Olasunmbo A. Ajayi,[1,2*] Jacob O. Oluwoye[3] and Leonard L. Williams[4]

[1,2]Dept. of Food and Animal Sciences, Alabama Agricultural and Mechanical University, Food Microbiology and Immunochemistry Laboratory, Normal, AL 35762, USA

[2]Dept. of Food Science and Technology, Bowen University, Iwo, Osun State, Nigeria

[3]Dept. of Community Planning and Urban Studies, Alabama Agricultural and Mechanical University, Normal, AL 35762, USA

[4]Center of Excellence in Post-Harvest Technologies, North Carolina Agriculture and Technical State University, the North Carolina Research Campus, Kannapolis, NC 28081, USA

PEER-REVIEWED ARTICLE

Food Protection Trends, Vol 35, No. 2, p.113–123

6200 Aurora Ave., Suite 200W, Des Moines, IA 50322-2864

Development of Hazard Risk Index of Mortality Caused by Foodborne Pathogens

ABSTRACT

Foods contain pathogenic microorganisms that can have mild effects, cause gastroenteritis, or result in more serious health effects, including death. FoodNet surveillance data from 1997 to 2004 for ten states show that *Campylobacter*, *Salmonella* and pathogenic *E. coli* are frequently implicated in foodborne disease outbreaks (FDO). Risk assessment is used to guide decisions about policies regarding food. There is a need to develop a hazard risk index (HRI) of mortality for frequently implicated foodborne pathogens, because populations at risk of contracting foodborne disease are increasing. The focus of this study was to develop a hazard risk index of mortality and to assess the relationship between HRI of mortality of pathogens and age, gender and ethnicity. Results showed FDO were caused by (per 100,000 individuals) *Salmonella* (37,790); *Campylobacter* (37,363); pathogenic *Escherichia coli* (4,196); *Shigella* (17,769); *Yersinia* (1,268); *Listeria monocytogenes* (858) and *Vibrio* (619). HRI for *Campylobacter*, pathogenic *E. coli, Salmonella, Shigella,* and *Yersinia* were 0.99–1.00; for *Listeria monocytogenes*, 0.71–0.87; and for *Vibrio* spp. 0.83–1.00. When the HRI was used to calculate the Spearman *rho* correlation coefficient, the HRI of mortality was shown to be strong for age distribution, ethnicity, and gender, depending on the foodborne pathogen. The conclusion is that the risk of mortality is strong and significant for *Salmonella* spp. for children age 1–<10 years, for *L. monocytogenes* for populations age 20–30 years, and for *L. monocytogenes* for age 50–60 among men.

INTRODUCTION

Although societal expectations are that food will be safe, foodborne diseases are increasing in frequency, creating public health and economic problems worldwide. The incidence of foodborne diseases and mortality is difficult to estimate. It has been reported that 2.2 million people, of which 1.8 million were children *(43)*, died from diarrheal diseases worldwide in 2002. A majority of these diarrheal cases can be attributed to contamination of food and drinking water.

According to Schlundt *(36)*, safe food contributes to the health and productivity of the community, providing

* Corresponding author: + 234 8082060386; E-mail: dr.sunmbo.ajayi@gmail.com

an effective platform for development and easing of poverty. Foodborne diseases affect the health and well-being of people and also have economic consequences for individuals, families, communities, businesses and countries. In the United States for example, foodborne diseases create an enormous economic burden on the health and social systems, costing $152 billion each year *(35)*. The significance of foodborne diseases as a current public health concern is underscored by the increasing numbers of "at-risk" populations worldwide. In the United States, about one-fourth of the population is considered to be at increased risk for a severe outcome related to a foodborne disease *(3, 17, 40)*.

Studies have documented that the individuals most vulnerable to foodborne diseases are those who are young, old, pregnant or immunocompromised *(2, 9)*, and some of the most severe and frequently encountered pathogens are *Campylobacter, Salmonella,* pathogenic *E. coli* and *Listeria monocytogenes (12)*. The outcome of exposure to pathogenic microorganisms depends on several factors, including preexisting immunity, nutrition, age, ability to elicit an immune response, and other nonspecific host factors, as well as the type and strain of microorganism *(19)*.

Risk assessment is a process of quantifying and showing the trail from contamination through exposure to health outcomes *(23)*. The use of risk assessment with regard to foodborne pathogens can be advantageous in estimating the ultimate impact of foodborne diseases on the population. New foods as vehicles of transmission and emerging new pathogens may elude traditional food inspection, contributing to the discrepancies between reported and actual foodborne disease outbreaks. Also, milder cases of foodborne illnesses often are not reported or detected through surveillance. According to the Scientific Opinion of the Panel on Biological Hazards, underlying forces such as the reemergence of pathogens may make foodborne diseases a greater problem in the years to come *(37)*. The component of risk assessment is a tool now used to guide decisions about policies with regard to food. There is a need to develop as hazard risk index (HRI) of mortality for frequently implicated pathogens in foods, particularly because the population of individuals considered at risk of contracting foodborne disease is on the rise. Therefore, the focus of this study was to develop a hazard risk index of mortality and to assess the strength of the association between HRI of mortality from commonly implicated foodborne pathogens and age, gender, and ethnicity.

MATERIALS AND METHODS

Surveillance data

Secondary data on foodborne disease outbreaks from 1997 to 2004 were obtained from the Foodborne Diseases Active Surveillance Network (FoodNet) *(11)*, the National Notifiable Disease Surveillance System, and Morbidity and Mortality Weekly Report (MMWR). FoodNet is an active population-based surveillance system. Data were retrieved from the summary tables and graphs report (part II), which contained information about foodborne outbreaks caused by the nine foodborne pathogens in the ten specific locations of interest, which consisted of Connecticut, Georgia, Maryland, Minnesota, New Mexico, Oregon, and Tennessee, and selected counties in California, Colorado, and New York. FoodNet data contained information on rates of infection, age, gender, ethnicity, hospitalizations and deaths. Foodborne diseases reported for each pathogen were cases per 100,000 individuals in the population.

Hazard risk index (HRI) development

A formula was used to develop the hazard risk index of mortality caused by foodborne diseases as described by Oluwoye (2006, unpublished). Briefly, HRI was calculated as the number of foodborne disease (FBD) cases from the FoodNet active surveillance data minus the foodborne disease mortality, divided by the number of cases. Hazard risk index (HRI) was developed for each of the seven bacterial pathogens under the FoodNet surveillance system for 1997–2004.

The formula is written:

$$HRI = \left[\frac{X - Y}{X} \right] \times 100 \qquad \text{Eq. (1)}$$

Where,

X = Number of cases of FBD per pathogen
Y = Number of deaths from FBD per pathogen

Research hypotheses and limitations

Ho: There is no relationship between hazard risk index (HRI) and age, gender or ethnicity in the population for each bacterial pathogen.

Ha: There are statistical relationships between the variables.

Statistical analysis

SPSS (Statistical Package for the Social Sciences)/ SAS (Statistical Analysis System) was used to perform descriptive analysis of the data. Frequency distributions and percentages were used for the descriptive analysis of the data. Descriptive analysis of the independent variable characteristics used to develop the hazard risk index (HRI) consisted of demographic characteristics of the foodborne disease cases: age, gender, ethnicity and mortality. The Spearman *rho* correlation coefficient was used to determine the strength of the association between the hazard risk index (HRI) of foodborne pathogens as the dependent variable and the set of independent (age, gender and ethnicity) variables.

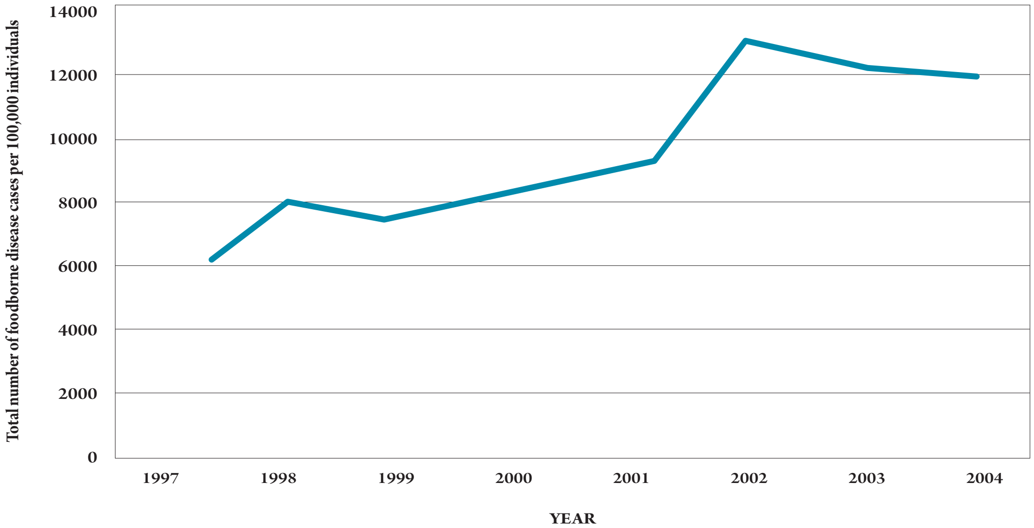

Figure 1A. Number of aggregate foodborne disease cases from FoodNet surveillance in ten catchment areas, 1997–2004

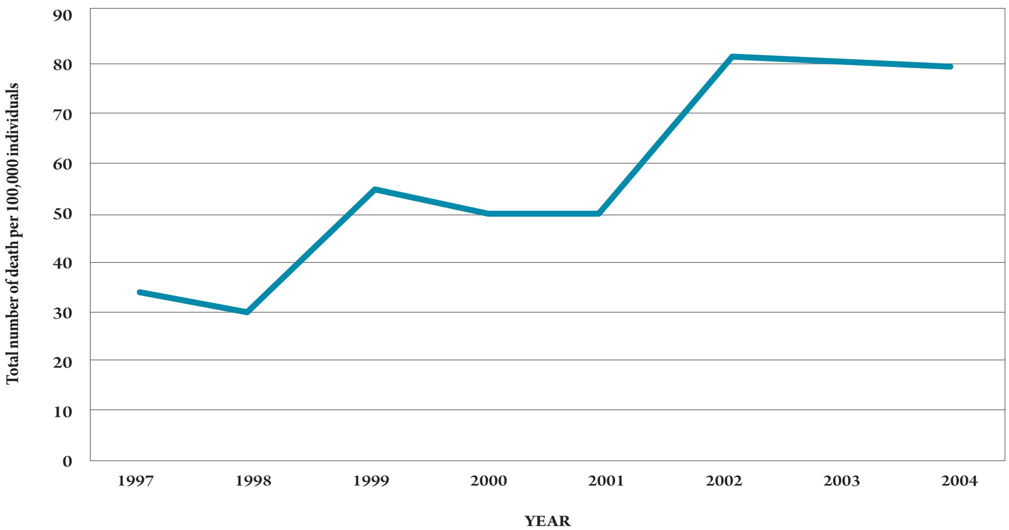

Figure 1B. Number of foodborne cases death per 100,000 individuals in the ten catchment areas, 1997–2004

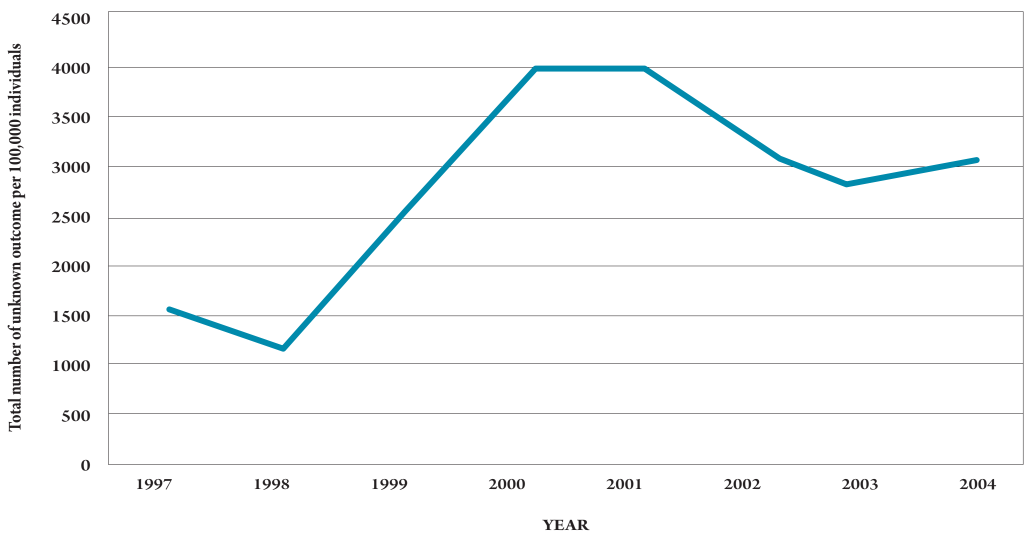

Figure 1C. Number of unknown outcome of foodborne cases per 100,000 individuals in the ten catchment areas, 1997–2004

RESULTS AND DISCUSSION

The number of deaths due to each foodborne pathogen recorded by FoodNet was used to calculate the hazard risk index. However, cases of mortality were not reported by age, gender or ethnicity. The aggregate number of foodborne disease cases and deaths documented by FoodNet from 1997 to 2004 is shown in *Fig. 1* A–C. The results indicated that despite the surveillance systems, the incidence of foodborne disease outbreaks is increasing, along with the mortality rate. The number of unknown outcomes, although it was not used in calculating HRI, is also increasing. This finding is especially problematic because of the aging population. Studies have demonstrated that in addition to the usual symptoms of diarrhea, fever, abdominal cramps, and vomiting, there are also long-term effects ranging from arthritis and heart and blood infections to acute kidney failure and serious neurological problems *(22)*. Furthermore, a study conducted by Helms et al. *(22)* indicated that the relative mortality in patients with gastrointestinal infections from four enteric bacteria (*Campylobacter, Salmonella, Yersinia* and *Shigella*) within one year was 3.1 times higher than in the control groups.

Descriptive statistics

Age distribution. The age distribution of the foodborne disease cases for bacterial pathogens reported between 1997 to 2004 ranged from 0– < 1 to > 60 years, as shown in *Fig. 2*. Total reported cases by age were 11,641 for 0 < 1; 21,042 for 1 < 10; 9,209 for 10 < 20; 12,478 for 20 < 30; 13,770 for 30 < 40; 11,816 for 40 < 50; 8,194 for 50 < 60; 10,615 for 60+; and 1,102 for unknown age. As shown in *Fig. 2*, the rate of foodborne disease cases varied by age for each pathogen. For *Campylobacter*, the three age groups 30–40; 40–50; and 20–30 years had the highest rates of reported cases (17.8%, 16.2% and 15.5% respectively), while the smallest number of cases, for age 0–1, was 6%. However, this percentage doubled (12%) in age group 1–10. According to the Centers for Disease Control (CDC), two age peaks were observed in *Campylobacter* infections, age 0– < 1 and age 15–44 *(12)*. However, information from surveillance used in this study also showed a peak in the 1– < 10 age group. Age groups with the highest reported pathogenic *E. coli* cases were 1–10 years (34%), 10–20 years (18.6%), and 60+ years (11.6%), and the smallest number of cases was for ages 30–40 years (5.4%). More cases were reported for *Listeria monocytogenes* (55.7%) in the 60+ age

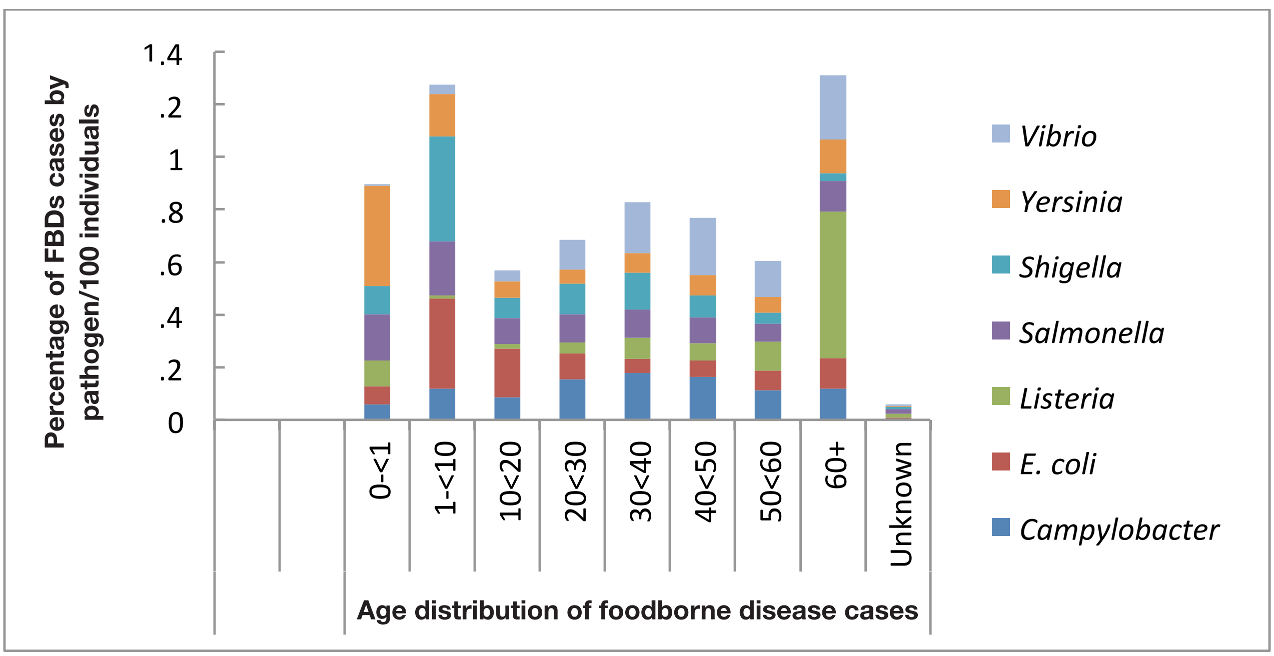

Figure 2. Percentage of foodborne disease cases and age distribution (in years) per 100,000 individuals in the ten catchment areas, 1997–2004

group, 50–60 years (11%) and 0–1 year (9.9%), but ages 1–10 years (1.3%) had the fewest reported cases. Ages 1–10 years (20.7%), 0–1 year (17.5%) and 60+ years (11.5%) were the most often reported groups for cases of *Salmonella*. Foodborne disease due to *Shigella* was reported in 40% for those 1–10 years old, 14% in ages 30–40 years and 11.5% in 20–30 years. Studies have shown that shigellosis has a high morbidity and mortality rate in children under the age of five *(5)*. *Yersinia* cases were highest for 0–1 (38%), 1–10 (15.9%), and 60+ years (12.8%). *Yersinia* foodborne outbreaks have been demonstrated to affect infants and children more because of the consumption of unpasteurized milk and chitterlings *(24)*. *Vibrio* cases were highest for those age 60+ years (24.4%), 40–50 years (22%), and 30–40 years (19.5%).

Gender distribution. The gender distribution of the foodborne disease cases from 1997 to 2004, as reported in the FoodNet final report for each bacterial pathogen, is shown in *Fig. 3*. However, the total number for gender (51,166 and 48,010) for males and females, respectively, did not match the total number of disease cases reported for age and race/ethnicity. Therefore, in those cases, the genders are classified as unidentified. Four foodborne pathogens that affected males far more than females were *Campylobacter* (55%); *Listeria monocytogenes* (50.3%); *Shigella* (51.2%) and *Vibrio* (64.9%). Reasons for this finding could be because of risky behavior, such as consumption of undercooked meat and raw milk or infrequent handwashing, particularly after touching pets. Previous studies have documented that males are at increased risk for *Campylobacter* infections *(2, 18)*. Reports also showed that the females had more reported cases of foodborne illness from pathogenic *E. coli* (53%), *Salmonella* (51.2%), and *Yersinia* (50.4%). Women and young children are more prone to infections from pathogenic *E. coli (20)*.

Race/ethnicity categories. Race categories, as defined by FoodNet, are American Indian or Alaskan Native, Asian or Pacific Islander, Black, White and Unknown. Ethnicity categories are Hispanic, Non-Hispanic, and Unknown *(Fig. 4)*. From *Fig. 4*, it can be seen that individuals characterized as whites were disproportionately affected by foodborne diseases caused by all the bacteria listed under FoodNet active surveillance, except *Yersinia*, in which case blacks had more cases. This finding could be due to consumption of chitterlings, a traditional holiday food by some African American households that has been documented to be a source of *Yersinia* outbreaks *(24)*. According to Jones *(24)*, exposure to the preparation of chitterlings was a substantial risk factor for disease; furthermore, even if the infants did not directly eat chitterlings, they could become infected.

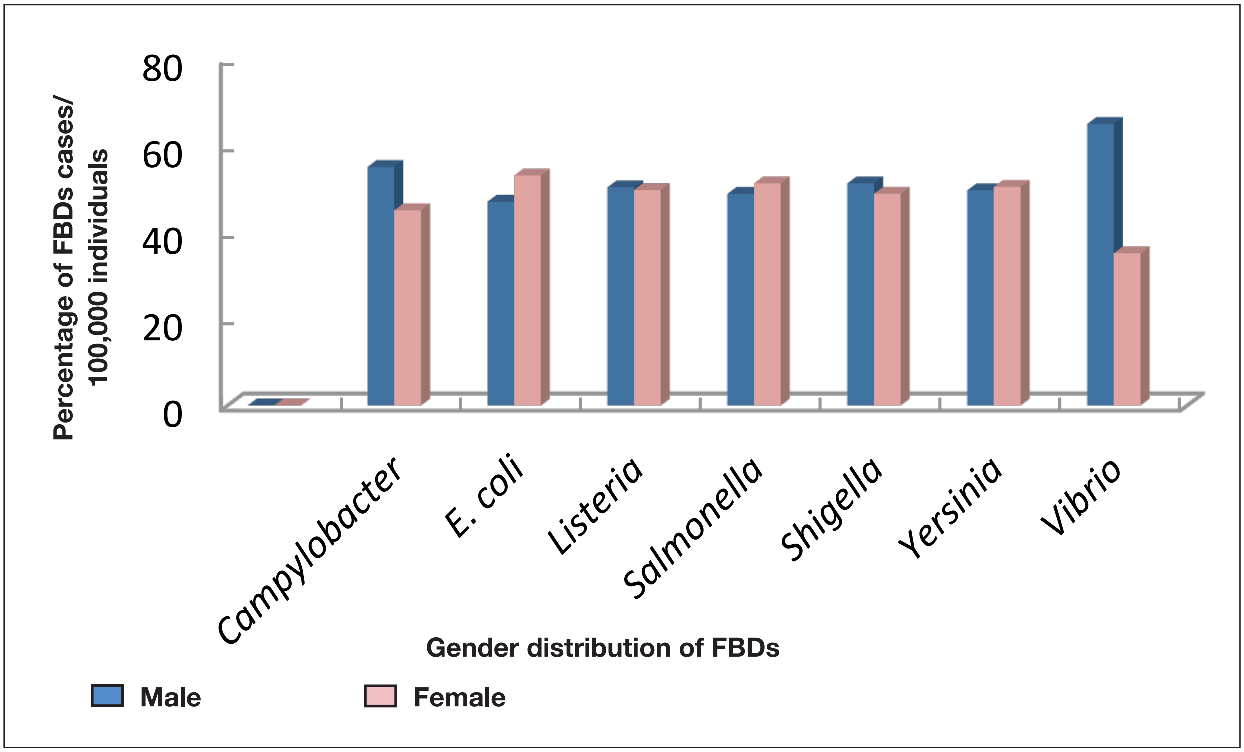

Figure 3. Percentage of foodborne disease cases and gender per 100,000 individuals in the ten catchment areas, 1997–2004

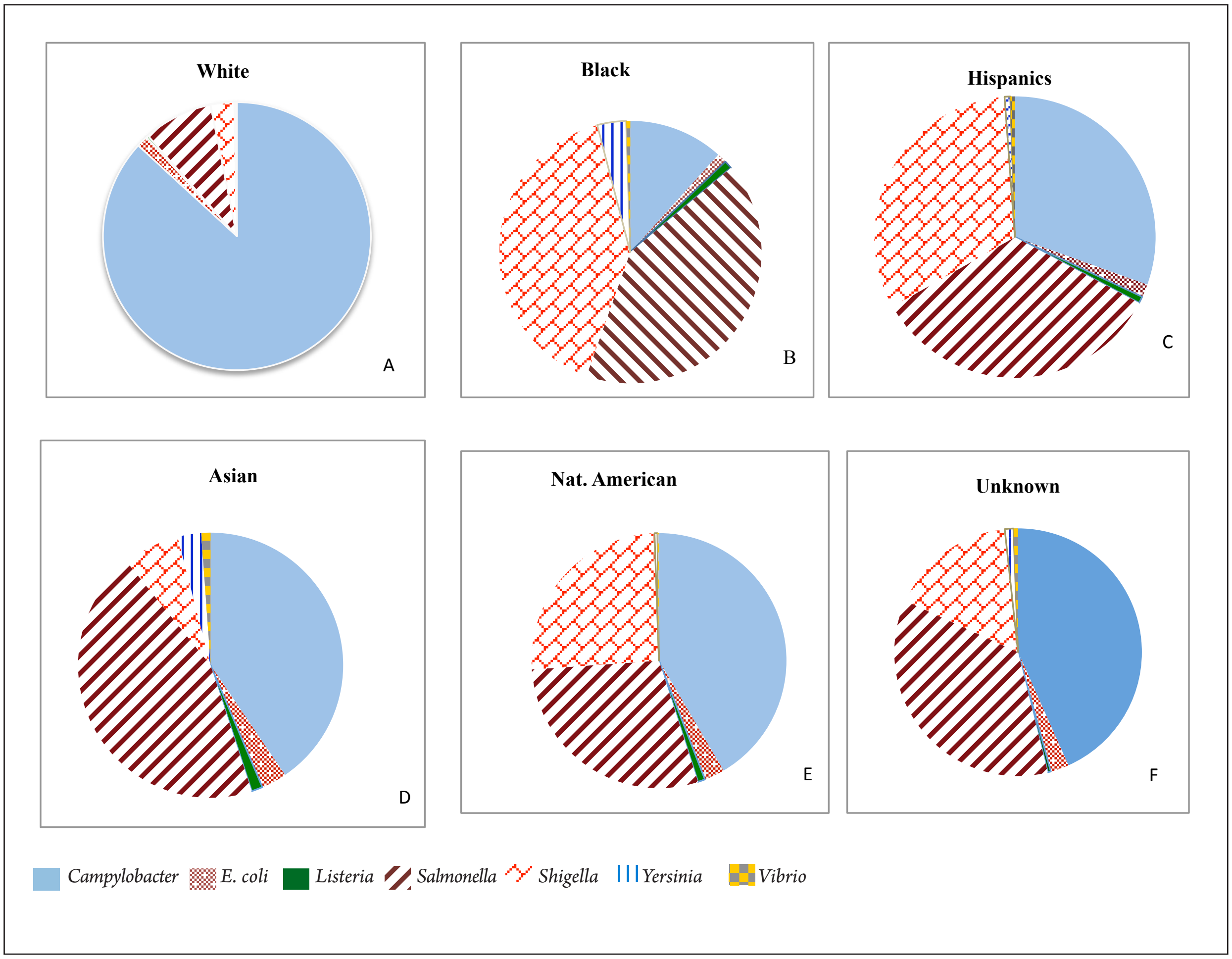

Figure 4. Foodborne disease cases and race and ethnicity per 100,000 individuals in the ten catchment areas, 1997–2004

Asians also are particularly affected by *Campylobacter* and *Salmonella*. However, in a sizeable number of foodborne disease cases, the ethnicity of the affected person was not known or reported.

Hazard risk index

The hazard risk index (HRI) of mortality was calculated annually for each bacterial pathogen under active surveillance for foodborne diseases, as explained in the methodology section. The hazard risk index (HRI) for *Campylobacter,* pathogenic *E. coli, Salmonella, Shigella,* and *Yersinia* were 0.99–1 for the years 1997–2004. However, *L. monocytogenes* had an HRI of mortality of 0.71–0.87, while *Vibrio* had an HRI of 0.83–1.00.

Spearman rho *correlation coefficient*. To further establish the relationship between the hazard risk index, age, gender and ethnicity variables, a Spearman *rho* correlation coefficient was calculated; the results are listed in Table 1.

The relationship between HRI and age. The data output shown in Table 1 indicate a direct correlation between HRI of mortality and age. *Campylobacter* is one of the most commonly reported causes of foodborne disease in the developed countries, including the United States *(38)*. Each year, *Campylobacter* causes an estimated 2 million cases of foodborne illness, 10,000 hospitalizations, and 100 deaths *(8)*; other infected individuals could develop secondary complications, such as reactive arthritis and Guillain-Barré Syndrome (GBS) *(1, 30, 33)*.

The risk of death due to complications from foodborne diseases, although rare in healthy people, is possible in vulnerable individuals. For example, individuals with AIDS are at increased risk of death *(18)*, making foodborne

TABLE 1. Spearman *rho* Correlation Coefficient of seven bacterial pathogens under active surveillance for foodborne diseases

Variables	CM[a]	Pathogenic *E. coli*	LM[b]	*Salmonella*	*Shigella*	*Yersinia*	*Vibrio*
Spearman *rho* Correlations Coeffcient *P* = 0.05							
HRI[c]	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Age (years)							
0–<1	-.689	.228	.103	-.200	-.086	-.181	-.094
1–<10	-.091	.500	-.244	.851**	.284	.491	-.805*
10–<20	-.663	.167	-.205	-.050	-.086	.098	-.599
20–<30	-.078	.216	.752*	-.050	.099	-.012	.181
30–<40	-.443	.548	-.097	.050	.161	-.115	-.790
40–<50	-.547	.071	.149	-.050	.161	-.115	-.790*
50–<60	-.417	-.119	.727*	-.150	.037	-.364	-.773*
60+	-.417	-.071	.157	-.150	-.185	-.329	-.731*
Gender							
Male	-.509	.429	.812*	-.100	.161	-.236	-.667
Female	-.509	.190	.220	-.150	-.086	-.072	-.810*
Ethnicity							
White	-.730*	.262	.261	.050	.099	-.361	-.833*
Black	-.091	.381	.250	.200	.037	-.515	-.874**
Hispanic		-1.00	1.00		1.00	1.00	-1.00
Asian	.313	.707	.161		-.259	.479	-.503
Native Americans	-.439	-.103	.462	.252	.043	-.064	-.247
Others			1.00		-1.00		-1.00
Unknown	.391	.253	.539	-3.00	-.124	.061	-.204

Sources of data used to compute the Spearman *rho* were extracted from CDC FoodNet from 1997 to 2004.
CM[a] = Campylobacter
LM[b] = Listeria monocytogenes
HRI[c] = Hazard risk index of mortality

disease of public health concern. As expected, the Spearman's correlation coefficient analysis found that the HRI of death due to *Campylobacter* infection is inversely related to age. Ages 0 < 1 years exhibited *rho* = -.689, *P* = .059), while 10 – < 20 years exhibited *rho* = -.663, *P* = .073. However, the 50 – < 60 years and the 60+ years age groups are at particularly high risk of mortality (Spearman's correlation coefficient = - .417, P = .304) *(Table 1)*. Although those age 0 – < 1 years have the highest reported incidence of campylobacteriosis *(8)*, the elderly experience higher mortality rates from enteric bacterial gastroenteritis *(19)*. There is a strong association between HRI of mortality and the age of individuals vulnerable to foodborne disease.

For pathogenic *E. coli*, as shown in *Table 1*, the HRI analysis indicated a positive correlation with each age group, except for those ages 50 – < 60 years and 60+ years. Although the Spearman's correlation coefficient is not statistically significant at 95 or 99% CI (2-tailed), it is worth noting that they are moderate (*rho* = .500, *P* = .207 and *rho* = .548, *P* = .160) for ages 1 – < 10 years and 30 – < 40 years, respectively. *E. coli* O157:H7 is estimated to cause infection in more than 73,000 foodborne disease cases and 61 deaths annually *(13)*. Also indicated by CDC data, the infection rate for pathogenic *E. coli* is higher in children aged 1 – < 10 years than in any other age group *(14)*. Most pathogenic *E. coli* infections are relatively mild and do not require medical care, but infections can result in hemorrhagic colitis (bloody inflammation of the colon), and a small percentage of cases can develop hemolytic uremic syndrome (HUS) or worse. Therefore, there is increased risk of mortality for these age groups.

Spearman's correlation coefficient for HRI for *Listeria monocytogenes* is statistically significant (*P* < 0.05) for two age groups, namely 20 – < 30 years and 50 – < 60 years *(Table 1)*. Other age groups (0 – < 1 years, 40 – < 50 years, and 60+ years) also had positive correlation with the HRI, but the correlation was not statistically (*P* < 0.05) significant. All other demographic groups had an inverse relationship with the HRI. Listeriosis may be manifested as a flu-like syndrome or placental infection, which is particularly problematic for pregnant women, as it may cause premature death or developmental complications for fetuses and newborns *(41)*. *Listeria monocytogenes* is widespread in nature and commonly present in raw milk products, vegetables, seafood, poultry, red meat, liquid whole egg, and ready-to-eat foods, such as hot dogs and luncheon meats *(8, 26)*. Furthermore, according to Kendall et al. *(26)*, elderly persons had the highest rate of infection and the highest mortality rate. In particular, immunocompromised elderly persons are at high risk *(7, 21)*. The fatality rate was higher among individuals over 50 years old, compared with all other age groups *(41)*.

Children, particularly ages 1 – < 10 years, are especially prone to contracting salmonellosis, a disease caused by *Salmonella*. Children, the immunocompromised and the elderly, face a relatively higher risk of death from salmonellosis than any other age group *(8, 15)*. As expected, the Spearman's correlation coefficient for children 1 – < 10 years was *rho* = .851**, *P* = .007, and statistically significant (*P* < 0.01). The risk of mortality is higher in this age group than in any other in this study. As shown in *Table 1*, persons aged 30 – < 40 years also had a weak but positive correlation coefficient, while all other age groups had an inverse relationship to HRI. Kennedy *(27)* reported that although food-related mortality due to salmonellosis occurred primarily among adults, it is minimally accounted for. Because infected older adults often have other serious underlying diseases, this finding might explain the inverse relationship observed with HRI in this study.

According to the CDC, about 14,000 cases of shigellosis are reported in the United States annually. With the majority of the cases in toddlers (2 to 4 years), many infections are related to the spread of illnesses in child-care settings, and many more others are the result of the spread of illness in families with small children *(13)*. As shown in *Table 1*, Spearman's correlation coefficient for children 1 – < 10 years was *rho* = .284, *P* = .495, though not statistically significant for this pathogen. As reported by the World Health Organization, over half of all the deaths attributable to shigellosis involve children less than 5 years of age *(42)*. Positive correlation coefficients were also seen in ages 20 – < 30 years; 30 – < 40 years, 40 – < 50 years, and 50 – < 60 years, while the remainder of the age groups had an inverse correlation with HRI.

A report by Ray et al. *(34)* indicated that infants under 1 year and adults over 60 had a higher risk for hospitalization with Yersinia infection than any other age groups. In this study, there was no significant correlation between risk of mortality and the different age groups; ages 1 – < 10 years (*rho* = .491, *P* = .217) and 30 – < 40 years (*rho* = .360, *P* = .381) had a positive Spearman's correlation coefficients *(Table 1)*. *Vibrio* foodborne disease HRI had a statistically significant (*P* < 0.05) inverse correlation with all age groups except for age 20 – < 30 years, which has a positive but weak association (*rho* = .181, *P* = .668). *Vibrio* foodborne outbreaks are associated with consumption of raw and undercooked seafood *(7)*. For age groups 40 to 60+ years, there is a statistically significant inverse correlation. These findings may be partly due to older persons being more cautious about food handling and food consumption than younger persons *(9)*.

Overall, all age groups are affected by foodborne diseases, but some age groups appear to be at particulary high risk. About 20% of the American population are at risk and could be characterized by suppressed immune response due to age (either not fully developed or loss of function), to pregnancy, or to pharmacologic therapy/AIDS/chronic diseases *(25)*. FoodNet surveillance system shows that for some foodborne pathogens, older adults have lower rates of infection than most or all of the other age groups, despite many other age-related factors.

The relationship between HRI and gender. Spearman's correlation coefficient between HRI and gender was similar for male and female populations (*rho* =.-509, *P* = .198) for *Campylobacter.* However, for pathogenic *E. coli, Listeria monocytogenes, Salmonella, Shigella, Yersinia*, and *Vibrio*, there was a difference in the correlation coefficient between the genders. For pathogenic *E. coli*, Spearman's correlation coefficient for males was *rho* =.429, *P* = .289, which, although not statistically significant from that of females, (*rho* =.190, *P* = .651) was noteworthy. *Listeria monocytogenes* showed a statistically significant difference between the sexes; Spearman's correlation coefficient for males was (*rho* =.812*, *P* = .014), as compared to (*rho* =.220, *P* = .601) for females *(Table 1)*. Furthermore, reports show that in cases where listeriosis occurred in infants, the majority were in male subjects *(41)*. The mortality rate of this pathogen is considerably higher than for most foodborne pathogens *(5, 29)*. Some researchers *(32, 39)* have shown that pregnant women may reduce their consumption of some foods to limit their exposure to *L. monocytogenes*. In the case of *Salmonella* infection from the years 1997–2004, the relationship between HRI and gender declined for both genders; *rho* =.-100, *P* = .814 and *rho* =.-150, *P* = .723 for males and females, respectively. While there was an increased risk of mortality in males infected with *Shigella* (*rho* =.161, *P* = .704), this study showed a decline for females (*rho* = -.086, *P* = .839). The Spearman's correlation coefficient declined for *Yersinia* for both males and females, and data for *Vibrio* revealed an inverse association for males, which was statistically significant ($P < 0.05$) for females *(Table 1)*. There is ample evidence that males eat significantly more risky foods than women *(10, 31)*. In addition, females have been documented to have a higher rate of proper hand hygiene practice than males *(4)*, perhaps explaining some of the differences in the data. Epidemiologic evidence also shows that consumer food-handling and sanitation practices play a major role in contracting foodborne illness *(16)*.

The relationship between HRI and ethnicity. Race categories, as defined by FoodNet, are American Indian or Alaskan Native; Asian or Pacific Islander; Black; White; and Unknown. Ethnicity categories are Hispanic Non-Hispanic and Unknown. Spearman's correlation coefficient for *Campylobacter* had a statistically significant inverse association between hazard risk index and all race and ethnic groups, except for the Asian ethnic group, which had a positive, although weak, association, with HRI (*rho* = .313, *P* = .450), as shown in *Table 1*. In 2003 *(38)*, the risk of *Campylobacter* infection was reported to be twice as high in the Asian community as in white populations and five times higher than among Indians. In that study, Pakistani, Asian Pakistani, and Asian Indian were placed in the same ethnic group. Cultural differences, as well as diet and behavior, might influence the risk of *Campylobacter* infection *(38)* and other foodborne diseases. Furthermore, another study showed that Halal meat, a traditional food, has been documented to contain the pathogen and might increase the risk of *Campylobacter* infection *(28)*.

Likewise, for pathogenic *E. coli*, there was a positive association between hazard risk index and Asian ethnicity (*rho* = .707, *P* = .050); for black and white populations, there were moderate correlations: *rho* = .381, *P* = .352 and *rho* = .262, *P* = .531, respectively. However, there was a strong inverse correlation between HRI and Hispanic ethnicity (*rho* = -1.00, *P* = 1.000).

The association between HRI for mortality from *Listeria monocytogenes* and Hispanics was stronger, (*rho* = 1.00) than for any other ethnic group. Studies have shown that a high percentage of Hispanics consume soft cheese made from unpasteurized milk and jellied meats. Furthermore, Voetsch et al. *(41)* reported that pregnant Hispanic women were more likely than non-Hispanic pregnant women to consume unpasteurized cheese and in 44% of the cases, infection could have led to either fetal loss or the death of the infant from *L. monocytogenes*. Spearman's correlation coefficient for HRI for *Salmonella* was positive for all ethnic groups, as shown in *Table 1*. HRI correlation for *Shigella* was positive (*rho* = 1.00) and strong for Hispanics, but weak for white, black and native American ethnicities. Asians and unknown ethnic groups, were inversely correlated. Also, Hispanics had a higher positive correlation with HRI (*rho* = 1.00), compared to all ethnic groups, when evaluated for *Yersinia* infections. Spearman correlation coefficient was moderate for Asian (*rho* = .479, *P* = .230), weak for the unknown (*rho* = .061, *P* = .886), but inversely correlated with the black, white and native American categories. Spearman's correlation was inversely related for all ethnic groups for *Vibrio* foodborne mortality risk *(Table 1)*.

Hypothesis testing

The null hypothesis in the materials and methods section states: There is no correlation between hazard risk index (HRI) and age, gender or ethnicity for bacterial foodborne disease outbreaks in the population. The testing of the hypothesis involved the Spearman's *rho* procedure, to determine the strength of the association between the dependent variable HRI and the independent variables (age, gender and ethnicity). The results of the analysis showed that there was a significant ($P < 0.05$) association between HRI of mortality from foodborne pathogens (*L. monocytogenes; Salmonella* spp.) and age. Therefore, the alternate hypothesis is accepted, which stated that there was an association between HRI and age.

The relationship between HRI and gender was also significant for males with foodborne disease from *L. monocytogenes*; however, a moderate association was observed for other bacterial foodborne pathogens, compared with HRI for females. The alternate hypothesis is thereby accepted. The strength of the relationship between HRI and race/ethnicity varied. It is considered to be significant, in particular between Hispanics and the foodborne pathogens *L. monocytogenes, Shigella,* and *Yersinia* and between Asians and pathogenic *E. coli*, *Campylobacter, Yersinia* and *Salmonella* spp.; it is of moderate strength for blacks in the case of pathogenic *E. coli, L. monocytogenes* and *Salmonella* spp. and for whites in the case of pathogenic *E. coli, L. monocytogenes,* in whom there is a significant association for *Campylobacter* and *Vibrio.* Hence, the null hypothesis must be rejected, and the alternate hypothesis is accepted.

CONCLUSIONS

In this study, hazard risk index (HRI) was calculated for each of the bacterial foodborne pathogens (*Salmonella*, pathogenic *E. coli, Campylobacter, L. monocytogenes, Shigella, Yersinia* and *Vibrio*) under surveillance and used to ascertain Spearman correlation coefficient with the various age groups, gender and ethnicity. Risk of mortality is strong and statistically significant ($P < 0.05$) for *Salmonella* in children ages 1 – < 10 years. Also, there was a positive correlation between risk of mortality and ethnicity with Asian, Native American, African American (black) and whites, having Spearman's correlation coefficient ranging from moderate to weak.

For pathogenic *E. coli*, in all age groups except 50 – < 60 years and 60+ years, that the risk of mortality increased. Both males (moderate) and females (weak) had positive correlation; and there were positive correlation coefficients with all ethnicity except Hispanics and Native American. Therefore, risk increases with the various variables. Even though foodborne disease outbreaks from *L. monocytogenes* were not as prevalent as outbreaks from *Salmonella*, pathogenic *E. coli* and *Campylobacter*, the rates of mortality were high, particularly for the young, for pregnant women aged 20 – < 30 years, for both males and females age 50 – < 60 years old, for males and for Hispanics. There were also positive, but not statistically significant, associations between HRI and *L. monocytogenes* for ages 0 – < 1 years, 40 – < 50 years, and 60+ years for all ethnic groups; with males having a stronger Spearman's correlation coefficient than females.

REFERENCES

1. Allos, B. M. 1997. Association between *Campylobacter* infection and Guillain-Barré syndrome. *J. Infect. Dis.* 176:S125–128.
2. Allos, B. M. 2001. *Campylobacter* jejuni infections: update on emerging issues and trends. *Clin. Infect. Dis.* 32:1201–1206.
3. American Dietetic Association. 1997. Position of the American Dietetic Association: food and water safety. *J. Am. Diet. Assoc.* 97:1048–1053.
4. Anderson, J. L., C. A. Warren, E. Perez, R. I. Louis, S. Phillips, J. Wheeler, M. Cole, and R. Misra. 2008. Gender and ethnic differences in hand hygiene practices among college students. *Am. J. Infect. Control.* 36:361–368.
5. Bhunia, A. K. 2008. *Staphylococcus aureus.* Foodborne microbial pathogens (Heldman, D. R. editor) Springer Science media, New York, NY pp. 125–134.
6. Bula, C. J., J. Bille, and M. P. Glauser. 1995. An epidemic of foodborne listeriosis in western Switzerland: description of 57 cases involving adults. *Clin. Infect. Dis.* 20:66–72.
7. Butt, A. A., K. E. Aldridge, and C. V. Sanders. 2004. Infections related to the ingestion of seafood, Part I: viral and bacterial infections. *The Lancet* 4:201–212.
8. Buzby, J. C. 2001. Children and microbial foodborne illness-examining the well-being of children. *Food Review* 24:32–37.
9. Buzby, J. C. 2002. Older adults at risk of complications from microbial foodborne illness. *Food Review* 25:30–35.
10. Byrd-Bredbenner, C., J. Maurer, V. Wheatley, D. Schaffner, C. Bruhn, and L. Blalock. 2007. Food safety self-reported behaviors and cognitions of young adults: results of a national study. *J. Food Protect.* 70:1917–1926.
11. Centers for Disease Control and Prevention. FoodNet. 1997–2007. Available at http://www.cdc.gov/foodnet/. Accessed August 2013.
12. Centers for Disease Control and Prevention. 2000. Surveillance for foodborne-disease outbreaks—United States, 1993—1997. In: surveillance summaries. *MMWR*; 49 (No. SS-1).
13. Centers for Disease Control and Prevention FoodNet. 2011. Questions and answers about the FoodNet MMWR with data from 2010. Available at http://www.cdc.gov/foodnet/. Accessed June 2012.
14. Centers for Disease Control and Prevention Division of Bacterial and Mycotic Diseases, Disease Information. 2002. *Escherichia coli* O157:H7. Available at http://www.cdc.gov/ncidod/dbmd/diseaseinfo/escherichiacoli_g.htm. Accessed February 2014.
15. Centers for Disease Control and Prevention. 2008. Outbreak of *Salmonella Serotype Saintpaul* infections associated with multiple raw produce items—United States. *MMWR* 57(34). Available at: http://www.cdc.gov/mmwr/preview/ mmwrhtml/mm5734a1.htm. Accessed January2014.
16. Cody, M. M., and M. A. Hogue. 2003. Results of the home food safety—it's in your hands 2002 survey: comparisons to the 1999 benchmark survey and healthy people 2010 food safety behaviors objective. *J. Am. Dietet. Assoc.* 103:1115–1125.
17. Cohen, M. L. 2000. Changing patterns of infectious disease. *Nature.* 406:762–767.
18. Friedman, C. R., J. Neimann, H. C. Wegener, and R. V. Tauxe. 2000. Epidemiology of *Campylobacter jejuni* infections in the United States and other industrialized nations. Second Edition. ASM Press, Washington, D.C.
19. Gerba, C. P., J. B. Rose, and C.N. Haas. 1996. "Sensitive populations: who is at the greatest risk?" *Internat. J. Food Microbiol.* 30:113–23.
20. Gould, H. L., L. Demma, T. F. Jones, S. Hurd, D. J. Vugia, K. Smith, B. Shiferaw, S. Segler, A. Palmer, S. Zansky, and P. M. Griffin. 2009. Hemolytic uremic syndrome and death in persons with *Escherichia coli* O156:H7 infection, foodborne diseases active surveillance network sites, 2000–2006. *Clin. Infect. Dis.* 49(10):1480–1485.
21. Goulet, V., and P. Marchetti. 1996. Listeriosis in 225 non-pregnant patients in 1992: clinical aspects and outcome in relation to predisposing conditions. *Scand. J. Infect. Dis.* 28:367–74.
22. Helms, M., P. Vastrup, P. GernerSmidt, and K. Mølbak. 2003. Short and long term mortality associated with foodborne bacterial gastrointestinal infections: registry based study. *Br. Med. J.* 326:357–362.
23. Hoffman, S. 2009. Attributing illness to food U.S. foodborne consumption. Available at http://www.rff.org/RFF/.../RFF-Resources-172_US_Foodborne illness pdf. Accessed December 2013.
24. Jones, T. F., S. C. Buckingham, C. A. Bopp, E. Ribot, and W. Schaffner. 2003. From pig to pacifier: chitterling-associated yersiniosis outbreak among black infants. *Emerg. Infect. Dis.* 9:1007–1009. Available at http://www.cdc.gov/ncidod/EID/vol9no8/03-0103.htm.
25. Kendall, P., L. C. Medeiros, V. Hillers, and G. Chen. 2003. Food handling behavior of special importance for pregnant women, infants and young children, the elderly, and immune-compromised people. *J. Am. Dietet. Assoc.* 103:1646–1649.
26. Kendall, P. A., V. V. Hillers, and L. C. Medeiros. 2006. Food safety guidance for older adults. *Clin. Infect. Dis.* 42:1298–304.
27. Kennedy, M., R. Villar, D. J. Vugia, T. Rabatsky-Her, M. M. Farley, M. Pass, K. Smith, P. Smith, P. R. Cieslak, B. Imhoff, and P. M. Griffin. 2004. Hospitalizations and deaths due to *Salmonella* infections, FoodNet, 1996–1999. *Clin. Infect. Dis.* 38:S142–148.
28. Little, C., I. Gillespie, J. de Louvois, and R. Mitchell. 1999. Microbiological investigation of halal butchery products and butchers' premises. *Commun. Dis. Publ. Health* 2:114–118.

29. Mead, P. S., L. Slutsker, V. Dietz, L. F. McCaig, J. S. Bresee, C. Shapiro, P. M. Griffin, and R. V. Tauxe. 1999. Food-related illness and death in the United States. *Emerg. Infect. Dis.* 5:607–625.

30. Mishu, B., A. A. Ilyas, C. L. Koski, F. Vriesendorp, S. D. Cook, F. Mithen, and M. Blaser. 1993. Serologic evidence of previous *Campylobacter jejuni* infection in patients with the Guillain-Barre´ syndrome. *Ann. Intern. Med.* 118:947–953.

31. Morrone, M., and A. Rathbun. 2003. Health education and food safety behavior in the university setting. *J. Environ. Health* 65:9–15.

32. Ogunmodede, F., J. L. Jones, J. Scheftel, E. Kirkland, J. Schulkin, and R. Lynfield. 2005. Listeriosis prevention knowledge among pregnant women in the USA. *Infect. Dis. Obstetrics and Gynecology* 13:11–15.

33. Peterson, M. C. 1994. Rheumatic manifestations of *Campylobacter jejuni* and *C. fetus* infections in adults. *Scand. J. Rheumatol.* 23:167–170.

34. Ray, S. M., S. D. Ahuja, P. A. Blake, M. M. Farley, M. Samuel, T. Rabatsky-Ehr, E. Swanson, M. Cassidy, J. C. Lay, T. Van Gilder, and the Emerging Infections Program FoodNet Working Group. 2004. Population-based surveillance for *Yersinia enterocolitica* infections in FoodNet sites, 1996–1999: Higher risk of disease in infants and minority populations. *Clin. Infect. Dis.* 38:S181–189.

35. Scharff, R. L. 2010. Health-related costs from foodborne illness in the United States. For the *Produce Safety Project* 1–28. Available at http://www.producesafetyproject.org. Accessed 7 March 2014.

36. Schlundt, J. 2002. New directions in foodborne disease prevention. *Int. J. Food Microbiol.* 78:3–17.

37. Scientific Opinion of the Panel on Biological Hazards on a request from the European Commission on Assessment of the Public Health significance of methicillin resistant *Staphylococcus aureus* (MRSA) in animals and foods. 2009. *The EFSA J.* 993:1–73.

38. The *Campylobacter* Sentinel Surveillance Scheme Collaborators. 2003. Ethnicity and *Campylobacter* infection: a population-based questionnaire survey. *J. Infect.* 47(3):210–216.

39. Torvaldsen, S., J. J. Kurinczuk, C. Bower, D. E. Parsons, and C. L. Roberts. 1999. *Listeria* awareness among new mothers in western Australia. *Australian and New Zealand J. of Publ. Health* 23:362–367.

40. U.S. Department of Health and Human Services. 2001. Healthy People 2010. Available at http://www.health.gov/healthypeople/ Document/tableofcontents.htm. Accessed 23 November 2009.

41. Voetsch, A. C., F. J. Angulo, T. F. Jones, M. R. Moore, C. Nadon, P. McCarthy, B. Shiferaw, M. B. Megginson, S. Hurd, B. J. Anderson, A. Cronquist, D. J. Vugia, C. Medus, S. Segler, L. M. Graves, R. M. Hoekstra, P. M. Griffin, and the Centers for Disease Control and Prevention Emerging Infections Program Foodborne Diseases Active Surveillance Network Working Group. 2007. Reduction in the incidence of invasive listeriosis in foodborne diseases active surveillance network sites, 1996–2003. *Clin. Infect. Dis.* 44:513–20.

42. World Health Organization. 1999. Global burden of *Shigella* infections: implications for vaccine development and implementation of control strategies. Bulletin of the World Health Organization. 77(8):651–666.

43. World Health Organization. 2007. Food safety and foodborne illness. Fact sheet No. 237.