HHS Public Access
Author manuscript
J Infect. Author manuscript; available in PMC 2021 November 17.

Published in final edited form as:
J Infect. 2018 March ; 76(3): 280–285. doi:10.1016/j.jinf.2017.11.010.

Heavy precipitation as a risk factor for shigellosis among homeless persons during an outbreak — Oregon, 2015–2016

Jonas Z. Hines[a,b,*], **Meredith A. Jagger**[b], **Thomas L. Jeanne**[c], **Nicole West**[c], **Andrea Winquist**[a], **Byron F. Robinson**[a], **Richard F. Leman**[b], **Katrina Hedberg**[b]

[a]Epidemic Intelligence Service, Centers for Disease Control and Prevention, 1600 Clifton Street NE, Atlanta, Georgia, 30333, USA

[b]Public Health Division, Oregon Health Authority, 800 NE Oregon Street, Portland, Oregon, 97232, USA

[c]Multnomah County Health Department, 425 SW Stark Street, Oregon, 97204, USA

Abstract

Objectives: *Shigella* species are the third most common cause of bacterial gastroenteritis in the United States. During a *Shigella sonnei* outbreak in Oregon from July 2015 through June 2016, *Shigella* cases spread among homeless persons with onset of the wettest rainy season on record.

Methods: We conducted time series analyses using Poisson regression to determine if a temporal association between precipitation and shigellosis incidence existed. Models were stratified by housing status.

Results: Among 105 infections identified, 45 (43%) occurred in homeless persons. With increasing precipitation, cases increased among homeless persons (relative risk [RR] = 1.36 per inch of precipitation during the exposure period; 95% confidence interval [CI] = 1.17–1.59), but not among housed persons (RR = 1.04; 95% CI 0.86–1.25).

Conclusions: Heavy precipitation likely contributed to shigellosis transmission among homeless persons during this outbreak. When heavy precipitation is forecast, organizations working with homeless persons could consider taking proactive measures to mitigate spread of enteric infections. Published by Elsevier Ltd on behalf of The British Infection Association.

Keywords

Shigella sonnei ; Disease outbreaks; Homeless persons; Rain, adverse effects; Climate change

Shigella species are the third most common cause of bacterial gastroenteritis in the United States, resulting in approximately 500,000 infections, 100,000 hospitalizations, and 500

*Corresponding author. Centers for Disease Control and Prevention, 1600 Clifton Street NE, Atlanta, Georgia, 30329, USA. jhines1@cdc.gov (J.Z. Hines).

Disclaimers statement: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Conflict of interest
The authors have no conflicts of interest to declare.

deaths annually.[1] Transmission occurs through the fecal–oral route, and outbreaks tend to occur in overcrowded settings where personal hygiene is challenging, such as at daycare centers and during mass population displacements.[2] In high-income countries, young children attending daycare, travelers to low-income countries, and men who have sex with men (MSM) are groups at increased risk for shigellosis.[3] Recently, several outbreaks have been reported among homeless persons,[4–6] a group not previously recognized as being at increased risk for shigellosis but that faces conditions favorable to *Shigella* transmission (e.g., inadequate access to potable water and sanitation facilities and a tendency toward crowded living conditions).

In June 2015, a multistate outbreak of *Shigella sonnei* began among MSM[7] and in July 2015, *S. sonnei* infections with pulsed-field gel electrophoresis (PFGE) patterns indistinguishable from the multistate outbreak strain began occurring among MSM in the Portland metropolitan area.[8] In November 2015, the outbreak strain spread among Portland's homeless population, coinciding with onset of the wettest rainy season on record in the state. Previous studies have shown a relationship between precipitation and diarrheal illnesses; although the relationship is complex, heavy rainfall, flooding, and droughts are associated with an increased number of enteric infections.[9–11] Moreover, the association between environmental exposures and infectious diarrhea is modified by social conditions, such as access to hygiene and sanitation.[12,13]

Most of the Oregon's approximately 4 million residents reside in Portland, the largest city, and the surrounding metropolitan area.[14] In 2015, an estimated 3801 homeless persons lived in Multnomah County, where Portland is located.[15] Oregon's rainy season extends from November to March. Consistent with the nationwide seasonal pattern,[16] shigellosis typically peaks in the summer in Oregon, when precipitation is at its lowest statewide. Thus, the observed peak of shigellosis during a period of unusually heavy precipitation was unusual. We sought to determine whether heavy precipitation was an independent risk factor for shigellosis during this outbreak, and whether experiencing homelessness during the incubation period was a modifying factor.

Methods

Case definition and study population

A confirmed case was defined as an *S. sonnei* infection with an isolate having a PFGE pattern indistinguishable from the outbreak strain in an Oregon resident with symptom onset during July 2015–June 2016. The state public health laboratory confirmed all *Shigella* cases by serotyping and PFGE.

Data sources

Data were collected during August 2015–July 2016. We identified cases through routine reporting of *Shigella* infections by clinicians and clinical laboratories, which is required by law in Oregon.[17] Contact information was collected for identified cases. We attempted to interview all persons identified with a confirmed case by using a standard questionnaire and a supplemental outbreak-specific questionnaire. We telephoned persons; if we could not reach the person after three attempts, we sent a text message and mailed a letter asking them to contact us. When resources allowed, we attempted to interview in person. To aid the investigation, we used identifying information to access and review available medical charts for persons identified with confirmed cases.[17] We collected epidemiologic information (e.g., known risk factors and contacts) and, when available, additional contact information (e.g., phone numbers of family members and email addresses). Information collected from medical chart review supplemented information collected during interviews. If we could not interview a person with a confirmed case, we relied upon information collected during medical chart review only.

The initial outbreak-specific questionnaire collected information about risk factors for sexual transmission of shigellosis among MSM, the population affected at the outset of the outbreak. However, when spread of cases into the homeless population was first recognized in December 2015, we updated the outbreak-specific questionnaire to gather information about housing status and use of homeless assistance programs (e.g., homeless shelters, homeless day programs, and soup kitchens).

Housing status was determined through interview or medical chart review. Persons interviewed during or after December 2015 were considered to be experiencing homelessness if they reported sleeping outdoors, in a homeless shelter, doubled-up with friends or family, in an abandoned building, or in a motor vehicle the week before illness. Persons interviewed prior to December 2015 or who we could not interview were considered homeless if the medical chart listed home-of-record as a homeless assistance program, or if there was specific mention of current homelessness in the medical chart. Otherwise persons were considered housed.

We obtained daily weather data (inches of precipitation and degrees Fahrenheit temperature) from the PRISM Climate Group.[18,19] The PRISM model combines weather station observations with elevation and physiographic variables to create modeled 4 km^2-gridded datasets for the United States; we used data for the centroid of Multnomah County, from which the majority of cases were reported.

Statistical analysis

To examine the temporal relationship between precipitation and shigellosis, we conducted a time series analysis using Poisson regression. The outcome variable was the daily number of confirmed shigellosis cases for a given symptom onset date. Two cases with uncertain onset dates were excluded from the final analysis. To explore how homelessness might have modified the association between heavy precipitation and shigellosis, we stratified our analysis by housing status after running the model for all cases together.

The exposure of interest was the cumulative precipitation over a 7-day period ending one week before symptom onset (day 0)—that is from day −14 to day −8. Previous studies of precipitation and shigellosis have reported lag times of days to months.[20–24] We prespecified a 1-week lag time because we expected a delay between heavy precipitation and increased risk of infection. This delay comprised two components: the time for precipitation-related behavioral and environmental changes that might increase risk of contact with *Shigella*-

contaminated matter that may occur, such as increased congregation and deterioration of hygienic conditions, and the incubation period of *Shigella* (0–7 days but typically 1–3 days). We hypothesized that heavy precipitation over multiple days, not just on one day, would be more likely to increase shigellosis risk through precipitation-related behavioral and environmental mechanisms; therefore, we selected precipitation accumulated over seven days as the exposure.

We controlled for temperature because previous research has shown associations between temperature and both precipitation (exposure)[25] and shigellosis (outcome).[26] Minimum and maximum temperatures were highly correlated (Pearson $r = 0.86$) during the outbreak. We selected minimum temperature as the temperature metric because it was one factor (the other being precipitation) considered in opening severe weather emergency shelters that might have served as points of increased congregation and, thus, *Shigella* transmission during this outbreak. We prespecified the same exposure period (day −14 to day −8) for temperature, using the 7-day average.

We controlled for autocorrelation between daily case counts by including model terms for lagged daily case counts that were significantly correlated with a given day's case count. Nonlinear transformation of the precipitation variable did not improve model fit, nor did including linear and quadratic variables for time; therefore, such terms were not included in the final model.

We performed sensitivity analyses substituting other biologically plausible lag times and exposure windows (from days: −7 to −1; −3 to −1; −10 to −4; and −10 to −8), limiting the analysis period to the rainy season (November 2015–March 2016), substituting maximum for minimum temperature, limiting analysis to only Multnomah County cases, adding to the model an indicator variable for holidays, and using National Oceanic and Atmospheric Administration weather station data instead of PRISM data. Additionally, we performed a sensitivity analysis restricted to homeless persons who indicated sleeping outdoors or in a shelter, as they might have been more likely to encounter potentially ill persons in these congregate settings.

All analyses were conducted using SAS software, version 9.4 (SAS Institute, Cary, NC, USA). We report 95% confidence intervals. The project was deemed nonresearch by the Centers for Disease Control and Prevention (CDC). All data were maintained and all analyses were performed on encrypted servers at the Oregon Health Authority (OHA) and CDC. Before any data were shared between OHA and CDC, unique IDs were assigned and all personally identifying information was deleted.

Results

During July 2015–June 2016, a total of 105 *S. sonnei* cases with PFGE patterns indistinguishable from the outbreak strain were identified among Oregon residents (Table 1); 79 (75%) were among men, and the median age was 42 years (interquartile range [IQR] = 32–55 years). Forty-five (43%) persons were identified as having experienced homelessness during the week before illness. We interviewed 68 (65%) persons with the standard questionnaire and 53 (51%) persons with the outbreak-specific questionnaire. We reviewed medical charts of 91 (87%) persons. We were unable to interview or review the chart of 1 person. The epidemiologic investigation did not identify a common source of *Shigella* exposure. Although multiple homeless persons during this outbreak indicated visiting several common homeless assistance programs during their incubation periods, no pattern emerged and environmental health inspections at these locations were unrevealing. In total, 48 (46%) persons were hospitalized; none died.

Cases were reported from 7 counties of residence; however, 101 (96%) cases occurred among residents in 4 contiguous counties that compose the Portland metropolitan area. The 4 (4%) persons from the other 3 counties outside the Portland metropolitan area all traveled to Portland during the week before illness. All but 1 case among homeless persons occurred in Portland.

Most precipitation during July 2015–June 2016 accumulated during the rainy season from November 2015–March 2016 (42.6 inches, 77%). Of all cases during the outbreak, 75 (71%) occurred during the rainy season. Of the 45 cases in homeless persons, 38 (84%) occurred during the rainy season (Figure 1). During November 2015–March 2016, the minimum temperature ranged from 25.6 °F to 52.0 °F (which was overall warmer than the historic average minimum temperature).

The time series analysis indicated that for each additional inch of precipitation during a 7-day period ending 1 week before symptom onset, the daily number of shigellosis cases increased by 18% (relative risk [RR] = 1.18; 95% confidence interval [CI] = 1.06–1.33). In the stratified analysis, the relative risk for the daily number of shigellosis cases per inch of precipitation was 1.36 (95% CI = 1.17–1.59) among homeless persons and 1.04 (95% CI = 0.86–1.25) among housed persons.

Sensitivity analyses demonstrated robustness of the primary model. For each analysis, precipitation was associated with shigellosis (results ranging from RR = 1.13–1.28), and when stratified by housing status, the association was stronger among homeless persons (results ranging from RR = 1.24–1.58) and not statistically significant among housed persons (results ranging from RR = 0.98–1.15) (Table 2). Limiting the analysis only to homeless persons who reported sleeping outdoors or in a homeless shelter (n = 32) yielded results similar to the primary analysis (RR = 1.33 [95% CI = 1.11–1.59]).

Discussion

During 2015–2016, Oregon experienced a large shigellosis outbreak in which heavy precipitation was associated with shigellosis transmission among homeless persons but not housed persons. Several epidemiologic studies have analyzed associations between precipitation and shigellosis and bacillary dysentery. Most are population-level studies spanning multiple years from Asian countries (predominately China). Varying methods and findings are reported; some have shown positive associations[21–23,27,28] while others have not.[20,24] Chen et al. reported that native Taiwanese persons experienced higher rates of bacillary dysentery following extreme precipitation in Taiwan,[22] but other studies have not examined specific groups disproportionately at-risk for shigellosis following heavy precipitation.

Our findings are consistent with prior research demonstrating links between environmental exposures and health problems among homeless persons.[29] Homeless persons face increased risk of hyperthermia- and hypothermia-related mortality.[30–32] In one report, wind patterns might have contributed to a Q fever outbreak at a homeless shelter.[33] In 3 qualitative studies, homeless persons identified heavy precipitation as a hardship.[34–36]

This outbreak demonstrates how interaction between host, agent, and environment can result in disease transmission in a new population. While the multistate outbreak affected primarily MSM, cases in Oregon increased during the fall and winter when *Shigella* spread into the homeless population in Portland. Heavy precipitation could have promoted *Shigella* transmission among homeless persons through several mechanisms. Heavy precipitation can exacerbate existing poor sanitary conditions,[13] creating favorable conditions for person-to-person spread of a highly infectious organism among a population with whom access to hygiene and sanitation are already inadequate. Unusually heavy precipitation would also likely increase crowding in shelters and encampments, increasing opportunities for person-to-person spread of *Shigella*, an organism that spreads in crowded settings.[37,38] Lastly, heavy precipitation might lead to waterborne *Shigella* transmission through contamination of untreated drinking water sources to which homeless persons might be exposed.

Our analysis is subject to several limitations. Because the outbreak-specific questionnaire did not specifically assess housing status until it was updated, we might have misclassified some homeless persons with shigellosis onset earlier in the outbreak as not being homeless. However, because homeless persons were difficult to locate for interview, throughout the outbreak we primarily ascertained housing status by reviewing medical records. Because the outbreak spanned a single year, we could not account for seasonality of shigellosis in our model. However, peak shigellosis incidence in Oregon typically occurs July to September, when statewide precipitation is at its lowest; thus, not controlling the seasonality would be expected to bias our findings toward the null, if at all. Although a relatively small proportion of Portland's homeless population was identified with confirmed cases during the outbreak, infections were likely more widespread because underreporting of shigellosis is common[16] and homeless persons have difficulty accessing health services.[39]

This outbreak investigation provides several lessons that can be considered by other public health practitioners. Preventing person-to-person spread of enteric infections among homeless persons during outbreaks requires special attention to promote good personal hygiene and ensure adequate infection prevention and control practices. This is especially important if potentially aggravating factors like heavy precipitation might be contributing to spread of infections, as was the case during this outbreak. When heavy precipitation is forecast, city governments and homeless assistance programs can consider taking proactive measures to mitigate spread of enteric infections among homeless persons, for instance, by conducting outreach at homeless shelters, encampments, and safety-net clinics to provide information and distribute hand sanitizing supplies. Because homeless shelters and encampments might serve as a nidus for infections during an outbreak occurring among homeless persons, control measures targeting these sites could include bolstering infection prevention and control practices, active surveillance, and environmental health inspections.

Global climate change is predicted to lead to a substantial increase in the burden of infectious diseases.[40,41] Although the mechanisms underlying how climate extremes can increase infectious diseases are complex, groups with the least resources will suffer the most.[42] In high-income countries, homeless persons will be disproportionately affected by climate change.[29,40] Outbreaks similar to the one reported here, during which extreme weather was associated with disease transmission in a particularly susceptible group might become more commonplace in the future. The special needs of homeless populations should be included in climate change mitigation and adaptation strategies.

Acknowledgements

The authors would like to thank Julie Hatch (Oregon Health Authority), Amy Sullivan (Multnomah County Health Department), Anna Bowen and Jacqueline Hurd (CDC), and Jane Yang and Cora Hoover (San Francisco Department of Public Health).

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson MA, Roy SL, et al. Foodborne illness acquired in the United States–major pathogens. Emerg Infect Dis 2011;17:7–15. [PubMed: 21192848]
2. Kotloff KL, Winickoff JP, Ivanoff B, Clemens JD, Swerdlow DL, Sansonetti PJ, et al. Global burden of *Shigella* infections: implications for vaccine development and implementation of control strategies. Bull World Health Organ 1999;77:651–66. [PubMed: 10516787]
3. Adams D, Fullerton K, Jajosky R, Sharp P, Ohweh D, Schley A, et al. Summary of notifiable infectious diseases and conditions – United States, 2013. MMWR Morb Mortal Wkly Rep 2015;62: 1–122.
4. Bowen A, Hurd J, Hoover C, Khachadourian Y, Traphagen E, Harvey E, et al. Importation and domestic transmission of Shigella sonnei resistant to ciprofloxacin – United States, May 2014–February 2015. MMWR Morb Mortal Wkly Rep 2015;64:318–20. [PubMed: 25837241]
5. Murti M, Louie K, Bigham M, Hoang LM. Outbreak of shigellosis in a homeless shelter with healthcare worker transmission – British Columbia, April 2015. Infect Control Hosp Epidemiol 2015;36: 1372–3. [PubMed: 26330023]
6. Lamba K, Nelson JA, Kimura AC, Poe A, Collins J, Kao AS, et al. Shiga toxin 1-producing *Shigella sonnei* infections, California, United States, 2014–2015. Emerg Infect Dis 2016;22:679–86. [PubMed: 26982255]
7. Bowen A, Grass J, Bicknese A, Campbell D, Hurd J, Kirkcaldy RD. Elevated risk for antimicrobial drug–resistant *Shigella* infection among men who have sex with men, United States, 2011–2015. Emerg Infect Dis 2016;22:1613–6. [PubMed: 27533624]
8. Hines JZ, Pinsent T, Rees K, Vines J, Bowen A, Hurd J, et al. Notes from the field: shigellosis outbreak among men who have sex with men and homeless persons – Oregon, 2015–2016. MMWR Morb Mortal Wkly Rep 2016;65:812–3. [PubMed: 27513523]
9. Guzman Herrador BR, de Blasio BF, MacDonald E, Nichols G, Sudre B, Vold L, et al. Analytical studies assessing the association between extreme precipitation or temperature and drinking water-related waterborne infections: a review. Environ Health 2015;14:29. [PubMed: 25885050]
10. Cann KF, Thomas DR, Salmon RL, Wyn-Jones AP, Kay D. Extreme water-related weather events and waterborne disease. Epidemiol Infect 2013;141:671–86. [PubMed: 22877498]

11. Levy K, Woster AP, Goldstein RS, Carlton EJ. Untangling the impacts of climate change on waterborne diseases: a systematic review of relationships between diarrheal diseases and temperature, rainfall, flooding, and drought. Environ Sci Technol 2016;50:4905–22. [PubMed: 27058059]
12. Mellor JE, Levy K, Zimmerman J, Elliott M, Bartram J, Carlton E, et al. Planning for climate change: the need for mechanistic systems-based approaches to study climate change impacts on diarrheal diseases. Sci Total Environ 2016;548–549:82–90. [PubMed: 27371770]
13. Reiner RC Jr, King AA, Emch M, Yunus M, Faruque AS, Pascual M. Highly localized sensitivity to climate forcing drives endemic cholera in a megacity. Proc Natl Acad Sci USA 2012;109:2033–6. [PubMed: 22308325]
14. Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2016. Washington DC: U.S. Census Bureau; 1 18, 2017.
15. Smock K 2015 Point-in-time; count of homelessness in Portland/Gresham/Multnomah County, Oregon. 6 2015. Available from: https://multco.us/file/42320/download [Accessed 27 Jul 2017].
16. Joh RI, Hoekstra RM, Barzilay EJ, Bowen A, Mintz ED, Weiss H, et al. Dynamics of shigellosis epidemics: estimating individual-level transmission and reporting rates from national epidemiologic data sets. Am J Epidemiol 2013;178:1319–26. [PubMed: 24008913]
17. 2015 Oregon Revised Statutes. Vol 10 § 433.004. 2015. Available from: https://www.oregonlegislature.gov/bills_laws/ors/ors433.html [Accessed 27 Jul 2017].
18. PRISM Climate Group, Oregon State University. Available from: http://prism.oregonstate.edu/documents/PRISM_terms_of_use.pdf, created 9 8 2016.
19. Kintziger KW, Jagger MA, Conlon KC, Bush KF, Haggerty B, Harduar-Morano L, et al. BRACE methods community of practice. Technical documentation on exposure - response functions for climate-sensitive health outcomes. Atlanta: Centers for Disease Control and Prevention; 2017. p. 14–6 5.
20. Li Z, Wang L, Sun W. Identifying high-risk areas of bacillary dysentery and associated meteorological factors in Wuhan, China. Sci Rep 2013;3:3239. [PubMed: 24257434]
21. Kelly-Hope LA, Alonso WJ, Thiem VD, Anh DD, Canh DG, Lee H, et al. Geographical distribution and risk factors associated with enteric diseases in Vietnam. Am J Trop Med Hyg 2007;76:706–12. [PubMed: 17426175]
22. Chen MJ, Lin CY, Wu YT, Wu PC, Lung SC, Su HJ. Effects of extreme precipitation to the distribution of infectious diseases in Taiwan, 1994–2008. PLoS ONE 2012;7:e34651. [PubMed: 22737206]
23. Huang D, Guan P, Guo J, Wang P, Zhou B. Investigating the effects of climate variations on bacillary dysentery incidence in northeast China using ridge regression and hierarchical cluster analysis. BMC Infect Dis 2008;8:130. [PubMed: 18816415]
24. Zhang Y, Bi P, Hiller JE, Sun Y, Ryan P. Climate variations and bacillary dysentery in northern and southern cities of China. J Infect 2007;55:194–200. [PubMed: 17258812]
25. Trenberth KE, Jones PD, Ambenje P, Bojariu R, Easterling D, Klein Tank A, et al. Chapter 3.3.5 Consistency and Relationships between Temperature and Precipitation. In: Climate Change 2007: Working Group I: The Physical Science Basis, IPCC Fourth Assessment Report: Climate Change 2007. Geneva: International Panel on Climate Change; 2007.
26. Gao L, Zhang Y, Ding G, Liu Q, Zhou M, Li X, et al. Meteorological variables and bacillary dysentery cases in Changsha City, China. Am J Trop Med Hyg 2014;90:697–704. [PubMed: 24591435]
27. Njuguna C, Njeru I, Mgamb E, Langat D, Makokha A, Ongore D, et al. Enteric pathogens and factors associated with acute bloody diarrhoea, Kenya. BMC Infect Dis 2016;16:477. [PubMed: 27600526]
28. Xiao G, Xu C, Wang J, Yang D, Wang L. Spatial–temporal pattern and risk factor analysis of bacillary dysentery in the Beijing–Tianjin–Tangshan urban region of China. BMC Public Health 2014;14:998. [PubMed: 25257255]
29. Ramin B, Svoboda T. Health of the homeless and climate change. J Urban Health 2009;86:654–64. [PubMed: 19444615]

30. Yip FY, Flanders WD, Wolkin A, Engelthaler D, Humble W, Neri A, et al. The impact of excess heat events in Maricopa County, Arizona; 2000–2005. Int J Biometeorol 2008;52:765–72. [PubMed: 18607646]
31. Meiman J, Anderson H, Tomasallo C. Hypothermia-related deaths – Wisconsin, 2014, and United States, 2003–2013. MMWR Morb Mortal Wkly Rep 2015;64:141–3. [PubMed: 25695318]
32. Tanaka M, Tokudome S. Accidental hypothermia and death from cold in urban areas. Int J Biometeorol 1991;34:242–6. [PubMed: 2055665]
33. Brouqui P, Badiaga S, Raoult D. Q fever outbreak in homeless shelter. Emerg Infect Dis 2004;10:1297–9. [PubMed: 15324553]
34. Cusack L, van Loon A, Kralik D, Arbon P, Gilbert S. Extreme weather-related health needs of people who are homeless. Aust J Prim Health 2013;19:250–5. [PubMed: 22950903]
35. Pendrey CG, Carey M, Stanley J. Impacts of extreme weather on the health and well-being of people who are homeless. Aust J Prim Health 2014;20:2–3. [PubMed: 24290233]
36. Wandel J, Riemer M, de Gómez W, Klein K, de Schutter J, Randall L, et al. Homelessness and global climate change: are we ready? A report from the study on the vulnerability to global climate change of people experiencing homelessness in Waterloo Region. Waterloo, ON; 2010.
37. Mosley WH, Adams B, Lyman ED. Epidemiologic and sociologic features of a large urban outbreak of shigellosis. JAMA 1962; 182:1307–11. [PubMed: 13936184]
38. el Bushra HE, Bin Saeed AA. Intrafamilial person-to-person spread of bacillary dysentery due to *Shigella dysenteriae* in southwestern Saudi Arabia. East Afr Med J 1999;76:255–9. [PubMed: 10750504]
39. Fazel S, Geddes JR, Kushel M. The health of homeless people in high-income countries: descriptive epidemiology, health consequences, and clinical and policy recommendations. Lancet 2014;384:1529–40. [PubMed: 25390578]
40. Trtanj J, Jantarasami L, Brunkard J, Collier T, Jacobs J, Lipp E, et al. Ch. 6: climate impacts on water-related illness. In: Crimmins A, et al., editors. The impacts of climate change on human health in the United States: a scientific assessment. Washington: U.S. Global Change Research Program; 2016. p. 157–88.
41. Shuman EK. Global climate change and infectious diseases. N Engl J Med 2010;362:1061–3. [PubMed: 20335580]
42. Hales S, Edwards SJ, Kovats RS. Impacts on health of climate extremes. In: McMichael AJ, Campbell-Lendrum DH, Corvalan CF, Ebi KL, Githeko AK, Scheraga JD, et al., editors. Climate change & human health: risks and responses. Geneva: World Health Organization; 2003. p. 79–102.

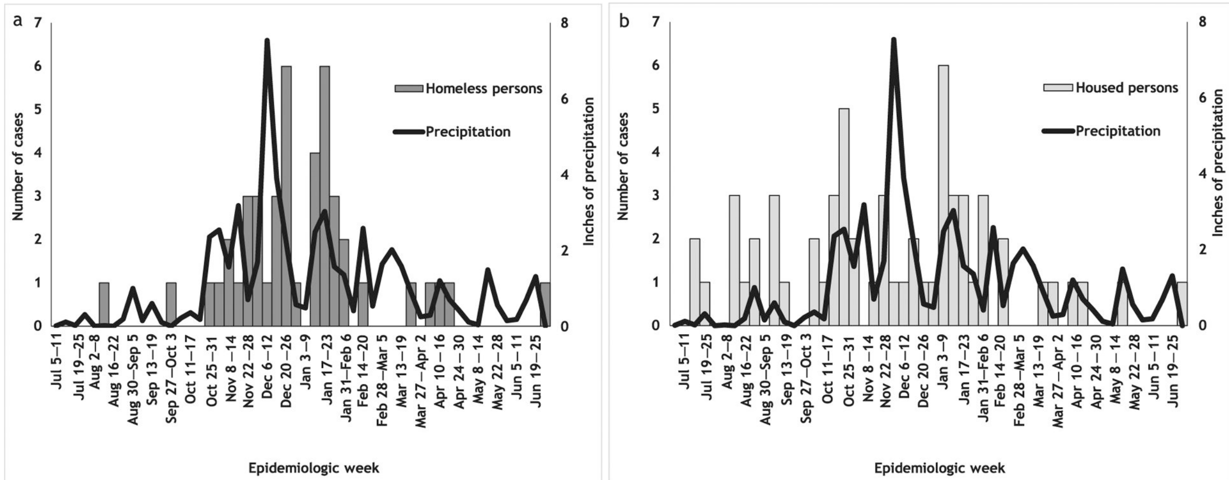

Fig. 1.

a. Cases of *Shigella sonnei* infections among homeless persons with overlay of precipitation during an outbreak – Oregon, July 2015–June 2016. b. Cases of *Shigella sonnei* infections among housed persons with overlay of precipitation during an outbreak – Oregon, July 2015–June 2016. Precipitation and *Shigella* cases are shown during the week in which they occurred. In the time series analysis, the daily shigellosis case count was regressed on the 1-week lagged cumulative weekly precipitation to account for the time for precipitation-related behavioral and environmental changes that might increase risk of contact with *Shigella*-contaminated matter that may occur and the effect of multiple days of accumulated precipitation.

Table 1

Selected characteristics of persons during a *S. sonnei* outbreak – Oregon, July 2015–June 2016.

	All persons (N =105)	Homeless persons (n = 45)	Housed persons (n = 60)
Men, N (%)	79 (75)	30 (67)	49 (82)
MSM, N (% of men)	41 (52)	3 (10)	38 (78)
Median age, years (IQR)	42.0 (32.0–55.0)	36.0 (32.0–53.0)	44.0 (31.5–57.0)
Hospitalized, N (%)	48 (46)	31 (69)	17 (28)
Deaths, N (%)	0 (0)	0 (0)	0 (0)

MSM = men who have sex with men; IQR = interquartile range.

Table 2

Sensitivity analyses of the association of heavy precipitation and shigellosis during a *Shigella sonnei* outbreak – Oregon, July 2015–June 2016.

Type of analysis	All cases RR [95% CI]	Homeless persons RR [95% CI]	Housed persons RR [95% CI]
Primary analysis[a]	1.18 [1.06–1.33]	1.36 [1.17–1.59]	1.04 [0.86–1.25]
Exposure window from days −7 to −1	1.13 [0.99–1.28]	1.24 [1.04–1.50]	1.08 [0.90–1.29]
Exposure window from days −3 to −1	1.19 [0.93–1.51]	1.48 [1.05–2.10]	1.06 [0.74–1.50]
Exposure window from days −10 to −4	1.16 [1.02–1.31]	1.29 [1.08–1.54]	1.07 [0.89–1.28]
Exposure window from days −10 to −8	1.28 [1.02–1.61]	1.58 [1.15–2.16]	1.04 [0.73–1.49]
Limited to the rainy season[b]	1.19 [1.03–1.37]	1.35 [1.10–1.66]	0.99 [0.78–1.26]
Maximum (instead of minimum) temperature	1.14 [1.01–1.29]	1.27 [1.09–1.48]	0.98 [0.80–1.21]
Limited to Multnomah County cases	1.27 [1.13–1.43]	1.35 [1.16–1.57]	1.15 [0.95–1.40]
Including a holidays indicator variable	1.14 [1.01–1.29]	1.27 [1.09–1.49]	1.00 [0.82–1.23]
Using NOAA data instead of PRISM data	1.14 [1.03–1.27]	1.27 [1.11–1.47]	1.02 [0.87–1.21]

[a] The primary analysis used an exposure period from days −14 to −8, including cases during the entire outbreak (July 2015–June 2016) and from all Oregon locations, controlled for minimum temperature (average from days −14 to −8) by using PRISM data, and did not include a holidays indicator variable. To account for autocorrelation, all analyses controlled for daily counts at lags in which counts were correlated with counts on a given day (lag 0); these included lags 1 and 7 (days −1 and −7) for the analyses with all persons and homeless persons and lag 7 (day −7) for the analysis with housed persons.

[b] Rainy season in Oregon is November–March.

RR, risk ratio; CI, confidence interval; NOAA, National Oceanic and Atmospheric Administration; PRISM, PRISM Climate Group, Oregon State University.