producers who indicated they were farmers were significantly higher (OR = 1.26, 95% CI [1.10, 1.43]) than for ranchers.

Table 4. Hearing PPE usage. Multinomial logistic regression, OR, 95% confidence intervals and p-values.

Effect	Hearing PPE Usage Odds Ratio (95% CI)	P-value
Year of Survey		
2018	Ref.	
2020	1.23 (0.68, 2.45)	>0.05
State		
South Dakota	Ref.	
Iowa	2.10 (1.32, 3.33)	<0.05
Kansas	1.83 (1.12, 2.98)	<0.05
Minnesota	1.89 (1.17, 3.04)	<0.05
Missouri	0.96 (0.60, 1.53)	>0.05
North Dakota	1.25 (0.71, 2.19)	>0.05
Nebraska	1.32 (0.80, 2.17)	>0.05
Age Group (quartiles)		<0.0001
0-50	Ref.	
51-60	0.92 (0.81, 1.05)	>0.05
61-67	0.85 (0.74, 0.98)	<0.05
68-100	0.71 (0.62, 0.82)	<0.05
Gender		
Female	Ref.	
Male	1.05 (0.93, 1.19)	0.4470
Type of Farm		<0.0001
Livestock	Ref.	
Grain	1.51 (1.28, 1.79)	<0.0001
Grain/Livestock	1.32 (1.11, 1.56)	0.0017
Percent Work Time on Farm/Ranch		0.1075
0-24%	Ref.	
25-49%	1.15 (0.97, 1.38)	0.1156
50-74%	1.33 (1.06, 1.65)	0.0129
75-99%	1.27 (1.01, 1.60)	0.0445
100%	1.19 (0.95, 1.49)	0.1205
Occupation Type		
Ranch	Ref.	
Farm	0.97 (0.81, 1.17)	0.7764

For the random effects, the odds of using hearing PPE for producers in Iowa (OR = 2.10 95% CI [1.32, 3.33]), Kansas (OR = 1.83, 95% CI [1.12, 2.98]), and Minnesota (OR = 1.89, 95% CI [1.17, 3.04]) were significantly higher than producers in South Dakota.

The age of the producers was significantly associated with the outcome of hearing PPE usage across all groups. The odds of using hearing PPE for those aged 61-67 were significantly lower (OR = 0.85, 95% CI [0.74, 0.98]) than those aged 0-50. The odds of using hearing PPE for those aged 68-100 were significantly lower (OR = 0.71, 95% CI [0.62, 0.82]) than those aged 0-50.

The percent of work time spent on the farm/ranch was not significantly associated with the outcome of hearing PPE usage across all groups. However, the odds of using hearing PPE for producers that spent 50-74% of their work time on the farm/ranch were significantly higher (OR = 1.33, 95% CI [1.06, 1.65]) as well as those that spent 75-99% of their work time on the farm/ranch were significantly higher (OR = 1.27, 95% CI [1.01, 1.60]) compared to those spending 0-24% of their work time on the farm/ranch.

The type of farm was significantly associated with the outcome of hearing PPE usage across all groups. The odds of using hearing PPE for producers on grain-only farms and those that produce both grain and livestock were significantly higher (OR = 1.51, 95% CI [1.28, 1.79]) and (OR = 1.31, 95% CI [1.11, 1.56]) respectively than those on livestock-only farms.

Table 5. Respiratory PPE usage. Multinomial logistic regression, OR, 95% confidence intervals and p-values.

Effect	Respiratory PPE Usage Odds Ratio (95% CI)	P-value
Year of Survey 2018 2020	Ref. 0.85 (0.48, 1.51)	>0.05
State South Dakota Iowa Kansas Minnesota Missouri North Dakota Nebraska	Ref. 1.53 (0.98, 2.39) 1.17 (0.73, 1.88) 1.44 (0.91, 2.30) 0.93 (0.59, 1.46) 1.46 (0.85, 2.52) 1.42 (0.88, 2.30)	>0.05 >0.05 >0.05 >0.05 >0.05 >0.05
Age Group (quartiles) 0-50 51-60 61-67 68-100	Ref. 0.90 (0.79, 1.03) 0.84 (0.73, 0.96) 0.66 (0.57, 0.75)	<0.0001 >0.05 <0.05 <0.05
Gender Female Male	Ref. 1.34 (1.18, 1.52)	<0.0001
Type of Farm Livestock Grain Grain/Livestock	Ref. 2.16 (1.81, 2.57) 1.37 (1.15, 1.64)	<0.0001 <0.0001 0.0005
Percent Work Time on Farm/Ranch 0-24% 25-49% 50-74% 75-99% 100%	Ref. 1.08 (0.90, 1.30) 1.42 (1.13, 1.79) 1.41 (1.11, 1.80) 1.58 (1.26, 1.99)	0.0011 0.4024 0.0026 0.0047 <0.0001
Occupation Type Ranch Farm	Ref. 1.19 (0.99, 1.44)	0.0700

The age of the producers was significantly associated with the outcome of respiratory PPE usage across all groups. The odds of using respiratory PPE for those aged 61-67 were significantly lower (OR = 0.84, 95% CI [0.73, 0.96]) than those aged 0-50. The odds of using respiratory PPE for those aged 68-100 were significantly lower (OR = 0.66, 95% CI [0.57, 0.75]) than those aged 0-50.

The odds using respiratory PPE for producers who were male were significantly higher (OR = 1.34, 95% CI [1.18, 1.52]) than those who were female.

The type of farm was significantly associated with the outcome of respiratory PPE usage across all groups. The odds of using respiratory PPE for producers on grain-only and grain and livestock farms were significantly higher (OR = 2.16, 95% CI [1.81, 2.57]), (OR = 1.37, 95% CI: [1.15, 1.64]) respectively than those on livestock-only farms.

The percent of work time spent on the farm/ranch was significantly associated with the outcome of respiratory PPE usage across all groups. The odds of using respiratory PPE for producers that spent 50-74% of their work time on the farm/ranch were significantly higher (OR = 1.422, 95% CI [1.13, 1.79]) than those that spent 0-24% of their work time on the farm/ranch. The odds of using respiratory PPE for producers that spent 75-99% of their work time on the farm/ranch were significantly higher (OR = 1.41, 95% CI [1.11, 1.80]) than those that spent 0-24% of their work time on the farm/ranch. The odds of using respiratory PPE for producers that spent 100% of their work time on the farm/ranch were significantly higher (OR = 1.58, 95% CI [1.26, 1.99]) than those that spent 0-24% of their work time on the farm/ranch.

Table 6. Skin Disease. Multinomial logistic regression, OR, 95% confidence intervals and p-values.

Effect	Reported Skin Disease Odds Ratio (95% CI)	P-value
Year of Survey 2018 2020	Ref. 0.68 (0.27, 1.70)	>0.05

State		
South Dakota	Ref.	
Iowa	0.62 (0.31, 1.24)	>0.05
Kansas	0.79 (0.39, 1.62)	>0.05
Minnesota	0.28 (0.12, 0.66)	<0.05
Missouri	1.39 (0.73, 2.67)	>0.05
North Dakota	0.39 (0.14, 1.08)	>0.05
Nebraska	0.65 (0.30, 1.41)	>0.05
Level of Chemical PPE Use		0.0029
High	Ref.	
Medium	1.14 (0.98, 1.31)	0.0825
Low	0.88 (0.77, 1.01)	0.0757
Age Group (quartiles)		<0.0001
0-50	Ref.	
51-60	1.42 (1.14, 1.75)	<0.05
61-67	2.21 (1.79, 2.74)	<0.05
68-100	4.09 (3.32, 5.03)	<0.05
Gender		
Female	Ref.	
Male	1.17 (0.99, 1.39)	0.0621
Type of Farm		0.2137
Livestock	Ref.	
Grain	0.84 (0.69, 1.03)	0.0894
Grain/Livestock	0.89 (0.73, 1.10)	0.2805
Percent Work Time on Farm/Ranch		0.9709
0-24%	Ref.	
25-49%	0.94 (0.74, 1.20)	0.6310
50-74%	0.97 (0.73, 1.30)	0.8468
75-99%	0.93 (0.69, 1.26)	0.6451
100%	0.92 (0.69, 1.23)	0.5905
Occupation Type		
Ranch	Ref.	
Farm	1.08 (0.86, 1.37)	0.5118

For the random effects, the odds of having a skin disease for producers in Minnesota (OR = 0.28, 95% CI [0.12, 0.66]) were significantly lower than producers in South Dakota.

The level of chemical PPE use was significantly associated with the outcome of reporting a skin disease across all groups. However, there were no significant differences when comparing the high, medium and low usage groups.

The age of the producers was significantly associated with the outcome of having a skin disease across all groups. The odds of having a skin disease for producers aged 51-60 were significantly higher (OR = 1.42, 95% CI [1.14, 1.75]) as were producers aged 61-67 (OR = 2.21, 95% CI [1.79, 2.74]) and producers aged 68-100 (OR = 4.09, 95% CI [3.32, 5.03]) compared to producers aged 0-50.

Table 7. Hearing Loss. Multinomial logistic regression, OR, 95% confidence intervals and p-values.

Effect	Reported Hearing Loss Odds Ratio (95% CI)	P-value
Year of Survey		
2018	Ref.	
2020	0.86 (0.43, 1.70)	>0.05
State		
South Dakota	Ref.	
Iowa	0.89 (0.53, 1.49)	>0.05
Kansas	0.98 (0.57, 1.68)	>0.05
Minnesota	0.86 (0.50, 1.48)	>0.05
Missouri	1.28 (0.77, 2.14)	>0.05
North Dakota	0.91 (0.48, 1.71)	>0.05
Nebraska	0.69 (0.39, 1.23)	>0.05
Level of Hearing PPE Use		0.0313
High	Ref.	
Medium	1.07 (0.94, 1.22)	0.3040
Low	0.93 (0.83, 1.04)	0.2062
Age Group (quartiles)		<0.0001
0-50	Ref.	
51-60	3.17 (2.75, 3.66)	<0.05
61-67	5.42 (4.66, 6.29)	<0.05

68-100	9.26 (7.95, 10.78)	<0.05
Gender	Ref.	
Female		
Male	3.09 (2.69, 3.55)	<0.0001
Type of Farm	Ref.	0.0369
Livestock		
Grain	0.81 (0.69, 0.96)	0.0142
Grain/Livestock	0.87 (0.74, 1.03)	0.1119
Percent Work Time on Farm/Ranch		0.0041
0-24%	Ref.	
25-49%	1.41 (1.17, 1.70)	0.0004
50-74%	1.16 (0.92, 1.47)	0.2205
75-99%	1.06 (0.83, 1.36)	0.6383
100%	1.11 (0.88, 1.40)	0.3976
Occupation Type	Ref.	
Ranch		
Farm	1.34 (1.10, 1.62)	0.0031

The level of hearing PPE use was significantly associated with the outcome of having hearing loss across all groups. However, there were no significant differences between the high, medium and low use groups.

The age of the producers was significantly associated with the outcome of having hearing loss across all groups. The odds of having hearing loss for producers aged 51-60 were significantly higher (OR = 3.17, 95% CI [2.75, 3.66]) and for producers aged 61-67 (OR = 5.42, 95% CI [4.66, 6.29]) and producers aged 68-100 (OR = 9.26, 95% CI [7.95, 10.78]) compared to those aged 0-50.

The odds of having hearing loss for male producers were significantly higher (OR = 3.09, 95% CI [2.69, 3.55]) than females.

The percent of work time spent on the farm/ranch was significantly associated with the outcome of having hearing loss across all groups. The odds of having hearing loss for those that

spent 25-49% of their work time on the farm/ranch were significantly higher (OR = 1.41, 95% CI [1.17, 1.70]) than those that spent 0-24% of their work time on the farm/ranch.

The odds of having hearing loss for those identifying as farmers were significantly higher (OR = 1.34, 95% CI [1.10, 1.62]) than for ranchers.

Table 8. Respiratory Disease. Multinomial logistic regression, OR, 95% confidence intervals and p-values.

Effect	Reported Respiratory Disease Odds Ratio (95% CI)	P-value
Year of Survey		
2018	Ref.	
2020	0.68 (0.32, 1.42)	>0.05
State		
South Dakota	Ref.	
Iowa	0.68 (0.39, 1.21)	>0.05
Kansas	1.04 (0.58, 1.85)	>0.05
Minnesota	0.52 (0.28, 0.96)	<0.05
Missouri	1.28 (0.74, 2.20)	>0.05
North Dakota	0.99 (0.50, 1.94)	>0.05
Nebraska	0.61 (0.32, 1.15)	>0.05
Level of Respiratory PPE Use		0.0044
High	Ref.	
Medium	1.17 (1.01, 1.36)	0.0392
Low	0.95 (0.83, 1.08)	0.4206
Age Group (quartiles)		<0.0001
0-50	Ref.	
51-60	1.05 (0.89, 1.24)	>0.05
61-67	1.27 (1.07, 1.50)	<0.05
68-100	1.53 (1.29, 1.81)	<0.05
Gender		
Female	Ref.	

Male	0.84 (0.73, 0.98)	0.0219
Type of Farm		0.0177
Livestock	Ref.	
Grain	0.81 (0.67, 0.98)	0.0309
Grain/Livestock	0.94 (0.78, 1.14)	0.5246
Percent Work Time on Farm/Ranch		0.0237
0-24%	Ref.	
25-49%	1.31 (1.06, 1.62)	0.0141
50-74%	1.30 (1.00, 1.69)	0.0540
75-99%	1.04 (0.79, 1.38)	0.7776
100%	1.11 (0.85, 1.45)	0.4477
Occupation Type		
Ranch	Ref.	
Farm	1.06 (0.86, 1.31)	0.5848

For the random effects, the odds of having a respiratory disease for producers in Minnesota (OR = 0.52, 95% CI [0.28, 0.96]) were significantly higher than producers in South Dakota.

The level of respiratory PPE use was significantly associated with the outcome of having a respiratory disease across all groups. The odds of having a respiratory disease for producers in the medium PPE usage group were significantly higher (OR = 1.17, 95% CI [1.01, 1.36]) than those in the high PPE usage group.

The age of the producers was significantly associated with the outcome of having a respiratory disease across all groups. The odds of having a respiratory disease for producers aged 61-67 were significantly higher (OR = 1.27, 95% CI [1.61, 1.50]) as was the odds for producers aged 68-100 compared to producers aged 0-50.

The odds of having a respiratory disease for male producers were significantly lower (OR = 0.84, 95% CI [0.73, 0.98]) than females.

The percent of work time spent on the farm/ranch was significantly associated with the outcome of having a respiratory disease across all groups. The odds of having a respiratory disease for producers that spent 25-49% of their work time on the farm/ranch were significantly higher (OR = 1.31, 95% CI [1.06, 1.06]) than those that spent 0-24% of their work time on the farm/ranch.

Chapter 5: Discussion

Chemical PPE

In the multinomial logistic regression focusing on chemical PPE usage as the outcome, producers in Iowa, Kansas, Minnesota, North Dakota, and Nebraska had significantly higher chemical PPE use than producers in South Dakota. Producers in Missouri had significantly lower chemical PPE use than producers in South Dakota.

The age group variable split into four quartiles was significantly associated with chemical PPE use. The first quartile (ages 0-50) had the largest odds of more frequent chemical PPE use followed by quartile 2 (ages 51-60), 3 (ages 61-67), and 4 (ages 68-100) respectively. This supports the hypothesis that as age increases, chemical PPE use appears to decrease. Previous studies have found similar trends in pesticide PPE use and age among farm producers²⁴. A possible explanation for the trend could be the perception of the threat of injury and education regarding PPE use²⁴. These factors could differ between different ages, and future research could explore these factors relating to the ages of farm producers.

Gender was also significantly associated with chemical PPE use. Males had significantly larger odds of using chemical PPE more often than females. Previous findings suggest that men may have more knowledge regarding the risks of pesticide use²⁵ thereby explaining the difference in PPE use between men and women.

Producers on farms that produced only livestock had significantly lower odds of using chemical PPE than those working on grain-only farms. A possible explanation could be that livestock farmers may be less likely to use pesticides compared to grain farms²⁶. However, there seems to be little research in the United States on the differences between grain and livestock farmers relating to pesticide use. This finding warrants further research.

Producers that spent only 0-24% of their work time on the farm/ranch had significantly smaller odds of higher chemical PPE use than all other categories producers that spent 25-49% and 50-74% of work time on the farm/ranch. Additionally, those identifying as farmers had significantly larger odds of higher chemical PPE use than identifying as ranchers. Full-time farmers may experience illness and injury more often due to levels of exposure to pesticides compared to part-time producers²⁷. Part-time producers experiencing less injuries and illness could result in less concern for hazards during work and less PPE use overall.

In the logistic regression focusing on the outcome of skin disease/injuries and chemical PPE usage including all other covariates, chemical PPE usage was significantly associated with the outcome. However, there were no significant differences between the categories of chemical PPE usage, so it is not clear if the use of PPE was positively or negatively associated with having a skin disease/injury.

Hearing PPE

In the multinomial logistic regression with hearing PPE usage as the outcome, producers in Iowa, Kansas, and Minnesota had significantly higher hearing PPE use than producers in South Dakota.

The age of the respondents split into four quartiles was significantly associated with the hearing PPE usage, with quartile 1 (ages 0-50) having the largest odds of higher hearing PPE usage followed by quartile, 2 (ages 51-60), 3 (ages 61-67), and 4 (ages 68-100). However, the 51-60 age group was not significantly different when compared to the 0-50 group. As seen with the chemical PPE regression results, as age increases, hearing PPE usage frequency decreases.

Unlike the results for chemical and respiratory PPE, gender was not significantly associated with hearing PPE use. It could be possible that while the difference for gender in chemical PPE could have been due to differences in knowledge of pesticide risk, men and women share a similar understanding of the risks of hearing loss in loud environments²⁵.

Producers on livestock-only farms had the smallest odds of higher hearing PPE use compared to grain-only farms and farms that produce both. The difference could be due to livestock producers encountering less noise while working, but there is no current research to validate this possibility. A large portion of the auditory risk in agriculture comes from machinery, grain farmers being more likely to use machinery such as tractors could result in differences in noise levels between the two farm types⁴.

The percentage of work time spent on the farm/ranch was not significantly associated with the hearing PPE use outcome. However, those in the 50-74% group and the 75-99% group had significantly higher odds of PPE use than the 0-24% group.

In the multinomial logistic regression modeling the odds of a lower level of hearing loss, hearing PPE use categories were significantly associated with the outcome of hearing loss. However, there were no significant differences between the categories of hearing PPE usage, so it is not clear if the use of PPE was positively or negatively associated with having hearing loss.

Respiratory PPE

The age groups split into four quartiles were significantly associated with the respiratory PPE use outcome. The results follow the same trend of the chemical and hearing PPE results with quartile 1 (ages 0-50) having the largest odds of respiratory PPE use followed by quartile 2 (ages 51-60), 3 (ages 61-67), and 4 (ages 68-100). However, the 51-60 age group was not significantly different when compared to the 0-50 group. This supports that higher age seems to be associated with lower respiratory PPE use frequency.

The respiratory PPE use results mirrored the chemical PPE results regarding gender, as males had significantly higher odds of higher respiratory PPE use than females.

The results for the type of farm were significantly associated with the outcome of respiratory PPE use as with chemical and hearing PPE use. Grain farmers had the highest PPE use compared to livestock farmers.

The percentage of work time spent on the farm/ranch was also significantly associated with the outcome of respiratory PPE use. The respiratory PPE regression showed a general trend that more time spent on the farm resulted in larger odds of respiratory PPE use.

Producers identifying as farmers had larger odds of higher respiratory PPE use compared to ranchers, which is similar to the results of the chemical PPE regression.

In the logistic regression modelling the odds of having a respiratory disease and use of respiratory PPE, the two variables were significantly associated. The medium usage group had significantly higher odds of having a respiratory disease than the high usage group.

Interpretation and Overall Trends

The primary goal of this analysis was to identify trends in the demographic and farm type variables of agriculture producers who responded to the CS-CASH survey in 2018 and 2020 and determine how these variables relate to PPE use. For all PPE types, age was found to be associated with PPE use, with the youngest quartile reporting the highest use of PPE. Males were more likely than females to use chemical and respiratory PPE, but gender difference was not seen in the use of hearing PPE. Livestock farmers tended to use PPE less often in all PPE types, while grain-only producers used PPE the most often. Those working 0-24% of work time on the farm/ranch had the lowest PPE usage across all types of PPE. Ranchers had lower chemical PPE use than did farmers. Iowa, Kansas, and Minnesota producers had significantly higher PPE use for chemical and hearing PPE use when accounting for all other variables.

Although training, and other interventions should continue for all agricultural sectors, special emphasis should focus on those groups reporting the lowest PPE usage: older agricultural producers, female producers, livestock producers, and those that only spend 0-24% of time on the farm/ranch and identify as ranchers.

A secondary goal of this analysis was to provide more insight based on the survey data on the effectiveness of PPE in preventing injuries and disease. All three regressions showed that the PPE usage variable was significantly associated with the outcome. However, respiratory PPE was the only type to have a significant difference between the categories themselves. The results

aren't very conclusive on these analyses even though the PPE use variable was significant in all the analyses. A possible explanation for the lack of significant difference between the individual categories is that already having an injury/disease could lead to more PPE use to prevent further damage. To better 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.

Strengths and Limitations

This analysis was able to take a large data set of survey data from seven central US states and provide insight into possible variables that may be associated with lower PPE use. While previous studies have looked at interventions to improve PPE use, there is not much data on what types of farms and producers may use PPE less often. A strength of this analysis was the use of data imputation in SAS to account for missing data, as not every survey participant responded to every question. However, these results are not generalizable beyond the states the survey was completed. Additionally, the survey data was only from two single points in time (2018 and 2020 surveys). PPE usage among the survey respondents could vary as time goes on. A beneficial next step would be completing a longitudinal analysis of the data when further years of surveys become available to provide a more accurate representation of the overall PPE use across the different variables.

Additionally, the results of the secondary analyses focused on injury/disease and PPE use were not very conclusive.

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