HHS Public Access

Author manuscript

Clin Infect Dis. Author manuscript; available in PMC 2020 October 15.

Published in final edited form as:

Clin Infect Dis. 2019 October 15; 69(9): 1545–1552. doi:10.1093/cid/ciy1142.

Characteristics of *Campylobacter, Salmonella* Infections and Acute Gastroenteritis in Older Adults in Australia, Canada, and the United States

Alice E. White[1], **Nadia Ciampa**[2], **Yingxi Chen**[3], **Martyn Kirk**[3], **Andrea Nesbitt**[2], **Beau B. Bruce**[4], **Elaine Scallan Walter**[1]

[1]Department of Epidemiology, Colorado School of Public Health, Aurora, CO, United States

[2]Public Health Agency of Canada, Centre for Foodborne, Environmental, and Zoonotic Infectious Disease, Guelph, Ontario, Canada

[3]Australian National University, Canberra, Australian Capital Territory, Australia

[4]Enteric Diseases Epidemiology Branch, Centers for Disease Control and Prevention, Atlanta, Georgia, United States

Abstract

Background—The early detection of enteric infections in older adults is challenging because typical signs and symptoms of disease may be less common, absent, or overlooked. Understanding illness characteristics of enteric infections among older adults could improve the timeliness and accuracy of clinical diagnoses, thereby improving patient outcomes and increasing cases reported to surveillance.

Methods—This study describes illness characteristics (percentage reporting bloody diarrhea, fever, vomiting, abdominal pain, percentage hospitalized, duration of hospitalization, and duration of illness) among older adults (≥65 years) with acute gastroenteritis and culture-confirmed *Campylobacter* and nontyphoidal *Salmonella* infections in Australia, Canada, and the United States, and compares these characteristics with those among younger adults (25–64 years) and children (<5 years, 5–24 years).

Results—A significant negative correlation was found between all symptoms and increasing age group, except for bloody diarrhea in cases of acute gastroenteritis. Adults ≥85 years old reported bloody diarrhea in only 9% of nontyphoidal *Salmonella* and 4% of *Campylobacter* infections, compared with 59% and 55% among children aged <5 years. Conversely, a greater percentage of older adults (≥65) than younger persons (<5, 5–24, 25–64) reported being hospitalized, with an increasing linear relationship in age groups 65 years and older.

Conclusions—Although older adults are more likely to have severe illness and be hospitalized, this study found that the proportion of persons reporting symptoms typically associated with

Correspondence to Alice E. White, 12477 East 19th Avenue, Mail Stop B119, Aurora, Colorado 80045, United States, Alice.White@ucdenver.edu, Ph. (303) 724-9319 Fx. (303) 724-4489.

Conflicts of Interest

The authors declare no conflict of interests.

enteric infections decreases with age. These findings have implications for clinical recognition and treatment of gastrointestinal illness, as well as for public health research.

Summary

Although older adults are more likely to have severe illness and be hospitalized, this study found that the proportion of persons reporting symptoms typically associated with enteric infections decreases with age.

Keywords

Aged; Campylobacter/pathogenicity; Salmonella/pathogenicity; Gastrointestinal illness/epidemiology; Hospitalization

Introduction

Older adults (aged ≥65 years) are more susceptible than younger adults to certain enteric infections such as invasive *Campylobacter* and *Salmonella* [1,2]. Illness among older adults is also more likely to be severe, leading to hospitalization, long-term complications, or death [3–7]. Several age-related factors may contribute to older adults' increased susceptibility and disease severity, including weakening of the immune system, changes to the gastrointestinal tract, higher prevalence of comorbid conditions, and more frequent use of antacids and immunosuppressants [1,8]. The rates of gastrointestinal hospitalizations and deaths are highest among older adults [3,5,9,10]. In the United States, the overall burden of nontyphoidal *Salmonella* in adults aged ≥65 years was estimated at 110,100 illnesses annually, resulting in 5,100 hospitalizations, and 220 deaths (296, 13 and 0.59 per 100,000, respectively). *Campylobacter* caused an estimated 110,200 illnesses annually, resulting in 3,200 hospitalizations, and 60 deaths (296, 9 and 0.16 per 100,000, respectively) [5]. In Canada, nontyphoidal *Salmonella* causes an estimated 534 hospitalizations and 27 deaths annually (11 and 0.29 per 100,000, respectively) among adults aged ≥60 years [9].

The rapid diagnosis of enteric infections in older adults can improve outcomes by providing timely and appropriate treatment. However, the early detection of enteric infections in older adults is challenging because typical signs and symptoms of disease may be less common or absent in this age group [11,12]. For example, episodes of vomiting and abdominal pain have been reported less frequently among older adults with viral gastrointestinal illness compared with younger adults [13]. Fever is also less common in older adults with a gastrointestinal infection [14]. Moreover, pre-existing conditions and comorbidities can make the diagnosis of an enteric infection more challenging. For example, it may be difficult to determine whether diarrhea, nausea, or vomiting is caused by an enteric infection or a non-infectious cause [15].

Understanding the clinical signs and symptoms among older adults with enteric infections could improve the timeliness and accuracy of clinical diagnoses, thereby improving patient outcomes and increasing the number of cases diagnosed and reported to surveillance. The aim of this study was to describe clinical characteristics by age among cases with culture-confirmed *Campylobacter* and nontyphoidal *Salmonella* infections and acute gastroenteritis

using data from surveillance and epidemiological studies conducted in Australia, Canada, and the United States.

Methods

Data Sources

In Australia, data were obtained from OzFoodNet, a national network established in 2000 to conduct enhanced foodborne disease surveillance for enteric pathogens transmitted commonly through food [16]. Data on culture-confirmed *Campylobacter* and *Salmonella* serotype Birkenhead infections were available from two 12-month case-control studies conducted during 2001 and 2002. The *Campylobacter* case-control study was conducted in 4 states and territories (i.e., New South Wales, Queensland, South Australia, and Tasmania) [17]. The *Salmonella* Birkenhead case-control study was conducted in Queensland and the Northern Rivers Area Health Service of New South Wales [18]. Data on acute gastroenteritis were obtained from two 12-month National OzFoodNet Gastroenteritis Surveys. These cross-sectional telephone surveys were conducted during 2001–2002 and 2008–2009 using a random sample of the Australian population [19,20]. OzFoodNet case-control studies excluded residents in long-term care facilities (LTCF), outbreak- and travel-associated cases.

In Canada, data on culture-confirmed *Campylobacter* and nontyphoidal *Salmonella* infections were available from the Public Health Agency of Canada's (PHAC) FoodNet Canada surveillance system from 2006–2013. Established in 2005, FoodNet Canada (formerly C-EnterNet) is a national, integrated, enteric pathogen surveillance system that conducts enhanced foodborne disease surveillance for 10 notifiable enteric pathogens, as well as active surveillance of enteric pathogens in retail food, farm animals and local water, in sentinel sites across the country (Ontario pilot site [Region of Waterloo] during 2005–2014, British Columbia [Fraser Health Authority] since 2010, Alberta [Alberta Health Services: Calgary and Central Zones] and Ontario [Middlesex-London Health Unit] since 2014) (FoodNet Canada., 2015). FoodNet Canada surveillance included residents in LTCF, sporadic, outbreak- and travel-associated cases. Data on acute gastroenteritis were obtained from PHAC's National Studies on Acute Gastrointestinal Illness (NSAGI) population surveys; 12-month, cross-sectional, population-based telephone surveys randomly selected respondents from households in three locations within Canada: Hamilton, Ontario (2001–2002); British Columbia (2002–2003); and Ontario (2005–2006) [22–25].

In the United States, data were available from the Centers for Disease Control and Prevention's (CDC) Foodborne Diseases Active Surveillance Network (FoodNet). FoodNet conducts active, population-based surveillance for culture-confirmed cases of 9 enteric pathogens transmitted commonly through food. The surveillance area in 2016 included approximately 48 million persons (15% of the US population) from 10 states (entire states or selected counties). Data on *Campylobacter* and nontyphoidal *Salmonella* infections were obtained from multiple 12-month FoodNet case-control studies: *Salmonella* serogroups B and D (1996–1997), *Campylobacter* (1998–1999), and *Salmonella* serotypes Enteritidis, Newport, Javiana, Infantis, and I 4,[5],12:i:- (2002–2003) [26–29]. US FoodNet case-control studies excluded residents in LTCF, and outbreak- and travel-associated cases. Data on acute gastroenteritis were available from five 12-month population-based telephone surveys

conducted among the general FoodNet population during 1996–1997, 1998–1999, 2000–2001, 2002–2003, and 2006–2007 [30–33].

Data analysis

For all culture-confirmed cases of *Campylobacter* and nontyphoidal *Salmonella* and respondents reporting acute gastroenteritis, the percentage reporting bloody diarrhea, fever (subjective), vomiting, and abdominal pain or cramps was calculated. The percentage hospitalized, above the median duration of illness, and above the median duration of hospitalization were calculated (medians were calculated using US data only, and percentage above the US median was calculated for all sites). A sub-analysis was performed to compare illness characteristics by age in hospitalized respondents in US studies. The percentage of missing data on symptoms and hospitalization was compared across studies and age groups. Additional characteristics, including dehydration, chronic gastrointestinal illness, antibiotic use, and proton pump inhibitor (PPI) use were available from select studies (Supplementary Information Table 1). Canadian and Australian data defined hospitalizations as hospital admission as a result of illness; the US defined hospitalization as an overnight stay within 7 days of specimen collection. In the US and Australia, duration of illness was defined as the number of self-reported days of diarrhea. In Canadian data, duration of illness was defined as the number of self-reported days experiencing any symptoms related to the illness. For the purpose of this analysis, acute gastroenteritis was defined as ≥3 loose stools or bowel movements in 24-hours.

We compared illness characteristics (i.e., percentage reporting bloody diarrhea, fever, vomiting, and abdominal pain or cramps, percentage hospitalized, duration of hospitalization, and duration of illness) among culture-confirmed cases of *Campylobacter* and nontyphoidal *Salmonella* infections, and respondents reporting acute gastroenteritis by age group (<5 years, 5–24 years, 25–64 years, and ≥65 years). Age-specific trends were compared between Australia, Canada, and the United States. An analysis of deviance test was used to compare a generalized linear mixed model (GLMM) fit with a random intercept and slope for each study to a GLMM fit with only a random intercept. If the model with random intercept and slope did not significantly differ ($p>0.05$) from the model with only a random intercept, it was concluded that there was no evidence that the slopes from different studies differed, and symptom data were pooled across studies. Pooled results were examined for graphical trends in symptoms across age groups. GLMM was used to test statistical significance of symptoms across age groups, assuming study as a random effect. Aggregate results from each country by pathogen and serotype were summarized in Microsoft Excel, and analyses were performed in SAS version 9.4 and R version 3.4.0.

Results

Data were available for 3,702 cases with a culture-confirmed *Campylobacter* infection (545 in Australia, 1,846 in Canada, and 1,311 in the United States); 2,736 with a culture-confirmed nontyphoidal *Salmonella* infections (111 in Australia, 1,337 in Canada, and 1,288 in the United States); and 6,876 people reporting an episode of acute gastroenteritis (792 in Australia, 548 in Canada, and 5,536 in the United States) (Table 1).

Across the three countries, the percentage reporting each symptom was similar by age group for *Salmonella*, *Campylobacter*, and acute gastroenteritis (Figures 1–3, Supplementary Information). In each country, there was a negative linear correlation between the percentage of symptoms reported and increasing age group. Conversely, a positive linear correlation was consistently observed between the percentage of cases hospitalized and increasingly older age groups (Figures 1–3, Supplementary Information). There was no significant difference between the slopes for each pathogen, so study data from the three countries were pooled.

The percentage reporting each symptom was similar among those with culture-confirmed *Campylobacter* and *Salmonella* infection. Most *Campylobacter* and *Salmonella* cases reported abdominal cramps (85% and 84%, respectively) and fever (74% and 76%). The percentage reporting bloody diarrhea was similar for *Campylobacter* (39%) and *Salmonella* (40%); vomiting was reported in 31% and 42% of cases, respectively. The median duration of illness was six days for *Campylobacter* and seven days for *Salmonella* (US cases only). Only 10% of *Campylobacter* cases were hospitalized for their illness (all sites), for a median of three days (US only) (Figure 1), compared with 20% of *Salmonella* cases for a median of seven days (Figure 2). The percentage of acute gastroenteritis respondents reporting symptoms was lower for all symptoms compared with culture-confirmed cases, ranging from 3% for bloody diarrhea to 60% for abdominal cramps (Table 2). The median duration of illness was two days (US only) and 2% were hospitalized (all sites) for a median of three days (Canada only) (Figure 3).

There was a significant negative correlation between symptoms and increasing age, except for bloody diarrhea in acute gastroenteritis (Table 2). For *Salmonella* and *Campylobacter* infections, there was a negative linear correlation between bloody diarrhea and age group; ranging from 59% and 55% for *Campylobacter* and *Salmonella* cases, respectively, in those aged <5 years, to 9% and 4%, respectively, in those aged ≥85 years. For both pathogens, the percentage reporting abdominal pain or cramps, fever, and vomiting was higher in persons aged 5–24 years than <5 years. The percentage reporting vomiting was similar across age categories (Table 2, Figures 1 and 2). For acute gastroenteritis, abdominal cramps were reported more frequently in persons aged 5–24 years compared to all other age groups. Fever and vomiting declined linearly with age, though less so in acute gastroenteritis. For all symptoms, reporting percentages plateaued among persons ≥65 years with acute gastroenteritis (Table 2, Figure 3). Among hospitalized US *Salmonella* and *Campylobacter* cases, there was a similar negative correlation between age group and bloody diarrhea, abdominal cramps, fever, and vomiting (Table 2).

There was a positive correlation between hospitalization and increasing age group, ranging from 7% among those aged <5 years to 48% among those aged ≥85 years for *Campylobacter* and 17% to 49% for *Salmonella*, respectively (Table 2, Figures 1 and 2). A similar trend was observed among those reporting acute gastroenteritis, ranging from 1% in those aged 5–24 years to 17% in cases aged ≥85 years (Table 2, Figure 3). Duration of hospitalization increased with age for *Campylobacter* and *Salmonella*, whereas duration of illness was more similar across age groups. Additional symptoms, including chills, headache, muscle pain, and nausea, were consistent across age groups. Dehydration increased with age in

Campylobacter cases. Chronic gastrointestinal illness diagnosis or symptoms increased with age in *Campylobacter* and acute gastroenteritis. Antibiotic use was consistent across age groups, and PPI use increased with age for *Campylobacter* and *Salmonella* cases (Supplementary Information Table 1). Percentage missing for symptoms and hospitalization was consistent across age groups (Supplementary Information Table 2).

Discussion

This study describes symptoms by age among persons with culture-confirmed *Campylobacter* and nontyphoidal *Salmonella* infections and acute gastroenteritis using data from surveillance and epidemiological studies conducted in Australia, Canada, and the United States. Whereas other studies have described the burden and severity of acute gastroenteritis by age [5,34], differences in reported symptoms by age group have not systematically been described. Although older adults are more likely to have severe illness and be hospitalized, this study found that the percentage reporting symptoms typically associated with enteric infections decreases with age. This has important implications for clinical diagnosis, treatment, and public health research.

Among persons with culture-confirmed *Campylobacter* and nontyphoidal *Salmonella* and acute gastroenteritis, older age groups were less likely than other adults and children to report classical gastrointestinal symptoms, including bloody diarrhea, abdominal pain or cramps, vomiting, and fever. Bloody diarrhea, which is often used as a marker for more severe illness in studies that estimate the number and human health impact of foodborne and enteric diseases [35–37], had the largest range between the youngest and oldest age groups (~50% for *Campylobacter* and *Salmonella* cases). Fever, a key diagnostic criteria and predictor of treatment and severity, was also significantly lower in older adults. Previous studies have reported that older adults with gastrointestinal illness are less likely than other adults to report symptoms such as abdominal cramps, fever, and myalgia [15,38]. Moreover, objectively measured fever may be absent or blunted in older adults with infections [39].

Despite fewer reported symptoms, our results show that hospitalization rates increased with age. This finding is consistent with other studies that have found an increase in invasive infection, hospitalization, length of hospitalization, and mortality with age [3–5]. Among those hospitalized, the percentage reporting symptoms remained lower among older adults compared with younger adults and children. This suggests that more older adults present with severe illness requiring hospitalization in the absence of fever or bloody diarrhea or other symptoms typically associated with severe illness. Alternatively, clinicians may be more likely to hospitalize older adults for other reasons, such as dehydration. Previous studies have found an association between PPI use and an increased risk of hospitalization with gastrointestinal infections [40]. We found that PPI use increased with age.

Among those hospitalized, length of hospitalization was of longer duration among older people compared with their younger counterparts although a longer overall duration of illness was not observed in older adults. Older adults are more likely to experience complications from gastrointestinal illness, including septicemia, meningitis, acute renal failure, hemolytic uremic syndrome, arrhythmias, and Guillain-Barré syndrome [41], which

may account for the longer duration of hospital stays. Some previous studies have found other pathogens, such as norovirus, have a longer illness duration in older adults [42,43].

This study found that older adults were more likely than younger adults and children to report dehydration associated with *Campylobacter*, but our evidence was limited because dehydration was only collected in Canada. However, other studies have also reported older adults may be at increased risk for dehydration and its complications, including electrolyte imbalance, delirium, falls resulting in bone fractures, hypertension, and prolonged infection. So, although infectious diarrhea may be more difficult to diagnose in older adults, close observation and fluid therapy for diarrhea are merited [15].

Without typical signs and symptoms, gastrointestinal infections may be underdiagnosed or misdiagnosed. The symptoms of infectious diarrhea are similar to other ailments common in older adults, including fecal incontinence, fecal impaction with overflow, laxative use, irritable bowel syndrome, or drug-induced diarrhea [41], and infections can present with different symptoms in older adults, such as falls, delirium, anorexia, or generalized weakness [12], which can be exacerbated by cognitive impairment [44]. In a review of *Escherichia coli* O157:H7 outbreaks in LTCF, one study concluded that with bloody diarrhea as the sole complaint, and in the absence of fever and pain, cases were initially misdiagnosed as hemorrhoids or diverticulosis [45]. Categorizing severe illness is an important and challenging aspect of estimating the overall burden of gastroenteritis. Previous estimates used bloody diarrhea as an indicator of severe illness [32,36,37] and assumed the percentage of severe illness was similar to the general population [5]. Given the results found in this study, it is likely that bloody diarrhea alone is not a good measure of severity when estimating the burden of gastrointestinal illness in older adults.

This study is subject to several limitations. First, the data were from three countries spanning different time periods, and studies used different methodologies. All three countries used the same case definition to extract data. However, Canadian surveillance included LTCF residents, sporadic, outbreak- and travel-associated cases, which were included in the analysis to increase case numbers. By design, US and Australian case-control studies excluded these groups. Despite these differences, this study found high concordance for symptoms regardless of country, time, and the serotype causing infection. Second, hospitalization and duration of hospitalization were used as indicators of severity, however clinicians may be more likely to hospitalize older adults, even if the symptoms and signs of illness are of the same severity as someone younger. In addition, after an older person is admitted to the hospital, there may be a higher likelihood of diagnosing and testing for gastroenteritis. There may have been similar biases with young children, as there are different treatment and management recommendations and practices. Third, this study was unable to distinguish between older adults in LTCF, who were excluded from most studies, and those living in the community, and there are important differences between these populations. Fourth, symptom information was based on self-report. Fifth, although missingness of symptom and hospitalization was consistent by age group, it may have been more challenging to enroll older adults with more severe illness, or there could have been age-specific differences in interviews. Finally, this study is subject to the inherent limitations of epidemiological case-control studies, cross-sectional surveys, and surveillance systems.

Moreover, while the case-control studies and surveillance included only culture-confirmed cases, cross-sectional surveys include self-reported illnesses, which may or may not have been diagnosed.

Conclusion

This study demonstrated older adults consistently report fewer symptoms across multiple studies from three countries, despite evidence from previous studies showing older adults are more susceptible to enteric infections and more likely to be hospitalized and experience severe outcomes. As the population ages, it is important to understand the clinical presentation of gastrointestinal illness in older adults to prioritize early recognition and rapid treatment to prevent hospitalizations and poor outcomes. This study highlights the importance and challenges of early clinical detection of gastrointestinal illness in older adults and the need for research on age-specific risk factors, symptoms, and severity indicators associated with gastrointestinal illness.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

We thank the individuals at each of the participating sites for the data used in this study, including OzFoodNet in Australia, FoodNet Canada and the National Studies on Acute Gastrointestinal Illness team in Canada, and FoodNet in the United States.

Funding

This article was 100% funded with federal funds from a federal program of $136,542. This article was supported by Cooperative Agreement # 5NU60OE000103 funded by the Centers for Disease Control and Prevention. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of CDC or the Department of Health and Human Services.

References

1. Crim SM, Iwamoto M, Huang JY, Griffin PM, Gilliss D, Cronquist AB, Cartter M, Tobin-D'Angelo M, Blythe D, Smith K, Lathrop S, Zansky S, Cieslak PR, Dunn J, Holt KG, Lance S, Tauxe R, Henao OL. Incidence and trends of infection with pathogens transmitted commonly through food--Foodborne Diseases Active Surveillance Network, 10 U.S. sites, 2006-2013. MMWR Morb Mortal Wkly Rep, 2014; 63:328–32. [PubMed: 24739341]
2. Lund BM, O'Brien SJ. The occurrence and prevention of foodborne disease in vulnerable people. Foodborne Pathog Dis, 2011; 8:961–73. [PubMed: 21561383]
3. Chen Y, Liu BC, Glass K, Kirk MD. High incidence of hospitalisation due to infectious gastroenteritis in older people associated with poor self-rated health. BMJ Open, 2015; 5:e010161.
4. Behravesh CB, Jones TF, Vugia DJ, Long C, Marcus R, Smith K, Thomas S, Zansky S, Fullerton KE, Henao OL, Scallan E. Deaths associated with bacterial pathogens transmitted commonly through food: Foodborne Diseases Active Surveillance Network (FoodNet), 1996–2005. J Infect Dis, 2011; 204:263–267. [PubMed: 21673037]
5. Scallan E, Crim SM, Runkle A, Runkle A, Henao OL, Mahon BE, Hoekstra RM, Griffin PM. Bacterial Enteric Infections Among Older Adults in the United States: Foodborne Diseases Active Surveillance Network, 1996-2012. Foodborne Pathog Dis, 2015; 12:492–499. [PubMed: 26067228]

6. Friesema IH, Lugnér AK, Van Duynhoven YT. Costs of gastroenteritis in the Netherlands, with special attention for severe cases. Eur J Clin Microbiol Infect Dis, 2012; 31:1895–1900. [PubMed: 22228374]
7. Kendall PA, Hillers VV, Medeiros LC. Food safety guidance for older adults. Clin Infect Dis, 2006; 42:1298–1304. [PubMed: 16586390]
8. Smith J Foodborne Illness in the Elderly. J Food Prot, 1998; 9:1093–1259.
9. Turgeon P, Murray R, Nesbitt A. Hospitalizations associated with salmonellosis among seniors in Canada, 2000–1010. Epidemiol Infect, 2017; 145:1527–1534. [PubMed: 28228183]
10. Kirk MD, Gregory J, Lalor K, Hall GV, Becker N. Foodborne and waterborne infections in elderly community and long-term care facility residents,Victoria, Australia. Emerg Infect Dis, 2012; 18:377–84. [PubMed: 22377177]
11. Kirk MD, Veitch MG, Hall GV. Gastroenteritis and food-borne disease in elderly people living in long-term care. Clin Infect Dis, 2010; 50:397–404. [PubMed: 20047497]
12. Gavazzi G, Krause KH. Ageing and infection. Lancet Infect Dis, 2002; 2:659–666. [PubMed: 12409046]
13. Sala MR, Broner S, Moreno A, Arias C, Godoy P, Minguell S, Martinez A, Torner N, Bartolome R, de Simon M, Guix S, Dominguez A. Cases of acute gastroenteritis due to calicivirus in outbreaks: Clinical differences by age and aetiological agent. Clin Microbiol Infect, 2013; 20:793–8.
14. High KP, Bradley SF, Gravenstein S, Mehr DR, Quagliarello VJ, Richards C, Yoshikawa TT. Clinical practice guideline for the evaluation of fever and infection in older adult residents of long-term care facilities: 2008 Update by the infectious diseases society of America. J Am Geriatr Soc, 2009; 57:375–394. [PubMed: 19278394]
15. Trinh C, Prabhakar K. Diarrheal Diseases in the Elderly. Clin Geriatr Med, 2007; 23:833–856. [PubMed: 17923341]
16. OzFoodNet. Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: Annual Report of the OzFoodNet Network, 2011. Commun Dis Intell, 2015; 39:E236–64.
17. Stafford RJ, Schluter P, Kirk M, Wilson A, Unicomb L, Ashbolt R, Gregory J. A multi-centre prospective case-control study of *Campylobacter* infection in persons aged 5 years and older in Australia. Epidemiol Infect, 2007; 135:978–988. [PubMed: 17134530]
18. Beard F, Stafford R, Terry J, Morgan G, Ayyar A, Birrell F. Risk factors for sporadic *Salmonella* Birkenhead infection in Queensland and Northern New South Wales: a case control study. NSW Public Heal Bull, 2002; 15:172–7.
19. Kirk MD, McKay I, Hall GV, Dalton CB, Stafford R, Unicomb L, Gregory J. Foodborne disease in Australia: the OzFoodNet experience. Clin Infect Dis, 2008; 47:392–400. [PubMed: 18558879]
20. Hall GV, Kirk MD, Ashbolt R, Stafford R, Lalor K, OzFoodNet Working Group. Frequency of infectious gastrointestinal illness in Australia, 2002: Regional, seasonal and demographic variation. Epidemiol Infect, 2006; 134:111–118. [PubMed: 16409657]
21. FoodNet Canada Bienial Report 2011–12: Government of Canada. Canadian National Enteric Pathogen Surveillance System (FoodNet Canada) 2015 Guelph, ON: Public Health Agency of Canada.
22. Febriani Y, Levallois P, Gingras S, Gosselin P, Majowicz SE, Fleury MD. The association between farming activities, precipitation, and the risk of acute gastrointestinal illness in rural municipalities of Quebec, Canada: a cross-sectional study. BMC Public Health, 2010; 10:48. [PubMed: 20113516]
23. Majowicz SE, Doré K, Flint JA, Edge VL, Read S, Buffett MC, McEwen S, McNab WB, Stacey D, Sockett P, Wilson JB. Magnitude and distribution of acute, self-reported gastrointestinal illness in a Canadian community. Epidemiol Infect, 2004; 132:607–17. [PubMed: 15310162]
24. Sargeant JM, Majowicz SE, Snelgrove J. The burden of acute gastrointestinal illness in Ontario, Canada, 2005–2006. Epidemiol Infect, 2008; 136:451–60. [PubMed: 17565767]
25. Thomas MK, Majowicz SE, MacDougall L, Sockett PN, Kovacs SJ, Fyfe M, Edge VL, Dore K, Flint JA, Henson S, Jones AQ. Population distribution and burden of acute gastrointestinal illness in British Columbia, Canada. BMC Public Health, 2006; 6:307. [PubMed: 17178001]

26. Friedman CR, Hoekstra RM, Samuel M, Marcus R, Bender J, Shiferaw B, Reddy S, Ahuja SD, Helfrick DL, Hardnett F, Carter M, Anderson B, Tauxe RV. Risk factors for sporadic *Campylobacter* infection in the United States: A case-control study in FoodNet sites. Clin Infect Dis, 2004; 38 Suppl 3:S285–S296. [PubMed: 15095201]
27. Kimura AC, Reddy V, Marcus R, Cieslak PR, Mohle-Boetani JC, Kassenborg HD, Segler SD, Hardnett FP, Barrett T, Swerdlow DL. Chicken Consumption Is a Newly Identified Risk Factor for Sporadic *Salmonella* enterica Serotype Enteritidis Infections in the United States: A Case-Control Study in FoodNet Sites. Clin Infect Dis, 2004; 38:S244–52. [PubMed: 15095196]
28. Varma JK, Marcus R, Stenzel SA, Hanna SS, Gettner S, Anderson BJ, Hayes T, Shiferaw B, Crume TL, Joyce K, Fullerton KE, Voetsch AC, Angulo FJ. Highly Resistant *Salmonella* Newport-MDRAmpC Transmitted through the Domestic US Food Supply: A FoodNet Case-Control Study of Sporadic Salmonella Newport Infections , 2002–2003. J Infect Dis, 2006; 194:222–30. [PubMed: 16779729]
29. Marcus R, Varma J, Medus C, Boothe EJ, Anderson BJ, Crume T, Fullerton KE, Moore MR, White PL, Lyszkowicz E, Voetsch AC, Angulo FJ. Re-assessment of risk factors for sporadic *Salmonella* serotype Enteritidis infections: a case-control study in five FoodNet Sites, 2002–2003. Epidemiol Infect, 2007; 135:84–92. [PubMed: 16756692]
30. CDC. Foodborne Diseases Active Surveillance Network (FoodNet): FoodNet Surveillance Report for 2014 (Final Report). Atlanta, Georgia: U.S. Department of Health and Human Services, CDC 2014.
31. Jones TF, McMillian MB, Scallan E, Frenzen PD, Cronquist AB, Thomas S, Angulo FJ. A population-based estimate of the substantial burden of diarrhoeal disease in the United States; FoodNet, 1996–2003. Epidemiol Infect, 2007; 135:293–301. [PubMed: 17291364]
32. Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson MA, Roy SL, Jones FL, Griffin PM. Foodborne illness acquired in the United States-Major pathogens. Emerg Infect Dis, 2011; 17:7–15. [PubMed: 21192848]
33. Shiferaw B, Verrill L, Booth H, Zansky SM, Norton DM, Crim S, Henao OL. Sex-based differences in food consumption: Foodborne diseases active surveillance network (FoodNet) population survey, 2006-2007. Clin Infect Dis, 2012; 54:2006–2007.
34. Scallan E, Mahon BE, Hoekstra RM, Griffin PM. Estimates of Illnesses, Hospitalizations, and Deaths Caused By Major Bacterial Enteric Pathogens in Young Children in the United States. Pediatr Infect Dis J, 2012; 32:1.
35. Scallan E, Jones TF, Cronquist A, Thomas S, Frenzen P, Hoefer D, Medus C, Angulo FJ. Factors associated with seeking medical care and submitting a stool sample in estimating the burden of foodborne illness. Foodborne Pathog Dis, 2006; 3:432–438. [PubMed: 17199525]
36. Thomas MK, Murray R, Flockhart L, Pintar K, Pollari F, Fazil A, Nesbitt A, Marshall B. Estimates of the Burden of Foodborne Illness in Canada for 30 specified pathogens and unspecified agents, circa 2006. Foodborne Pathog Dis, 2013; 10:639–648. [PubMed: 23659355]
37. Kirk M, Ford L, Glass K, Hall G. Foodborne illness, Australia, circa 2000 and circa 2010. Emerg Infect Dis, 2014; 20:1857–1864. [PubMed: 25340705]
38. Kirk M, Hall GV, Becker N. Gastroenteritis in older people living in the community: results of two Australian surveys. Epidemiol Infect, 2012; 140:2028–36. [PubMed: 22230110]
39. Castle S, Norman D, Yeh M, Miller D, Yoshikawa T. Fever response in elderly nursing home residents: are the older truly colder? J Am Geriatr Soc, 1991; 39:853–7. [PubMed: 1885858]
40. Chen Y, Liu B, Glass K, Du W, Banks E, Kirk M. Use of proton pump inhibitors and the risk of hospitalization for infectious gastroenteritis. PLoS One, 2016; 11.
41. Kirk MD, Veitch MG, Hall GV. Gastroenteritis and food-borne disease in elderly people living in long-term care. Clin Infect Dis, 2010; 50:397–404. [PubMed: 20047497]
42. Lopman BA, Reacher MH, Vipond IB, Sarangi J, Brown DW. Clinical manifestation of norovirus gastroenteritis in health care settings. Clin Infect Dis, 2004; 39:318–24. [PubMed: 15306997]
43. Said MA, Perl TM, Sears CL. Gastrointestinal Flu: Norovirus in Health Care and Long-Term Care Facilities. Clin Infect Dis, 2008; 47:1202–1208. [PubMed: 18808354]

44. Rowe T, Geetha I. Challenges to diagnosis and management of infections in older adults, 2016. In New Directions in Geriatric Medicine: Concepts, Trends, and Evidence-Based Practice, pp. 31–47. Springer International Publishing.

45. Reiss G, Kunz P, Koin D, Keeffe EB. Escherichia Coli O157:H7 Infection in Nursing Homes: Review of Literature and Report of Recent Outbreak. J Am Geriatr Soc, 2006; 54:680–684. [PubMed: 16686882]

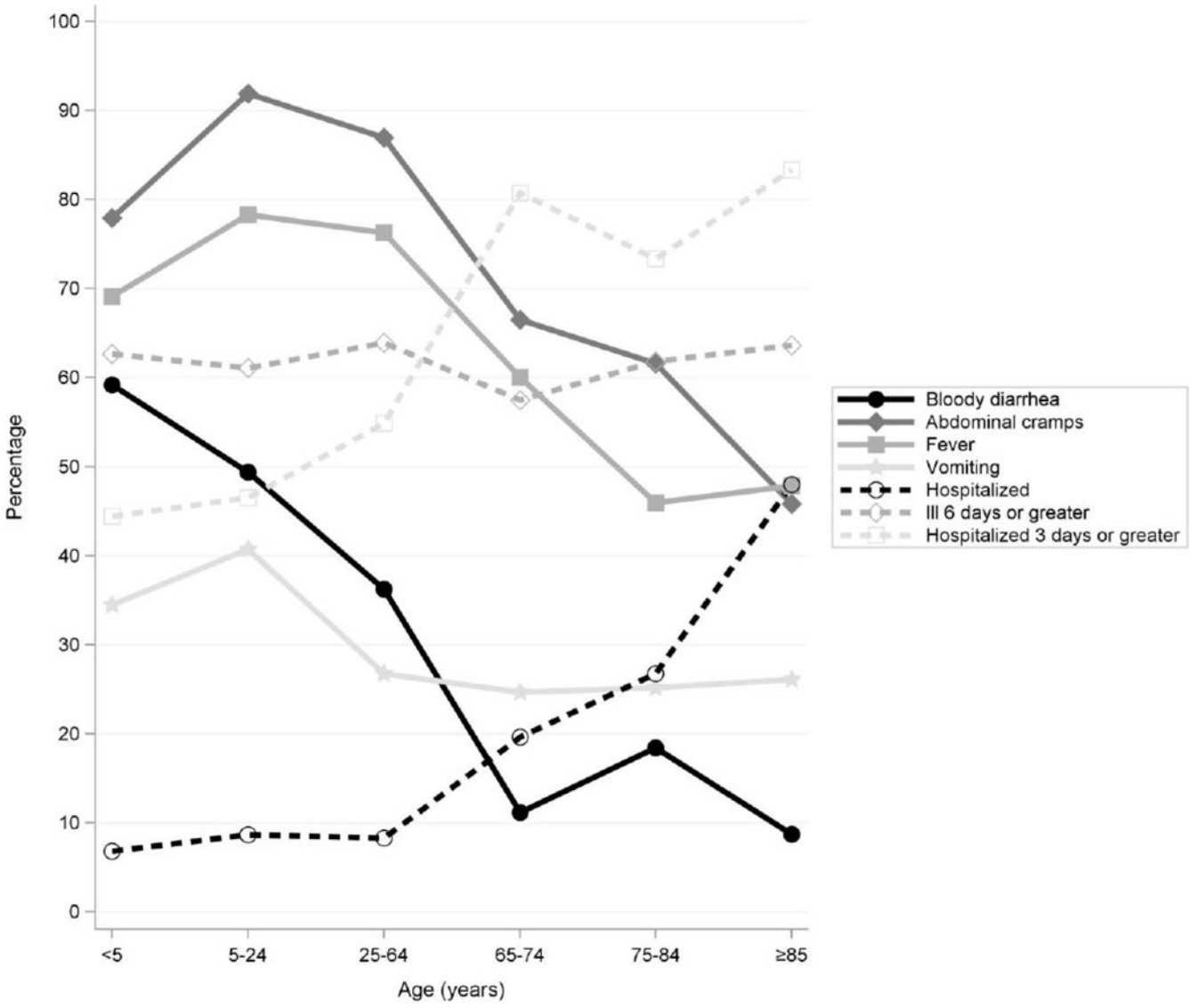

Figure 1.

Percentage of cases with *Campylobacter* infection by reported illness characteristics in Australia, Canada, and the United States, by age group [a, b, c]

[a] Data for aged under 5 years not available from OzFoodNet *Campylobacter* case-control study

[b] FoodNet Canada surveillance did not collect hospitalization duration

[c] Illness and hospitalization duration median calculated using US data only

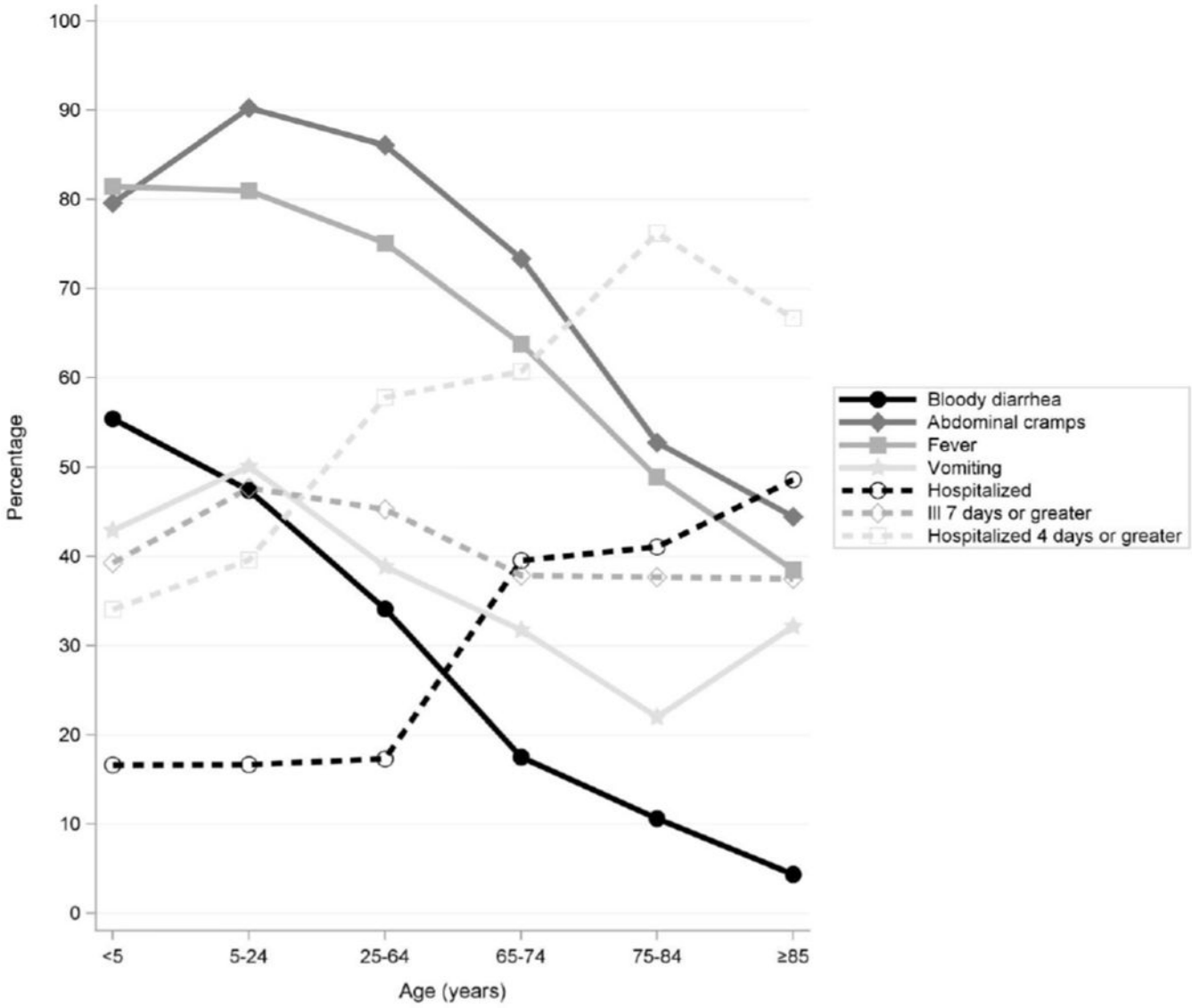

Figure 2.

Percentage of cases with nontyphoidal *Salmonella* infection by reported illness characteristics in Australia, Canada, and the United States, by age group [a, b, c]

[a] OzFoodNet *Salmonella* Birkenhead case-control study did not collect hospitalization or illness duration

[b] FoodNet Canada surveillance did not collect hospitalization duration data

[c] Illness and hospitalization duration median calculated using US data only

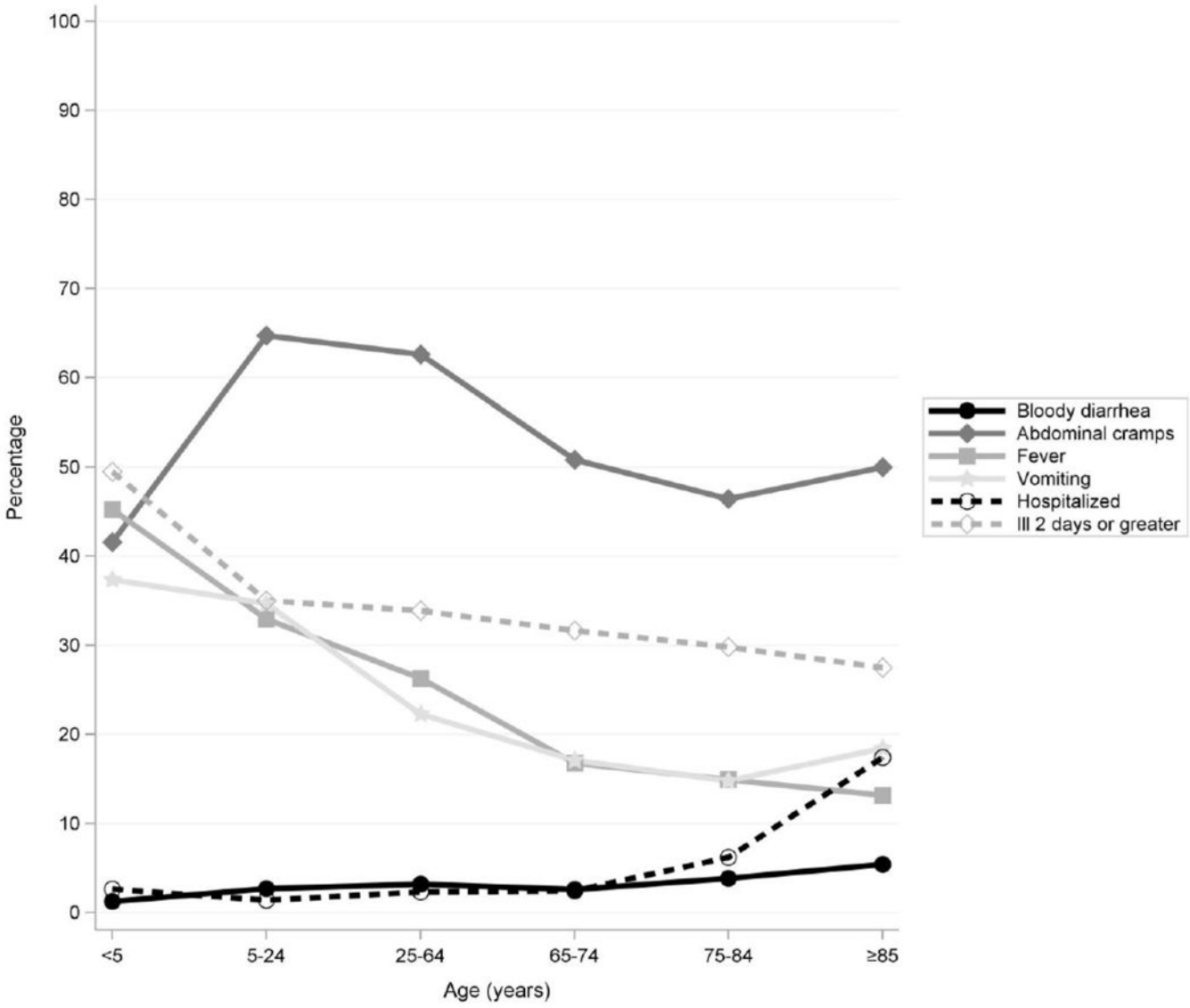

Figure 3.

Percentage of cases with acute gastroenteritis by reported illness characteristics in Australia, Canada, and the United States, by age group [a]

[a] Illness duration median calculated using US data only

Table 1.

Summary of *Campylobacter, Salmonella*, and acute gastroenteritis studies and surveillance from Australia, Canada, and the United States

	Time Period	No. of Cases	Population	References
Campylobacter				
OzFoodNet case-control study	2001–02	545	New South Wales (NSW), Queensland (QLD), South Australia (SA), Tasmania (TAS), Victoria (VIC)	Stafford, 2007
FoodNet Canada surveillance	2006–13	1,846	Ontario (ON), British Columbia (BC)	
US FoodNet case-control study	1998–99	1,311	Connecticut (CT), Georgia (GA), Minnesota (MN), Oregon (OR), select counties in California (CA), Maryland (MD), New York (NY)	Friedman, 2004 Kassenborg, 2004 Nelson, 2004
Salmonella				
OzFoodNet case-control study – Birkenhead	2001–02	111	QLD, NSW	Beard, 2002
FoodNet Canada surveillance – Enteritidis	2006–13	532	ON, BC	
US FoodNet case-control study – Enteritidis	2002–03	214	CT, MN, Tennessee (TN), selected counties in Colorado (CO), NY	Marcus, 2007
FoodNet Canada surveillance – Newport	2006–13	37	ON, BC	
US FoodNet case-control study – Newport	2002–03	215	CT, GA, MN, OR, TN, selected counties in CA, CO, NY	Varma, 2006 Devasia, 2005
FoodNet Canada surveillance – (excluding Enteritidis, Newport, and Typhi)	2006–13	768	ON, BC	
US FoodNet case-control study – serogroups B and D	1996–97	463	MN, OR, selected counties in CA, CT, GA	Kimura, 2004 Hennessy, 2004
US FoodNet case-control study – nontyphoidal *Salmonella* Javiana, Salmonella Infantis, and Salmonella I 4,[5],12:i:-	2002–03	396	CT, GA, MD, MN, New Mexico (NM), OR, TN, selected counties in CA, CO, NY	
Acute gastroenteritis				
Australian National Gastroenteritis Survey (NGSI)	2001–02	451	Stratified random sampling across all Australian states and territories	Kirk, 2012
Australian National Gastroenteritis Survey (NGSII)	2008–09	341	Stratified random sampling across all Australian states and territories	Kirk, 2012
Canadian National Studies on Acute GI (NSAGI)	2001–02	201	Hamilton, ON	Sargeant, 2007
Canadian National Studies on Acute GI	2002–03	282	BC	Thomas, 2006
Canadian National Studies on Acute GI	2005–06	65	ON	Sargeant, 2007
US FoodNet Population Survey (Cycle 1)	1996–97	843	CT, GA, MN, OR, selected counties in CA	Jones, 2007
US FoodNet Population Survey (Cycle 2)	1998–99	1,178	CT GA, MD, MN, OR, selected counties in CA, NY	Imhoff, 2004
US FoodNet Population Survey (Cycle 3)	2000–01	948	CT, GA, MD, MN, OR, TN, selected counties in CA, NY	
US FoodNet Population Survey (Cycle 4)	2002–03	1,107	CT, GA, MD, MN, OR, TN, selected counties in CA, CO, NY	Green, 2005 Scallan, 2006

	Time Period	No. of Cases	Population	References
US FoodNet Population Survey (Cycle 5)	2006–07	1,460	CT, GA, MD, MN, NM, OR, TN, selected counties in CA, CO, NY	Shiferaw, 2012

Table 2.

Illness characteristics across age categories for *Campylobacter* and nontyphoidal *Salmonella* infections, and acute gastroenteritis (Australia, Canada, United States combined)

	Age categories (years)							
	Total	**<5**	**5–24**	**25–64**	**65–74**	**75–84**	**≥85**	***p-value***
	n (%)	***n (%)***	***n (%)***	***n (%)***	***n (%)***	***n (%)***	***n (%)***	
Campylobacter[a]								
Bloody diarrhea	*1,247 (39)*	190 (59)	361 (49)	648 (36)	23 (11)	23 (18)	2 (9)	*<0.01*
Abdominal cramps	*2,849 (85)*	212 (78)	728 (92)	1,676 (87)	145 (67)	77 (62)	11 (46)	*<0.01*
Fever	*2,446 (74)*	226 (69)	609 (78)	1,420 (76)	123 (60)	57 (46)	11 (48)	*<0.01*
Vomiting	*1,032 (31)*	109 (35)	320 (41)	512 (27)	53 (25)	32 (25)	6 (26)	*<0.01*
Hospitalization	*331 (10)*	21 (7)	66 (9)	156 (8)	42 (20)	34 (27)	12 (48)	*<0.01*
Hospitalized Cases[b]								
Bloody diarrhea	*65 (46)*	6 (60)	15 (60)	36 (53)	4 (19)	3 (23)	1 (25)	*0.01*[e]
Abdominal cramps	*122 (82)*	9 (100)	26 (96)	66 (89)	13 (59)	7 (54)	1 (25)	*<0.01*[e]
Fever	*128 (86)*	6 (60)	24 (89)	67 (92)	17 (77)	11 (85)	3 (75)	*0.15*[e]
Vomiting	*66 (44)*	6 (60)	18 (67)	32 (43)	8 (36)	2 (15)	0 (0)	*0.01*[e]
Salmonella								
Bloody diarrhea	*974 (40)*	267 (55)	335 (47)	344 (34)	18 (18)	9 (11)	1 (4)	*<0.01*
Abdominal cramps	*2,059 (84)*	320 (80)	675 (90)	927 (86)	77 (73)	48 (53)	12 (44)	*<0.01*
Fever	*1,873 (76)*	404 (82)	592 (81)	764 (75)	60 (6)	43 (49)	10 (39)	*<0.01*
Vomiting	*1,058 (42)*	209 (43)	370 (50)	417 (39)	33 (32)	20 (22)	9 (32)	*<0.01*
Hospitalization[c]	*560 (19)*	85 (17)	144 (17)	217 (17)	49 (40)	48 (41)	17 (49)	*<0.01*
Hospitalized Cases[b]								
Bloody diarrhea	*144 (48)*	33 (72)	43 (50)	57 (46)	7 (26)	4 (27)	0 (0)	*<0.01*[e]
Abdominal cramps	*283 (88)*	36 (92)	88 (97)	122 (88)	21 (75)	13 (62)	3 (60)	*<0.01*[e]
Fever	*295 (91)*	47 (98)	86 (95)	124 (93)	24 (92)	12 (67)	2 (33)	*<0.01*[e]
Vomiting	*219 (67)*	32 (67)	69 (77)	93 (68)	14 (50)	8 (40)	3 (50)	*0.01*[e]
Acute GI illness								
Bloody diarrhea	*203 (3)*	6 (1)	29 (3)	147 (3)	11 (3)	8 (4)	2 (5)	*0.14*
Abdominal cramps	*4,098 (60)*	185 (42)	688 (65)	2,893 (63)	216 (51)	97 (46)	19 (50)	*<0.01*
Fever	*1,889 (28)*	217 (45)	357 (33)	1,208 (26)	71 (17)	31 (15)	5 (13)	*<0.01*[e]
Vomiting	*1,699 (25)*	180 (37)	377 (35)	1,031 (22)	73 (17)	31 (15)	7 (18)	*<0.01*
Hospitalization[d]	*77 (2)*	6 (3)	7 (1)	47 (2)	6 (2)	7 (6)	4 (17)	*<0.01*

[a]Data for aged under 5 years not available from OzFoodNet *Campylobacter* case-control study

[b] Individual-level data for symptoms among hospitalized cases available from US studies only

[c] OzFoodNet *Salmonella* Birkenhead case-control study did not collect hospitalization

[d] Canada National Studies on Acute Gastrointestinal Studies (NSAGI) did not collect hospitalization

[e] Random effects model did not converge, so did not adjust for random effect of study