Occupational Association of Salmonellosis and Shiga toxin producing E. coli Cases in Washington State 2005-2016

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Abstract

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Abstract

Background: Salmonellosis is a common food-borne gastrointestinal infection causing diarrhea, upset stomach, and sometimes vomiting. Each year there are 600-800 cases of salmonellosis reported to the Washington State Department of Health. Shiga Toxin Escherichia Coli (STEC) is also a foodborne bacterial illness which can have serious health sequelae, including hemolytic uremic syndrome or death. There are approximately 140-200 cases per year in Washington State. As part of the investigation into reported cases of salmonella and STEC, DOH asks affected individuals about their occupation. It is suspected that individuals working in some occupations may be at higher risk of salmonellosis than others.

Methods: Using Washington State Department of Health notifiable conditions data for Salmonella and Shiga toxin producing E. coli cases and Current Population Survey records through the Employed Labor Force (ELF) query system, we calculated standardized incidence ratios for risk of Salmonella and E.coli cases reported to WA DOH during the years 2005 through 2016 for each occupation category using major Standard Occupation Classification, both as total and separated by male and female gender.

Results: Salmonella and STEC infections were associated most with the occupational group Arts, Design, Entertainment, and Sports (SIR=2.41, CI 2.08-2.82 / 2.01, CI 1.41-2.84 for Salmonella / STEC respectively). Healthcare workers were at increased risk for both Salmonella and STEC (SIR=1.52, CI 1.33-1.73 and 1.73, CI 1.33-2.25 for Salmonella/STEC respectively). Notable gender differences in stratified risk analysis included female construction workers and Salmonella (SIR=3.20, CI 2.05-4.97) males in farming, fishing, forestry for STEC (SIR-2.11, CI 1.18-3.77) even while overall risk in this occupation were reduced; and males in personal services (SIR=6.67, CI 4.44-10.05) for STEC risk.

Discussion: Several categories of increased risk were expected, such as healthcare workers and scientists working in the field. Surprising was the high level of association with office jobs such as business/finance or arts and entertainment workers. The inverse association with farming occupation was the most surprising, and may have other factors, such as reluctance to seek health care. This should be explored to accurately understand occupational infection risk. Future studies should include repeating this method with data of enteric pathogens in other states or regions. Education or care for occupation groups at increased risk for the short and long-term effects of enteric pathogen infection may be implemented.

Introduction

Salmonella and Shiga toxin producing E.coli (STEC) are major causes of acute diarrheal illnesses, causing an estimated 1.2 million cases of Salmonella and 265,000 cases of STEC each year in the United States (CDC, 2019), leading to potentially serious outcomes. STEC can cause hemolytic uremic syndrome and death, while Salmonella is usually self-limited, though can be more serious, at times even leading to death. Long term, Salmonella is associated with an increased risk of colon cancer (Mughini-Gras, 2018). In some occupational groups, including healthcare workers, food service workers, and childcare workers, workers may be more at risk of contracting either of these, and also in a position to spread the pathogens to the general population. This study aims to describe occupational classification as risk factor for having a lab-confirmed Salmonella or STEC infection.

To ascertain the average hours worked in each occupational category, we will use publicly available Bureau of Labor Statistics data. Using the number of cases reported to DOH each year by occupation group and BLS data describing the number of person-hours worked in each group, the current study seeks to establish a relative risk of contracting salmonellosis and/or Shiga Toxin Escherichia Coli by occupational group. Based on previously published surveillance data, we expect that the categories of farming, food service, healthcare, and childcare may be the most at-risk occupational groups for salmonellosis risk.

Diarrheal illness

With 37.2 million cases per year in the U.S. (Scallan, 2011) of diarrhea, there may be a range of possible causes and patient responses. Some may alter diet or wait. Others seek care with a health care provider, who may or may not order confirmatory analysis of that stool. Washington State Department of Health guidelines recommend ordering stool cultures for acute diarrhea only if no signs of inflammation (bloody, small volume stools with fecal leukocytes) (DOH). Current guidelines from the American College of Gastroenterologists recommends diagnostic testing of stool when there is public health concern for risk of spreading infection (healthcare workers, food service workers), in cases of dysentery (bloody diarrhea), moderate to severe disease (fever), and when symptoms last more than seven days (Riddle, 2016). Overall 19% of patients seeking care submitted a stool specimen for culture (Scallan, 2006). In a study of residents of Miyagi Prefecture, Japan, salmonella incidence was estimated to be 199/100,000 population (Kubota, 2005), which is lower than the 528/100,000 previously estimated for the United States (Mead, 1999).

Causes of diarrhea include infection including Salmonella, Shigella, norovirus, and Escherichia coli.

Salmonella epidemiology

Salmonellosis is a common food-borne gastrointestinal infection causing diarrhea, upset stomach, and sometimes vomiting. Each year there are 600-800 cases of salmonellosis reported to the Washington State Department of Health. While most common in young children, there is a slight increased risk over age 60 (Arshad, 2007). Boys less than age 15 have higher rates than girls, and women have higher rates than men (Olsen, 2001).

Salmonella is a gram negative, flagellated, facultative anaerobic bacilli bacteria that is one of the top causes of foodborne illness in the United States (Gianella, 1996), resulting in approximately 1.2 million cases each year and 450 deaths (CDC). The pathogen enters the body via consumption of contaminated foods, or less commonly by fecal oral route (or just oral after touching a contaminated animal or object). Salmonella is present in poultry, eggs, beef, and sometimes fruits or vegetables that have come in contact with water containing the bacteria, usually from contamination by animal feces. Handling pet turtles or backyard poultry with inadequate hand hygiene has more recently been identified as a source of infection (FDA, 2016). Minimum dose needed for illness ranges from $<10^1 – 10^9$ CFU (Grieg 2010). Contamination by food service workers is a common mechanism of exposure. Because of the predominant foodborne route of infection, adequate cooking of foods which might contain the bacteria and appropriate handling of food to avoid fecal-oral contamination are the main prevention recommendations. (WHO)

Definitive diagnosis of Salmonellosis may require culture of feces or blood. However, most cases recover before this is necessary, and may be diagnosed based on clinical symptoms. Detection of Salmonella has traditional been through culturing. However, due to the nature of the hazard being food, which may have a short shelf-life, other detection methods which are faster may be more practical, including PCR (Bell, 2016).

Symptoms of non-typhoidal Salmonella infection most commonly include abdominal pain, vomiting, and diarrhea (enterocolitis), but may also cause dehydration or fever which may be life threatening (Giannella, 1996). Infection is typically self-limited, lasting 4-7 days and causing vomiting and diarrhea starting about 12-72 hours after ingestion of contaminated food (CDC). In rare cases symptoms could start as early as six hours after infection, or as long as fourteen days. In most cases recovery progresses without treatment, but in some cases, oral or intravenous rehydration may be needed.

Typhoidal types of Salmonella may cause more serious illness. While abdominal pain, vomiting, and diarrhea may be a part of a typhoidal illness, more prominent symptoms include a gradual-onset fever and/or chills, a rosy skin rash, and higher risk of death. If enteric fever (typhoid or paratyphoid fever) is present, antibiotics may be necessary to treat and disease may be life-threatening.

Median shedding time of 50 days in dairy cattle was observed following infection with various single serotypes of Salmonella (Cummings). Shedding duration may depend on initial dose and specific serovar of infection. In pigs, shedding lasted 10-17 days longer when infected with S. cubana compared with 3 other subtypes, and dose of each subtype also determined cessation of shedding (Ivanovek, 2012).

Salmonella lives in the intestinal tracts of many kinds of domestic and wild animals including cattle, swine, poultry, wild birds, and pets (especially reptiles), and flies. Humans are the final host; for Salmonella Typhi, humans are the only host. (MSDSonline). Once in the gastrointestinal tract, it induces phagocytosis into intestinal epithelial cells and alters the structure of the vacuole containing it to avoid destruction by the cell (Eng 2015). At any given time, Salmonella can be found in 48% of U.S. swine GI tracts, and may persist up to five months in wallows, with indicators that pathogenic bacteria were constantly moving between animal and immediate environment (Carraway 2005).

Salmonella can be found anywhere animal feces, or water containing animal feces is found. This may include surfaces of animals including turtles and lizards, or surfaces of recently laid poultry eggs. Salmonella Typhimurium isolated from dust outside of nest boxes at a high rate, and very low levels inside nest boxes or on shells. Rate of contamination varied widely by season, with peaks during high or low temperatures (Chousalkar, 2016). Salmonella can survive in low-moisture environments for extended periods and has therefore been implicated in food-borne outbreaks of low-moisture foods (Finn, 2013).

Primary prevention of infection includes avoidance of exposure by washing hands before and after handling potential pathogen sources such as raw meat, eggs, or animals who carry the bacteria, especially ones likely to have fecal matter on the outsides of their bodies like water-dwelling turtles and other reptiles. Appropriate cooking temperature and time is also critical to kill any Salmonella organisms that might be on food items such as meat. Poultry, for example, should be cooked to a minimum temperature of 150 degrees for at least 3 minutes. Prevention should also include awareness of risk factors and personal attributes which make an individual more likely to become ill from infection. This may include medical history of diseases such as HIV or other immune system suppression which might make transmission beyond the gut more likely. It may also include anyone taking medication to reduce stomach acid content, since Salmonella is vulnerable to stomach acid and therefore would be more likely to survive in an individual with a less acidic stomach environment. There is an association between use of acid-suppressive medication and increased risk of enteric infection including salmonellosis (Leonard, 2007). The effect of current H2 blocker use, but not past use, indicates a causal relationship between acid blocker use and salmonellosis (Neal, 1994). Antibiotic use is also associated with salmonellosis (Gradel, 2008).

STEC epidemiology

Shiga Toxin Escherichia Coli (STEC) is also a foodborne bacterial illness which can have serious health sequelae, including hemolytic uremic syndrome or death. There are approximately 140-200 cases per year in Washington State. Prevalence of E.coli O157 in beef cattle 0.3 to 19.7% in feedlots and 0.7 to 27.3% on pasture, with higher rates of non-O157. Many of the serotypes isolated from beef cattle were found in HUS patients and are known to cause other human illness (Hussein, 2007). A Minnesota study of 206 STEC cases found that O157 cases were more likely to cause bloody diarrhea (78% vs 53%), hospitalization (34% vs 8%), and hemolytic uremic syndrome (7% vs 0%) (Hedican, 2009). In children presented with diarrhea, 4% tested positive for STEC and 2% for Salmonella (Stockmann, 2017 & Goode, 2009). Age and gender may be a predictor of outcome severity, with age >75 resulting in a higher risk for HUS (De Rauw, 2018).

An outbreak of Shiga toxin producing E.coli infections was tied to flour consumption in 24 states (Crowe, 2017). An Australian study found that compared with non-O157 controls, patients infected with STEC 0157 strains of E.coli were more likely to eat hamburgers, eat in restaurants, used antibiotics, and have family members working near red meat (McPherson, 2009). Isolation rate of STEC from dairy cattle in Brazil raged from 3.8 to 84.6% depending on farm analyzed with STEC identified in 25% of animals, mostly a single STEC serotype (Irino, 2005). Petting zoos have been found to be a source of STEC infections leading to HUS (Schlager, 2018). A study in England found a higher rate of outbreaks attributed to animal contact than food and environmental sources combined (Awofisayo-Okeyulu, 2019).

In a study of shiga toxin producing E. coli O157 and non-O157 isolates from humans, cattle, sheep, and food in Spain, 41% showed resistance to at least one antimicrobial tested, with a higher percentage of resistance in the O157 in those recovered from beef meat than humans compared with non-O157 isolates (Mora, 2005). E. coli 0157:H7 and Salmonella typhimurium can survive up to a year, including a winter season, in cowpats in the field, allowing for transmission through groundwater or other contact (Nyberg, 2018).

Occupation as Risk Factor for Enteric Pathogens

Some occupations may be at higher risk of infection with enteric pathogens. Compared with workers in other occupations, Maryland, Ohio, and Virginia workers in farming, fishing, and forestry occupations and health care and technical occupations had higher rates of campylobacteriosis (RR = 10.0 and 1.5) and salmonellosis (RR = 3.2 and 2.0) (Su et al., 2017). In a 10-year surveillance study in Nebraska, 16.6% of campylocateriosis and 8.7% of cryptosporidiosis cases were associated with occupational animal exposure, with cattle the most commonly cited animal and animal production (farming or ranching) the most common industry type and feedlot exposure the most common specific location of potential exposure (Su, 2017). In Germany 2013-2014, two large outbreaks of Salmonella were linked to pig farming (Schielke, 2017). Construction workers in a chicken processing facility were more likely to have gastrointestinal illness including diarrhea if performing electrical work, taking breaks in unofficial areas, bringing drinks into work areas, and have contact with poultry fluids (Hall, 2019).

Workers as Pathogen Carriers (Typhoid Mary)

Not only may certain workers be at higher risk of acquiring enteric infections, but they may participate in spreading them to others. In a study of Department of Health data, food workers in Minnesota had half the expected number of Salmonella infections of the general population, though 18% were associated with outbreaks (Medus, 2010). A salmonella outbreak in Minnesota was associated with infected delicatessen workers who did not experience recent gastrointestinal symptoms (Hedican, 2010). A study of Korean slaughterhouse workers showed a high rate of anti-Shiga toxin antibodies, indicating a significant risk of exposure (Hong, 2012). Increased rates of antibodies to E.coli O157 were found in farmers with recent contact with beef cattle, having a private water supply, and contact with a child under 5 years old, though low rates of diarrhea reported, which may indicate acquired immunity with prolonged farming exposures (Quilliam, 2012). Food handlers in tourist hotels in Kenya show high rates of carriage of enteroaggregative E. Coli but not STEC (Oundo, 2008).

Reportable conditions in Washington State

The Washington State Department of Health requires reporting of any confirmed case of several foodborne pathogens, including Salmonellosis or Shiga toxin producing E.coli (DOH Notifiable Conditions website). After notification, public health workers contact the patient to gather additional information, including occupation, potential sources of exposure, and additional details about disease course.

Research Question

Which occupations are at highest risk of developing Salmonella or STEC in Washington state?

Does gender modify the occupational association with Salmonella infection?

Public Importance of this Research

Persons working in certain occupations are in positions to transmit foodborne pathogens to the public. These may include food service workers, food production workers, health and childcare workers, and others. Therefore, an understanding of occupations at highest risk of contracting pathogens may assist in public health efforts to devote educate or surveillance to these occupational groups or work locations.

Methods

Cases

Data regarding all laboratory-confirmed Salmonella and Shiga toxin producing E.coli infections in Washington State from 2005-2016 were obtained from the Washington State Department of Health after Institutional Review Board (IRB) exempt review application was completed and approved by WA state IRB. The request was limited to cases age 14 and older, the legal working age in Washington State, and later limited to age 15 and above to align with available total worker population data. Data obtained were gender, occupation (if available), age, year of diagnosis, and answers to several binary questions regarding employment in a sensitive occupation (childcare, healthcare, or food service). All cases older than age 89 were coded as age "89+" due to identifiability (HIPAA, 2002).

Occupations of cases were categorized into major groups using the Office of Management and Budget Standard Occupational Classification (SOC) system according to the stated occupation at the time of diagnosis. Any identifiable employment information was redacted or altered to be unidentifiable before data receipt. Cases were excluded from analysis if occupation was not provided, was listed as a non-income job such as "housewife", "unemployed", "retired", "disabled", or if occupation description was insufficient to code, such as "self-employed" or "government worker." Cases classified as military were removed, since the basis of the worker population did not include military personnel.

Worker Population

Total counts of workers in Washington State, classified by Bureau of the Census (BOC) code was obtained from the publicly available Employed Labor Force query system, based on the Bureau of Labor Statistics (BLS) Current Population Survey (CPS), a monthly survey of the non-institutionalized population of the U.S. BOC codes were grouped by SOC category according to 2010 crosswalk lists.

Analysis

Descriptive statistics were performed to describe total numbers of cases in each occupational group, number excluded, male/female distribution, and median age in order to account for the modification of all ages over 90.

Standardized incidence ratio (SIR) was calculated for each of 22 major occupational group strata, and in each gender by occupation strata. [For the highest risk occupations in each pathogen type, those with confidence intervals wholly above 1.0, SIR's were examined in 3 year increments over the 12 year study period to determine trends over time.] I haven't done this yet.

Secondary analysis of SIR by yes/no response to any of the sensitive occupation questions was performed using the following BOC codes as the worker population. For childcare workers, SOC codes 39-9031/9030, 25-2010, 25-2041, 25-9040 were used to determine worker population for comparison. For healthcare workers, SOC codes 2909999, 31-0000, and 11-9021 were used. For food service workers, SOC codes 35-0000, 11-9051, 51-3020, and 51-3011 were used. US Census data for Washington state by age and gender were obtained for population comparison. Because the Census uses age 18 as a cutoff for easily-obtainable figures, the case population for analysis was limited to age 18 and above.

Results

Descriptive statistics of Salmonella and STEC case populations including median age, gender, and number of eliminated cases presented in Table 1. The median age of Salmonella cases was slightly higher (40 years employed/43 years unemployed) than median age of STEC (30 employed/33 unemployed). Not surprisingly, median age of employed cases was lower than unemployed cases. There was a large amount of missing data about occupation. In the Salmonella cases, 1661 (25%) of the total cases had unknown employment, leaving just 3061 (46%) for analysis by employed occupation. In the STEC cases, there were 305 (20%) unknown occupation, with 703 (46%) employed with known occupation. Gender balance was not reflective of the population. In the Salmonella cases, 2879 (56.4%) were male and 3760 (56.4%) were female, with 28 (0.4) unknown gender. Of the employed Salmonella cases, 1398 (45.6%) were male and 1646 (53.7%) female, with 19 (0.6%) unknown. The STEC gender distribution was even more extreme in its gender imbalance: 580 of total cases were male

(38%) with 943 (62%) female and 5 (0.3%) unknown. IN the employed STEC cases, 257 (36.5%) were male, 436 (61.8%) female, and 12 (1.7%) unknown gender.

Total numbers of cases of both Salmonella and STEC over the twelve study years (2005-2016) has increased, as shown in Figures 1. Whether this reflects more accurate reporting or an actual increase in incidence is unknown.

Distribution of total and gender-specific employed cases over 22 occupational groups defined by major SOC category are shown in Table 2 (Salmonella cases) and Table 3 (STEC cases). For STEC cases, one total and many gender-specific occupation groups had to be redacted due to insufficient number to allow for de-identification (>10 cases per cell).

Risk by Occupational Group

For Salmonella, SIRs for 22 occupation groups, arranged from highest to lowest risk, are shown in Table 4 and Figure 2. Overall, the occupational groups with significant risk of infection are Arts/Design/Entertainment (SOC27) with SIR of 2.41 (CI 2.07-2.83, $p<0.0001$); Science (SOC19), with SIR of 1.81 (CI 1.39-2.35, $p<0.0001$); Community Service (SOC21) with SIR of 1.71 (CI 1.37-2.12, $p<0.0001$); Healthcare (SOC29) with SIR of 1.52 (CI 1.33-1.74, $p<0.0001$), Business ((SOC13) with SIR of 1.50 (CI 1.30-1.72, $p<0.0001$), Food Service (SOC35) with SIR of 1.21 (CI 1.05-1.39, $p=0.009$); and Personal Service (SOC39) with SIR of 1.20 (CI 1.02-1.42, $p=0.03$). The occupational groups with the lowest risk are Groundskeepers (SOC37); Office workers (SOC 43) with SIR 0.66 (CI 0.58-0.75, $p<0.0001$), Management (SOC11) with SIR of 0.47 (CI 0.40-0.54, $p<0.0001$); and Farming (SOC45) with SIR 0.37 (CI 0.28-0.48, $p<0.0001$).

Gender and Occupation Group

When stratified by gender as well as occupation, risk is slightly different than overall for Salmonella cases. Most notably, the highest risk for females was Construction (SOC47) with SIR 3.20 (CI 2.05-4.97, $p<0.0001$) and Community Service workers (SOC 21) SIR 2.50 (CI 1.90-3.27, $p<0.0001$). The lowest risk for females was Management (SOC11) with SIR 0.54 (CI 0.43-0.66, $p<0.0001$) and Office Work (SOC43) with SIR 0.62 (CI 0.53-0.72, $p<0.0001$).

When stratified, risk of Salmonella in males was highest for Science (SOC19) SIR 2.21 (1.55-3.16, $p<0.0001$); Healthcare (SOC29) with SIR 1.47 (CI 1.11-1.94, $p=0.006$); and Business (SOC13) SIR 1.47 (CI 1.16-1.85, $p=0.001$).

For STEC, SIRs for 22 occupation groups, arranged from highest to lowest risk, are shown in Table 5 and Figure 3. One group (Legal-SOC2) had to be redacted due to <10 case count in that cell. In males and females, 9 of 22 occupation groups had to be redacted due to low case count, though not the same groups in all cases.

Age and Occupation

There were a relatively small number of cases over age 60, the age at which there is a potential increase in risk of Salmonella infection, and over age 65, the age at which there is a reported increase in STEC risk. Only 8 of the 22 occupational groups had sufficient cases (>10) to allow reporting of results, according to DOH rules regarding potentially identifiable information reporting.

Secondary Analysis of "Specialized Populations"

Analysis of the three special groups of workers based on public health risk due to occupation was performed. See Table 5 (Salmonella) and Table 6 (STEC) for summary of case distribution and SIR's. For Salmonella, all three categories indicated reduced risk of infection, with SIR of 0.42, 0.82, and 0.90 for childcare workers, food service workers, and healthcare workers, respectively. For STEC, all three groups showed none to moderately increased risk with SIR of 1.00, 1.36, and 1.11 for childcare, food service, and healthcare workers, respectively.

Discussion

Overall, cases of both Salmonella and STEC have higher rates among women than men. This is consistent with previously reported higher morbidity overall and with digestive illnesses (Verbrugge, 1982). Women were found to have higher risk of bloody diarrhea and developing HUS when infected with STEC (Werber, 2013).

The current analysis showed highest risk of Salmonella in Arts/Design, Science, Community Service, Healthcare, Business, Food Service, and Personal Service. Many of those can be easily understood based on exposure likelihood. Healthcare workers are known to have an increased risk of many communicable diseases, likely based on their frequent exposure to various pathogens and despite handwashing campaigns (ref?). Community outreach workers have known risks of tuberculosis (Agaya, 2015) and all care workers have risk of compassion fatigue (Cocker, 2016). In a study of health risks of wildlife scientists, 49% reported diarrheal disease within the previous year, while only 14% saw a doctor for it and only 3% perceived it to be work-related (Garland-Lewis, 2017). There are many examples of illnesses, sometimes fatal, in field biologists working without adequate personal protective equipment (PPE) when working around animals or in regions with known pathogens (Mouldin 2016). It stands to reason that transmission of potentially zoonotic pathogens including Salmonella and E.coli may be transmitted in these conditions.

The highest risk occupational group for both Salmonella and STEC infections was the group including Arts, Design, Entertainment, and Sports. While this does not easily associate with exposure likelihood as healthcare or healthcare assistants, personal service (including home health care workers and animal care workers), a study of self-reported quality of life measures including frequent physical distress, frequent mental distress, frequent overall unhealthy days, and frequently activity limitations found that this same occupational group overwhelmingly higher scores compared with other groups (Shockey, 2017). Stress has been associated with increased rates of allergy and respiratory infections (Runeson-Broberg, 2014). The same mechanism could be responsible for the association of enteric pathogens and a high-stress occupation group.

Healthcare workers, healthcare assistants, and personal service workers (including home health and animal care workers) are at increased risk for Salmonella and STEC infections. These make sense in light of exposures from infected patients and animal sources. Healthcare workers, especially those working in gastroenterology units, have been found to be at increased risk of H.pylori infections based on likely workplace exposure (Kheyre, 2018). As H. pylori is also transmitted by fecal-oral route, there is likely a similar pathway of infection as STEC and possibly Salmonella. Also not a surprise is the increased risk of STEC in Farming, Fishing, & Forestry groups in the combined and male gender. Risk for female gender was not calculable due to low case count in that group per DOH rules concerning identifiability.

The increased risk of Salmonella infections in SOC category 13 (business and money management) is not as easily explainable. Despite a long history of evidence of bacterial transmission on currency (Angelakis, 2014), workers in this group are more likely to use computers than handle physical money. Unless they are sharing surfaces such as keyboards with substandard cleaning and sharing with multiple other workers, this is unlikely to be a major vector of transmission (Zhang, 2018).

The secondary analysis indicated reduced risk of Salmonella for all three “special populations” of childcare, food service, and healthcare workers. While in contrast to some of the individual occupation groups, overall it makes sense given that these three professions are reminded to wash hands regularly. For STEC, childcare workers had neither increased nor decreased risk of infection, while food service workers showed a significantly increased risk and healthcare workers had a non-significantly, very small increased risk.

Limitations

The biggest limitation was the sheer amount of missing data. Of the 6667 cases of Salmonella in WA state, 1661 (25%) did not have an occupation listed at all. Of the 1522 cases of STEC, 305 (20%) did not have an occupation listed. Public health workers who follow up on diagnosed cases should be notified of the importance of gathering this information, both to understand the source of the infection as well as risks posed to the public.

Our study used only confirmed cases, notified to the WA state department of health. However, we know that not all cases of diarrhea result in a visit to a doctor, a culture test being ordered, or that test being positive for one of these pathogens. There are many cases of each of these that are contracted each year, cause symptoms, and resolve without any official involvement in the healthcare reporting system or inclusion in the notifiable conditions database. This happens for a number of reasons. Estimated total numbers of Salmonella each year are xxx in WA state. Estimated number of E. coli cases are xxx, and of those, xxx% are Shiga toxin producing. On the other hand, a Virginia study recommends better adherence to testing guidelines, but found that net positive results would not have changed significantly if results had been more closely followed (Clark, 2019).

Misclassification of occupation group may have altered results in some of the groups. Though the majority were very easy to classify (teachers, secretaries, nurses, accountants, etc.), some required making some decisions. Electricians, for example, were all classified under Construction (SOC 47) rather than Maintenance (SOC49) due to lack of more specific information. “Tech employee” was classified under Computers-15, though depending on the specifics of their job, they may have been Office worker-43 if a secretary, or Business-13 if an accountant. At the time the occupation data was collected from the person, there was no view on attempting to classify it later according to this system, so generally no further clarification was sought. It is possible that the very low risk in Management-11 was due to misclassification of some higher-level managers wrongly as first-line managers, which are typically classified in the same group as the industry. For example, a “restaurant manager” could be classified in Food Service-35, and a “nursing manager” could be classified in Healthcare-29. If the person was in fact a higher-level manager instead of a first-line manager, this misclassification would reduce the apparent risk of Management-11, and potentially increase the apparent risk of the other occupation group.

Notifiable condition reporting

One concern with the method of using only laboratory-confirmed and Department of Health-notified cases calls into question the accuracy of the reporting systems. There are differences between reporting rates by laboratories (84.4%) compared with providers (19.1%) diagnosing notifiable conditions, with provider reports coming in later but more complete than laboratories (Dixon, 2017). A study of physicians and nurses showed that 55% of physicians and 63% of nurses were aware of notifiable condition reporting procedures (Turnberg, 2010). Clinic staff reported variability in frequency of notifiable condition reporting in Indiana, with uncertainty about reporting requirements and use of the information being cited as barriers to reporting (Revere, 2017). Use of death records could increase accuracy of notifiable conditions reporting system (Oltean, 2016).

Future Recommendations

Models of viral transmission have been developed based on office workers' frequency of touching hands to mucous membranes on the face as a method (Beamer, 2015). Risk of E. coli transmission to hands of Vietnamese farmers using human-feces containing fertilizer found relatively less hand to face contact than the office worker study (Julian 2018). A similar method could be developed to evaluate other enteric pathogen transmission in the highest risk occupations from the current study to determine infection pathway.

The military routinely uses a vaccination against Salmonella typhi (Porter, 2017). In addition to military personnel, this may be a recommendation for members of other occupations including field scientists or healthcare workers, depending on their individual exposure likelihood.

In a study of pediatric patients with E.coli-induced HUS, there was a higher risk of dialysis in females (VanSickle, 2018). Therefore, extra risk messaging may be appropriate in occupational groups that include high numbers of women.

Our analysis included 25% of the Salmonella and 20% of E.coli cases with unknown or unrecorded occupation in addition to the 30.1% / 34.2% for Salmonella / STEC respectively, eliminated from analysis due to non-employment. Analysis of occupation as a risk factor would be easier to ascertain in local areas if public health workers directly responsible for collecting occupation information during the follow up process.

As mentioned above, following the strict criteria of major occupation group may “dilute” apparent risk in some specific professions, and workers with similar risk may be spread across several occupation groups. More detailed analysis of some specific occupations, classified by exposure to pathogens, may help elucidate actual risk. For example, workers in the veterinary field may be classified as health care workers (veterinarians and veterinary technicians), health care assistants (veterinary assistants), office staff (veterinary clinic receptionists), and personal service workers (animal care attendants). Combining these groups may reveal specific risk faced by this time of occupation group.

Poverty has been shown to be an independent risk factor for STEC infections (Hadler, 2018). Since occupation is related to income, risk of developing enteric pathogens may be associated with wages rather than other inherent aspects of occupation group. As stated above for the farming group, the intersection of healthcare-seeking behavior should also be considered with overall infection risk, especially when considering severe outcomes.

Tables & Figures

Table 1—Demographics of Study Population, WA State Salmonella and STEC Cases, 2005-2016, age 15+

	Males n (%)	Females n (%)	Unknown n (%)	All n (%)	Median age (yr)
Salmonella All	2879 (43.2)	3760 (56.4)	28 (0.4)	6667 (100)	43
Employed	1398 (45.6)	1646 (53.7)	19 (0.6)	3061 (46)	40
Unemployed				1903 (28.5)	
Unknown				1661 (25)	
Military				42 (0.6)	
STEC All	580 (38.0)	943 (62.0)	5 (0.3)	1522 (100)	33
Employed	257 (36.5)	436 (61.8)	12 (1.7)	703 (46)	30
Unemployed				510 (33.5)	
Unknown				305 (20)	
Military				10 (0.7)	

Figure 1—Total Salmonella & STEC Cases by Study Year [planning to combine these two bar charts]

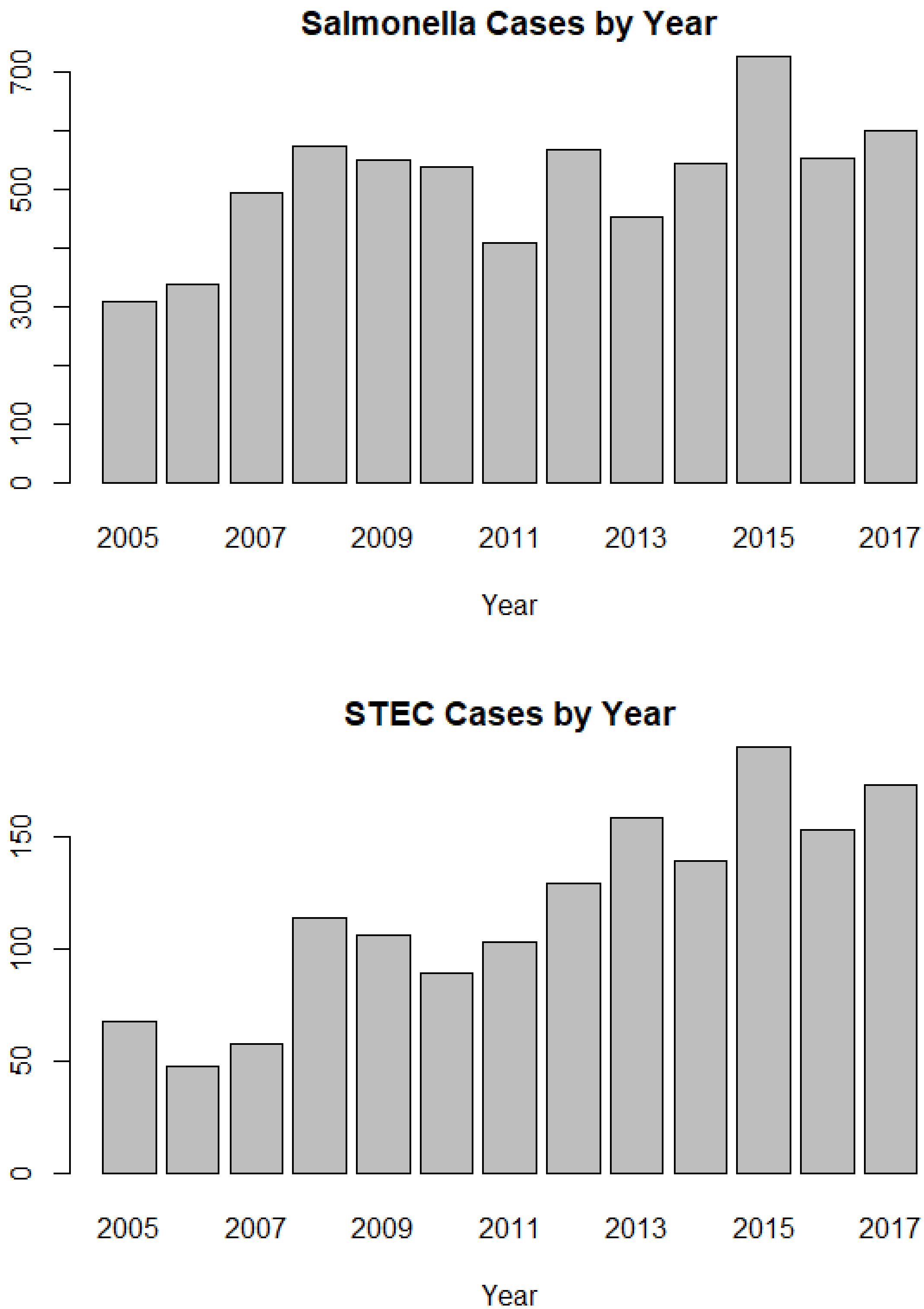

Table 2—Distribution of Salmonella Cases by Standard Occupational Category (SOC)

SOC	Total		Male		Female		Unknown sex	Age >60
	N	%	N	%	N	%	N	
11	173	5.7	83	2.7	90	2.9	0	13
13	210	8.9	74	2.4	136	4.4	0	11
15	161	5.3	113	3.7	47	1.5	0	2
17	74	2.4	57	1.9	17	0.6	0	5
19	57	1.9	31	1.0	26	0.8	0	3
21	86	2.8	31	1.0	54	1.8	1	9
23	43	1.4	19	0.6	24	0.8	0	3
25	159	5.2	25	0.8	134	4.4	0	10
27	91	3.0	44	1.4	47	1.5	0	5
29	233	7.6	51	1.7	182	5.9	0	20
31	76	2.5	11	0.4	64	2.1	0	3
33	62	2.0	42	1.4	20	0.7	0	5
35	206	6.7	60	2.0	146	4.8	0	9
37	71	2.3	37	1.2	34	1.1	0	6
39	145	4.7	23	0.8	121	4.0	1	6
41	319	10.4	166	5.4	152	5.0	1	22
43	245	8.0	54	1.8	190	6.2	1	17
45	58	1.9	39	1.3	19	0.6	0	7
47	167	5.5	146	4.8	20	0.7	0	12
49	114	3.7	102	3.3	12	0.4	0	7
51	150	4.9	110	3.6	40	1.3	0	7
53	161	5.3	125	4.1	36	1.2	0	13

Will redact the shaded boxes due to identifiability for any cell <10.

Table 3—Distribution of STEC Cases by Standard Occupational Category (SOC)

SOC	N	% of employed cases	Male n	Male %	Female n	Female %	Unknown n	Age >65
11	12	1.7					0	
13	44	6.2	14	2.0	30	4.2	0	
15	43	6.0	29	4.1	13	1.8	1	
17	14	2.0	10	1.4			0	
19	11	1.5					0	
21	15	2.1			14	2.0	0	
23							0	
25	37	5.2			31	4.4	0	
27	33	4.6			24	3.4	0	
29	61	8.6			53	7.4	0	
31	28	3.9			26	3.7	0	
33	15	2.1	10	1.4			0	
35	54	7.6	19	2.7	35	4.9	0	
37	28	3.9	11	1.5	17	2.4	0	

39	47	6.6	25	3.5	49	6.9	0	
41	75	10.5	25	3.5	49	6.9	1	
43	62	8.7			54	7.6	0	
45	16	2.2	12	1.7			0	
47	25	3.5	20	2.8			0	
49	19	2.7	18	2.5			0	
51	33	4.6	22	3.1	11	1.5	0	
53	23	4.5	19	2.7			0	

Shaded boxes redacted due to identifiability for any cell <10.

Table 4: Standardized Incidence Ratios for Salmonella Infections Stratified by Major Occupation Group (combined, Male, Female)

Boldface=significant p value, increased or decreased risk

Salmonella	**All**			
SOC_name	Est	CI Low	CI High	P-value
27-Arts/Design	**2.42**	2.08	2.83	<0.0001
19-Science	**1.82**	1.40	2.36	<0.0001
21-Community Service	**1.71**	1.38	2.12	<0.0001
29-Healthcare	**1.52**	1.33	1.74	<0.0001
13-Business	**1.49**	1.30	1.72	<0.0001
35-Food Service	**1.21**	1.05	1.39	0.009
39-Personal Services	**1.20**	1.02	1.42	0.03
15-Computers	1.18	1.01	1.38	0.04
33-Protection	1.13	0.88	1.46	0.33
23-Legal	1.10	0.81	1.48	0.55
31-Healthcare Assistant	1.08	0.86	1.35	0.51
47-Construction	1.07	0.91	1.24	0.43
49-Maintenance	1.02	0.85	1.23	0.84
41-Sales	1.00	0.90	1.12	0.97
25-Teaching	0.95	0.81	1.12	0.54
51-Production	0.94	0.80	1.10	0.44
53-Transportation	0.87	0.74	1.02	0.08
17-Engineering	0.86	0.69	1.09	0.21
37-Grounds	0.73	0.58	0.93	0.01
43-Office	0.66	0.58	0.75	<0.0001
11-Management	0.47	0.40	0.55	<0.0001
45-Farming	0.37	0.29	0.48	<0.0001

Negative risk

Salmonella	**Male**			

SOC_name	Est	CI Low	CI High	P-value
19-Science	**2.21**	1.55	3.16	<0.0001
29-Healthcare	**1.47**	1.11	1.94	0.007
13-Business	**1.47**	1.16	1.85	0.001
31-Healthcare Assistant	**1.47**	0.81	2.65	0.20
27-Arts/Design	**1.38**	1.02	1.86	0.03
45-Farming	1.32	0.96	1.82	0.09
15-Computers	1.24	1.03	1.51	0.03
41-Sales	1.22	1.04	1.43	0.02
39-Personal Services	1.18	0.78	1.78	0.43
21-Community Service	1.16	0.81	1.65	0.42
23-Legal	1.13	0.72	1.78	0.59
47-Construction	1.11	0.94	1.32	0.22
49-Maintenance	1.11	0.91	1.36	0.31
33-Protection	1.10	0.81	1.50	0.53
51-Production	1.06	0.88	1.29	0.54
53-Transportation	0.95	0.79	1.14	0.59
35-Food Service	0.95	0.73	1.29	0.69
17-Engineering	0.91	0.70	1.19	0.50
37-Grounds	**0.72**	0.52	1.00	0.05
43-Office	**0.66**	0.50	0.86	0.002
25-Teaching	**0.65**	0.44	0.96	0.03
11-Management	**0.44**	0.35	0.54	<0.0001

Salmonella	**Female**			
SOC_name	Est	CI Low	CI High	P-value
47-Construction	**3.1982**	2.05763	4.971028	4.70E-08
21-Community Service	**2.4948**	1.90226	3.272006	7.91E-12
49-Maintenance	**1.8777**	1.06406	3.313396	0.02708
33-Protection	**1.6566**	1.06584	2.574811	0.02338
19-Science	**1.5309**	1.03907	2.255383	0.03
13-Business	**1.4832**	1.245074	1.76694	8.87E-06
29-Healthcare	**1.4445**	1.23922	1.683771	2.26E-06
35-Food Service	**1.34**	1.13116	1.587338	0.000679
37-Grounds	**1.34**	1.13116	1.587338	0.000679
15-Computers	1.32398	0.99064	1.769491	0.05709
27-Arts/Design	1.21415	0.90846	1.622699	0.1891
45-Farming	1.14532	0.7286	1.800373	0.5563

17-Engineering	1.11688	0.69257	1.80115	0.6501
39-Personal Services	1.1032	0.9171	1.327073	0.2973
23-Legal	1.08091	0.72234	1.617477	0.7051
25-Teaching	0.98051	0.82209	1.169455	0.8267
53-Transportation	0.96551	0.69392	1.343402	0.835
31-Healthcare Assistant	0.9297	0.72418	1.193554	0.5673
51-Production	0.88291	0.64516	1.20829	0.4363
41-Sales	**0.84559**	0.71603	0.998588	0.04782
43-Office	**0.62055**	0.53393	0.721231	3.40E-10
11-Management	**0.53776**	0.4349	0.664948	5.91E-09

Table 4: Standardized Incidence Ratios for Shiga toxin E. coli Infections Stratified by Major Occupation Group (combined, Male, Female)

Boldface=significant p value, increased or decreased risk

STEC	All			
SOC_name	Est	CI Low	CI High	P-value
27-Arts/Design	**2.00965**	1.41744	2.849285	6.37E-05
29-Healthcare	**1.73477**	1.33544	2.253508	2.92E-05
31-Healthcare Assistant	**1.73068**	1.18626	2.524956	0.00395
39-Personal Services	**1.69225**	1.25956	2.27358	0.000412
19-Science	1.525293	0.84082	2.766966	0.1616
45-Farming	1.423601	0.86732	2.336682	0.1603
35-Food Service	1.377098	1.04415	1.816213	0.02287
15-Computers	1.36954	1.0066	1.86335	0.04442
13-Business	1.363598	1.00556	1.849125	0.04511
21-Community Service	1.297745	0.77817	2.164232	0.3165
37-Grounds	1.259932	0.8636	1.838159	0.2295
33-Protection	1.193361	0.71558	1.990151	0.4976
41-Sales	1.026234	0.80881	1.302104	0.8312
25-Teaching	0.963554	0.69231	1.341064	0.8258
51-Production	0.89774	0.63319	1.272814	0.5446
23-Legal	0.887535	0.44211	1.781724	0.7371
49-Maintenance	0.740077	0.46922	1.167289	0.1938
43-Office	0.729872	0.56296	0.946273	0.017
17-Engineering	0.711047	0.41894	1.206833	0.2042
47-Construction	0.694124	0.4658	1.034378	0.07125
53-Transportation	**0.54104**	0.35716	0.819587	0.003233
11-Management	**0.14129**	0.07986	0.24999	4.22E-15

STEC	Male			
SOC_name	Est	CI Low	CI High	P-value
39-Personal Services	**6.6797**	4.43599	10.05817	2.20E-16
45-Farming	**2.1172**	1.18785	3.77349	0.009219
15-Computers	**1.6615**	1.13333	2.435701	0.008557
35-Food Service	1.56472	0.98303	2.490592	0.05696
13-Business	1.44504	0.84471	2.472024	0.1765
33-Protection	1.3685	0.7282	2.571795	0.3278
37-Grounds	1.11387	0.60973	2.034833	0.7256
51-Production	1.10688	0.71705	1.708623	0.6465
49-Maintenance	1.01956	0.63294	1.642325	0.9365
41-Sales	0.95732	0.63577	1.441504	0.8345
47-Construction	0.7945	0.50467	1.25078	0.3194
53-Transportation	0.75267	0.47287	1.198039	0.2293
17-Engineering	**0.16**	0.0859	0.298002	3.64E-11
11-Management	**0.0821**	0.02631	0.25601	3.39E-08
19-Science				
21-Community Service				
23-Legal				
25-Teaching				
27-Arts/Design				
29-Healthcare				
31-Healthcare Assistant				
43-Office				

(Shaded boxes redacted due to unreportable counts per DOH rules.)

STEC	Female			
SOC_name	Est	CI Low	CI High	P-value
21-Community Service	**2.3207**	1.36335	3.950433	0.001401
19-Science	1.9013	0.98284	3.678081	0.05219
47-Construction	1.72126	0.55304	5.357207	0.3426
39-Personal Services	**1.6029**	1.19357	2.15269	0.001549
29-Healthcare	**1.5093**	1.13537	2.006322	0.004316
33-Protection	1.48596	0.61549	3.587549	0.3754
37-Grounds	1.46216	0.90089	2.373101	0.1219
31-Healthcare Assistant	1.35515	0.91261	2.012284	0.1304

15-Computers	1.31394	0.75701	2.280631	0.3303
13-Business	1.17392	0.81119	1.698861	0.3946
35-Food Service	1.15255	0.8171	1.625715	0.4181
41-Sales	0.97805	0.72827	1.313485	0.8827
17-Engineering	0.9429	0.35235	2.523271	0.9068
51-Production	0.87117	0.47899	1.584437	0.6511
45-Farming	0.86513	0.32328	2.315143	0.7728
25-Teaching	0.81387	0.56557	1.171192	0.2666
27-Arts/Design	0.81387	0.56557	1.171192	0.2666
23-Legal	0.64638	0.24154	1.72975	0.3812
43-Office	**0.6328**	0.47716	0.839213	0.001352
49-Maintenance	0.56142	0.07891	3.994307	0.5588
53-Transportation	**0.3849**	0.14384	1.030049	0.04838
11-Management	**0.1929**	0.09974	0.37325	4.83E-08

Table 5: Sensitive Occupation Analysis of Salmonella Cases

(Cases limited to age >=18 to correspond with available US Census data of WA state population)

		Total		Male		Female		No gender
	SOC Codes Included	n (Total)	SIR	n (Total)	SIR	n (Total)	SIR	
Childcare Worker	**39-9011 25-2010 25-2041 25-9040 11-9031 (2000) 11-9030 (2010)**	53 (6667)	0.42 (0.32-0.55), p<0.0001			52		0
Food Service Worker	**35-0000 11-9051 51-3020 51-3011**	247 (6667)	0.82 (0.72-0.93) p=0.0	72		174		1
Healthcare Worker	**29-0000 31-0000 11-9021**	306 (6667)	0.90 (0.80-1.00), p=0.06	60		244		2

Table 6: Sensitive Occupation Analysis of STEC Cases

(Cases limited to age >=18 to correspond with available US Census data of WA state population)

		Total		Male		Female		No gender
	SOC Codes Included	n (Total)	SIR	n (Total)	SIR	n (Total)	SIR	
Childcare Worker	**39-9011** **25-2010** **25-2041** **25-9040** **11-9031 (2000)** **11-9030 (2010)**	26	1.00 (0.68-1.47), p=0.99			26		
Food Service Worker	**35-0000** **11-9051** **51-3020** **51-3011**	84	1.36 (1.09-1.69), p=0.006	31		53		
Healthcare Worker	**29-0000** **31-0000** **11-9021**	78	1.11 (0.89-1.40), p=0.35	14		64		