The Relationship Between Census Tract Poverty and Shiga Toxin–Producing E. coli Risk, Analysis of FoodNet Data, 2010–2014

James L. Hadler,1 Paula Clogher, Jennifer Huang, Tanya Libby, Alicia Cronquist, Siri Wilson, Patricia Ryan, Amy Saupe, Cyndy Nicholson, Suzanne McGuire, Beletshachew Shiferaw, John Dunn, and Sharon Hurd

1Emerging Infections Program, Yale School of Public Health, New Haven, Connecticut; 2Division of Foodborne, Waterborne, and Environmental Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia; 3California Emerging Infections Program, Oakland, California; 4Emerging Infectious Diseases Program, Colorado Department of Public Health and Environment, Denver, Colorado; 5Emerging Infections Program, Georgia Department of Public Health, Atlanta, Georgia; 6Emerging Infections Program, Maryland Department of Health, Baltimore, Maryland; 7Emerging Infections Program, Minnesota Department of Health, St Paul, Minnesota; 8Emerging Infections Program, New Mexico Department of Health, Santa Fe, New Mexico; 9Emerging Infections Program, New York State Department of Health, Albany, New York; 10Emerging Infections Program, Oregon Health Authority, Portland, Oregon; 11Emerging Infections Program, Tennessee Department of Health, Nashville, Tennessee

Background. The relationship between socioeconomic status and Shiga toxin–producing Escherichia coli (STEC) is not well understood. However, recent studies in Connecticut and New York City found that as census tract poverty (CTP) decreased, rates of STEC increased. To explore this nationally, we analyzed surveillance data from laboratory-confirmed cases of STEC from 2010–2014 for all Foodborne Disease Active Surveillance Network (FoodNet) sites, population 47.9 million.

Methods. Case residential data were geocoded and linked to CTP level (2010–2014 American Community Survey). Relative rates were calculated comparing incidence in census tracts with <20% of residents below poverty with those with ≥20%. Relative rates of age-adjusted 5-year incidence per 100 000 population were determined for all STEC, hospitalized only and hemolytic-uremic syndrome (HUS) cases overall, by demographic features, FoodNet site, and surveillance year.

Results. There were 5234 cases of STEC; 26.3% were hospitalized, and 5.9% had HUS. Five-year incidence was 10.9/100 000 population. Relative STEC rates for the <20% compared with the ≥20% CTP group were >1.0 for each age group, FoodNet site, surveillance year, and race/ethnic group except Asian. Relative hospitalization and HUS rates tended to be higher than their respective STEC relative rates.

Conclusions. Persons living in lower CTP were at higher risk of STEC than those in the highest poverty census tracts. This is unlikely to be due to health care–seeking or diagnostic bias as it applies to analysis limited to hospitalized and HUS cases. Research is needed to better understand exposure differences between people living in the lower vs highest poverty-level census tracts to help direct prevention efforts.

Keywords. census tract; E. coli; incidence; Shiga toxin; poverty.

Infections with Shiga toxin–producing Escherichia coli (STEC), both O157 and non-O157 serogroups, are an important public health problem, causing an estimated 40 000–570 000 infections per year in the United States, including 549–5585 hospitalizations and as many as 113 deaths [1]. Death usually results from intravascular complications such as hemolytic-uremic syndrome (HUS). Although most human exposures to STEC come from contaminated food, people can be exposed from contaminated water and direct contact with infected ruminants and humans. Demographically in the United States, children <5 years of age, females, whites, and residents of north-central and northwestern states have the highest incidence of diagnosed infection [2, 3].

Data to determine which demographic groups are most affected by a disease help to guide public health prevention efforts. Much of our knowledge in the United States of which demographic groups are most affected by STEC has come through mandated reporting to state and local health departments, ultimately to the Centers for Disease Control and Prevention. As part of disease reporting in general, including STEC, there have been no systematic efforts to collect information on socioeconomic measures. Although data are not systematically collected with individual socioeconomic information (eg, education level, income), area-based socioeconomic measures, such as census tract poverty level, can be used if an individual’s residential location is known. Residential address can be geocoded, matched to the census tract in which a person lives, and linked to the socioeconomic measures of that census tract as determined by the US Census and the American Community Survey [4]. Increasingly in the past.

Received 16 April 2018; editorial decision 14 June 2018; accepted 29 June 2018.
Correspondence: J. L. Hadler, MD, MPH, Emerging Infections Program, Yale School of Public Health, One Church Street, 7th floor, New Haven, CT 06511 (hadler@epi@gmail.com).
Open Forum Infectious Diseases®
Published by Oxford University Press on behalf of Infectious Diseases Society of America 2018.
This work is written by (a) US Government employee(s) and is in the public domain in the US.
DOI: 10.1093/ofid/ofy148
decade, area-based socioeconomic measures, particularly census tract–level poverty, have been used and found to shed a new perspective on the epidemiology of a number of diseases under public health surveillance [5–12].

Analyses of combined data from multiple years of surveillance in Connecticut and in New York City using census tract–level poverty found that STEC and HUS incidence were consistently higher among those living in census tracts with lower levels of poverty (ie, high socioeconomic status [SES]) than in those with the highest levels of poverty [6, 13]. To determine whether these findings were more generalizable to the United States, we analyzed geocoded data linked to census tract poverty level from all reported cases of STEC and HUS occurring in the Foodborne Disease Active Surveillance Network (FoodNet) from 2010 to 2014.

METHODS

FoodNet is the principal foodborne disease surveillance component of the Centers for Disease Control and Prevention’s (CDC’s) Emerging Infections Program (EIP), a collaboration of the CDC, the US Department of Agriculture’s Food Safety and Inspection Services (USDA-FSIS), the Food and Drug Administration (FDA), and 10 state health departments. FoodNet includes the states of Connecticut, Georgia, Maryland, Minnesota, New Mexico, Oregon, and Tennessee and selected counties in California, Colorado, and New York. FoodNet staff conduct active population-based surveillance for laboratory-confirmed cases of STEC, including O157 and non-O157 serogroups, and hemolytic-uremic syndrome (HUS). Enhanced surveillance methods have been previously described [14]. Data collected on each laboratory-confirmed case of STEC and each case of HUS meeting a specific HUS clinical case definition include demographic information (age, sex, race/ethnicity, street address of residence), whether a person was hospitalized or died, whether the infection was part of an outbreak, and whether the patient had traveled internationally in the 7 days before onset of illness.

For this analysis, each FoodNet site geocode the residential address of all STEC and HUS cases for the years 2010–2014 inclusive. Geocoded addresses were assigned to census tracts. Census tract poverty level, defined as the percentage of households in the census tract living below the federal poverty level, was determined from the 2010–2014 American Community Survey 5-Year Estimates [15]. Census tracts were categorized by their percentage of households living below the poverty level (<5%, 5%–9%, 10%–19%, ≥20%), as recommended by the Public Health Disparities Geocoding Project [4, 16] and as used for other multisite EIP data analysis projects [9, 10]. Census tract–specific denominators were determined from the 2010 US Census.

Data Analysis

Age-adjusted (2000 US standard population) incidence rates per 100,000 person-years overall and for each of the 4 poverty categories were calculated for all STEC combined, for the O157 serotype only, and for all non-O157 serotypes combined. Age standardization was done using 5 age categories: 0–4 years, 5–17 years, 18–49 years, 50–64 years, and ≥65 years. These categories were based on overall age group–specific incidence rates, combining age-specific rates that were similar into the same age groups.

At this stage of analysis, we made 2 decisions to guide further analyses. First, we decided to combine STEC O157 with STEC non-O157 as they had a similar relationship to poverty (Figure 1) and to conduct all further analyses using all STEC combined only. Second, we decided to combine the 3 lowest poverty groups (0%–<5%, 5%–<10% and 10%–20%) into a single “lower poverty” group as age-adjusted incidence did not vary significantly between them (Figure 1). Further analyses by poverty compared this lower poverty group (<20% below poverty) with the high poverty group (≥20% below poverty).

Figure 1. Age-adjusted 5-year incidence of O157, non-O157, and all Shiga toxin–producing Escherichia coli (STEC) by census tract poverty category, Foodborne Disease Active Surveillance Network, 2010–2014.
To account for possible bias introduced by this post hoc decision, a \( P \) value of <.01 instead of \( P < .05 \) was considered statistically significant in comparing the newly defined lower poverty group with the high poverty group, and 99% confidence limits were calculated.

We then calculated incidence rate ratios (IRRs) comparing age-adjusted incidence in the lower vs high poverty categories for (1) all STEC cases, (2) hospitalized cases, and (3) HUS cases. IRRs were determined by year, by site, by sex, and by race/ethnicity to determine if the relationship was consistent by each of these variables.

Finally, STEC cases were separated into international travel–associated cases and cases acquired in the United States to determine how the overall findings of the relationship of census tract poverty level to STEC and its severe outcomes were influenced by international travel. International travel–associated cases were those occurring in a person who had been out of the country at any time during the 7 days before illness onset.

Statistical analyses were performed using SAS, version 9.3 (SAS Institute Inc, Cary, NC, USA). IRRs and 95% confidence intervals were calculated using the Statcalc function in Epi Info 7.

RESULTS

There were a total of 5234 cases (96% of total) that were able to be geocoded to the rooftop level. The characteristics of these cases and average annual incidence of each of the 3 outcomes are shown in Table 1. Overall, 26.3% were hospitalized and 5.9% had HUS. The majority (55%) of STEC cases were non-O157. Crude incidence rates of all 3 outcomes were highest among the youngest age groups, non-Hispanic whites, residents of lower poverty census tracts, and in the later years of the 5-year period. Numbers of cases by site ranged from a low of 223 in New Mexico to a high of 1274 in Minnesota. Site-specific incidence ranged from a low of 0.99 in Georgia to a high of 4.74 in Minnesota (data not shown).

Figure 1 shows age-adjusted rates of STEC O157, STEC non-O157, and all STEC by census tract poverty level. Overall and for each group of serotypes, the highest poverty group (≥20%) had the lowest rate, and it was statistically significantly lower than for each of the other poverty groups (\( P < .001 \)). There was no consistent hierarchical relationship of incidence rate within the other poverty groups. Based on these findings, we combined O157 and non-O157 serotypes and collapsed the 3 lowest poverty groups into 1 group <20% below the federal poverty level for subsequent analyses.

Age-adjusted IRRs comparing incidence of all STEC, hospitalized cases, and HUS cases in the combined lower poverty group with the highest poverty group are shown in Table 2. For all STEC, IRRs were consistently significantly greater than 1.0 for each age group, by sex, by surveillance year, and for all major race/ethnic groups except for non-Hispanic Asian/Pacific Islanders. When examined by FoodNet site, the same was true for each site except for California and Colorado where IRRs of >1.0 had 95% confidence limits that overlapped with 1 (Figure 2).

For hospitalized and HUS cases, the IRR was higher than for all STEC cases overall and for most demographic subgroups (Table 2). There were 4 states with IRRs for hospitalized cases that were statistically significantly greater than 1 at a \( P < .01 \) level. For all 4, the IRR for hospitalized cases was higher than for all STEC cases (Figure 2).

Of the 5234 STEC cases, 437 (8.3%) had traveled internationally in the 7 days before symptom onset. 4455 (85.1%) had not, and travel status was unknown for 342 (6.5%). Table 2 shows overall age-adjusted IRRs of lower to high (≥20%) poverty groups for each STEC outcome by international travel status. For cases in each travel group (international travel and domestic exposure only), infection was associated with living in lower poverty census tracts. Point estimates of the relative rates were greater than 1.0 for each age group for both domestic and internationally acquired cases, although for some groups with small numbers of cases, this was not statistically significant (data not shown).

Because most cases were acquired from domestic exposure, domestic cases were examined by serogroup (O157 vs non-O157), age, and surveillance site. The findings were consistent with those from the analyses of all STEC cases: for all groups, sites, and serogroups, the rate of STEC was higher in the less poor census tracts than the poorest census tracts and of a similar magnitude to that using all STEC cases regardless of international travel status (data not shown).

DISCUSSION

This study had several important findings. First, it demonstrated that persons in the United States of higher SES status, including very young children, have had a consistently higher risk of acquiring clinically consequential STEC infection than those living in poverty. Second, the findings were similar for O157 and non-O157 STEC. These findings have implications for both current intervention efforts and future research.

Before this analysis, there have been 3 published analyses of the relationship of SES to STEC in the United States, all using area-based SES measures, all with similar findings. The first was a national study from the National Notifiable Disease System covering nationally reported data from 1993–2002. Using counties as the area-based unit of analysis, it found lower county-level incidence with higher county poverty levels [17]. However, its findings were limited. It analyzed nationally notifiable data for E. coli O157:H7 (not all STEC) from 1993–2002, used a very broad area-based level, and only used county-level, not individual, variables. It was further limited in shedding no light on the contribution of neighborhood poverty to risk in specific age groups or on whether the risk associated with neighborhood poverty changed over time. The other 2 were the...
more recent studies in Connecticut and New York City using the census tract as the area size for analysis and individual demographic variables rather than percentage of the population in selected age groups [6, 13]. They each found an association of lower STEC incidence with higher census tract poverty levels. However, as they were local and in the Northeast (mostly urban and suburban), it was not clear what would happen with more nationally representative data. With our data set, we were able to confirm this relationship at the national level, that it was consistent across 5 consecutive years, strongest for young children, and present more recently than 1993–2002. Our findings were also consistent across all 10 FoodNet sites by sex and within most race/ethnic groups, and for each of the 3 STEC health outcomes examined (laboratory-confirmed disease, hospitalization, and HUS), the relationship between STEC and SES appears to be universal across the United States and enduring. Of interest, this relationship does not necessarily hold in other developed countries. A study in Denmark covering national data from 1993–2004 found no association between individual income or education level and STEC [18], and a study from Alberta, Canada, covering reported data from 2000–2002 found no association with census subdivision rates of STEC and percentage of individuals living in low-income households [19].

That the overall findings for STEC O157 and STEC non-O157 were similar with respect to poverty is consistent with other aspects of their epidemiology. Although different STEC serotypes may differ in pathogenicity [20, 21], those that cause severe human disease appear to share a similar ecology and many of the same risk factors for acquisition [20–22]. This is a likely explanation for why they have a similar relationship to

| Characteristic | No (%) of STEC Cases | Population | STEC Incidence | Incidence of Hospitalized Cases | Incidence of HUS |
|----------------|----------------------|------------|----------------|---------------------------------|-----------------|
| All cases      | 5234                 | 47 898 745 | 2.19           | 0.57                            | 0.13            |
| Serotype       |                      |            |                |                                 |                 |
| O157           | 2355 (45.0)          | 47 898 745 | 0.98           | 0.38                            |                 |
| Non-O157       | 2879 (55.0)          | 47 898 745 | 1.20           | 0.19                            |                 |
| Severity       |                      |            |                |                                 |                 |
| Hospitalized   | 1374 (26.3)          | 47 898 745 | 0.57           | -                               | -               |
| HUS            | 308 (5.9)            | 47 898 745 | 0.13           | -                               | -               |
| Age group, y   |                      |            |                |                                 |                 |
| 0–4            | 1267 (24.2)          | 2 986 919  | 8.48           | 1.65                            | 0.92            |
| 5–17           | 1391 (26.6)          | 8 103 964  | 3.43           | 0.96                            | 0.31            |
| 18–49          | 1615 (30.9)          | 20 897 307 | 1.55           | 0.34                            | 0.02            |
| 50–64          | 455 (8.7)            | 9 508 512  | 0.96           | 0.33                            | 0.01            |
| ≥65            | 506 (9.7)            | 6 402 043  | 1.58           | 0.70                            | 0.07            |
| Sex            |                      |            |                |                                 |                 |
| Male           | 2331 (44.5)          | 23 513 733 | 1.98           | 0.52                            | 0.12            |
| Female         | 2903 (55.5)          | 24 385 012 | 2.38           | 0.62                            | 0.14            |
| Race/ethnicity |                      |            |                |                                 |                 |
| Hispanic       | 536 (10.2)           | 5 253 918  | 2.04           | 0.32                            | 0.08            |
| Non-H white    | 3554 (67.9)          | 30 919 814 | 2.30           | 0.71                            | 0.15            |
| Non-H black    | 237 (4.5)            | 7 123 093  | 0.67           | 0.18                            | 0.02            |
| Non-H Asian/PI | 116 (0.3)            | 2 277 853  | 1.02           | 0.25                            | 0.10            |
| Non-H other/unknown | 791 (15.2) | 1 382 468  | -              | -                               | -               |
| Census tract poverty |            |            |                |                                 |                 |
| <5%            | 1098 (21.0)          | 8 940 621  | 2.46           | 0.62                            | 0.12            |
| 5%–<10%        | 1401 (26.8)          | 10 888 246 | 2.57           | 0.69                            | 0.16            |
| 10%–<20%       | 1701 (32.5)          | 14 713 758 | 2.31           | 0.64                            | 0.17            |
| ≥20%           | 1031 (19.7)          | 12 415 515 | 1.66           | 0.40                            | 0.08            |
| Year           |                      |            |                |                                 |                 |
| 2010           | 826 (15.8)           | 47 898 745 | 1.72           | 0.52                            | 0.11            |
| 2011           | 982 (18.8)           | 47 898 745 | 2.05           | 0.61                            | 0.12            |
| 2012           | 1122 (21.4)          | 47 898 745 | 2.34           | 0.60                            | 0.13            |
| 2013           | 1147 (21.9)          | 47 898 745 | 2.39           | 0.69                            | 0.20            |
| 2014           | 1157 (22.1)          | 47 898 745 | 2.42           | 0.55                            | 0.10            |

Abbreviations: H, Hispanic; HUS, hemolytic-uremic syndrome; PI, Pacific Islander; STEC, Shiga toxin–producing Escherichia coli.

*Three cases missing poverty status.

*Combined population denominator for all FoodNet sites. Based on 2012 US Census Bureau population estimates, except for race/ethnicity and census tract poverty, which are based on the 2010 US Census.

*Incidence per 100,000 person-years.
poverty in the United States, as differences in rates of exposure to STEC are the likely reasons for those in high poverty census tracts to be at lower risk in the United States.

One important consideration in interpretation of results from this study is that persons in higher SES census tracts might be more likely to seek health care for STEC symptoms, especially diarrhea, and to get diagnosed than those in high poverty census tracts. This consideration was examined for FoodNet sites during 2000–2003 and found not to be true [23]. In fact, this analysis of FoodNet population survey data found that those in the lowest income category (household income <$25 000) were more likely to seek care for acute diarrheal illness. As this

| Variable | All STEC (n = 5234) | | Hospitalized Cases (n = 1374) | | HUS Cases (n = 308) | |
|----------|-------------------|---|-------------------|---|-------------------|---|
|          | IRR    | 95% CI | IRR    | 95% CI | IRR    | 95% CI |
| All cases | 1.53* | 1.43–1.64 | | 1.63* | 1.43–1.87 | | 2.08* | 1.53–2.81 |
| Age group, y | | | | | | |
| 0–4 | 1.39* | 1.22–1.58 | | 1.98* | 1.43–2.75 | | 2.25* | 1.42–3.54 |
| 5–17 | 1.69* | 1.47–1.94 | | 1.95* | 1.48–2.57 | | 1.71 | 1.07–2.73 |
| 18–49 | 1.69* | 1.49–1.91 | | 1.79* | 1.37–2.38 | | 2.11 | 0.61–7.22 |
| 50–64 | 1.27 | 1.01–1.62 | | 0.93 | 0.65–1.34 | | 1.76 | 0.21–14.66 |
| ≥65 | 1.26 | 1.01–1.57 | | 1.19 | 0.86–1.65 | | 6.13 | 0.88–45.65 |
| Sex | | | | | | |
| Male | 1.42* | 1.28–1.57 | | 1.84* | 1.49–2.26 | | 2.83* | 1.71–4.68 |
| Female | 1.56* | 1.43–1.71 | | 1.48* | 1.24–1.77 | | 1.60 | 1.10–2.34 |
| Race/ethnicity | | | | | | |
| Hispanic | 1.62* | 1.32–2.00 | | 1.71 | 1.07–2.74 | | 3.20 | 0.91–11.22 |
| Non-H white | 1.20* | 1.10–1.30 | | 1.37* | 1.16–1.61 | | 1.34 | 0.96–1.85 |
| Non-H black | 1.61* | 1.23–2.11 | | 1.24 | 0.75–2.04 | | 0.90 | 0.18–4.48 |
| Non-H Asian/PI | 0.71 | 0.48–1.06 | | 1.43 | 0.50–4.13 | | 2.87 | 0.37–22.04 |
| Year | | | | | | |
| 2010 | 1.98* | 1.64–2.38 | | 1.84* | 1.32–2.57 | | 1.03 | 0.56–1.89 |
| 2011 | 1.22* | 1.06–1.42 | | 1.30 | NS | | 2.33 | 1.11–4.92 |
| 2012 | 1.59* | 1.37–1.84 | | 1.69* | 1.24–2.29 | | 2.56* | 1.22–5.37 |
| 2013 | 1.71* | 1.47–1.98 | | 1.89* | 1.41–2.53 | | 2.11* | 1.22–3.65 |
| 2014 | 1.52* | 1.32–1.76 | | 1.57* | 1.15–2.14 | | 4.04* | 1.45–11.24 |
| International travel 7 d before symptom onset | | | | | | |
| No (n = 4454) | 1.52* | 1.42–1.64 | | 1.60* | 1.39–1.83 | | 1.81* | 1.35–2.42 |
| Yes (n = 435) | 1.72* | 1.35–2.20 | | 2.64 | 0.79–8.81 | | - | - |

Abbreviations: CI, confidence interval; H, Hispanic; HUS, hemolytic-uremic syndrome; IRR, incidence rate ratio; PI, Pacific Islander; STEC, Shiga toxin–producing Escherichia coli.

*P < .01.
analysis took place before our study time period, it is possible that health care–seeking behaviors might have changed. Thus, in addition to laboratory-confirmed, largely outpatient illness, we examined the outcomes of hospitalization and HUS, both likely to be less influenced by income or health care access. For both outcomes, the association with higher SES was, if anything, even stronger.

An important risk factor for acquisition of STEC in the United States, especially STEC non-O157, is international travel [20, 21]. In our study, 8.9% of STEC cases had traveled internationally in the 7 days before illness onset, and international travel–associated STEC was least likely among persons living in high poverty census tracts. However, after excluding international travel, those in high poverty areas still had the lowest risk of laboratory-confirmed STEC and its complications.

There are some data to support the hypothesis that adults of higher SES status in the United States have had a higher prevalence of some consumer-level STEC risks other than international travel. Such risks include eating raw or undercooked beef [24–26], eating in restaurants [25], eating raw fresh vegetables, fruits, and nuts [27], and poorer hygiene practices to prevent cross-contamination from raw products despite higher knowledge levels [26]. Although more current studies are needed, as stated in a recent systematic review, “SES should be considered when targeting consumer level public health interventions for foodborne pathogens,” including STEC [28].

Risk factors for young children (<5 years) in the United States have been identified but have not been put in a relative attribution context or examined by SES, despite these children having the highest age-specific risk of laboratory-confirmed infection and HUS. Widely recognized means of exposure for young children include person-to-person transmission, particularly in day care centers and from contact with other children with diarrhea, consumption of contaminated foods and beverages, particularly undercooked beef products and other food items cross-contaminated from them, and direct or indirect contact with farm animals, particularly ruminants. Although all these potential exposure factors could be more common in those of higher SES, documentation of their association with SES first, and then of the factors leading to exposure (eg, hygiene in day care centers and at home, including handling raw beef), is needed to guide prevention efforts targeted at the consumer.

This study has some notable strengths. These include the high percentage of cases geocoded to the census tract level, participation from all 10 FoodNet sites encompassing more than 48 million people enabling generalization to the US population, and analysis by 3 levels of severity of STEC infection.

There are also some important limitations. Most importantly, this study used census tract SES rather than individual SES. Although the 2 are usually correlated, they do not measure exactly the same thing. In particular, census tract SES includes possible neighborhood SES factors contributing to the observed findings (eg, some poor neighborhoods may have a high prevalence of relatively bacteria-free fast food and lack stores with fresh meat and produce, lowering the potential for foodborne STEC exposure) and may have a stronger association if the neighborhood SES is more of a factor than individual-level SES. In addition, not everyone in the neighborhood has the same individual SES. Thus, the findings need to be interpreted in this context. Second, most of the cases were identified because they sought medical care, and stool specimens were taken for diagnosis. Not everyone with STEC infection seeks medical care, and not all those who do have specific diagnostic testing. Thus, the cases used in this population-based study do not comprise the universe of all STEC infections in FoodNet sites [1]. To the extent that there might have been bias by SES in who sought medical care and was diagnosed, the true magnitude of the associations found could be different in either direction. Third, we used relatively broad age groups to age-adjust and to examine age group–specific associations. However, those ages comprising each age group were selected because they had a similar age-specific incidence. In addition, there were several statistical limitations. As previously described, we made a post hoc recategorization of 4 census tract poverty levels to 2; thus, only P values of ≤.01 should be considered statistically significant. In addition, the 95% confidence limits on the incidence rate ratios presented in Table 2 were calculated assuming there was no clustering of outcomes within individual census tracts as we did not have individual census tract identifiers; thus, they are possibly narrower than they might actually be. Finally, this study was limited to descriptively defining the relationship between census tract poverty used as a single recommended SES surveillance variable and STEC incidence in the national foodborne disease sentinel surveillance system, FoodNet. Examination of other area-based SES variables and conducting an analysis to determine the relative importance of census tract poverty compared with each of the other descriptive variables available were beyond the scope of this analysis.

CONCLUSIONS

In summary, the findings from analysis of population-based data from FoodNet, the national sentinel foodborne disease surveillance system, confirm those from more localized studies that people living in lower poverty neighborhoods are at higher risk of acquiring STEC infection and suffering its more severe complications. These findings point to a need to consider higher SES when targeting specific public health interventions to prevent STEC infection. However, a current understanding of SES differences in risk factors, for children in particular, is needed to enable potentially effective interventions.

Acknowledgments

We thank the many FoodNet surveillance staff at each site and at the CDC for their work in collecting, geocoding, and collating the data used in this paper.
Financial support. This work was supported by the Centers for Disease Control and Prevention (CI05-026, CK12-1202, CK17-1701).

Potential conflicts of interest. All authors: no reported conflicts of interest. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

References
1. Scallan E, Hookstra RM, Angelo FJ, et al. Foodborne illness acquired in the United States—major pathogens. Emerg Infect Dis 2011; 17:77–15.
2. Gould LH, Mody RK, Ong KL, et al. 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. Foodborne Pathog Dis 2013; 10:453–60.
3. Adams DA, Thomas KR, Jajosky R, et al. Summary of notifiable infectious diseases and conditions—United States, 2014. MMWR Morb Mortal Wkly Rep 2016; 63:1–152.
4. Krieger N, Chen JT, Waterman PD, et al. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities. The Public Health Disparities Geocoding Project. Am J Public Health 2005; 95:212–23.
5. Toprani A, Hadler JL. Selecting and applying a standard area-based socioeconomic status measure for public health data: analysis for New York City. New York City Department of Health and Mental Hygiene: Epi Research Report. 2013. Available at: http://www1.nyc.gov/assets/doh/downloads/pdf/epi/epire-search-SES-measure.pdf. Accessed 8 March 2018.
6. Greene SK, Levin-Rector A, Hadler JL, Fine AD. Disparities in reportable communicable indicators by census tract-level poverty, New York City, 2006–2013. Am J Public Health 2015; 105:227–34.
7. Centers for Disease Control and Prevention. Social determinants of health among adults diagnosed with HIV infection in 11 states, the District of Columbia and Puerto Rico, 2013. HIV Surveillance Supplemental Report. 2015. http://www.cdc.gov/hiv/pdf/library/reports/surveillance/cdc-hiv-surveillance-report-vol20-no3.pdf. Accessed 8 March 2018.
8. Boscoe FP, Johnson CJ, Sherman RL, et al. The relationship between area poverty rate and site-specific cancer incidence in the United States. Cancer 2014; 120:2191–8.
9. Hadler JL, Vugia DJ, Bennett NM, Moore MR. Emerging infections program efforts to address health equity. Emerg Infect Dis 2015; 21:1589–94.
10. Hadler JL, Yousey-Haines K, Perez A, et al. Influenza-related hospitalizations and poverty levels—United States 2010–2012. MMWR Morb Mortal Wkly Rep 2016; 65:101–5.
11. Soto K, Petit S, Hadler JL. Changing disparities in invasive pneumococcal disease by socioeconomic status and race in Connecticut, 1998–2008. Public Health Reports 2011; 126(Suppl 3):81–8.
12. Bernis K, Marcus R, Hadler JL. Campylobacteriosis incidence is associated with low poverty: Connecticut, 1999–2009. Emerg Infect Dis 2014; 20:1240–2.
13. Whitney BM, Mainero C, Humes E, Hard S, Niccolai L, Hadler JL. Socioeconomic status and foodborne pathogens in Connecticut, USA, 2000–2011. Emerg Infect Dis 2015; 21:1617–24.
14. Henao OL, Jones TE, Vugia DJ, Griffin PM. Foodborne Diseases Active Surveillance Network (FoodNet) Workgroup. Foodborne diseases active surveillance network—2 decades of achievements, 1996–2015. Emerg Infect Dis 2015; 21:1529–36.
15. US Census Bureau. American fact finder advanced. Available at: https://factfinder.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t. Accessed 8 March 2018.
16. Public Health Disparities Geocoding Project. Available at: http://www.lsphs.harvard.edu/thesegocodingproject. Accessed 8 March 2018.
17. Chang M, Grossecolse SL, Zaidi AA, Braden CR. An ecological analysis of sociodemographic factors associated with the incidence of salmonellosis, shigellosis, and E. coli O157:H7 infections in US counties. Epidemiol Infect 2009; 137:810–20.
18. Simonsen J, Frisch M, Etblerg S. Socioeconomic risk factors for bacterial gastrointestinal infections. Epidemiology 2008; 19:282–90.
19. Pearl DL, Louie M, Chui L, et al. A multi-level approach for investigating socio-economic and agricultural risk factors associated with rates of reported cases of Escherichia coli O157 in humans in Alberta, Canada. Zoonoses Public Health 2009; 56:455–64.
20. Hedican E, Medus C, Besser JM, et al. Characteristics of O157 versus non-O157 Shiga toxin-producing Escherichia coli infections in Minnesota, 2000–2006. Clin Infect Dis 2009; 49:358–64.
21. Hadler JL, Clogher P, Phan Q, et al. Ten year trends and risk factors for non-O157 Shiga-toxin producing E. coli found through Shiga-toxin testing, Connecticut, 2000–2009. Clin Infect Dis 2011; 53:269–76.
22. Bettelheim KA. The non-O157 shiga-toxigenic (verocytotoxigenic) Escherichia coli: under-rated pathogens. Crit Rev Microbiol 2007; 33:67–87.
23. Scallan E, Jones TB, Cronquist A, et al. Factors associated with seeking medical care and submitting a stool sample in estimating the burden of foodborne illness. Foodborne Pathog Dis 2006; 3:432–8.
24. Taylor EV, Holt KG, Mahon BE, Ayers T, Norton D, Gould LH. Ground beef consumption patterns in the United States, FoodNet, 2006 through 2007. J Food Prot 2012; 75:341–6.
25. Wagner JA. Foodnet Population Survey 2006–2007: Differences in Prevalence of Health Care Seeking Behaviors and Exposures to Risk Factors for Foodborne Illness by Socioeconomic Status [master’s thesis]. New Haven, CT: Yale University; 2014. Available at: http://elsischolar.library.yale.edu/cgi/viewcontent.cgi?article=13048&context=ysphdl. Accessed 8 March 2018.
26. Patil SR, Cates S, Morales R. Consumer food safety knowledge, practices, and demographic differences: findings from a meta-analysis. J Food Prot 2005; 68:1884–94.
27. Dubowitz T, Heron M, Bird CE, et al. Neighborhood socioeconomic status and fruit and vegetable intake among whites, blacks, and Mexican Americans in the United States. Am J Clin Nutr 2008; 87:1883–91.
28. Newman KL, Leon JS, Rebollodo PA, Scallan E. The impact of socioeconomic status on foodborne illness in high-income countries: a systematic review. Epidemiol Infect 2015; 143:2473–85.