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Examining Health Disparities Related to Foodborne Illnesses Across Racial and Ethnic Groups

Reese Tierney

ABSTRACT

EXAMINING HEALTH DISPARITIES RELATED TO FOODBORNE ILLNESSES ACROSS RACIAL AND ETHNIC GROUPS

By

REESE TAYLOR TIERNEY

May 13th, 2022

INTRODUCTION: Over the past decade, changes to surveillance systems and increased research studies examining health inequities across foodborne illnesses have created a new opportunity for additional research on this topic. There is a growing interest in using this lens to understand foodborne illness in the United States and the inclusion of variables such as race and ethnicity in active surveillance systems can help.

AIM: The purpose of this thesis was to identify current trends of documenting disparities of foodborne illness across populations and evaluate the mechanism of data representations through a literature review. To further explore the topics identified in the literature review, an analysis of salmonellosis data on the county level was conducted.

METHODS: The literature review was conducted as a pseudo-systematic review with the use of keywords and a restricted year timeline. For the salmonellosis analyses, the Laboratory-based Enteric Disease Surveillance (LEDS) system dataset was aggregated to the county-level for each year between 1997 and 2018, and joined with relevant metadata, including census data on race and ethnicity, CDC data on county urbanicity and social vulnerability indices (SVI), and USDA data on food environment.

RESULTS: Disparities of foodborne illnesses across racial and minority populations are prevalent across studies included in the literature review. Of the 35 studies reviewed, methods of racial and ethnic representation were inconsistent throughout with practices of collapsing and removal of different minority and ethnic groupings due to low numbers. The salmonellosis analysis found disparities of geometric mean salmonellosis incidence across both social vulnerability index themes and food insecurity variables when examined across levels of urbanicity.

DISCUSSION: Evidence of disparities in burden of foodborne illnesses are prevalent in literature. The categorization of race and ethnicity is inconsistent across studies which may cause misrepresentation of these disparities. Understanding the influence of these socioeconomic, geographical, and environmental factors on the incidence of salmonellosis may help us understand the reason for differences in burden across populations with different community demographics.

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by

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CHAPTER 1
INTRODUCTION

1.1 Background

A primary pathway for transmission of foodborne and enteric pathogens is through consumption of contaminated food and water. Over 250 pathogens cause illness through consumption of contaminated food; the resultant illnesses vary in severity and prognosis. Foodborne illnesses are both prevalent and costly in the United States, with an estimated 48 million cases a year and an average cost of 15.6 million USD dollars a year (1). Due to burden and cost of foodborne illnesses, monitoring and reducing these illnesses is a public health priority, which requires a multi-lateral partnership between industry, and federal and state partners.

Understanding the burden of foodborne illnesses is important because it helps set public health goals and determines allocation of resources (2). In the United States, foodborne illnesses cause substantial disease burden, with an estimated 128,000 hospitalizations and 3,000 deaths each year (3.) However, the burden of foodborne illnesses is not equal across populations, Quinlan (2013) found that certain populations may experience higher rates of salmonellosis, shigellosis, listeriosis, and yersiniosis due to increased exposures and risk (4). Unravelling the causes of these disparities is difficult as current literature on the role of social and environmental determinants' is limited. Specifically, the Health Information Innovation Consortium of the Centers of Disease Control and Prevention (CDC) recognizes the influence of social, geographic, and economic factors on foodborne disease but also notes that current surveillance efforts collect limited information on these factors (5). Our ability to unravel differences in foodborne illness that result in health disparities is further limited by comparability of the evidence between past studies. For instance, differences in approaches to collecting and working with race and ethnicity data make comparing findings between these studies impractical. Of particular concern is the combination of race and ethnicity into a single variable or the combination of distinct populations into a single category. Disadvantages related to the use of combined categories include limitation of conclusions to broad assumptions, using subjective labels that can consist of bias/stereotypes, and underestimating the extent of variation between groups (6). Alternatively, data sparsity can result in disparities not being investigated due to limited sample size

A semi-structured review was undertaken to describe the current state of foodborne illness and documented health disparities in the literature, and to compare and assess methods for collecting and analyzing race and ethnicity data by past studies on foodborne illness that examine these differences and identify disparities. This review will help with identification of methodological and knowledge gaps, specific questions that the review aimed to answer were:

1. What does the existing literature indicate about current racial and ethnic disparities of foodborne illnesses?
2. How are racial and ethnic groups represented in recent studies related to foodborne illness?

Along with a literature review, this thesis investigated select population variables that are linked to increased rates of foodborne illnesses but have limited literature available. These variables include urbanicity, food insecurity and social vulnerability index themes. An analysis describing and comparing patterns in county-level salmonellosis incidence using Laboratory-based Enteric Disease Surveillance (LEDS) for 1997 to 2018 against county-level demographics was conducted. This analysis was done to understand the frequency of these variables and how they may affect the incidence of salmonellosis. Along with the results of the literature review, the findings from this analysis will assist in the guidance of future research projects.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Epidemiology of Selected Foodborne Pathogens

` The epidemiology of foodborne pathogens is complex as there are a variety of organisms, toxins and chemicals that can cause foodborne illness as well different symptoms associated with each one (7). Understanding the basic epidemiology of each pathogen is helpful as both epidemiology and surveillance are vital elements in preventing health risks and measuring consequences (8). The epidemiology of the four selected pathogens in this review differ by burden, severity, and risk – all of which are important components to consider when examining foodborne illnesses.

Campylobacter spp.

Campylobacter is a bacterium transmitted mainly through foodborne routes with raw milk and undercooked meat products estimated as the significant source of attribution (9). The burden of *Campylobacter* can be seen worldwide as the pathogen has been labeled the most common bacterial cause of human gastritis in the world (10). In terms of reported measures, the World Health Organization considers *Campylobacter* to have a substantial burden of disease with a reported 33 million healthy years of life lost due to the pathogen annually (10). The symptoms of *Campylobacter* range in severity, with some people having no symptoms and others, especially those in vulnerable populations, experiencing severe outcomes such as blood stream infection and ulcerative colitis (7). In the United States, *Campylobacter* is one of the most common causes of diarrheal disease, with an estimated 1.3 million people getting sick each year from the pathogen (10).

Salmonella spp.

Salmonella infections are caused by a group of *Salmonella* bacteria that are made up of two species: *Salmonella enterica* and *Salmonella bongri* (11,12). Infections caused by *Salmonella* bacteria are known as salmonellosis and the disease is associated with transmission to humans by eating foods contaminated with animal feces (13). The prevalence of salmonellosis is significant in the United States as the CDC estimated a total of 1.3 million cases, 26,500 hospitalizations, and 420 deaths in the United States (14). *Salmonella* infections are tracked using public health surveillance systems, specifically known as active surveillance data, which can be used to keep track of the number and location of illnesses. Using this active surveillance data, Scallan et al. (2011) estimated that non-typhoidal *Salmonella* spp made up 11% (1.0 million) of the cases of foodborne illnesses in the United States between the years 2000 and 2008 (15).

Shigella

Shigella is a bacterium that causes a bacterial infection in the lining of the stomach known as shigellosis or bacterial dysentery (16). *Shigella* is very contagious and is transmitted in infected stool through food, drink, or direct contact (17). In the United States, shigellosis results in 450,000 cases annually, with most cases from daycare and residential institutions (16). The risk of shigellosis is not equal across different populations in the United States with at-risk groups including young children, travelers, gay or bisexual men, people with a weakened immune system, and members of small social groups (18).

Shiga-Toxin producing *Escherichia coli*

Shiga-Toxin producing *Escherichia coli*, also known as STEC, is a type of *Escherichia coli* that produces a toxin known as shiga toxin and is transmitted through contaminated water and food sources or contact with people and animals (19). Shiga-Toxin *Escherichia coli* can cause severe illness and is associated with increased levels of burden. This pathogen can cause a range of illness from watery diarrhea or bloody diarrhea to clinical manifestations such as hemolytic uremic syndrome (20). In the United States, STEC cases are reported to the CDC from state and territorial public health laboratories, allowing for the annual publishment of STEC summaries

(21). As of 2016, the CDC stated that “52 state and regional public health laboratories reported 5,441 cases of culture-confirmed shiga toxin-producing *Escherichia coli* (STEC) infections, including 2,323 O157 and 3,104 non-O157 cases.” (22).

2.2 History of Surveillance Systems

Foodborne illness in the United States has been a public health burden since the beginning of the country's history, with outbreaks of dysentery and typhoid fever plaguing early settlers during the European colonization of the states (23). Unsanitary conditions, crowded living quarters, and unsafe cooking practices provided conditions in which foodborne illnesses could thrive and spread in foods, water and from person-to-person contact. Typhoid fever was a significant source of mortality for soldiers during the Civil War, with a total of 75,148 documented cases and 27,058 deaths within the Union army alone (24). These pathogens and other related foodborne illnesses would continue to be a source of sickness and mortality throughout the history of the United States with only the magnitude of outbreaks decreasing in modern times. The CDC identified contaminated food, milk, and water as a source of many foodborne infections during the early 20th century (25). This is demonstrated in the 1924 outbreak of *Salmonella* Typhi caused by unregulated oysters in which there were 150 deaths and 1,500 cases (25).

As seen with other infectious diseases in the 20th century, the introduction of public health measures assisted in the regulation and reduction of foodborne illnesses. Between the mid-1800's and early 1900’s, the creation of government agencies such as the United States Department of Agriculture (USDA) and the Food and Drug Administration (FDA) led to the passing of fundamental food safety laws, including the Pure Food and Drug act of 1906 (26). The main component that aided in reducing foodborne illnesses was the introduction of surveillance systems that tracked cases of foodborne illnesses. Surveillance of foodborne illness assist in the control and prevention diseases acquired through food as well as identify any significant changes in frequency or distribution of cases (27). The first official record of U.S foodborne disease reporting occurred in 1923 when the U.S. Public Health Service began publishing annual summaries of foodborne illnesses linked to milk consumption (28).

Currently, foodborne illness surveillance is conducted between the state, territorial and federal levels. Federal surveillance systems include the Foodborne Disease Active Surveillance Network (FoodNet), Foodborne Disease Outbreak Surveillance System (FDOSS), and National Antimicrobial Resistance Monitoring System for Enteric Bacteria (NARMS). These surveillance systems are essential in protecting the public from foodborne illnesses as they detect and prevent additional disease by identifying sources and outbreaks as well as supporting food safety policy and prevention efforts (28). The data collected from surveillance systems are also used when creating and implementing public health interventions related to food safety and disease prevention. For instance, the National Outbreak Reporting System tracks all outbreaks reported to the CDC from 1998 and publishes verified multi-state outbreaks (29). Surveillance systems play an essential role in providing information that can highlight disparities of illnesses across populations.

2.3 Data Representation

Surveillance systems and research studies are essential to identify trends and disparities related to foodborne illness. A literature review published by Quinlan et al. identified the significant gaps in representation as foodborne illnesses are not usually tracked by race, ethnicity, and income (5). Under-representation in surveillance data is not a new concept and has been evaluated in current literature. For instance, when examining CDC surveillance systems between the years of 2010-2013, only 80% reported collecting data on race and ethnicity, and only 23% offered non-English data collection instruments (29).

In existing literature, the under-representation of racial and minority groups in foodborne disease surveillance data has been highlighted. Particularly, the FoodNet catchment sites were reported to have limited generalizability and misrepresentation of Asian and Hispanic populations (70). However, FoodNet has taken steps to improve its surveillance system, notably the inclusion of race and ethnicity in case reports since 2008. FoodNet data plays a crucial role in foodborne disease research as it provides active surveillance of eight pathogens: *Campylobacter*, *Listeria*, *Salmonella*, Shiga toxin-producing *Escherichia coli* (STEC) O157, *Shigella*, *Vibrio*, *Yersinia*; *Cyclospora*, and STEC non-O157. The introduction of race and ethnicity variables in FoodNet data allowed studies to examine trends and disparities related to minority populations. Scallan et al. (2012) highlights the use of the FoodNet data in studies published by Ong et al. and Pouilliot et al., both of which had significant findings related to foodborne pathogens and race and/or ethnicity (31). FoodNet is not the only surveillance system used to collect data on foodborne diseases. Other surveillance systems include the Laboratory-based Enteric Disease Surveillance (LEDS) system, the Listeria initiative, and the National Outbreak Reporting System (NORS). However, not all surveillance systems have expanded to include demographic variables. For instance, according to the Compendium of

Federal Datasets Addressing Health Disparities, NORS does not report race, ethnicity, or socioeconomic variables (33).

2.4 Health Inequities and Foodborne illness

Health inequities are defined by the World Health Organization as "differences in health status or in the distribution of health resources between different population groups, arising from the social conditions in which people are born, grow, live, work and age"(34). While the terms health disparities and health inequities are sometimes used interchangeably, it is important to recognize that health inequities are related to health disparities. Specifically, they are interrelated in which the CDC acknowledges reducing health disparities as a way to achieve health equity (35).

Health inequities are prevalent across the United States, especially among minority communities who face a disproportionate burden of diseases, death, and disability compared to non-minority groups (35). There is a growing interest in using this lens to understand foodborne illness in the United States and the inclusion of variables such as race and ethnicity in active surveillance systems can help.

A literature review examining incidence rates of foodborne illnesses across minority/racial groups and low socio-economic status (SES) populations found that these populations do experience greater rates of foodborne illnesses (4). Specifically, Quinlan (2013) found that burden differed by pathogen as in "minority populations appear to suffer from greater rates of some pathogens (*Salmonella*, *Shigella*, *Listeria monocytogenes*, and *Yersinia enterocolitica)"* (4). Evidence of these disparities can be found in current literature in which more studies examining the role of race and ethnicity on foodborne illness have become available. In particular, Chang et al. found that incidence of salmonellosis was moderately correlated (r=0.2) with the county percentage population of Black or African American persons and incidence of shigellosis was associated with the Hispanic and/or Latino population (r=0.3) (36). Chang et al. also concluded that race, age groups, ethnicity, urbanization, and poverty were positively associated with both the incidence of salmonellosis and shigellosis (36). Regarding shigellosis, Libby et al. and Hadler et al. found a higher incidence of *Shigella* among children under the age of 5 years, Black or African American individuals, and Hispanic individuals (37, 38). Notably, Hadler et al. reported the difference in the burden of *Shigella* among Black or African American individuals and Hispanic individuals as 1.5 times that of White individuals (39). Davis et al. examined risk factors of campylobacteriosis in two Washington state counties and found a strong association between *Campylobacter* infection and Hispanic ethnicity (40). This study also examined unique risk factors related to *Campylobacter* infection to identify trends related to increased risk across racial and ethnic groups. While documenting differences is a start, understanding why they exist and identifying tools to document and identify risk factors would help in prevention.

Understanding the reason for disparities in foodborne illness across racial and minority populations has been difficult due to the variety of mediators and external variables related to foodborne illness. One variable highlighted in current literature is the role of urbanicity on foodborne illness, in which two studies found significance between urbanicity, race, and *Campylobacter* infection (41,42). The relationship between urbanicity and foodborne illnesses may be related to variables that are associated with the two independently. For instance, Dutko et al. (2012) identified the inter-relatedness of race, urbanicity, and access to food. Across all but one urbanicity level, the higher the percentage of the minority population, the more likely the area is considered a food desert. Similarly, the influence of poverty level on the risk of foodborne illnesses has been highlighted in current literature. In which, Hadler et al. examined the relationship between the census tract poverty level and risk of STEC O157 and found that poverty level was significant across all races except for Asian persons (38). Similarly, Hadler et al. identified a relationship between census tract poverty level and risk of *Salmonella* in which children and older adults living at a higher poverty level had a higher incidence of salmonellosis (39). Incidence rates of salmonellosis have also been shown to be influenced by community socioeconomic factors and incidences of unique exposures.

2.5 Study Rationale

Over the past decade, changes to surveillance systems and increased research studies examining health inequities across foodborne illnesses have created a new opportunity for additional research on this topic. Surveillance networks such as the Foodborne Diseases Active Surveillance Network (FoodNet), Emerging Infections Program (EIP), and the Laboratory-based Enteric Disease Surveillance (LEDS) began including race and ethnicity variables in their datasets in 2008. These networks have created a foundation for epidemiological studies to examine the role of race and ethnicity in foodborne illnesses as a component of study design. Studies are needed to identify both differences in burden of foodborne illnesses as well as reasons for why these differences occur. The goal of the literature review was to identify current trends in the literature as well as understand the breakdown of race and ethnicity across datasets. Not only will the results of this review provide attention to populations who are disproportionately burdened, but it will also provide an overview of the treatment of race and ethnicity variables. The analysis of the salmonellosis data examines variables that are highlighted in the literature review allowing for further investigation of these variables across a large dataset.

CHAPTER 3

METHODS AND PROCEDURES

3.1 Pseudo-Systematic Review

Measured Outcomes

The literature review for this thesis was conducted as a pseudo-systematic review, focusing on two main components:

1. Identifying current studies that explore health disparities and health inequalities in enteric and foodborne disease.
2. Assessment of how racial and ethnic groups are considered during data collection and analysis.

Data Source

While an overview of disparities and inequities related to foodborne illnesses is provided, this literature review focuses on *Campylobacter, Salmonella, Shigella,* and Shiga toxin-producing *Escherichia coli* (*STEC*). The selection of these pathogens is based on the 2019 FoodNet Annual Report, in which *Campylobacter, Salmonella, Shigella,* and Shiga toxin-producing *Escherichia coli* (STEC) had the highest incidence rates. A search for peer-reviewed articles using PUBMED, Medline, Embase, CINAHL, and Scopus (Table 1) was conducted using keywords developed by librarians from the CDC. To keep the search broad, all twelve of FoodNet's priority pathogens were included in the keywords. Then after screening, articles were selected based on the subject content of the four chosen pathogens (*Campylobacter, Salmonella, Shigella,* and Shiga toxin-producing *Escherichia coli* (STEC).

Inclusion and Exclusion Criteria

For the purpose of this review, studies were included in the literature review if they met the following criteria: (1) published in English, (2) published after the year 1999, and (3) provided data and results on variables of race or ethnicity (4) used data that pertained to the United States and (5) scope included one of the selected focus pathogens (*Campylobacter, Salmonella, Shigella* and Shiga toxin-producing *Escherichia coli* (*STEC*

Table 1. Search Terms By Database, Date, Number of Hits, and Keywords

Database	**Strategy**	**Records**
Medline (OVID) 1946-	Exp Foodborne Diseases/ OR (Foodborne OR foodborne OR foodnet OR *Campylobacter* OR Cyclospora OR Listeria OR Salmonell* OR Shiga toxin* OR *Escherichia coli*OR e?coli OR *Shigella** OR Vibrio OR Yersinia OR Cryptosporidium).ti,ab,kf,hw. AND (Ethnic group* OR minority group* OR African American* OR Black American* OR Asian American* OR Hispanic* OR Native American* OR American Indian* OR immigrant* OR ((social determinant* OR social class* OR minorit* OR ethnic* OR race* OR racial) AND (equit* OR disparit* OR inequit*)) OR (Health* ADJ5 (equit* OR disparit* OR inequit*))).ti,ab,kf,hw.	386
Embase (OVID) 1974-	Exp Foodborne Diseases/ OR (Foodborne OR foodborne OR foodnet OR *Campylobacter* OR Cyclospora OR Listeria OR Salmonell* OR Shiga toxin* OR *Escherichia coli*OR e?coli OR *Shigella** OR Vibrio OR Yersinia OR Cryptosporidium).ti,ab,kf,hw. AND (Ethnic group* OR minority group* OR African American* OR Black American* OR Asian American* OR Hispanic* OR Native American* OR American Indian* OR immigrant* OR ((social determinant* OR social class* OR minorit* OR ethnic* OR race* OR racial) AND (equit* OR disparit* OR inequit*)) OR (Health* ADJ5 (equit* OR disparit* OR inequit*))).ti,ab,kf,hw.	278 -185 duplicates =93 unique items

CINAHL (EbscoHost)	(TI (Foodborne OR foodborne OR *Campylobacter* OR Cyclospora OR Listeria OR Salmonell* OR "Shiga toxin*" OR "Escherichia coli" OR e?coli OR *Shigella** OR Vibrio OR Yersinia OR Cryptosporidium)) OR (AB (Foodborne OR foodborne OR *Campylobacter* OR Cyclospora OR Listeria OR Salmonell* OR "Shiga toxin*" OR "Escherichia coli" OR e?coli OR *Shigella** OR Vibrio OR Yersinia OR Cryptosporidium)) AND (TI ("Ethnic group*" OR "minority group*" OR "African American*" OR "Black American*" OR "Asian American*" OR Hispanic* OR "Native American*" OR "American Indian*" OR immigrant* OR (("social determinant*" OR "social class*" OR minorit* OR ethnic* OR race* OR racial) AND (equit* OR disparit* OR inequit*)) OR (Health* N5 (equit* OR disparit* OR inequit*)))) OR (AB ("Ethnic group*" OR "minority group*" OR "African American*" OR "Black American*" OR "Asian American*" OR Hispanic* OR "Native American*" OR "American Indian*" OR immigrant* OR (("social determinant*" OR "social class*" OR minorit* OR ethnic* OR race* OR racial) AND (equit* OR disparit* OR inequit*)) OR (Health* N5 (equit* OR disparit* OR inequit*)))) Limit English ; 1999 - ;	56 -45 duplicates =11 unique items
Scopus	TITLE-ABS-KEY(Foodborne OR foodborne OR *Campylobacter* OR Cyclospora OR Listeria OR Salmonell* OR "Shiga toxin*" OR "Escherichia coli" OR e?coli OR *Shigella** OR Vibrio OR Yersinia OR Cryptosporidium) AND TITLE-ABS-KEY("Ethnic group*" OR "minority group*" OR "African American*" OR "Black American*" OR "Asian American*" OR Hispanic* OR "Native American*" OR "American Indian*" OR immigrant* OR (("social determinant*" OR "social class*" OR minorit* OR ethnic* OR race* OR racial) AND (equit* OR disparit* OR inequit*)) OR (Health* W/5 (equit* OR disparit* OR inequit*))) AND NOT INDEX(medline) Limit English ; 1999 - ;	169 -57 duplicates =112 unique items
PubMed	(((Foodborne OR foodborne OR *Campylobacter* OR Cyclospora OR Listeria OR Salmonell* OR Shiga toxin* OR *Escherichia coli*OR E.coli OR *Shigella** OR Vibrio OR Yersinia OR Cryptosporidium)) AND (Ethnic group* OR minority group* OR African American* OR Black American* OR Asian American* OR Hispanic* OR Native American* OR American Indian* OR immigrant*)) AND ((social determinant* OR social class* OR minorit* OR ethnic* OR race* OR racial OR equit* OR disparit* OR inequit*)) AND (United States OR USA)	44 - 34 duplicates = 10 unique

3.2 Salmonellosis Analysis

Data Sample

The data source for this analysis was taken from the Laboratory-based Enteric Disease Surveillance (LEDS) system, a passive surveillance dataset managed by the CDC. The LEDS dataset was aggregated to the county-level for each year between 1997 and 2018, and joined with relevant metadata, including county-level census data on race and ethnicity, CDC data on county urbanicity and social vulnerability indices (SVI), and USDA data on food environment.

The SVI dataset comprises 15-metrics, including metrics of socioeconomic status (e.g., median income, percent unemployed), community composition (e.g., percent of county population under 17 and over 65, percent that speaks English less than well, percent that is an underrepresented minority) and access to resources/physical environment (e.g., percent without access to a car). The USDA data on food environment was used to obtain the variable of food insecurity while the SVI dataset was used to obtain the level of English spoken and community composition variables). Census data is available for each year of the study, while SVI data was available for 2000, 2010, 2014, 2016 and 2018, and USDA data are available for 2011 to 2017. The definition of urbanicity was obtained though the National Center for Health Statistics and included large central metropolitan counties, large fringe metropolitan counties, medium and small metropolitan counties, micropolitan counties and noncore (rural) counties.

Analytical Approach

The purpose of this analysis was to provide a descriptive summary of the dataset, with the primary variable of measurement being the incidence of salmonellosis on the county level. All analyses for this thesis were conducted using R Studio. To account for the skewedness in the dataset, the incidence rate was log transformed and back transformed to the original scale. Distribution of social metrics and demographic variables including race, ethnicity and age in this dataset was summarized using five number summary tables. For both food insecurity variables and social vulnerability index themes, counties were categorized into equal quartiles that represented the lowest (Q1) and highest levels (Q4). Using R studio, the geometric mean incidence of salmonellosis across social vulnerability themes, levels of food insecurity and urbanicity was calculated.

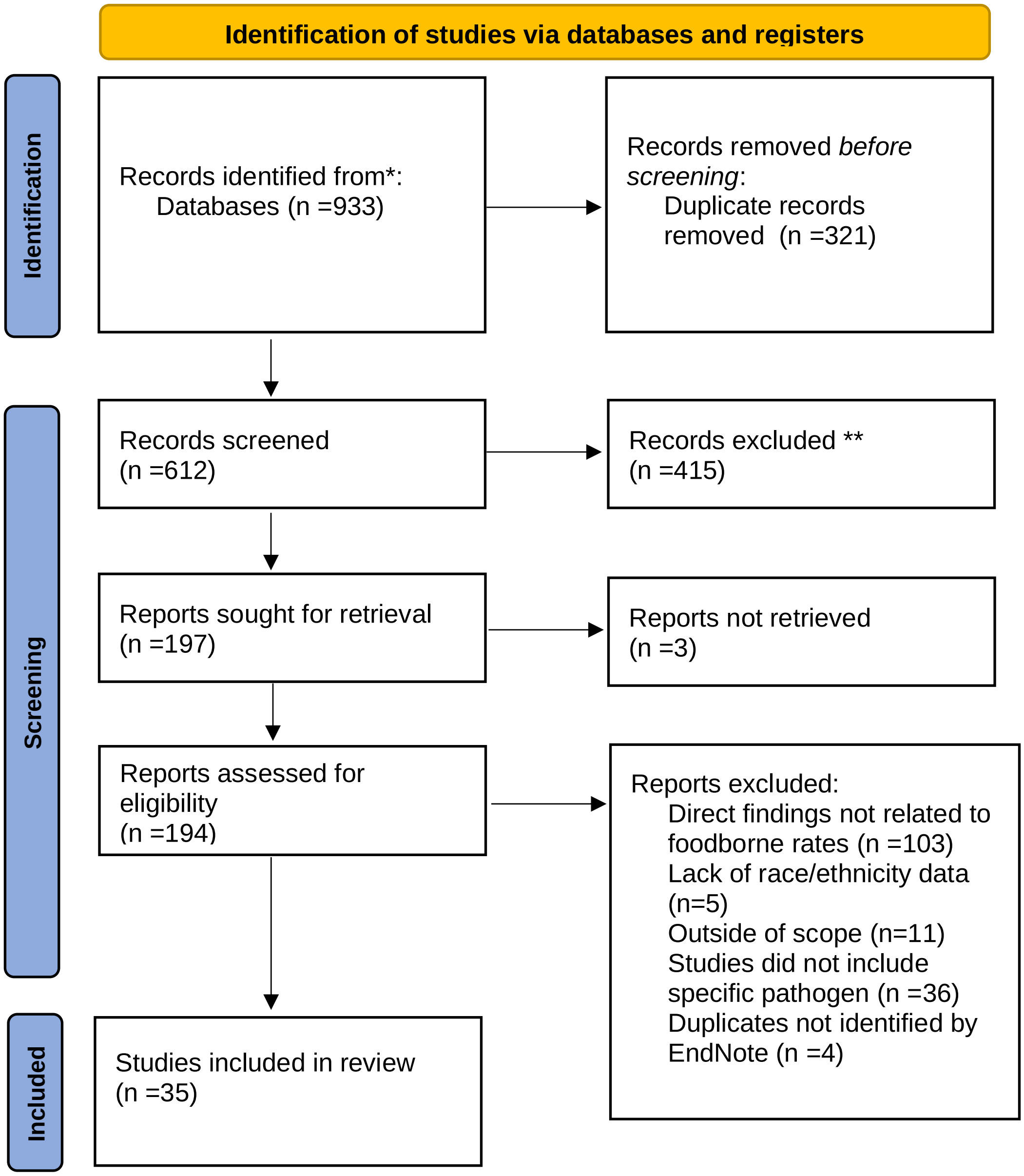
CHAPTER 4

RESULTS

4.1 Literature Review Results

Summary of Findings

A total of 933 articles were obtained from the initial search using the keywords. Out of the 933 articles, 321 articles were automatically removed as duplicates using reference citation software EndNote. The author screened a total of 612 articles by reading the title and abstracts from each article. Once identified, studies were screened further based on the following exclusions: (1) study was conducted outside of the United States or, (2) study focus was outside of foodborne pathogens, (3) study did not report any race and/or ethnicity data. After screening, a total of 197 reports were retained, and 194 were retrieved. Of the 194 articles that were assessed for eligibility, 103 studies were removed due to their focus being outside of foodborne illness, 36 articles were removed since they did not focus on *Salmonella, Campylobacter*, Shiga Toxin-producing *E. coli* and *Shigella*, 4 were removed as duplicates, and 5 were removed for lack of race/ethnicity data. After assessing eligibility, 35 articles were included in this review.



** Excluded based on title and abstract

Figure 1. PRISMA Flow Diagram

Table 2. Number of findings included in review by pathogen

Pathogen	Number of Findings
Campylobacter	7
Shiga-Toxin Producing *Escherichia coli*	3
Salmonella	20
Shigella	8
Total Number of Findings*	38

**Total is greater than total number of studies because some studies included more than one pathogen*

Current Trends in Literature

As seen in figure 2, the number of publications per year ranged from 1 to 6, with 2018 having the largest number of articles. The majority of articles in this review focused on *Salmonella* (51%), followed by *Shigella* (20%), *Campylobacter* (17%), and STEC (6%). Of these studies, 2 papers reported findings for multiple pathogens (6%). Of the 35 articles included in this review, 29 (82%) reported findings of differences in rates and risk of foodborne illnesses by race and/or ethnicity.

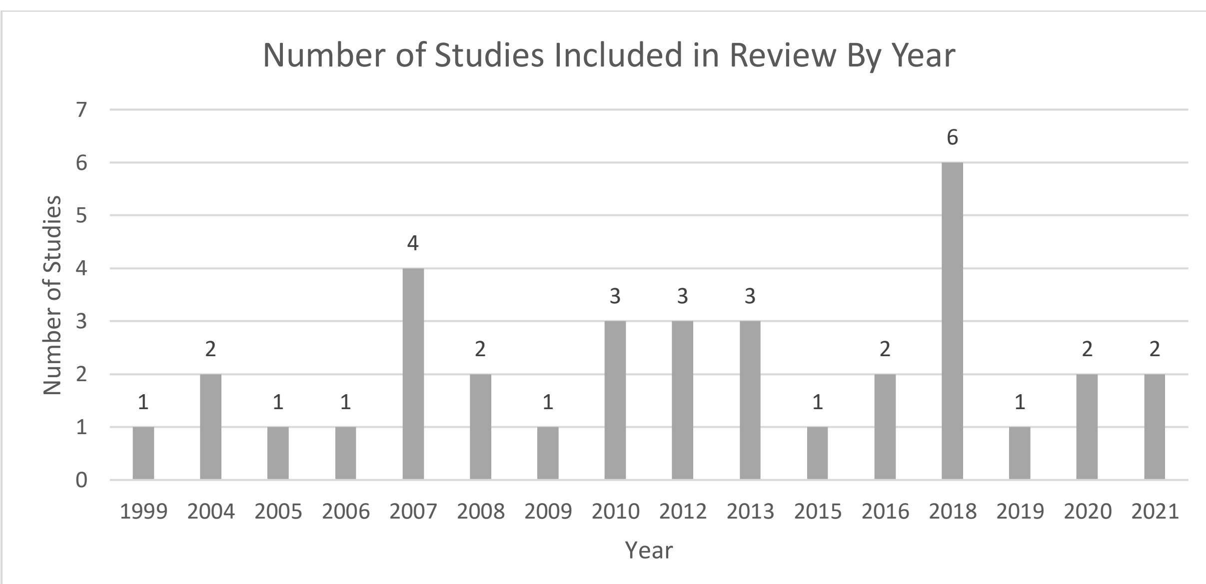


Figure 2. Number of articles retained for full analysis (N=35) in the literature review that included information on race or ethnicity by year (1999-2021)

Table 3. Studies by Findings Related to Differences in Foodborne Illness by Race/Ethnicity

Pathogen	Response Value	Count of Reported Response
Campylobacter spp.		
	No	1
	Yes	5
Multiple Pathogens		
	Yes	2
Salmonella spp.		
	No	4
	Yes	14
Shigella spp.		
	No	1
	Yes	6
Shiga Toxin producing *Escherichia coli*		
	Yes	2
Grand Total		**35**

*Multiple pathogen papers reported a difference in findings for *Salmonella, Campylobacter, Shigella* and Shiga Toxin producing *Escherichia coli*

4.2 Review Results by Pathogen

Campylobacter

In this review, 6 out of the 7 *Campylobacter* articles reported a difference in *Campylobacter* rates when comparing between racial and ethnic groups. Of the 6 articles that reported a difference in campylobacteriosis incidence between racial or ethnic groups, 5 of them identified increased incidence among Hispanic individuals compared to non-Hispanic individuals. The sixth article (Weisent, Rohbrach, Dunn & Odoi (2012)) found a significant association between race, *Campylobacter* risk, and socioeconomic factors (42).

Weisent, Rohbrach, Dunn & Odoi (2012) examined the role of socioeconomic factors on geographic disparities in *Campylobacter* risk using global and local modeling approaches. This study analyzed FoodNet data between 1991 and 2008 at the census tract level. Both models reported in the paper found that race, unemployment rate, education, urbanicity, and divorce rate were significantly associated with campylobacteriosis at the community level. In terms of spatial factors, the strongest association reported was between urbanicity and campylobacteriosis risk, with areas with higher percentages of those who identified as Black or African American as having an increased strength of association compared to areas with lower percentages. It is important to note that even though this study did report a lower risk of *Campylobacter* in census tracts with higher percentages of those who identified as Black or African American, this may be due to other factors related to misrepresentation and/or underreporting.

A case-control study conducted by Pogreba-Brown et al. (2015) that assessed risk factors of sporadic *Campylobacter* infections in Arizona found that Hispanic persons had a higher odds of disease compared to non-Hispanic persons. The study hypothesized that the difference in dietary practices by ethnicity may explain difference in disease but suggested future studies to explore this topic.

Another case-control study conducted by Davis et al. (2013) examined risk factors of campylobacteriosis in two Washington counties with a high number of dairy farms. Cases were reported from the Washington State Department of Health and interviewed with a standardized campylobacteriosis questionnaire, while controllers were matched by county and age. The conditional logistic regression analysis from both counites found that the following factors were significantly associated with campylobacteriosis: living or working on a dairy farm (odds ratio [OR], 6.7, 95% CI [7 to 26.4]) and Hispanic ethnicity (OR, 6.4, 95% CI [3.1 to 13.1]) (40).

Salmonella

In this review, 15 out of the 20 (75%) *Salmonella* articles reported a difference in *Salmonella* results when comparing across different racial and ethnic groups. Of the 15 articles that reported a difference in study measurements, 8 reported an increased illness among the Hispanic individuals compared to non-Hispanic individuals. For example, Arshad et al. who examined the incidence of salmonellosis in Michigan, reported a significantly higher age-adjusted incidence rate of salmonellosis for Hispanic individuals compared to non-Hispanic individuals (1.0 vs. 0.5; RR, 1.9; 95% CI, 1.21–2.98) (43). Similarly, a case-control study (Vulga et al., 2004) that examined invasive salmonella infections in the United States found that both salmonellosis incidence and the proportion of invasive infections were higher among Hispanic individuals (IR:1.3 cases/100,000, proportion (9%)) compared to non-Hispanic, White individuals (IR: 0.4 cases/100,000, proportion: 5%)).

Eight studies also reported an increased risk and/or incidence of salmonellosis for Black or African American individuals compared to other races. For example, Vugia et al. also found that both salmonellosis incidence and invasiveness were highest among non-Hispanic, Black or African American individuals, non-Hispanic, Asian individuals ,and Hispanic individuals compared to and non-Hispanic White individuals (2.5, 2.0, and 1.3 cases/100,000 population, respectively, vs. 0.4 cases/100,000; all P < .001) (44). Similar findings were reported for infants by Cheng et al, when comparing salmonellosis incidence across other races, incidence was highest among the Black or African American population (IR:177.8, [95 %CI] 152.7–202.8) followed by the Asian population (IR: 29.7, [95% CI] 94.8–164.7). This study also found that the

Hispanic population had a higher incidence of salmonellosis (IR: 86.7,(95% CI, 74.6—98.9) compared to the non-Hispanic population (45).

Variables related to socioeconomic status (SES), environment, and population demographics were found to be differentially associated with salmonellosis burden for different populations. Most recently, Gourishankar (2021) examined the association of salmonellosis and socioeconomic factors in Texas and found that SES indicators such as low access to grocery stores, percent unemployed and percentage by ethnicity were significant in counties with high clusters of salmonellosis. Similarly, Hadler et al. (2020) reported a higher age-adjusted incidence for census tracts with higher poverty levels ($p < 0.01$) regardless of stratification by race and ethnicity. This relationship between age-adjusted salmonellosis incidence and poverty level was examined across the 10 FoodNet sites to further explore this relationship, in which 5 out of 10 proved to be significant (California, Colorado, Georgia, Maryland, and Minnesota) (39).

Shigella

Of the articles including *Shigella* in this review, 6 out of 8 articles (75%) reported a difference in burden of illnesses across race and ethnicity. Of the 6 articles that reported a difference, 5 reported an increased burden among Hispanic individuals compared to non-Hispanic individuals. While 4 of the 6 articles reported increased burden across those who identified as Black or African American compared to other races included in the paper.

Haley et al. (2010) investigated the risk factors of sporadic shigellosis by questioning cases about exposures the week before symptoms began. The highest incidence of shigellosis was among children aged 1-4 years (IR:16.4) and the following populations: Hispanic (8.4), Native American/Alaskan Native (7.0), Black or African American (3.8), and White (3.0). The identification of increased incidence among both Hispanic and Native American children was also documented in a study conducted by Gharpure et al., who examined disparities in the incidence of *Shigella*. In this study, Hispanic children had a higher proportion of severe disease (17.6%) compared to non-Hispanic children. While Native American/Alaskan Native children had a higher proportion of severe disease (16.5%) compared to Asian/Pacific Islander, Black or African American, or White children. However, the overall incidence of *Shigella* was highest in Black or African American children (IR: 16.2 total infections per 100,000 child-years) compared to Asian/Pacific Islander, Black or African American, or White children (47).

In direct comparison to the White population, McCrickard et al. (2018) and Hill et al. (2005), identified an increased burden of disease among those who identified as Black or African American. Specifically, McCrickard et al. (2018) investigated disparities in severe shigellosis and found that Black or African American individuals had higher odds of disease when compared with White individuals (OR: 1.36, 95% CI: 1.22–1.52, $p < 0.01$) and other racial groups (OR: 1.27, 95% CI: 1.02–1.58, $p = 0.04$). When examining rates across racial groups the study also found that the highest median annual incidence of severe shigellosis (2.76 cases) was among those who identified as Black or African American males between the age of 18-49 years. Similarly, Hill et al. (2005) examined the association of select bacterial infections with contact with animal waste across racial groups and found that sex-race specific rates were highest among Black or African American men (8.3 per 100,00) and Black or African American women (5.9 per 100,000) (48).

STEC O157

All three STEC O157 articles reported a difference in burden of illness by race and/or ethnicity with increased burden among Hispanic individuals, and two reported differences between racial groups. Chang et al. (2009) conducted an ecological analysis of sociodemographic factors associated with incidence of STEC O157 infections on the US county level. Using data from the National Notifiable Diseases Surveillance System (NNDSS), the correlation between incidence and multiple factors including poverty level, education level, urbanicity, region, race, ethnicity, age, and gender. The three factors that were correlated with incidence of STEC O157 was percentage of Hispanic population (r=0.3), percentage of population aged <5 years (r=0.3), and percentage of aged 45-64 years (r=0.3) (36).

Gould et al. (2013) compared incidence of non-0157 STEC to 0157 STEC infection using data reported from FoodNet between the years of 2000-2010. Along with incidence, proportions by age group, gender and FoodNet site were also given. The results indicated that there was a higher proportion of non-O157 infections among Hispanic individuals compared to case demographics of O157 infections (16% vs. 6%) (49).

4.3 Data Representation

Racial Groupings

Out of the 35 articles reviewed, race and ethnicity were reported 12 different ways. The three most common groupings of race and ethnicity included ethnicity only and mix of the following racial groups: Asian, Black, Native American, Unknown, Other, and White. For each study that reported only ethnicity, all of them used the grouping of Non-Hispanic or Hispanic.

Among studies that reported race, the racial groupings of Black and White were the most common followed by Asian, Native American, and Chinese. Only 6 out of the 35 articles used the recommended minimum racial groupings listed in the Race and Ethnic Standards for Federal Statistics.

Structure of Groupings/Missingness

The use of "Other" as a racial grouping was used in studies with 17 of the 35 (48%) studies that considered race in their analyses. The most common use of the "Other" racial grouping was for cases that did not meet the definition of the racial groupings in the given study. Further collapsing of minority variables was seen in 9 (26%) out of the 35 articles reviewed. For example, individuals that reported identifying as non-Hispanic and multiple races were grouped as other by Gharpure et al.

4.2 Salmonellosis Analysis

<u>Dataset Characteristics and Demographics</u>

A total of 65,758 geo-referenced salmonellosis cases were reported to the National *Salmonella* Surveillance System between 1997 and 2018.

<u>Salmonellosis Incidence and Proportion of Population by Race and Ethnicity</u>

Counties where a larger proportion (i.e., counties that fell into quartile 4) of the population identified as Black or African American, American Indian or Native American, Asian or Pacific Islander, or Native Hawaiian or Other Pacific Islander compared to counties where a smaller proportion (i.e., counties that fell into quartile 1) of the population identified as such (Table 5).

Salmonellosis Incidence and Urbanicity

Urbanicity is made up of six levels defined by county population size and categorized most urban (large central metro) to least urban (noncore/rural). The highest geometric mean salmonellosis incidence was 8.03 per 100,000 in large central metro counites (Table 6).

Salmonellosis Incidence by Urbanicity and SVI Themes

The SVI is an index comprised of four ranked sub-indices, each representing a separate theme. The four themes are: (1) socioeconomic status, (2) household composition & disability, (3) minority status and language, and (4) housing type and transportation. A higher ranking for any given theme indicates that a county has a higher potential for negative health effects compared to lower ranked counties. As a result, comparing salmonellosis incidence for counties in the first quartile for a given ranking to incidence for counties in the fourth quartile will allow for identification of health disparities associated with each theme.

SVI Theme 1 (Socioeconomic Status): The geometric mean salmonellosis incidence per 100,000 was 5.67, 4.93, 4.56, and 5.48 for counties that fell into quartiles one, two, three, and four for the Socioeconomic SVI Theme (Theme 1); this is a difference of -0.19 between counties in the first (least socioeconomically disadvantaged counties) and fourth (most socioeconomically disadvantaged counties) quartiles (Table 7). When the difference in quartiles one and four are calculated after stratifying by urbanicity, the difference between counties that fell into the first and fourth quartiles was -6.75, -1.5, -0.82, 1.22, 2.23 and 0.91 for large metro counties, suburban counties, medium metro, small metro, micropolitan, and noncore (rural) counties, respectively.

SVI Theme 2 (Housing Composition and Disability): The geometric mean salmonellosis incidence per 100,000 was 8.60, 8.03, 8.22, and 3.18 for counties that fell into quartiles one, two, three, and four for the Housing Composition and Disability SVI Theme (Theme 2); this is a difference of -0.61 between counties in the first and fourth quartiles (Table 7). When the difference in quartiles one and four are calculated after stratifying by urbanicity, the difference between counties that fell into the first and fourth quartiles was -4.85, 0.47, 0.24, 3.77, 2.25 and 1.72 for large metro counties, suburban counties, medium metro, small metro, micropolitan, and noncore (rural) counties, respectively.

SVI Theme 3 (Minority Status & Language): The geometric mean salmonellosis incidence per 100,000 was 3.34, 4.56, 5.77 and 7.72 for counties that fell into quartiles one, two, three, and four for the Minority Status and Language SVI Theme (Theme 3); this is a difference of 4.38 between counties in the first and fourth quartiles (Table 7). When the difference in quartiles one and four are calculated after stratifying by urbanicity, the difference between counties that fell into the first and fourth quartiles was 5.58, 4.42, 6.29, 4.58 and 2.19 for suburban counties, medium metro, small metro, micropolitan, noncore (rural). A difference in the first and fourth quartiles for SVI Theme 3 could not be calculated for large central metro because no counties were reported at that SVI theme ranking and urbanicity level.

SVI Theme 4 (Housing Type and Transportation): The geometric mean salmonellosis incidence per 100,000 was 5.26, 5.00, 4.53, and 5.86 or counties that fell into quartiles one, two, three, and four for the Housing Type and Transportation SVI Theme (Theme 4); this is a difference of 0.60 between counties in the first and fourth quartiles (Table 7). When the difference in quartiles one and four are calculated after stratifying by urbanicity, the difference between counties that fell into the first and fourth quartiles was 1.18, 0.23, 1.88, 3.01, 2.8, and -0.19 for large metro counties, suburban counties, medium metro, small metro, micropolitan, noncore (rural).

Salmonellosis Incidence by Urbanicity and Food Insecurity Variables

The two variables were used to measure food insecurity: (1) percent of the population that was food insecure and (2) percent of the population that had low access to grocery stores (i.e., that lived in a food desert).

Food Insecurity: The geometric mean salmonellosis incidence per 100,000 was 5.10, 6.15, 5.88, and 3.75 for counties that fell into quartiles one, two, three, and four for the percent of population that is food insecure (Table 8). When the difference in quartiles one and four are calculated after stratifying by urbanicity, the difference between counties that fell into the first and fourth quartiles for food insecurity was -2.89, -1.83, -0.2, 3.64, 1.86, and 1.33 for large metro counties, suburban counties, medium metro, small metro, micropolitan, and noncore (rural) counties, respectively.

Food Desert: The geometric mean salmonellosis incidence per 100,000 was 5.09, 4.91, 5.16, and 5.79 for counties that fell into quartiles one, two, three, and four for the percent of population that is food insecure (Table 8). When the difference in quartiles one and four are calculated after stratifying by urbanicity, the difference between counties that fell into the first and fourth quartiles for store access was 4.6, 0.84, 1.51,0.66, -1.02 and -2.34 for large metro counties, suburban counties, medium metro, small metro, micropolitan, and noncore (rural) counties, respectively.

Table 4. Summary statistics of population characteristics on the county level

Variable	Min-Max	Mean (SD)	Median (Q1-Q3)
Socioeconomic Status			
Living Below Poverty **(%)**	1.0-56.7	15.1 (6.5)	14.0 (10.4-18.6)
Unemployed **(%)**	0.0-30.9	5.7 (3.7)	4.9 (2.7-7.9)
Per Capita Income ($)	6,670.00-72,832.00	21,278.50 (6021.0)	20325.8 (17008.8-24368.0)
Without a High School Diploma **(%)**	0.7-53.3	15.4 (6.6)	14.1 (10.5-19.7)
Household Composition & Disability			
Aged 65 or Older **(%)**	0.0-34.7	6.1 (7.7)	0.2 (0.2-13.5)
Aged 17 or Younger**(%)**	0.1-43.9	10.5 (12.5)	0.3 (0.2-24.5)
Civilian with a Disability **(%)**	3.8-37.2	17.3 (4.6)	16.9 (14.1-20.3)
Single-Parent Households **(%)**	0.0-38.4	8.7 (3.2)	8.3 (6.5-10.3)
Minority Status & Language			
Minority **(%)**	0.0-99.3	20.9 (19.6)	13.5 (5.5-32)
Speaks English "Less than Well" **(%)**	0.0-29.3	0.6 (1.7)	0.0 (0.0-0.5)
Housing Type & Transportation			
Living in Multi-Unit Structures **(%)**	0.0-90.1	4.3 (5.4)	2.6 (1.2-5.4)
Living in Mobile Homes **(%)**	0.0-63.1	13.8 (9.5)	12.0 (6.2-19.7)
Living in Crowded Housing **(%)**	0.0-51.4	2.6 (2.5)	1.9 (1.3-3.1)
Does Not Own a Vehicle **(%)**	0.0-87.8	6.5 (4.2)	5.8 (4.4-7.7)
Living in Group Quarters **(%)**	0.0-59.3	3.4 (4.3)	2.0 (1.3-3.8)

Table 5. Geometric mean incidence of salmonellosis across levels of proportion of population reported by race and ethnicity

	Incidence by Race					Incidence by Ethnicity
	Asian or Pacific Islander	**Black or African American**	**Native American or Alaskan Native**	**Native Hawaiian or Other Pacific Islander**	**White**	**Hispanic**
Percent of County Population Reported						
Q1 (Lowest)	2.31	2.40	4.21	3.49	6.96	3.16
Q2	4.74	5.23	6.35	8.54	6.46	5.52
Q3	7.24	6.67	5.99	5.68	5.17	6.25
Q4 (Highest)	8.10	7.76	4.32	6.79	2.89	6.24

Table 6. Geometric mean incidence of salmonellosis by urbanicity ranking

	Urbanicity					
	Large central metro	**Large fringe metro (Suburban)**	**Medium metro**	**Small metro**	**Micropolitan**	**Noncore (Rural)**
Geometric Mean Incidence (per 100,000)	8.03	7.28	7.00	7.38	6.58	3.34

Table 7. Geometric mean salmonellosis Incidence across urbanicity and Social Vulnerability Index themes

		Incidence (95%) by Urbanicity					
	Overall Incidence by SVI Theme	**Large central metro**	**Large fringe metro (Suburban)**	**Medium metro**	**Small metro**	**Micropolitan**	**Noncore (Rural)**
Socioeconomic Status							
Q1 (Lowest)	5.67	10.52 (9.53,11.59)	8.45 (8.18,8.72)	7.65 (7.28,8.03)	7.36 (6.94,7.81)	5.78 (5.47,6.11)	3.28 (3.11,3.45)
Q2	4.93	8.64 (8.07,9.24)	6.05 (5.73,6.39)	6.85 (6.52,7.18)	6.76 (6.4,7.14)	6.29 (6.02,6.57)	2.82 (2.68,2.97)
Q3	4.56	6.78 (6.1,7.53)	5.94 (5.44,6.47)	6.53 (6.13,6.96)	7.29 (6.88,7.72)	6.11 (5.86,6.38)	2.85 (2.73,2.98)
Q4 (Highest)	5.48	3.77 (2.7,5.16)	6.95 (6.22,7.74)	6.83 (6.31,7.38)	8.58 (7.95,9.26)	8.01 (7.65,8.38)	4.19 (4.03,4.35)
Disparity (Q4-Q1)	-0.19	-6.75	-1.5	-0.82	1.22	2.23	0.91
Household Composition & Disability							
Q1 (Lowest)	6.34	8.6 (7.94,9.3)	8.48 (8.2,8.76)	8.28 (7.89,8.68)	8.43 (8.02,8.86)	6.82 (6.5,7.15)	3.54 (3.35,3.73)
Q2	4.49	8.03 (7.41,8.7)	6.28 (5.95,6.63)	6.67 (6.34,7.01)	5.8 (5.45,6.17)	5.6 (5.33,5.88)	2.69 (2.56,2.82)
Q3	4.25	8.22 (7.29,9.27)	5.62 (5.18,6.09)	6.08 (5.71,6.46)	6.79 (6.38,7.22)	6.01 (5.75,6.27)	2.74 (2.63,2.86)
Q4 (Highest)	5.73	3.18 (1.96,4.88)	6.75 (6.07,7.5)	6.91 (6.4,7.44)	9.57 (8.91,10.26)	7.85 (7.51,8.21)	4.41 (4.24,4.59)
Difference in Incidence (Q4-Q1)	-0.61	-4.85	0.47	0.24	3.77	2.25	1.72
Minority Status & Language							
Q1 (Lowest)	3.34	NA (NA)*	4.65 (4.31,5.02)	5.25 (4.86,5.67)	4.35 (3.98,4.75)	4.5 (4.26,4.75)	2.65 (2.54,2.75)
Q2	4.56	8.69 (7.35,10.23)	6.28 (5.97,6.61)	5.3 (4.98,5.64)	6.12 (5.76,6.51)	5.93 (5.68,6.19)	3.17 (3.03,3.31)

Q3	5.77	6.43 (5.78,7.13)	7.41 (7.04,7.8)	6.96 (6.6,7.34)	8.52 (8.14,8.93)	7.09 (6.8,7.4)	3.62 (3.44,3.8)
Q4 (Highest)	7.72	8.83 (8.3,9.38)	10.23 (9.81,10.66)	9.67 (9.26,10.09)	10.64 (10.06,11.25)	9.08 (8.68,9.5)	4.84 (4.59,5.1)
Difference in Incidence (Q4-Q1)	4.38	-	5.58	4.42	6.29	4.58	2.19
Housing Type & Transportation							
Q1 (Lowest)	5.26	7.03 (5.33,9.19)	8.02 (7.74,8.32)	7.46 (7.04,7.91)	6.68 (6.19,7.2)	5.25 (4.91,5.62)	3.76 (3.6,3.93)
Q2	5.00	8.12 (7.47,8.82)	6.56 (6.24,6.9)	5.98 (5.68,6.3)	6.35 (6,6.73)	6.22 (5.95,6.51)	3.29 (3.14,3.45)
Q3	4.53	7.86 (7.02,8.79)	6.09 (5.63,6.57)	6.04 (5.69,6.41)	7.06 (6.65,7.5)	6.28 (6.03,6.54)	2.75 (2.63,2.88)
Q4 (Highest)	5.86	8.21 (7.52,8.94)	8.25 (7.56,8.99)	9.34 (8.84,9.86)	9.69 (9.19,10.21)	8.05 (7.72,8.39)	3.57 (3.42,3.73)
Difference in Incidence (Q4-Q1)	0.60	1.18	0.23	1.88	3.01	2.8	-0.19

*No counties were reported at this level

Table 8. Geometric mean Salmonellosis Incidence by Urbanicity and Food Insecurity Variables

		Incidence (95%) by Urbanicity					
	Overall Incidence by Food Insecurity Variable	Large central metro	Large fringe metro	Medium metro	Small metro	Micropolitan	Non-core
Food Insecure							
Q1 (Lowest)	5.10	9.66 (8.59, 10.84)	8.94 (8.65, 9.25)	7.46 (7.06, 7.88)	6.57 (6.16, 6.99)	5.54 (5.25,5.84)	2.74 (2.61, 2.87)
Q2	6.15	10.93 (10.05,11.89)	6.35 (6.04, 6.68)	6.9 (6.56,7.26)	6.64 (6.25, 7.06)	6.29 (6.03,6.57)	3.04 (2.9,3.19)
Q3	5.88	8.27 (7.34, 9.29)	5.56 (5.16, 5.98)	6.55 (6.19, 6.92)	6.79 (6.43, 7.18)	6.9 (6.61,7.21)	3.61 (3.45, 3.77)
Q4 (Highest)	3.75	6.77 (6.24, 7.35)	7.11 (6.41, 7.88)	7.26 (6.79, 7.77)	10.21 (9.58,10.88)	7.4 (7.07,7.75)	4.07 (3.9,4.24)
Difference in Incidence (Q4-Q1)	-1.35	-2.89	-1.83	-0.2	3.64	1.86	1.33
Living in Food Desert							
Q1 (Lowest)	5.09	7.93 (7.17,8.77)	6.38 (5.94, 6.84)	5.02 (4.63, 5.45)	6.21 (5.7,6.77)	6.16 (5.86, 6.47)	4.36 (4.21, 4.53)
Q2	4.91	7.35 (6.63,8.13)	8.14 (7.74, 8.57)	7.68 (7.28, 8.1)	7.4 (6.99,7.84)	7.5 (7.23,7.77)	4.16 (3.97, 4.35)
Q3	5.16	7.63 (7.01,8.31)	7.38 (7.02, 7.75)	7.92 (7.57, 8.28)	8.41 (8.04, 8.79)	7.19 (6.87, 7.53)	3.25 (3.08, 3.42)
Q4 (Highest)	5.79	12.53 (11.01,14.24)	7.22 (6.9,7.55)	6.53 (6.15, 6.93)	6.87 (6.41, 7.36)	5.14 (4.85, 5.44)	2.02 (1.92, 2.12)
Difference in Incidence (Q4-Q1)	0.70	4.6	0.84	1.51	0.66	-1.02	-2.34

CHAPTER 5

Discussion

5.1 Discussion of Research Questions

In the pseudo-systematic review, multiple studies (29 out of 35) reported disparities in foodborne illness between different populations. When examining overall results by race, 13 studies reported a higher foodborne illness incidence among Black or African American individuals compared to individuals who identified as another race. Studies also identified higher salmonellosis incidence among those who identified as Asian population (4 out of 29) as well as those who identified as Native American or Alaskan Natives (3 out of 29) compared to other races.

When the number of studies that identified a higher incidence of illness among Black or African American individuals compared to individuals of other races was compared between pathogens, more studies found evidence of this disparity for salmonellosis and shigellosis compared to other races. Similarly, these findings support similar findings related to the incidence of *Salmonella* in the literature review conducted by Quinlan (2013). As well, the majority of *Campylobacter* studies reported a difference between results for the Hispanic individuals compared to non-Hispanic individuals.

The importance of population dynamics and how they may influence the rates of foodborne illnesses across communities was highlighted in both the review and analysis. The practice of using multiple data sources to understand population demographics was common in the literature review. In particular, Halder et al. (2018), Halder et al. (2020), and Libby et al. (2020) used geocoding to link area-based social metrics, including Census denominators and areas-based socioeconomic measures, to public health surveillance data (37,38,39). The analyses reported as part of this thesis in Chapter 4 using LEDS data also included area-based social metrics and found evidence of differences in incidence of salmonellosis for different urbanicity levels, and for counties with high versus low food insecurity and social vulnerability indexes rankings. Follow-on analyses to Chapter 4 are being conducted to statistically model the association between salmonellosis incidence and county-level characteristics and determine if this association differs by urbanicity. Based on the results reported in Chapter 4, there does appear to be an interactive effect of urbanicity and county-level characteristics. This supports the findings of a similar salmonellosis analysis. Gourishankar (2021) found that severe housing problems, social association rates, college education, and low access to the store were all associated with salmonellosis (46). Other studies may benefit by including the use of the Social Vulnerability Index to measure multiple themes across the population.

Understanding the influence of these socioeconomic, geographical, and environmental factors on the incidence of salmonellosis may help us understand the reason for differences in burden across populations. For instance, a nationally representative study examining racial and ethnic disparities in household food insecurity during the pandemic found that “racial/ethnic minorities were significantly less confident about their household food security for the next four weeks than White persons” (51). Recognizing the prevalence of food insecurity across specific groups and the importance of that variable on the incidence of salmonellosis may provide more information on populations at increased risk.

5.2 Implications of Findings

Overall, this review found current disparities in foodborne illnesses across different racial and ethnic groups. Disparities appear to be most prevalent across all four pathogens among Black/African American and Hispanic persons. These findings also suggest that socioeconomic, geographical, and environmental factors play a significant role in the burden of foodborne illness and should be considered in future studies. Further investigation is needed to understand the prevalence of burden outside of the four selected pathogens in this study.

Across the review, it was apparent that data representation is dependent on data availability and design as research studies differed in how minority populations are presented in the study. Of the 35 studies, 13 reported have missing ethnicity or race data. The inconsistency of data representation across studies in this review is seen in the 12 different reported data representation methods across the 35 studies. The current approach includes the use of collapsing minority groups and the inconsistent use of racial groupings across the field. One way to minimize this practice is to implement the use of the Race and Ethnic Standards for Federal Statistics and Administrative reporting, which provides detailed guidelines on data collection. Future studies should also consider alternative methods when dealing with missingness to prevent collapsing of minority groups.

5.3 Limitations

A significant limitation faced during the review was the lack of access to three papers that were identified as eligible. These three papers could have provided important insight into data representation and findings across all four selected pathogens. As well, this review was set up as a pseudo-systematic review which did not include the use of a tiebreaker or a second reviewer. The analysis also faced the limitation of unequal sample sizes within SVI and food insecurity variables across urbanicity.

Supplemental Table

Supplemental Table 1. Studies Included in Review by Author, Year, Title and Pathogen			
Author	**Year**	**Title**	**Pathogen**
Kristen Pogreba-Brown, Erika Barrett	2018	Campylobacter and Ethnicity—A Case–Case Analysis to Determine Differences in Disease Presentation and Risk Factors	*Campylobacter*
M. E. Patrick, O. L. Henao, T. Robinson, A. L. Geissler, A. Cronquist, S. Hanna, et al.	2018	Features of illnesses caused by five species of Campylobacter, Foodborne Diseases Active Surveillance Network (FoodNet) – 2010–2015	*Campylobacter*
Rachel E. Rosenberg Goldstein, Raul Cruz-Cano, Chengsheng Jiang, Amanda Palmer, David Blythe, Patricia Ryan, Brenna Hogan, Benjamin White, John R. Dunn, Tanya Libby, Melissa Tobin-D'Angelo, Jennifer Y. Huang, Suzanne McGuire, Karen Scherzinger, Mei-Ling Ting Lee, and Amy R. Sapkota corresponding author	2016	Association between community socioeconomic factors, animal feeding operations, and campylobacteriosis incidence rates: Foodborne Diseases Active Surveillance Network (FoodNet), 2004-2010	*Campylobacter*
POGREBA-BROWN, K., BAKER, A., ERNST, K., STEWART, J., HARRIS, R., & WEISS, J.	2015	Assessing risk factors of sporadic Campylobacter infection: a case-control study in Arizona	*Campylobacter*
M. A. Davis, D. L. Moore, K. N. Baker, N. P. French, M. Patnode, J. Hensley, et al.	2013	Risk factors for campylobacteriosis in two washington state counties with high numbers of dairy farms	*Campylobacter*
J. Weisent, B. Rohrbach, J. R. Dunn and A. Odoi	2012	Socioeconomic determinants of geographic disparities in campylobacteriosis risk: a comparison of global and local modeling approaches	*Campylobacter*
K. Pogreba-Brown1, P. O'Connor1, J. Matthews2, E. Barrett1 and M. L. Bell1	2018	Case-case analysis of Campylobacter and Salmonella - using surveillance data for outbreak investigations and monitoring routine risk factors	Multiple Pathogens
M. Chang, S. L. Groseclose, A. A. Zaidi and C. R. Braden	2009	An ecological analysis of sociodemographic factors associated with the incidence of salmonellosis, shigellosis, and E. coli O157:H7 infections in US counties	Multiple Pathogens
R. G. Villar, M. D. Macek, S. Simons, P. S. Hayes, M. J. Goldoft, J. H. Lewis, et al.	1999	Investigation of multidrug-resistant Salmonella serotype typhimurium DT104 infections linked to raw-milk cheese in Washington State	*Salmonella*
D. J. Vugia, M. Samuel, M. M. Farley, R. Marcus, B. Shiferaw, S. Shallow, et al.	2004	Invasive Salmonella infections in the United States, FoodNet, 1996-1999: incidence, serotype distribution, and outcome	*Salmonella*
Younus M, Wilkins MJ, Arshad MM, Rahbar MH, Saeed AM:	2006	Demographic risk factors and incidence of Salmonella enteritidis infection in Michigan. Foodborne Pathog Dis 2006, 3(3):266-273.	*Salmonella*

Muhammad Younus 1, Edward Hartwick, Azfar A Siddiqi, Melinda Wilkins, Herbert D Davies, Mohammad Rahbar, Julie Funk, Mahdi Saeed	2007	The role of neighborhood level socioeconomic characteristics in Salmonella infections in Michigan (1997-2007): assessment using geographic information system	*Salmonella*
M. M. Arshad, M. J. Wilkins, F. P. Downes, M. H. Rahbar, R. J. Erskine, M. L. Boulton, et al.	2007	A registry-based study on the association between human salmonellosis and routinely collected parameters in Michigan, 1995-2001	*Salmonella*
G. R. Richard and R. C. Ratard	2007	An Update on Salmonella in Louisiana	*Salmonella*
M. M. Arshad, M. J. Wilkins, F. P. Downes, M. H. Rahbar, R. J. Erskine, M. L. Boulton, et al.	2007	Epidemiology of infant salmonellosis in Michigan: Records of 1995-2001	*Salmonella*
C Conover, MD, K Kelly-Shannon, P Ward, R Lucht, MBA, D Hennings, Div of Infectious Diseases, Illinois Dept of Public Health; P Dombroski, J Price, MS, Div of Laboratories, Illinois Dept of Public Health; and G Ewald, MSPH, S Greene, MPH, M Lynch, MD, and M Biggerstaff, MPH, National Center for Zoonotic, Vector-Borne, and Enteric Diseases, CDC.	2008	Outbreak of multidrug-resistant Salmonella enterica serotype Newport infections associated with consumption of unpasteurized Mexican-style aged cheese--Illinois, March 2006-April 2007	*Salmonella*
M. Younus,M. J. Wilkins,H. D. Davies,M. H. Rahbar,J. Funk,C. Nguyen,A. E. Siddiqi,S. Cho,A. M. Saeed	2010	The role of exposures to animals and other risk factors in sporadic, non-typhoidal Salmonella infections in Michigan children	*Salmonella*
Patricia L. Cummings, Frank Sorvillo, and Tony Kuo	2010	Salmonellosis-related mortality in the United States, 1990-2006	*Salmonella*
Loharikar, A., Newton, A., Rowley, P., Wheeler, C., Bruno, T., Barillas, H., Pruckler, J., Theobald, L., Lance, S., Brown, J. M., Barzilay, E. J., Arvelo, W., Mintz, E., & Fagan, R.	2012	Typhoid fever outbreak associated with frozen mamey pulp imported from Guatemala to the western United States, 2010	*Salmonella*
Lay Har Cheng,1,a Stacy M. Crim,2 Conrad R. Cole,3 Andi L. Shane,4 Olga L. Henao,2 and Barbara E. Mahon2	2013	Epidemiology of Infant Salmonellosis in the United States, 1996–2008: A Foodborne Diseases Active Surveillance Network Study	*Salmonella*
K. S. Shaw, R. Cruz-Cano, C. Jiang, L. Malayil, D. Blythe, P. Ryan, et al.	2016	Presence of animal feeding operations and community socioeconomic factors impact salmonellosis incidence rates: An ecological analysis using data from the Foodborne Diseases Active Surveillance Network (FoodNet), 2004-2010	*Salmonella*
A. Mba-Jonas, W. Culpepper, T. Hill, V. Cantu, J. Loera, J. Borders, et al.	2018	A Multistate Outbreak of Human Salmonella Agona Infections Associated With Consumption of Fresh, Whole Papayas Imported From Mexico--United States, 2011	*Salmonella*

Debbie Lee,1 Howard H. Chang,2 Stefanie Ebelt Sarnat,1 and Karen Levy	2019	Precipitation and salmonellosis incidence in Georgia, USA: Interactions between extreme rainfall events and antecedent rainfall conditions	*Salmonella*
James L Hadler, Paula Clogher, Tanya Libby, Elisha Wilson, Nadine Oosmanally, Patricia Ryan, Luke Magnuson, Sarah Lathrop, Suzanne Mcguire, Paul Cieslak, Melissa Fankhauser, Logan Ray, Aimee Geissler, Sharon Hurd	2020	Relationship Between Census Tract-Level Poverty and Domestically Acquired Salmonella Incidence: Analysis of Foodborne Diseases Active Surveillance Network Data, 2010-2016	*Salmonella*
A. Gourishankar	2021	Geospatial analysis of salmonellosis and its association with socioeconomic status in Texas	*Salmonella*
Radhika Gharpure, Zachary A Marsh, Danielle M Tack, Sarah A Collier, Jonathan Strysko, Logan Ray, Daniel C Payne, Amanda G Garcia-Williams	2021	Disparities in Incidence and Severity of Shigella Infections Among Children—Foodborne Diseases Active Surveillance Network (FoodNet), 2009-2018	*Shigella*
T. Libby, P. Clogher, E. Wilson, N. Oosmanally, M. Boyle, D. Eikmeier, et al	2020	Disparities in Shigellosis Incidence by Census Tract Poverty, Crowding, and Race/Ethnicity in the United States, FoodNet, 2004-2014	*Shigella*
Lindsey S. McCrickard,corresponding author Stacy M. Crim, Sunkyung Kim, and Anna Bowen	2018	Disparities in severe shigellosis among adults — Foodborne diseases active surveillance network, 2002–2014	*Shigella*
B. Shiferaw, S. Solghan, A. Palmer, K. Joyce, E. J. Barzilay, A. Krueger, et al.	2012	Antimicrobial susceptibility patterns of Shigella isolates in Foodborne Diseases Active Surveillance Network (FoodNet) sites, 2000-2010	*Shigella*
C. C. Haley, K. L. Ong, K. Hedberg, P. R. Cieslak, E. Scallan, R. Marcus, et al.	2010	Risk factors for sporadic shigellosis, FoodNet 2005	*Shigella*
D. D. Hill, W. E. Owens and P. B. Tchounwou	2005	Prevalence of Selected Bacterial Infections Associated with the Use of Animal Waste in Louisiana	*Shigella*
P. Kalluri, K. C. Cummings, S. Abbott, G. B. Malcolm, K. Hutcheson, A. Beall, et al.	2004	Epidemiological features of a newly described serotype of Shigella boydii	*Shigella*
James L Hadler, Paula Clogher, Jennifer Huang, Tanya Libby, Alicia Cronquist, Siri Wilson, Patricia Ryan, Amy Saupe, Cyndy Nicholson, Suzanne McGuire, Beletshachew Shiferaw, John Dunn, Sharon Hurd	2018	The Relationship Between Census Tract Poverty and Shiga Toxin-Producing E. coli Risk, Analysis of FoodNet Data, 2010-2014	STEC
L. H. Gould, R. K. Mody, K. L. Ong, P. Clogher, A. B. Cronquist, K. N. Garman, et al.	2013	Increased recognition of non-O157 Shiga toxin-producing Escherichia coli infections in the United States during 2000-2010: epidemiologic features and comparison with E. coli O157 infections	STEC

References

1. Centers for Disease Control and Prevention. (2020, March 18). Foodborne germs and illnesses. Centers for Disease Control and Prevention. Retrieved February 21, 2022, from https://www.cdc.gov/salmonella/.html

2. Scharff RL: Economic Burden from Health Losses Due to Foodborne Illness in the United States. J Food Prot. 2012, 75 (1): 123-131. 10.4315/0362-028X.JFP-11-058.

3. Centers for Disease Control and Prevention. (2018, November 5). Burden of foodborne illness: Findings. Centers for Disease Control and Prevention. Retrieved February 21, 2022, from https://www.cdc.gov/foodborneburden/2011-foodborne-estimates.html

4. Quinlan J. J. (2013). Foodborne illness incidence rates and food safety risks for populations of low socioeconomic status and minority race/ethnicity: a review of the literature. International journal of environmental research and public health, 10(8), 3634–3652. https://doi.org/10.3390/ijerph10083634

5.Centers for Disease Control and Prevention. (2019, February 15). FoodNet geocoding to address disparities in foodborne illness. Centers for Disease Control and Prevention. Retrieved February 19, 2022, from https://www.cdc.gov/ddphss/chiic/projects/2015/ideas/foodnet-geocoding-to-address-disparities-in-foodborne-illness.html

6. Ross, P. T., Hart-Johnson, T., Santen, S. A., & Zaidi, N. (2020). Considerations for using race and ethnicity as quantitative variables in medical education research. Perspectives on medical education, 9(5), 318–323. https://doi.org/10.1007/s40037-020-00602-3

7. *Causes and symptoms of foodborne illness*. Minnesota Dept. of Health. (2019). Retrieved April 3, 2022, from https://www.health.state.mn.us/diseases/foodborne/basics.html

8. *Epidemiology and surveillance | Anses - Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail*. (n.d.). Www.anses.fr. Retrieved April 11, 2022, from https://www.anses.fr/en/content/epidemiology-and-surveillance#:~:text=Epidemiology%20and%20surveillance%20Epidemiology%20and%20surveillance%20are%20key

9. World Health Organization. (2020, May). Campylobacter. World Health Organization. Retrieved February 8, 2022, from https://www.who.int/news-room/fact-sheets/detail/campylobacter

10. Campylobacteriosis. Campylobacteriosis Fact Sheet. (2022, February). Retrieved February 8, 2022, from https://www.health.ny.gov/diseases/communicable/campylobacteriosis/fact_sheet.html

11. Salmonella infections. Johns Hopkins Medicine. (2022). Retrieved February 8, 2022, from https://www.hopkinsmedicine.org/health/conditions-and-diseases/salmonella-infections

12. Brenner, F. W., Villar, R. G., Angulo, F. J., Tauxe, R., & Swaminathan, B. (2000). Salmonella nomenclature. Journal of clinical microbiology, 38(7), 2465–2467. https://doi.org/10.1128/JCM.38.7.2465-2467.2000

13. Causes and symptoms of salmonellosis. Minnesota Dept. of Health. (2019, January). Retrieved February 8, 2022, from https://www.health.state.mn.us/diseases/salmonellosis/basics.html#:~:text=Salmonellosis%20is%20an%20infection%20with,foods%20contaminated%20with%20animal%20feces.

14. Centers for Disease Control and Prevention. (2022, February 2). *Salmonella homepage*. Centers for Disease Control and Prevention. Retrieved April 16, 2022, from https://www.cdc.gov/salmonella/index.html

15. Scallan, E., Hoekstra, R. M., Angulo, F. J., Tauxe, R. V., Widdowson, M. A., Roy, S. L., Jones, J. L., & Griffin, P. M. (2011). Foodborne illness acquired in the United States--major pathogens. Emerging infectious diseases, 17(1), 7–15. https://doi.org/10.3201/eid1701.p11101

16. U.S. National Library of Medicine. (2022, February 4). Shigellosis: Medlineplus medical encyclopedia. MedlinePlus. Retrieved February 8, 2022, from https://medlineplus.gov/ency/article/000295.htm

17. Shigella infection (shigellosis). Disease Prevention and Control, San Francisco Department of Public Health. (2019, February 13). Retrieved February 8, 2022, from https://www.sfcdcp.org/infectious-diseases-a-to-z/shigella-infection-shigellosis/

18. Aslam A, Okafor CN. Shigella. [Updated 2021 Aug 11]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK482337/

19. Centers for Disease Control and Prevention. (2014, December 1). Questions and Answers E. coli (Escherichia coli). Centers for Disease Control and Prevention. Retrieved February 26, 2022, from https://www.cdc.gov/ecoli/general/index.html

20. Department of Health Shiga toxin-producing E. coli (STEC) Infections. Shiga toxin-producing E. coli (STEC) Infections Fact Sheet. (2021, November). Retrieved February 26, 2022, from https://www.health.ny.gov/diseases/communicable/e_coli/stec.htm

21. Centers for Disease Control and Prevention. (2017, October 23). National shiga toxin-producing escherichia coli (STEC) surveillance. Centers for Disease Control and Prevention. Retrieved February 26, 2022, from https://www.cdc.gov/nationalsurveillance/ecoli-surveillance.html

22. Centers for Disease Control and Prevention (CDC). National Shiga toxin-producing Escherichia coli (STEC) Surveillance Overview. Atlanta, Georgia: US Department of Health and Human Services, CDC, 2012.

23. Hagan, A. (2019). The toxin-based diseases common in North America during the 1600-1700s. ASM.org. Retrieved February 7, 2022, from https://asm.org/Articles/2019/July/The-Toxin-Based-Diseases-Common-in-North-America-d

24. Mahr, M. (2021, August 2). Typhoid fever - one of the Civil War's deadliest diseases. National Museum of Civil War Medicine. Retrieved February 7, 2022, from https://www.civilwarmed.org/typhoid-fever/

25. Andrews, J. (2018, July 31). Looking back: 100 Years of U.S. Food Safety History. Food Safety News. Retrieved February 7, 2022, from https://www.foodsafetynews.com/2014/08/looking-back-100-years-of-food-safety-history-in-the-u-s/

26. Council to Improve Foodborne Outbreak Response (CIFOR). Guidelines for Foodborne Disease Outbreak Response. 2nd edition. Atlanta: Council of State and Territorial Epidemiologists; 2014.

27. Centers for Disease Control and Prevention. (2019, September 12). Annual summaries of foodborne outbreaks. Centers for Disease Control and Prevention. Retrieved February 8, 2022, from https://www.cdc.gov/fdoss/annual-reports/index.html

28. Centers for Disease Control and Prevention. (2021, November 15). Foodborne and Waterborne Disease Surveillance & Data Systems. Centers for Disease Control and Prevention. Retrieved March 2, 2022, from https://www.cdc.gov/ncezid/dfwed/keyprograms/surveillance.html

29. Centers for Disease Control and Prevention. (2019, November 4). About national outbreak reporting system (NORS). Centers for Disease Control and Prevention. Retrieved March 2, 2022, from https://www.cdc.gov/nors/about.html

30. Rodriguez-Lainz, A., McDonald, M., Fonseca-Ford, M., Penman-Aguilar, A., Waterman, S. H., Truman, B. I., Cetron, M. S., & Richards, C. L. (2018). Collection of Data on Race, Ethnicity, Language, and Nativity by US Public Health Surveillance and Monitoring Systems: Gaps and Opportunities. Public health reports (Washington, D.C. : 1974), 133(1), 45–54. https://doi.org/10.1177/0033354917745503

31 . Hardnett, F. P., Hoekstra, R. M., Kennedy, M., Charles, L., Angulo, F. J., & Emerging Infections Program FoodNet Working Group (2004). Epidemiologic issues in study design and data analysis related to FoodNet activities. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America, 38 Suppl 3, S121–S126. https://doi.org/10.1086/381602

32. Elaine Scallan, Barbara E. Mahon, Foodborne Diseases Active Surveillance Network (FoodNet) in 2012: A Foundation for Food Safety in the United States, Clinical Infectious Diseases, Volume 54, Issue suppl_5, June 2012, Pages S381–S384, https://doi.org/10.1093/cid/cis257

33. Centers for Disease Control and Prevention. (2019, November 4). National Outbreak Reporting System (NORS). Centers for Disease Control and Prevention. Retrieved February 21, 2022, from https://www.cdc.gov/nors/index.html

33. Centers for Disease Control and Prevention. (2019, February 15). FoodNet geocoding to address disparities in foodborne illness. Centers for Disease Control and Prevention. Retrieved February 19, 2022, from https://www.cdc.gov/ddphss/chiic/projects/2015/ideas/foodnet-geocoding-to-address-disparities-in-foodborne-illness.html

34.World Health Organization. (2018). Health Inequities and Causes. World Health Organization. Retrieved February 28, 2022, from https://www.who.int/news-room/facts-in- pictures/detail/health-inequities-and-their-causes#:~:text=Health%20inequities%20are%20differences%20in,right%20mix%20of%20government%20policies.

35. Strengthening Health Systems in Developing Countries. American Public Health Association. (2008, October 28). Retrieved February 23, 2022, from https://www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2014/07/23/09/09/strengthening-health-systems-in-developing-countries

36. Chang, M., Groseclose, S. L., Zaidi, A. A., & Braden, C. R. (2009). An ecological analysis of sociodemographic factors associated with the incidence of salmonellosis, shigellosis, and E. coli O157:H7 infections in US counties. Epidemiology and infection, 137(6), 810–820. https://doi.org/10.1017/S0950268808001477

37. Libby, T., Clogher, P., Wilson, E., Oosmanally, N., Boyle, M., Eikmeier, D., Nicholson, C., McGuire, S., Cieslak, P., Golwalkar, M., Geissler, A., & Vugia, D. (2020). Disparities in Shigellosis Incidence by Census Tract Poverty, Crowding, and Race/Ethnicity in the United States, FoodNet, 2004-2014. Open forum infectious diseases, 7(2), ofaa030. https://doi.org/10.1093/ofid/ofaa030

38. Hadler, J. L., Clogher, P., Huang, J., Libby, T., Cronquist, A., Wilson, S., Ryan, P., Saupe, A., Nicholson, C., McGuire, S., Shiferaw, B., Dunn, J., & Hurd, S. (2018). The Relationship Between Census Tract Poverty and Shiga Toxin-Producing E. coli Risk, Analysis of

FoodNet Data, 2010-2014. Open Forum Infectious Diseases, 5(7), ofy148. https://doi.org/https://dx.doi.org/10.1093/ofid/ofy148

39. Hadler, J. L., Clogher, P., Libby, T., Wilson, E., Oosmanally, N., Ryan, P., Magnuson, L., Lathrop, S., McGuire, S., Cieslak, P., Fankhauser, M., Ray, L., Geissler, A., & Hurd, S. (2020). Relationship Between Census Tract-Level Poverty and Domestically Acquired Salmonella Incidence: Analysis of Foodborne Diseases Active Surveillance Network Data, 2010-2016. J Infect Dis, 222(8), 1405-1412. https://doi.org/10.1093/infdis/jiz605

40. Davis, M. A., Moore, D. L., Baker, K. N., French, N. P., Patnode, M., Hensley, J., Macdonald, K., & Besser, T. E. (2013). Risk factors for campylobacteriosis in two washington state counties with high numbers of dairy farms [Research Support, N.I.H., Extramural]. Journal of Clinical Microbiology, 51(12), 3921-3927. https://doi.org/https://dx.doi.org/10.1128/JCM.01433-13

41. Rosenberg Goldstein, R. E., Cruz-Cano, R., Jiang, C., Palmer, A., Blythe, D., Ryan, P., Hogan, B., White, B., Dunn, J. R., Libby, T., Tobin-D'Angelo, M., Huang, J. Y., McGuire, S., Scherzinger, K., Lee, M. L., & Sapkota, A. R. (2016). Association between community socioeconomic factors, animal feeding operations, and campylobacteriosis incidence rates: Foodborne Diseases Active Surveillance Network (FoodNet), 2004-2010. *BMC Infectious Diseases*, *16*, 354. https://doi.org/https://dx.doi.org/10.1186/s12879-016-1686-9

42. Weisent, J., Rohrbach, B., Dunn, J. R., & Odoi, A. (2012). Socioeconomic determinants of geographic disparities in campylobacteriosis risk: a comparison of global and local

modeling approaches. International journal of health geographics, 11(1), https://doi.org/10.1186/1476-072X-11-45

43. Arshad, M. M., Wilkins, M. J., Downes, F. P., Rahbar, M. H., Erskine, R. J., Boulton, M. L., Younus, M., & Saeed, A. M. (2007). Epidemiology of infant salmonellosis in Michigan: Records of 1995-2001. Journal of Pediatric Infectious Diseases, 2(2), 89-94 https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emed10&AN=354999110

44. Vugia, D. J., Samuel, M., Farley, M. M., Marcus, R., Shiferaw, B., Shallow, S., Smith, K., Angulo, F. J., & Emerging Infections Program FoodNet Working, G. (2004). Invasive Salmonella infections in the United States, FoodNet, 1996-1999: incidence, serotype distribution, and outcome [Research Support, U.S. Gov't, Non-P.H.S.

45. Cheng, L. H., Crim, S. M., Cole, C. R., Shane, A. L., Henao, O. L., & Mahon, B. E. (2013). Epidemiology of Infant Salmonellosis in the United States, 1996-2008: A Foodborne Diseases Active Surveillance Network Study. *Journal of the Pediatric Infectious Diseases Societ*, *2*(3), 232-239. https://doi.org/https://dx.doi.org/10.1093/jpids/pit020

46. Gourishankar A. (2021). Geospatial analysis of salmonellosis and its association with socioeconomic status in Texas. *Family medicine and community health*, *9*(4), e001214. https://doi.org/10.1136/fmch-2021-001214

47. Gharpure, R., Marsh, Z. A., Tack, D. M., Collier, S. A., Strysko, J., Ray, L., Payne, D. C., & Garcia-Williams, A. G. (2021). Disparities in Incidence and Severity of Shigella Infections Among Children—Foodborne Diseases Active Surveillance Network (FoodNet), 2009-

2018. *Journal of the Pediatric Infectious Diseases Society*, *10*(7), 782-788. https://doi.org/10.1093/jpids/piab045

48. Hill, D. D., Owens, W. E., & Tchounwou, P. B. (2005). Prevalence of selected bacterial infections associated with the use of animal waste in Louisiana [Research Support, N.I.H., Extramural

49. Gould, L. H., Mody, R. K., Ong, K. L., Clogher, P., Cronquist, A. B., Garman, K. N., Lathrop, S., Medus, C., Spina, N. L., Webb, T. H., White, P. L., Wymore, K., Gierke, R. E., Mahon, B. E., Griffin, P. M., & Emerging Infections Program Foodnet Working, G. (2013). Increased recognition of non-O157 Shiga toxin-producing Escherichia coli infections in the United States during 2000-2010: epidemiologic features and comparison with E. coli O157 infections [Research Support, U.S. Gov't, P.H.S.]. *Foodborne Pathogens & Disease*, *10*(5), 453-460. https://doi.org/https://dx.doi.org/10.1089/fpd.2012.1401

50. Akil, L. (2021). Trends of Foodborne Diseases in Mississippi: Association with Racial and Economic Disparities. *Diseases*, *9*(4), 13. https://doi.org/https://dx.doi.org/10.3390/diseases9040083

51. Morales, D. X., Morales, S. A., & Beltran, T. F. (2021). Racial/Ethnic Disparities in Household Food Insecurity During the COVID-19 Pandemic: a Nationally Representative Study. *Journal of racial and ethnic health disparities*, *8*(5), 1300– 1314. https://doi.org/10.1007/s40615-020-00892-7