5-2023

Assessing Occupational Exposure Risk and COVID-19 Incidence Rates in Nebraska by Industry and Occupation, 2020

Christopher Austin
University of Nebraska Medical Center

Assessing Occupational Exposure Risk and COVID-19 Incidence Rates in Nebraska by Industry and Occupation, 2020

Christopher Austin, University of Nebraska Medical Center, MPH Student

College of Public Health: Environmental and Occupational Health Concentration

<u>Capstone Committee</u>

Committee Chair: Eleanor Rogan, PhD, UNMC – College of Public Health, Professor, and Interim Chair
Committee Member: Cheryl Beseler, PhD, UNMC – College of Public Health, Associate Professor
Committee Member: Derry Stover, MPH, Nebraska Department of Health and Human Services, Office of Epidemiology, Epidemiology Surveillance Coordinator.

Abstract: Occupational outbreaks of COVID-19 have been described during the pandemic, yet the epidemiology of COVID-19 across a larger workforce population is currently not well characterized in the United States. Describing COVID-19 incident rates by industry and occupation will elucidate how the pandemic affected the workforce in Nebraska. However, nonresponse bias occurs in the employment information when participants are unwilling or unable to respond to contract tracer questions, thus affecting the results. Nonresponse bias will be analyzed, and appropriate statistical approaches will be utilized to adjust for any bias in the data. Adjusting for bias, incidence rates by detailed industry and occupation groups will be calculated using employment data from American Community Survey Public Use Microdata Sample data. Comparison of occupational incidence rates to the Council of State and Territorial Epidemiologists SARS-CoV-2 Occupational Exposure Matrix highlights its potential use to identify occupations with high, medium, and low exposure risks. By describing how Nebraska's workforce was affected by the COVID-19 pandemic, and identifying what occupations are at higher risk for COVID-19 exposures, we can better to develop improved prevention strategies.

Glossary

ACS: American Community Survey

CSTE: Council of State and Territorial Epidemiologists

FTE: Full-time Equivalency

NIOCCS: NIOSH Industry and Occupation Computerized Coding

NIOSH: National Institute for Occupational Safety and Health

PUMS: Public Use Microdata Sample

SOEM: SARS-CoV-2 Occupational Exposure Matrix

CHAPTER 1: INTRODUCTION

In 2020, COVID-19 outbreaks in workplaces across the United States emphasize that the work environment contributes to the risk of disease transmission in these settings [1-4]. To effectively prevent the spread of COVID-19 in the workplace and protect workers and their communities, it is vital to understand which occupations pose a higher risk of SARS-CoV-2 exposure. Therefore, this project seeks to identify occupational exposure risk using Nebraska COVID-19 case investigation data in conjunction with the Council of State and Territorial Epidemiologists (CSTE) SARS-CoV-2 Occupational Exposure Matrix (SOEM) developed by the CSTE Occupational Health Subcommittee - Exposure Measures Team. In doing so, this project will analyze COVID-19 incidence rates by industry and occupation and test whether occupation exposure risk to SARS-CoV-2, the virus the causes COVID-19, corresponds to risk levels as outlined in the SOEM. This information can guide the development of intervention strategies to reduce exposure and determine vaccination priorities. Furthermore, validating occupational exposure risk levels for can help develop better public health policies and interventions and understand which occupations are at the highest risk of exposure to SARS-CoV-2; policymakers can develop targeted interventions to reduce transmission rates.

Nebraska's COVID-19 work-related information, such as industry and occupation, is often underreported in case investigation data due to nonresponses during investigations. Thus, individuals less likely to respond during the case investigation survey are typically underrepresented in the final sample, leading to biased estimates of population responses [5]. This study proposes developing a logistical regression model to calculate response probabilities. To adjust for nonresponse bias in the data the inverse of the predicted response probability for each individual response represents the weighting factor for that individual [6]. By assigning the response weight estimates to each respondent, COVID-19 incidence rates by industry and occupation can be adjusted to correct for any over- or underrepresentation in the final sample.

The Creation of the SARS-CoV-2 Occupational Exposure Matrix

An Occupational Exposure Matrix (OEM) is used in occupational epidemiology to systematically quantify and document potential workplace exposures to various chemicals, physical agents, and other hazards. In addition, an OEM can be used to evaluate associations between exposure and health outcomes such as occupational diseases [7].

A simple OEM typically consists of a matrix with occupation titles or categories listed along one axis and exposures or hazard agents listed along the other axis. The cells of the matrix indicate the level or frequency of exposure for each job and hazard combination. The level of exposure can be represented in different ways, such as categorical, ordinal, or continuous values.

An example OEM matrix shows the potential exposure levels for benzene, asbestos, and silica dust for different occupations (Table 1). The level of exposure is categorized as low, medium, or high. The OEM can be used to identify jobs with high levels of exposure and to investigate the association between exposure and health outcomes. It is worth noting that OEMs can vary in complexity and detail, depending on the scope of the study, the available data sources, and the specific exposure categories of interest.

Table 1 An Occupational Exposure Matrix for benzene, asbestos, and silica dust

Job title	**Benzene**	**Asbestos**	**Silica dust**
Painter	Low	Low	Low
Welder	Medium	High	Low
Carpenter	Low	Low	Medium
Electrician	Low	Low	Low

In 2021 the SOEM was created as a risk-based approach to identifying non-healthcare occupations when in the workplace that are likely to be at increased risk of exposure to SARS-CoV-2. The CDC and state jurisdictions had already defined health care workers as a distinct group at high risk of exposure to SARS-CoV-2 to prioritize exposure controls and vaccine allocation, so they focused on non-health care occupations [8].

The SOEM categorizes the risk of exposure based on three criteria: occupations involving routine in-person interaction with the public (Public-Facing), working indoors (Working Indoors), and working in close physical proximity to others, either co-workers or the public (Close Proximity) [8]. These criteria are derived from the Bureau of Labor Statistics O*NET questionnaire, a national database with information on occupational characteristics surveying workers in each occupation and occupational experts.

The workgroup developed an ordinal ranking of the level of exposure for each of the three risk factors – Public-Facing work, Working Indoors, and Close Proximity, to classify occupations into high, low, and medium exposure levels. However, two Close Proximity measures were designated; Close Proximity Measure 1, based only on O*NET scores, and Close Proximity Measure 2, based on O*Net scores coupled with expert review that reranked Close Proximity measure. The workgroup manually reviewed job descriptions using the O*NET questionnaire responses and their knowledge to determine occupation exposure level designations. The workgroup consulted with health and safety experts and developed decision rules to modify O*NET exposure levels for some occupations where they believed the exposure level designation was too high or low. However, because the exposure designations for Close Proximity were changed for many occupations two Close Proximity measures were designated [8]. Finally, higher-risk occupations were designated as having the highest exposure level for at least two of the three exposure measures. Lower-risk occupations were designated as Not Close and Not Public Facing, regardless of whether they worked indoors or outdoors. Medium-risk occupations were all remaining exposure combinations [8].

Using the SOEM along with occupation incidence rates in Nebraska, we can understand the relationship between occupational exposures and COVID-19 incidence rates better. Specifically, developing a method to categorize occupation incidence rates by the SOEM exposure risk levels to determine that higher exposure risks lead to higher incidence rates. This may contribute to a better understanding of the risks of occupational exposure to SARS-CoV-2 and can inform the development of workplace policies and practices to reduce the risk of COVID-19 transmission among workers. It also may provide a valuable tool for researchers and policymakers to better understand the relationship between occupational exposures and COVID-19 incidence rates, which can inform the development of evidence-based policies and programs to reduce the risk of COVID-19 transmission among workers.

Specific Aims

Specific Aim 1: Develop a logistic regression model to calculate the predicted probability of response for each individual as the estimated probability that the individual will respond to a survey or questionnaire based on their characteristics (i.e., age, sex, race, ethnicity, local health district, and sample month). Adjust for nonresponse using a weighting factor to account for differences between respondents and non-respondents.

Specific Aim 2: Using weighted responses from Aim 1, calculate and analyze incident rates for industry and occupation using the Census American Community Survey Public Use Microdata Sample data for denominator values, adjusting for full-time equivalent.

Specific Aim 3: The SOEM utilizes O*NET, a national database with information on occupational characteristics, to determine occupational COVID-19 exposure risk levels. Using occupational incidence rates calculated in Aim 2, validate the SOEM by determining if there are any significant differences among adjusted occupation incident rates when grouped by their exposure risk levels in the SOEM. A Kruskal-Wallis test will determine if there are any significant differences between risk levels.

CHAPTER 2: BACKGROUND AND SIGNIFICANCE

Background

On February 17, 2020, 13 individuals who tested positive for COVID-19 were evacuated from the Diamond Princess cruise ship and transported to the University of Nebraska Medical Center's National Quarantine Unit [9]. Nebraska had its first case in early March, separate from the cruise ship passengers. Multiple outbreaks followed at meat processing facilities in Nebraska and the United States in April and May 2020 [10-12]. Work conditions that require workers to work close to each other for long periods and evidence that SARS-CoV-2 spreads through airborne transmission increase the risks of infections among this population [13]. These outbreaks affected the country's meat supply and temporarily closed several meatpacking plants in Nebraska. These meatpacking outbreaks pushed Nebraska's overall case rates to one of the highest in the U.S. in the first wave of 2020 [14-17].

COVID-19 and other infectious diseases highlight the importance of occupational health surveillance in preventing the spread of illness in the workplace. Since the onset of the COVID-19 pandemic, employers have implemented various measures to protect workers from exposure to the virus, including social distancing, personal protective equipment, and screening measures [18]. Occupational health surveillance programs have played a critical role in identifying and monitoring potential COVID-19 outbreaks in the workplace, facilitating contact tracing and testing, and implementing appropriate interventions to prevent further virus transmission. Effective occupational health surveillance programs can ensure that workers remain healthy and productive while preventing the spread of infectious diseases in the workplace.

The transmission of SARS-CoV-2 is affected by work condition characteristics, such as routine in-person interaction with the public, working indoors, and frequent or prolonged contact with customers or colleagues in close physical proximity [18]. These occupations are associated with increased rates of severe illness and even death due to COVID-19, especially for healthcare workers who experienced high exposure rates and infection rates during the pandemic [19, 20]. While most studies mainly focused on healthcare occupations and industries, only a few studies have compared COVID-19 risk across different occupations and industries in the United States due to the need for more standardization in collecting and reporting occupational data among public health systems in the United States [21]. This lack of real-time occupational COVID-19 surveillance has resulted in delays in identifying and responding to outbreaks or increased workplace transmission. In addition, it has limited the ability to identify high-incidence occupations and industries that require public health resources and policy considerations. Moreover, this limitation could exacerbate COVID-19-related racial and ethnic disparities linked to occupational differences.

Furthermore, the impact of essential workers on incidence rates cannot be overstated. According to data from the US Bureau of Labor Statistics (BLS), the incidence rate for COVID-19 among healthcare and social assistance workers was about 3.9 times higher than the overall incidence rate for all workers in 2020 [22]. Similarly, workers in the transportation and warehousing industry had an incidence rate about 2.4 times higher than the overall rate, and those in the retail industry had an incidence rate about 2.2 times higher [22].

Other essential workers, such as those in food processing and agriculture, also had elevated incidence rates for COVID-19. In some cases, outbreaks among workers in these industries led to temporary closures of facilities and disruptions in the food supply chain [23, 24].

Therefore, the impact of essential workers on occupational incidence rates for COVID-19 in 2020 highlights the critical role these workers played in responding to the pandemic. However, it also indicates the need for protective measures, such as personal protective equipment, workplace modifications, and access to vaccines, to help mitigate the risk of exposure and ensure the safety of essential workers [25].

The COVID-19 pandemic has underscored the significance of occupational health and safety in safeguarding workers against infectious diseases. It has also shed light on the need for improved occupational health surveillance to understand better the public health impact of occupational exposures to infectious diseases and to develop effective prevention and control strategies. By improving the collection and analysis of data on work-related exposures and health outcomes, occupational health surveillance can provide more timely and accurate information to support public health interventions and protect worker health and safety.

Nebraska ranks third nationally with the highest concentration of jobs in the meat processing occupation, with 1.88 employment per 1,000 jobs [26]. Therefore, it should not be surprising that Nebraska's meat processing occupations were among the first to experience large outbreaks of COVID-19 early in the pandemic; however, there is limited knowledge regarding which other occupations and industries in Nebraska were affected by COVID-19. Thus, this project aimed to elucidate COVID-19 incidence rates among other occupations and industries in Nebraska using occupational data collected from March 2020 through the end of December 2020. This period corresponds to the initial significant COVID-19 surge in Nebraska. It offers a clearer understanding of work settings with high COVID-19 risk during this time and where initial vaccines were limited to select populations across the United States.

Nebraska was among the first jurisdiction in the United States to use standardized occupational data collection for COVID-19 starting in the initial month of the pandemic, and the main priority was to showcase the benefits of this method for occupational surveillance of COVID-19 and other illnesses to elucidate industry and occupational incidence rates.

Occupational health has its roots in the industrial revolution of the 18th and 19th centuries, when large numbers of workers were exposed to hazardous working conditions in factories and mines [27]. As a result, measures to protect workers' health became increasingly necessary. Today, this remains even more valid. However, with the emergence of COVID-19, occupational health has been a rapidly evolving field, with new challenges arising as the nature of work and the workplace continuously evolves.

Significance

Published literature on COVID-19 statewide incidence rates by industry and occupation during the initial months of the COVID-19 pandemic is limited. Nebraska COVID-19 case investigation data is unique in capturing employment narratives during the initial months of the pandemic; gaining insight into the industries and occupations that encountered a higher burden of COVID-19 cases is a critical step in understanding more accurately how industries and occupational work settings and characteristics facilitated SARS-CoV-2 exposure before public health officials implemented mitigation measures to reduce virus transmission and before researchers developed any vaccines. In addition, knowing which industries and occupations have higher incidence rates can help implement mitigation measures to reduce exposure.

Currently, no published research utilizes statewide occupation incidence rates of COVID-19 to confirm that increased exposure risk to SARS-CoV-2 is associated with higher incidence rates. This work is the first known attempt to relate statewide occupational incidence rates to occupational exposure risk from the SOEM. The fact that this work is the first known attempt to relate statewide occupational incidence rates to occupational exposure risk is particularly noteworthy because it provides a new perspective on understanding the impact of work characteristics on COVID-19 incidence rates. By demonstrating that higher exposure risks lead to higher incidence rates, this work can serve as a valuable tool for epidemiologists and public health officials to identify high-risk occupations and develop targeted interventions to reduce the spread of the virus in occupational settings.

Lastly, we must address nonresponse bias in COVID-19 case investigation surveys, a crucial issue in biased data. An established method for dealing with nonresponse bias survey data can help analyze bias and establish a method to adjust for it. It is imperative to calculate incidence rates and identify occupational exposure risks accurately. As Nebraska moves towards more effective methods of capturing employment narratives, like using REDCap, developing a method to deal with nonresponse bias in survey data will significantly improve data analysis and will be a significant step to deal with bias since there is not a well-established method within NDHHS Epidemiology division to address bias in survey data. Thus, by establishing a method for calculating weighted incidence rates a hypothesis that higher SARS-CoV-2 exposure risk led to higher occupation incidence rates can be tested with more accuracy.

CHAPTER 3: DATA AND METHODS

Study Design

Aim 1, n=126,667 COVID-19 total cases, are analyzed for response rates. Cases with an industry response, n=63,490 (50.1%), cases with an occupation response, n=103,169 (81.4%); and n=45,051 cases with missing employment data. The logistical regression model used to calculate response probabilities:

$$log(\text{odds of response}) = \beta_0 + \beta_1(age) + \beta_2(sex) + \beta_3(race) + \beta_4(local\_health\_district) + \beta_5(sample\_month)$$

β_0 is the intercept (the log-odds of response when all predictor variables are zero). β_1, β_2, β_3, β_4, β_5 are the regression coefficients for age, sex, race, local_health_district, and sample_month, respectively.

Aim 2, incidence rates calculated from cases with industry sector codes (n= 56,963), occupation major group codes (n=51,932), and 5-year workforce estimates for denominator values.

Aim 3 calculates mean and median occupational incidence rates categorized by their occupational exposure risk: low (n=133), medium (n=98), and high (n=92) for proximity measure 1 and low (n=98), medium (n=101), and high (n=124) for proximity measure two. A Kruskal-Wallis test for significance between risk categories.

Study Population and Setting

For this study, we will use confirmed and probable COVID-19 case investigation data of working-age 16 – 64 individuals living in Nebraska. Case data in Nebraska was collected via phone-based interviews from March 1st, 2020, through December 31st, 2020. Excluded from this study were retired, unemployed, or military responses. Although reinfection during the early period of the pandemic was rare, this study does not include any cases that meet the criteria of reinfection.

Data Sources and Key Variables

Nebraska COVID-19 case investigation data comes from the State of Nebraska's Department of Health and Human Services Nebraska Electronic Disease Surveillance System (NEDSS). Coding industry and occupation free text fields to standard North American Industry Classification System (NAICS), Standard Occupational Classification (SOC) system, and Census Occupation Code (COC) using NAICS Industry and Occupation Computerized Coding System (NIOCCS) web application that autocodes industry and occupation free text fields to standardized industry and occupation titles and codes, using the NAICS, SOC, and COC classification systems.

Industry and occupation incidence rates using denominator values from the American Community Survey (ACS) Public Use Microdata Sample (PUMS) data for industry and occupation using 5-year estimates values for the industry sector, subsector, and major occupational groups. Denominator values are adjusted for full-time equivalent (FTE) using the estimated weekly work hours included in the ACS PUMS data, including 95% confidence intervals for each corresponding denominator value.

FTE is a unit of measurement that represents the total number of hours worked by one employee on a full-time basis. It is used to compare the workload of part-time or temporary employees to that of full-time employees. For example, two part-time employees who each work 20 hours per week would be equivalent to one full-time employee who works 40 hours per week, or one FTE. Thus, by dividing weekly work hours provided in the PUMS data by 40 we can adjust estimated workforce populations to FTE workforce estimates for each industry sector, subsector, and major occupational groups.

Critical variables included in the COVID-19 dataset include test results, age, sex, race, ethnicity, sample collection, local health department jurisdiction, employer, occupation, industry, and healthcare worker. The logistic regression model's response predictors include age, sex, race, sample collection month, and local health department, with created variables "industry response" and "occupation response" as the response outcome. Key variables to calculate incidence rates include industry sector code, industry sub-sector code, occupation code, major occupation code, and ACS 5-year FTE estimates.

Analytic plan

For Aim 1, n=126,667 COVID-19 cases were analyzed from the 2020 case investigation dataset. For the logistic regression model, the response variable, industry or occupation, is binary (i.e., yes/no or 1/0), representing whether or not an individual responds to the case investigation survey. The logistic regression model estimates the probability of response as a function of the independent variables (i.e., age, sex, race, local health district, and sample month) and will generate a predicted probability of response for each individual in the dataset. Generation of the logistic regression model was based on respondents' age, sex, race, local health district, and sample month using the statistical programming language GNU R version 4.2.2. To guide the model building and evaluation draws upon the techniques described in Hosmer et al. [28]. The glm() function is used in R to fit the logistic regression model. In addition, the family = binomial() argument specifies that we want to use a binomial distribution for the response variable, which is appropriate for binary outcomes. The predicted response probability for each individual is the estimated probability that the individual will respond to a survey or questionnaire based on their characteristics (i.e., age, sex, race, ethnicity, local health district, and sample month) as modeled by a logistic regression model.

To adjust for nonresponse bias, I followed the weighting method described by Bethlehem et al. [29]. Specifically, calculating the weighting factor for each individual as the reciprocal of their predicted probability of response, or 1/p, where individuals with a lower predicted response probability receive a higher weighting factor. In contrast, individuals more likely to respond to the survey (i.e., have a higher predicted response probability) are assigned a lower weighting factor, drawing upon the broader concepts and methods related to survey design and nonresponse bias, as described in Groves et al. [30].

For Aim 2, industries and occupations are autocoded, using the NIOCCS web application, to NAICS, SOC, and COC classification systems. In addition, some missing industry information may use existing employer data when present to manually code missing industry sectors. Therefore, I calculated weighted industry and occupation (Aim 1) incidence rates using denominator values from ACS PUMS 5-year estimates, adjusting rates to FTE. Standard error values used to calculate the relative standard error to determine which estimates to exclude from the analysis. Workforce estimates adjust to FTE that have a relative standard of 0.30 or greater are excluded from analysis due to unreliability in their estimates.

For Aim 3, weighted incidence rates for occupations will be categorized by their exposure risk levels (low, medium, or high) from the SOEM that estimates the potential occupational exposure risk of COVID-19. I generated a box plot to analyze occupation incidence rates categorized by low, medium, and high exposure risk levels, along with the corresponding mean and median calculations. I explored two statistical approaches to determine if there was a significant difference between any of the three exposure risk groups. After checking assumptions, I used Kruskal-Wallis rank test to determine significant differences between the groups ($p<0.05$) for nonparametric datasets.

CHAPTER 4: RESULTS

Study outcomes

For Aim 1, the primary outcome is response weights calculated using logistic regression with response as an outcome and sex, age, race, local health departments, and specimen collection month as significant predictors of response ($p < 0.05$). In Aim 2, the main outcomes are weighted and non-weighted incidences rates by industry sectors, industry sub-sectors, and occupation major groups. For Aim 3, the primary outcome is a significant difference ($p < 0.01$) between occupational incidence rates when categorized by their exposure occupational exposure risk levels using the Kruskal-Wallis rank test.

Proportional Distribution of Cases and Workforce by Industry Sector

The proportional distribution of Nebraska COVID-19 cases and workforce by industry sector revealed that Healthcare had the highest proportion of cases, with 20%, despite only representing 14% of the workforce (Fig 1). Manufacturing makes up 15% of the cases while only representing 12% of the workforce followed by Educational Services having 11% of the cases, while only representing 10% of the workforce. Accommodation and Food Services account for 6% of the cases while only representing 5% of the workforce. However, Professional, Scientific, and Technical Services comprise 3% of the cases while representing a higher percentage of the workforce with 5%.

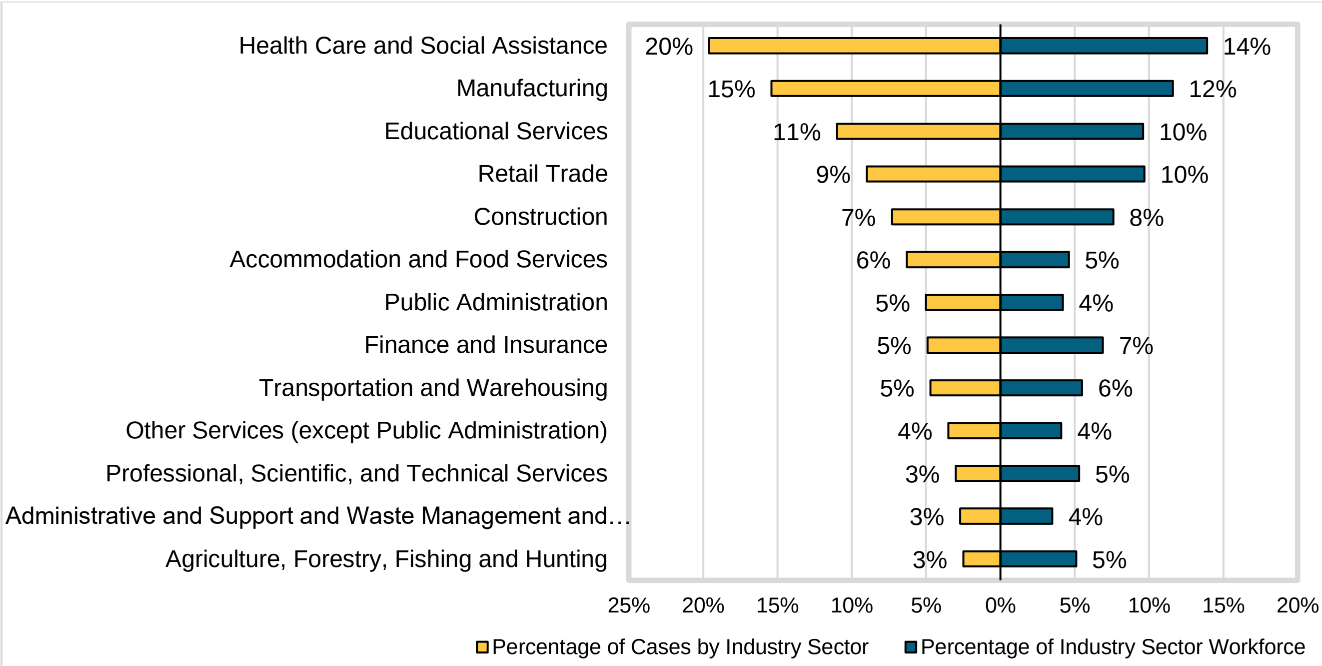

Figure 1 Proportions of COVID-19 Cases and Workforce by Industry Sectors, March 2020 – December 2020. *The proportions of COVID-19 cases by industry sectors represents the percentage of COVID-19 cases by industry sector from the total number of cases. The proportion of each industry sector as a percentage of the total workforce.*

Incidence Rates by Industry Sector

Incidence rates by industry sector show that the Healthcare sector had the highest incidence rate of COVID-19 with 18.4 per 100 FTE, followed closely by the Accommodation and Food Service industry with an incidence rate of 17.8 per 100 FTE (Fig 2). The Manufacturing industry had the third highest incidence rate with 17.3 per 100 FTE. The Public Administration sector had the fourth highest incidence rate with 15.5 per 100 FTE. This sector includes government workers responsible for essential services, such as law enforcement and emergency management. Next, Educational Services had an incidence rate of 14.8 per 100 FTE. This sector includes workers in schools, colleges, and universities. These industries all had significantly elevated risk when compared to all other industries.

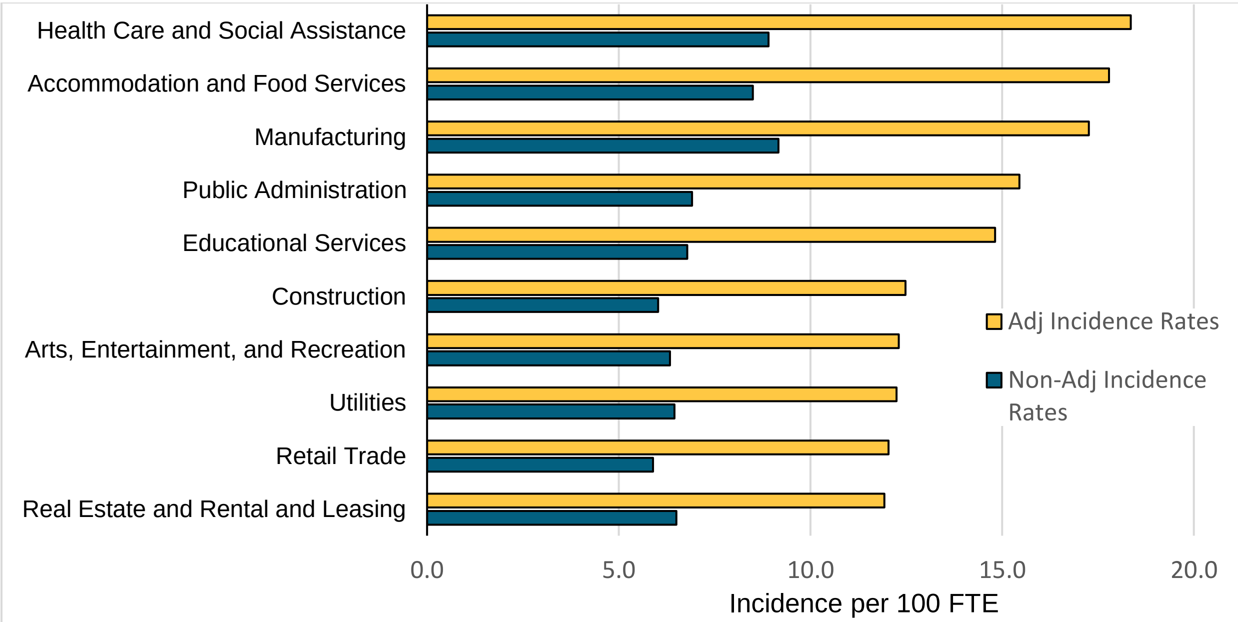

Figure 2 Incidence per 100 full-time equivalent (FTE) worker by industry sector Nebraska, March 2020 – December 2020. *Industry classified using the 2012 North American Industry Classification System (NAICS).*

Incidence Rates by Industry Sub-Sector

COVID-19 incidence rates among 86 industry sub-sectors analyzed found that Food Manufacturing had the highest incidence rate with 32.9 per 100 FTE (Fig 3). This sub-sector includes establishments that process and package food products like meat, dairy, and baked goods. Workers in this industry may include food production workers, machine operators, and quality control inspectors. Executive, Legislative, and Other General Government Support (921) had the second highest incidence rate with 32.9 per 100 FTE, followed by Couriers and Messengers (492) at 27.4 per 100 FTE, and Private Households (814) at 27.4 per 100 FTE. Workers in Executive, Legislative, and Other General Government Support may include government officials, administrative staff, and support personnel.

In contrast, workers in the Couriers and Messengers industry include delivery drivers, package handlers, and administrative staff. Private Households include workers who provide services to individual households, such as cleaners, nannies, and personal assistants.

Warehousing and Storage (493) had the fifth highest incidence rate with 26.6 per 100 FTE. Workers in this industry may include forklift operators, warehouse associates, and logistics coordinators. Support Activities for Transportation had an incidence rate of 23.9 per 100 FTE, while Forestry and Logging (113) had a rate of 21.7 per 100 FTE. Some occupations in the Support Activities for Transportation industry may include mechanics, technicians, and administrative staff, while workers in the Forestry and Logging industry may include loggers, foresters, and equipment operators.

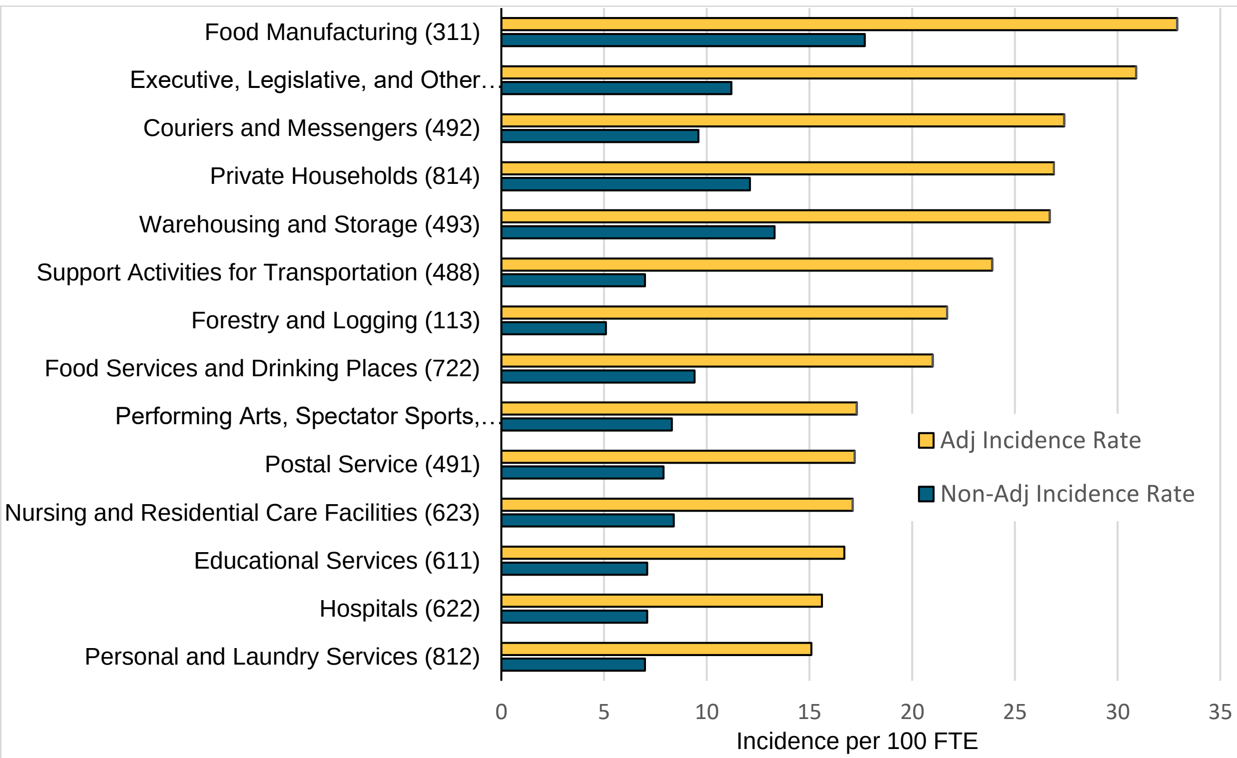

Figure 3 Incidence per 100 full-time equivalent (FTE) worker by industry sub-sector – Nebraska, March 2020 – December 2020. *Industry sub-sectors coded using the 2012 North American Industry Classification System (NAICS) classification. Adj. Incidence rate are adjusted for non-response. Non-Adj incidence rate not adjusted for non-response. Industry sub-sectors were excluded if relative standard error of estimate > 0.3.*

Incidence Rates by Major Occupation Group

Twenty-two major occupational groups were analyzed to determine the incidence rates of COVID-19 (Fig 4). Adjusting for the size of the employed workforce and full-time equivalency in each occupation group, Personal Care (39) had the highest incidence rate of COVID-19 at 21.8 per 100 FTE, followed by Food Preparation and Serving Related (35) with a rate of 21.2 per 100 FTE. Production (51) had the third highest incidence rate of 20.1 per 100 FTE. Building and Grounds Cleaning and Maintenance (37) had an incidence rate of 18.7 per 100 FTE, while Educational Instruction and Library (25) had a rate of 18.1 per 100 FTE. Protective Service (33) and Community and Social Service (21) had the same incidence rate of 16.4 per 100 FTE.

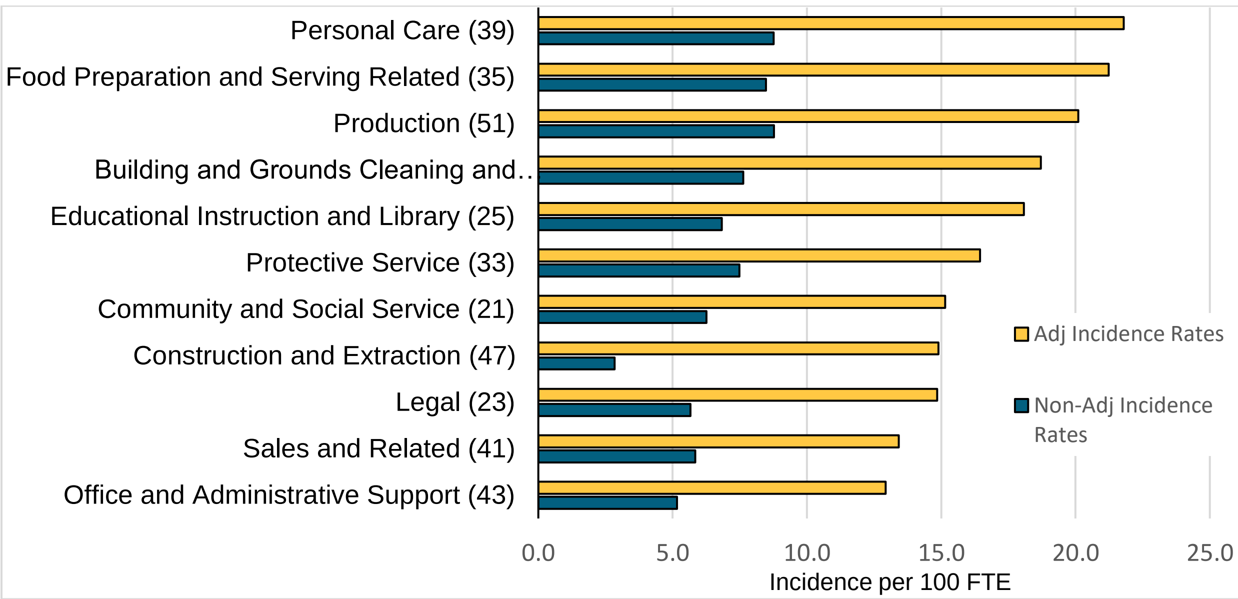

Figure 4 Incidence per 100 full-time equivalent (FTE) worker by major occupational group – Nebraska, March 2020 – December 2020*. Major occupations classified using the 2018 Standard Occupational Classification (SOC) System. Adj. Incidence rate are adjusted for non-response. Non-Adj incidence rate not adjusted for non-response.*

Incidence Rates by Occupational Exposure Risk to SARS-CoV-2

Number of Occupations and Cases by SOEM Proximity Measures

For proximity measure 1, there were 133 occupations categorized as low exposure risk, 98 as medium exposure risk, and 92 as high exposure risk (Table 2). For proximity measure 2, there were 98 occupations categorized as low exposure risk, 101 occupations, and 124 occupations categorized as medium and high exposure risk, respectively.

Table 2 Total occupations, cases, cumulative incidence, by relative risk of by the CSTE SOEM risk categories using either proximity measure 1 or proximity measure 2, Nebraska, March 2020 – December 2020.

Risk Category	Prox Measure 1		Prox Measure 2	
	Occupations	Cases	Occupations	Cases
Low	133	30,635	98	17,993
Medium	98	37,874	101	34,919
High	92	47,194	124	62,791
Totals	271	115,703	271	115,703

Testing for statistical difference among occupational the exposure risks

For proximity measure 1, incidence rates for occupations categorized as low exposure risk had a mean of 9.2 per 100 FTE and a median of 7.5 per 100 FTE. Medium exposure risk occupations had a mean of 11.8 per 100 FTE and a median of 9.1 per 100 FTE. Lastly, High exposure risk occupations had a mean of 16.6 per 100 FTE and a median of 12.4 per 100 FTE. A Kruskal-Wallis rank test to determine the significant difference among the occupational exposure risks indicated no significant difference between low and medium exposure risk occupations ($p=0.06$). However, there was a significant difference between medium exposure risk and high exposure risk occupations ($p=0.001$) and between low exposure risk and high exposure risk occupations ($p<0.001$).

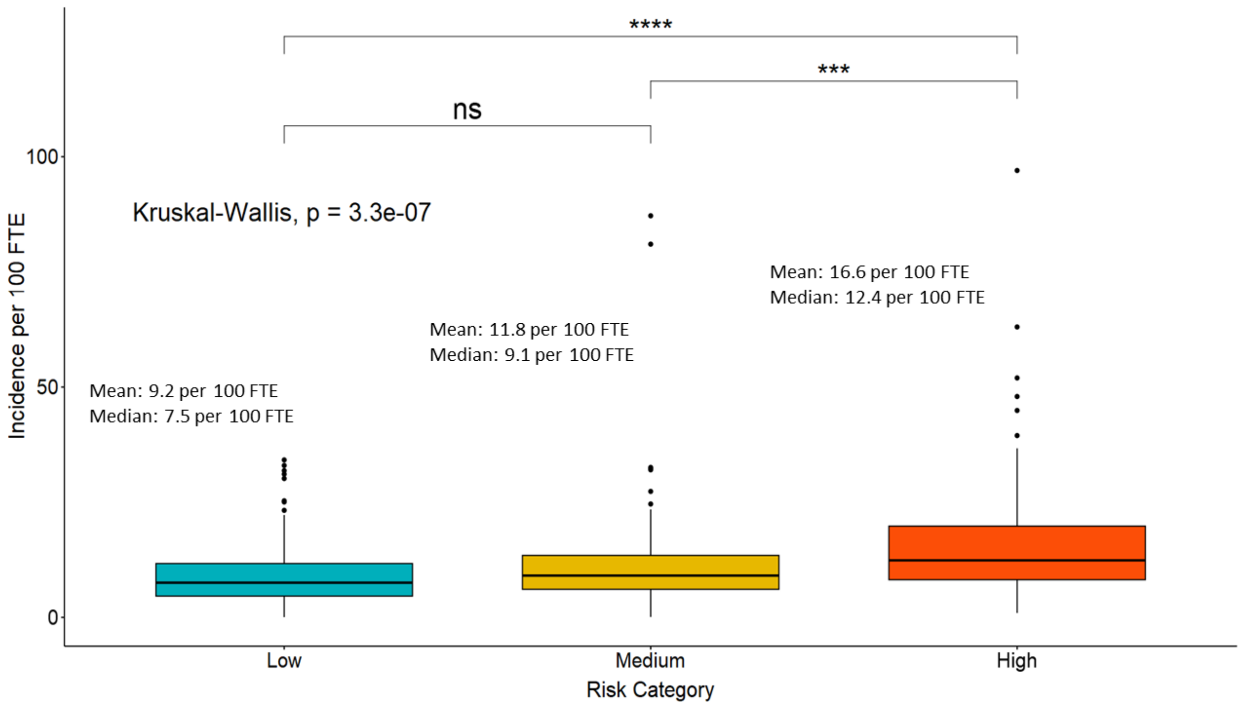

Figure 5 Proximity measure 1 occupational incidence per 100 full-time equivalent (FTE) worker categorized by exposure risks, low, medium, or high – Nebraska, March 2020 – December 2020. *Occupations classified using the 2010 Census Occupation Code (COC). For significant differences; ns (not significant), p-value < 0.001 (***), p-value < 0.0001 (****).*

For proximity measure 2, incidence rates for occupations categorized as low exposure risk had a mean of 8.1 per 100 FTE and a median of 7.0 per 100 FTE. Medium exposure risk occupations had a mean of 11.8 per 100 FTE and a median of 9.1 per 100 FTE. Lastly, High exposure risk occupations had a mean of 16.6 per 100 FTE and a median of 12.4 per 100 FTE. A Kruskal-Wallis test by ranks to determine the significant difference among any of the exposure risk categories indicated significant differences among all three. Comparing low-exposure and medium-exposure risk occupations showed a significant difference (p=0.05). Comparing medium and high exposure risk occupations also showed a significant difference (p<0.01). Finally, comparing low-exposure and high-exposure risk occupations showed a significant difference (p<0.01).

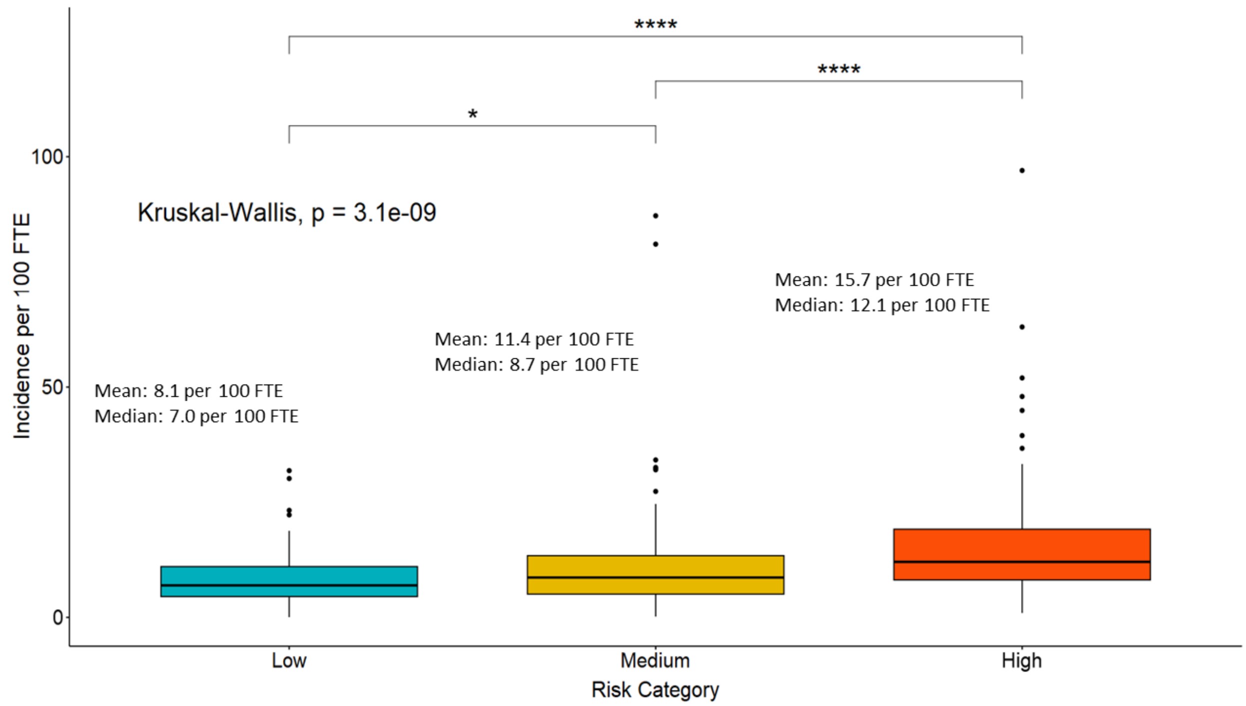

Figure 6 Proximity measure 2 occupational incidence per 100 full-time equivalent (FTE) worker categorized by exposure risks, low, medium, or high – Nebraska, March 2020 – December 2020. *Occupations classified using the 2010 Census Occupation Code (COC). For significant differences; p-value < 0.05 (*), p-value < 0.0001 (****).*

CHAPTER 4: DISCUSSION

Importance of Adjusting for Nonresponse Bias

When nonresponse bias is not adjusted for, the incidence rates may be overestimated or underestimated in the population, depending on the nature of the bias. This can result in biased rate estimates for COVID-19 cases by industry and occupation. Failure to adjust for nonresponse bias can lead to discrepancies between the actual incidence rates and the crude incidence rates obtained from survey data, which can lead to inaccurate conclusions about the extent and distribution of COVID-19 rates among Nebraska's workforce.

The non-adjusted incidence rate is calculated based on the total number of COVID-19 cases reported by individuals who responded to phone interviews, regardless of whether they were representative of the entire population of interest. In contrast, the adjusted incidence rate takes into account the characteristics of both respondents and non-respondents and uses statistical techniques to adjust for any differences between these groups.

Since nonresponse bias can lead to an under-representation of certain industries or occupations in the data, it is possible that the non-adjusted incidence rate is underestimating the true rate of COVID-19 cases in these industries and occupations. Adjusting for nonresponse bias can help to correct this issue and provide a more accurate estimate of the true incidence rate.

It is important to note that adjusting for nonresponse bias can increase the estimated incidence rate, as it accounts for cases that may not have been captured in the unadjusted rate. Therefore, observed adjusted rate is higher than the unadjusted rate.

For example, the unadjusted incidence rate for the health care industry is the second highest among all industries, while the adjusted rate is the highest (Fig 2). Given what we know about the high risk of exposure to COVID-19 among health care workers, it makes sense that the health care industry would have the highest industry incidence rate overall.

However, without adjusting for nonresponse bias, the results may not accurately represent the true incidence rate for the health care industry. Adjusting for nonresponse bias can help to correct for any differences in response rates between different industries or occupations and provide a more accurate estimate of the true incidence rate.

Thus, the fact that the adjusted rate for the health care industry is the highest suggests that adjusting for nonresponse bias is a more accurate method of estimating incidence rates, particularly in cases where there may be a greater risk of nonresponse bias in certain industries or groups.

For variables that contributed the most to the inclusion probability can be found in the summary outputs of logistical regression models found in the supplemental material.

Industry and Occupational Incidence Rates

Certain industries and occupation groups are disproportionately affected by COVID-19. For example, healthcare has the highest proportion of cases, which is unsurprising given the high risk of exposure for healthcare workers due to the nature of their work, which often involves close contact with infected patients and exposure to infectious aerosols [31, 32]. Additionally, healthcare workers may have been at higher risk due to inadequate personal protective equipment or other workplace safety measures [33]. However, it is concerning that healthcare workers represent only 14% of the workforce but account for 20% of COVID-19 cases, highlighting the urgent need for effective measures to protect healthcare workers and prevent the spread of the virus in healthcare facilities.

Manufacturing and educational services are also highly affected by COVID-19, despite representing a smaller proportion of cases compared to healthcare. Meatpacking facilities have also been highly affected by COVID-19, with many experiencing outbreaks among their workers, which might be due to the close physical proximity of workers and the nature of the work, which often involves shared equipment and enclosed spaces. For example, a Nebraska meatpacking plant found that nearly 40% of workers tested positive for COVID-19. In addition, many reported working close to others and sharing equipment without adequate personal protective equipment (PPE) or other workplace safety measures [34]. The results suggest that specific sub-sectors within industries, such as food manufacturing and government support, are at higher risk for COVID-19.

The high incidence rates of COVID-19 among healthcare workers observed in this study are consistent with previous reports [35]. However, an interesting finding in our data is the lack of corresponding high incidence rates among healthcare subsectors. The data indicate that healthcare subsectors did not have higher incidence rates, contrary to what might be expected given the high overall incidence rates in the healthcare sector.

A possible reason for the difference in COVID-19 incidence rates among healthcare workers in this study could be a data quality problem. The industry information collected by contact tracers may not be accurate due to various reasons. However, most likely during case interviews, respondents' industry information was not provided but indicated they were healthcare workers (yes or no). Indicating they were a healthcare worker can only be coded the healthcare sector; however, not the subsectors within it if no industry information is provided. As a result, healthcare sector coding was more comprehensive than subsector coding, as filling in missing data for subsectors without using other data sources like employer information data was more difficult.

The incidence rates for different occupation groups are also noteworthy. Personal care and food preparation, and serving-related occupations have the highest incidence rates, likely due to close contact with others required for these jobs. The high incidence rates for production, building, grounds cleaning, educational instruction, and library occupations suggest that adequate measures are also needed to protect workers in these areas.

The results of this analysis underscore the importance of implementing effective measures to prevent the spread of COVID-19 in the workplace, including providing PPE, increasing ventilation and air filtration, promoting social distancing, and implementing regular testing and contact tracing. It is also essential to prioritize vaccination for workers in high-risk industries and occupation groups to protect their health and reduce the spread of the virus.

Assessing Occupational incidence Rates categorized by the SOEM

The three factors identified as contributing to increased risk of exposure to SARS-CoV-2 in the workplace - Public Facing, Working Indoors, and Close Proximity - provide a valuable framework for assessing the risk of COVID-19 transmission among non-healthcare occupations [36]. The results show that these factors are strongly associated with differences in the incidence of COVID-19 among workers.

For example, occupations that involve routine in-person interaction with the public, such as retail salespersons, food service workers, and personal care aides, had significantly higher rates of COVID-19 incidence compared to occupations with less public interaction. Similarly, working indoors was associated with higher COVID-19 incidence rates, particularly for occupations that involve close proximity to others, such as healthcare support workers and production workers.

These results also demonstrate that working in close physical proximity to others, whether co-workers or the public, is a particularly strong predictor of COVID-19 incidence, with high-exposure risk occupations having significantly higher rates of COVID-19 incidence compared to low and medium-exposure risk occupations.

Furthermore, this study's results indicate a significant difference in incidence rates among occupational exposure risks and that the level of risk depends on the proximity measure used. For proximity measure 1, there was only a significant difference between the high-exposure risk category and the other two risk levels. In contrast, for proximity measure 2, there were significant differences among all three occupational exposure risks, suggesting that proximity measure two might be the better measurement of the two.

The findings for proximity measure 1 indicate that low and medium-exposure-risk occupations have similar incidence rates. In contrast, high-exposure-risk occupations have significantly higher incidence rates than the other two risk levels. This suggests that interventions targeted at high-risk occupations reduce overall incidence rates more effectively than those targeted at low and medium-risk occupations.

The results for proximity measure 2, on the other hand, suggest significant differences in incidence rates across all three occupational exposure risks. This highlights the importance of considering the exposure type and the proximity degree when assessing risk. It may be necessary to implement different interventions and safety measures depending on the level of exposure risk.

These findings have implications for workplace safety policies and interventions aimed at reducing the incidence of COVID-19 in the workplace. Considering the type and degree of exposure when assessing risk and designing interventions is essential. Employers and policymakers should prioritize high-risk occupations and implement measures to reduce exposure to COVID-19 in the workplace.

Strengths

One of the strengths of this study is the large sample size of workers from various industries and occupational groups in Nebraska, providing a representative sample of the state's workforce. Additionally, the study used a comprehensive approach to analyze the data by examining industry sectors, industry sub-sectors, occupational groups, and estimated exposure risk levels. The use of both weighted and non-weighted incidence rates adds to the study's strength, allowing for more accurate comparisons across different groups. Additionally, this study is the first to validate whether the SOEM risk categories correlates with the occupational incidence rates using statewide case data.

Limitations

There are several limitations to this study. First, the study only includes data from Nebraska, limiting the generalizability of the results to other states or countries. Second, the study did not account for potential confounding factors that could influence the incidence rates, such as the use of personal protective equipment or workplace policies and procedures. Fourth, the study did not differentiate between community-acquired and work-related COVID-19 cases, making it difficult to assess the effectiveness of workplace interventions. Finally, the study did not include information on workers' underlying health conditions, which could affect their risk of contracting COVID-19.

Conclusion

This study aimed to explore the incidence rates of COVID-19 by industry sector, industry sub-sector, occupational group, and SARS-CoV-2 occupational exposure risk among Nebraska workers. This study revealed that the healthcare industry had the highest incidence rate of COVID-19 among workers, followed by the accommodation and food services, and manufacturing industries. Moreover, the study found that workers in specific industry sub-sectors, such as food manufacturing and government support, had higher incidence rates than others. The study also showed that workers in personal care, food preparation and serving, and production had the highest incidence rates among major occupational groups. Additionally, the study demonstrated a significant difference in incidence rates among different occupational exposure risk levels. Finally, this study provides valuable insights into the impact of COVID-19 on different industries and occupations, highlighting the need for targeted interventions to protect workers in high-risk industries and occupations.

References

1. Centers for Disease Control and Prevention (CDC). COVID-19 Outbreaks in Meat and Poultry Processing Facilities - United States, April-May 2020. MMWR Morb Mortal Wkly Rep. 2020 Jun 19;69(24):887-892. doi: 10.15585/mmwr.mm6925a3. PMID: 32555130.

2. Osterberg L, Barton K, Boehmer T, Mcknight-Eily L, Meiman J. Investigations of COVID-19 outbreaks in workplaces — Utah, March-June 2020. Occup Med (Lond). 2020 Nov 6;kqaa188. doi: 10.1093/occmed/kqaa188. Epub ahead of print. PMID: 33155110.

3. National Institute for Occupational Safety and Health (NIOSH). COVID-19: Guidance for Businesses and Employers. Centers for Disease Control and Prevention (CDC). 2020 Sep 28 [cited 2021 Mar 24]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/community/guidance-business-response.html.

4. Calvert GM, Sussell A, Schulte PA, Sweat D, He X, Kisting S, et al. The Impact of COVID-19 on Workers and Their Families: A Review. Ann Work Expo Health. 2020 Dec 7;64(8):747-757. doi: 10.1093/annweh/wxaa113. PMID: 33118090.

5. National Center for Health Statistics. Health, United States, 2019. Hyattsville, MD: National Center for Health Statistics; 2020. Available from: https://www.cdc.gov/nchs/hus/index.htm.

6. Groves RM, Peytcheva E. The impact of nonresponse rates on nonresponse bias: A meta-analysis. Public Opin Q. 2008;72(2):167-189. doi:10.1093/poq/nfn011

7. Gardiner, K., & Koh, D. (2014). Principles of occupational health & hygiene: An introduction. Oxford University Press.

8. Council of State and Territorial Epidemiologists Occupational Health Subcommittee WGoEWEMt. Characterizing the risk of exposure to SARS-CoV-2 among non-health care occupations based on three workplace risk factors: public facing work, working indoors, and working in close physical proximity to others. Council of State and Territorial Epidemiologists; 2021 8/18/2021.

9. University of Nebraska Medical Center. (2020, February 17). UNMC receives 13 patients from cruise ship. UNMC Newsroom. https://www.unmc.edu/news.cfm?match=25291

10. "COVID-19 in Nebraska: Tracking cases, deaths and latest restrictions." (2020, December 16). KETV. https://www.ketv.com/article/covid-19-in-nebraska-tracking-cases-deaths-and-latest-restrictions/31717363#

11. "Coronavirus in Nebraska, Iowa: The latest headlines and resources to keep you informed." (2020, May 19). KETV. https://www.ketv.com/article/coronavirus-in-nebraska-iowa-latest-information-where-to-get-help/31626475

12. "Meat processing plants emerge as new coronavirus hot spots in U.S." (2020, April 23). Reuters. https://www.reuters.com/article/us-health-coronavirus-meatpacking/meat-processing-plants-emerge-as-new-coronavirus-hot-spots-in-u-s-idUSKCN2253WB

13. Morawska, L., & Milton, D. K. (2020). It is Time to Address Airborne Transmission of COVID-19. Clinical Infectious Diseases, ciaa939. https://doi.org/10.1093/cid/ciaa939

14. Smith, H. J. (2020, April 27). Coronavirus outbreaks at meatpacking plants are forcing a rethink of the US food supply. CNN Business. https://www.cnn.com/2020/04/27/business/meat-supply-coronavirus/index.html

15. "Meat processing plants emerge as new coronavirus hot spots in U.S." (2020, April 23). Reuters. https://www.reuters.com/article/us-health-coronavirus-meatpacking/meat-processing-plants-emerge-as-new-coronavirus-hot-spots-in-u-s-idUSKCN2253WB

16. "The Worst Outbreaks in the U.S. Are Now in Rural Areas" (2020, May 25). The New York Times. https://www.nytimes.com/2020/05/25/us/coronavirus-deadliest-outbreaks.html

17. "Analysis: America's meatpacking plants are a Covid-19 disaster zone" (2020, May 4). The Guardian. https://www.theguardian.com/environment/2020/may/04/americas-meatpacking-plants-are-covid-19-disaster-zones-heres-why

18. OSHA. (2021). Protecting Workers: Guidance on Mitigating and Preventing the Spread of COVID-19 in the Workplace. U.S. Department of Labor. https://www.osha.gov/sites/default/files/publications/OSHA4120.pdf

19. Bureau of Labor Statistics. (2023, March 21). Women accounted for 70.8 percent of workplace illnesses caused by viruses in 2020. The Economics Daily. Retrieved from https://www.bls.gov/opub/ted/2023/women-accounted-for-70-8-percent-of-workplace-illnesses-caused-by-viruses-in-2020.htm

20. Tai, D. B. G., Shah, A., Doubeni, C. A., Sia, I. G., & Wieland, M. L. (2020). The Disproportionate Impact of COVID-19 on Racial and Ethnic Minorities in the United States. Clinical Infectious Diseases, 72(4), 703–706. https://doi.org/10.1093/cid/ciaa815

21. Bureau of Labor Statistics. (2020). Occupational Employment and Wage Statistics: May 2020 State Occupational Employment and Wage Estimates - Nebraska. U.S. Department of Labor. https://www.bls.gov/oes/current/oes_ne.htm#00-0000

22. Bureau of Labor Statistics. (2021). Workplace injuries and illnesses - 2020. Retrieved from https://www.bls.gov/news.release/pdf/osh.pdf

23. Centers for Disease Control and Prevention. (2021). COVID-19 among workers in meat and poultry processing facilities — United States, April–May 2020. Morbidity and Mortality Weekly Report, 69(27), 887-892. https://doi.org/10.15585/mmwr.mm6927e2

24. World Health Organization. (2020). COVID-19 and food safety: guidance for food businesses. Retrieved from https://www.who.int/publications/i/item/covid-19-and-food-safety-guidance-for-food-businesses

25. Occupational Safety and Health Administration. (2021). COVID-19. Retrieved from https://www.osha.gov/coronavirus

26. Occupational Employment and Wages, May 2019, Slaughterers and Meat Packers. U.S. Bureau of Labor Statistics Accessed December 14, 2020. https://www.bls.gov/oes/current/oes513023.htm

27. Rosner, D., & Markowitz, G. (2020). A Short History of Occupational Safety and Health in the United States. American journal of public health, 110(5), 622–628. https://doi.org/10.2105/AJPH.2020.305581

28. Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). Applied logistic regression (3rd ed.). John Wiley & Sons.

29. Bethlehem, J. G., Cobben, F., & Schouten, B. (2011). Handbook of nonresponse in household surveys. John Wiley & Sons.

30. Groves, R. M., Fowler Jr, F. J., Couper, M. P., Lepkowski, J. M., Singer, E., & Tourangeau, R. (2009). Survey methodology (2nd ed.). John Wiley & Sons.

31. Ran L, Chen X, Wang Y, Wu W, Zhang L, Tan X. Risk Factors of Healthcare Workers with Coronavirus Disease 2019: A Retrospective Cohort Study in a Designated Hospital of Wuhan in China. Clin Infect Dis. 2020 Nov 28;71(16):2218-2221. doi: 10.1093/cid/ciaa287. PMID: 32271399; PMCID: PMC7184366

32. Nguyen LH, Drew DA, Graham MS, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. Lancet Public Health. 2020 Sep;5(9):e475-e483. doi: 10.1016/S2468-2667(20)30164-X. Epub 2020 Aug 27. PMID: 32861308; PMCID: PMC7454337.

33. Shah AS, Duff RE, Balfour-Lynn IM, et al. COVID-19 in children: analysis of the first pandemic peak in England. Arch Dis Child. 2021 Apr;106(4):367-372. doi: 10.1136/archdischild-2020-319929. Epub 2020 Oct 21. PMID: 33087403; PMCID: PMC7932278.

34. Fischer EP, Fischer MC, Grass D, Henrion I, Warren WS, Westman E. Low-cost measurement of face mask efficacy for filtering expelled droplets during speech. Science Advances. 2020;6(36):eabd3083. DOI: 10.1126/sciadv.abd3083.

35. Pray, I. W., Grajewski, B., Morris, C., Modji, K., DeJonge, P., McCoy, K., Tomasallo, C., DeSalvo, T., Westergaard, R. P., & Meiman, J. (2022). Measuring work-related risk of coronavirus disease 2019 (COVID-19): Comparison of covid-19 incidence by occupation and industry—wisconsin, September 2020 to May 2021. *Clinical Infectious Diseases*. https://doi.org/10.1093/cid/ciac586

36. Council of State and Territorial Epidemiologists Occupational Health Subcommittee WGoEWEMt. Characterizing the risk of exposure to SARS-CoV-2 among non-health care occupations based on three workplace risk factors: public facing work, working indoors, and working in close physical proximity to others. Council of State and Territorial Epidemiologists; 2021 8/18/2021.

APPENDIX: SUPPLEMENTAL MATERIAL

Summary Output of Logistical Regression Model for Industry Response Probabilities

```
##
## Call:
## glm(formula = ind_response ~ age_calc + gender + patient_race_calc +
##     jurisdiction_FINAL + sample_month, family = "binomial", data = covid_caseio_workage_coded2)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.1740  -0.8760   0.6430   0.8933   2.7346
##
## Coefficients:
##                                                                   Estimate  Std.Error   z-value  Pr(>|z|)
## (Intercept)                                                      0.1893005  0.0796775   2.376 0.017509 *
## age_calc                                                         0.0037558  0.0004649   8.079 6.55e-16 ***
## genderM                                                          0.0755599  0.0129287   5.844 5.08e-09 ***
## genderU                                                         -0.2154974  0.1181472  -1.824 0.068156 .
## patient_race_calcAsian                                           0.7546668  0.0759033   9.942  < 2e-16 ***
## patient_race_calcBlack or African American                       0.6371983  0.0704154   9.049  < 2e-16 ***
## patient_race_calcNative Hawaiian or Other Pacific Islander       0.6333248  0.1650588   3.837 0.000125 ***
## patient_race_calcOther Race                                      0.8597352  0.0753058  11.417  < 2e-16 ***
## patient_race_calcUnknown                                        -1.6463584  0.0653136 -25.207  < 2e-16 ***
## patient_race_calcWhite                                           0.8598547  0.0631131  13.624  < 2e-16 ***
## jurisdiction_FINALDakota County Health Department                0.3136497  0.0593981   5.280 1.29e-07 ***
## jurisdiction_FINALDouglas County HD                             -0.2998284  0.0351468  -8.531  < 2e-16 ***
## jurisdiction_FINALEast Central Health Department                 0.1417054  0.0490727   2.888 0.003881 **
## jurisdiction_FINALElkhorn Logan Valley Public Health Department -0.3717575  0.0478891  -7.763 8.30e-15 ***
## jurisdiction_FINALFour Corners Health Department                -0.2260882  0.0524061  -4.314 1.60e-05 ***
## jurisdiction_FINALLancaster County HD                           -1.7369824  0.0370414 -46.893  < 2e-16 ***
## jurisdiction_FINALLoup Basin Public Health Department            0.4796213  0.0755582   6.348 2.19e-10 ***
## jurisdiction_FINALNorth Central District Health Department      -0.7875849  0.0555019 -14.190  < 2e-16 ***
## jurisdiction_FINALNortheast Nebr Public Health Department       -0.4960832  0.0642368  -7.723 1.14e-14 ***
## jurisdiction_FINALPanhandle Public Health Department            -0.5450921  0.0528652 -10.311  < 2e-16 ***
## jurisdiction_FINALPublic Health Solutions                       -0.1957723  0.0515783  -3.796 0.000147 ***
## jurisdiction_FINALSarpy/ Cass Dept. of Health and Wellness      -0.4319504  0.0384644 -11.230  < 2e-16 ***
## jurisdiction_FINALScotts Bluff County Health Department         -0.4927545  0.0522087  -9.438  < 2e-16 ***
```

```
## jurisdiction_FINALSouth Heartland District Health Department     0.2033770  0.0565736   3.595 0.000324 ***
## jurisdiction_FINALSoutheast District Health Department          -0.3869675  0.0640310  -6.043 1.51e-09 ***
## jurisdiction_FINALSouthwest Nebraska Public Health Department   -0.3515598  0.0589961  -5.959 2.54e-09 ***
## jurisdiction_FINALThree Rivers Health Department                -0.3921115  0.0450128  -8.711  < 2e-16 ***
## jurisdiction_FINALTwo Rivers Public Health Department            0.0587924  0.0437663   1.343 0.179167
## jurisdiction_FINALWest Central District Health Department       -0.1513751  0.0571598  -2.648 0.008090 **
## sample_monthAugust                                               0.0210337  0.0472786   0.445 0.656400
## sample_monthDecember                                            -0.2399761  0.0406728  -5.900 3.63e-09 ***
## sample_monthJuly                                                 0.0591654  0.0483619   1.223 0.221182
## sample_monthJune                                                 0.2051116  0.0514203   3.989 6.64e-05 ***
## sample_monthMarch                                               -2.0445441  0.1641670 -12.454  < 2e-16 ***
## sample_monthMay                                                  0.5023681  0.0472824  10.625  < 2e-16 ***
## sample_monthNovember                                            -0.3769000  0.0399534  -9.433  < 2e-16 ***
## sample_monthOctober                                             -0.0844930  0.0416653  -2.028 0.042571 *
## sample_monthSeptember                                           -0.1190863  0.0450407  -2.644 0.008194 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 175710  on 126959  degrees of freedom
## Residual deviance: 143338  on 126922  degrees of freedom
## AIC: 143414
##
## Number of Fisher Scoring iterations: 4
```

Summary Output of Logistical Regression Model for Occupation Response Probabilities

```
##
## Call:
## glm(formula = occ_response ~ age_calc + gender + patient_race_calc +
##     jurisdiction_FINAL + sample_month, family = "binomial", data = covid_caseio_workage_coded2)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -1.9010  -0.9893  -0.4392   0.9789   2.8848
##
```

```
## Coefficients:
##                                                                   Estimate Std.Error   z-value   Pr(>|z|)
## (Intercept)                                                     -0.6890054  0.0792188  -8.698  < 2e-16 ***
## age_calc                                                         0.0066599  0.0004568  14.578  < 2e-16 ***
## genderM                                                          0.3557804  0.0127506  27.903  < 2e-16 ***
## genderU                                                          0.0391977  0.1211715   0.323 0.746325
## patient_race_calcAsian                                           0.6388605  0.0769602   8.301  < 2e-16 ***
## patient_race_calcBlack or African American                       0.5008383  0.0718592   6.970 3.18e-12 ***
## patient_race_calcNative Hawaiian or Other Pacific Islander       0.6962541  0.1619268   4.300 1.71e-05 ***
## patient_race_calcOther Race                                      0.8206510  0.0756434  10.849  < 2e-16 ***
## patient_race_calcUnknown                                        -1.6480633  0.0677144 -24.338  < 2e-16 ***
## patient_race_calcWhite                                           0.7967593  0.0650681  12.245  < 2e-16 ***
## jurisdiction_FINALDakota County Health Department               -0.6011250  0.0559157 -10.751  < 2e-16 ***
## jurisdiction_FINALDouglas County HD                             -0.2224048  0.0329061  -6.759 1.39e-11 ***
## jurisdiction_FINALEast Central Health Department                 0.0193193  0.0451909   0.428 0.669012
## jurisdiction_FINALElkhorn Logan Valley Public Health Department -0.9635602  0.0461141 -20.895  < 2e-16 ***
## jurisdiction_FINALFour Corners Health Department                -0.2715547  0.0498805  -5.444 5.21e-08 ***
## jurisdiction_FINALLancaster County HD                           -1.7180971  0.0356621 -48.177  < 2e-16 ***
## jurisdiction_FINALLoup Basin Public Health Department            0.1589202  0.0698015   2.277 0.022801 *
## jurisdiction_FINALNorth Central District Health Department      -0.5807904  0.0541039 -10.735  < 2e-16 ***
## jurisdiction_FINALNortheast Nebr Public Health Department       -0.4941022  0.0626385  -7.888 3.07e-15 ***
## jurisdiction_FINALPanhandle Public Health Department            -0.6352853  0.0509547 -12.468  < 2e-16 ***
## jurisdiction_FINALPublic Health Solutions                       -0.2158938  0.0490127  -4.405 1.06e-05 ***
## jurisdiction_FINALSarpy/ Cass Dept. of Health and Wellness      -0.2424819  0.0364037  -6.661 2.72e-11 ***
## jurisdiction_FINALScotts Bluff County Health Department         -0.4353078  0.0502419  -8.664  < 2e-16 ***
## jurisdiction_FINALSouth Heartland District Health Department     0.1254535  0.0525157   2.389 0.016900 *
## jurisdiction_FINALSoutheast District Health Department          -0.4064441  0.0618956  -6.567 5.15e-11 ***
## jurisdiction_FINALSouthwest Nebraska Public Health Department   -0.4315044  0.0566991  -7.610 2.73e-14 ***
## jurisdiction_FINALThree Rivers Health Department                -0.3328027  0.0428225  -7.772 7.74e-15 ***
## jurisdiction_FINALTwo Rivers Public Health Department           -0.0205787  0.0407862  -0.505 0.613875
## jurisdiction_FINALWest Central District Health Department       -0.2237998  0.0544056  -4.114 3.90e-05 ***
## sample_monthAugust                                               0.3105392  0.0446608   6.953 3.57e-12 ***
## sample_monthDecember                                             0.1480981  0.0381721   3.880 0.000105 ***
## sample_monthJuly                                                 0.3590226  0.0458494   7.830 4.86e-15 ***
## sample_monthJune                                                 0.5205624  0.0487129  10.686  < 2e-16 ***
## sample_monthMarch                                               -1.5934649  0.1715482  -9.289  < 2e-16 ***
## sample_monthMay                                                  0.7281874  0.0442222  16.467  < 2e-16 ***
## sample_monthNovember                                             0.0721165  0.0374324   1.927 0.054032 .
```

```
## sample_monthOctober                                  0.1095352  0.0390652   2.804 0.005049 **
## sample_monthSeptember                                0.1408949  0.0426162   3.306 0.000946 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 174886  on 126959  degrees of freedom
## Residual deviance: 146326  on 126922  degrees of freedom
## AIC: 146402
##
## Number of Fisher Scoring iterations: 4
```