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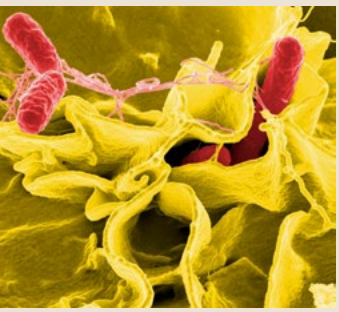

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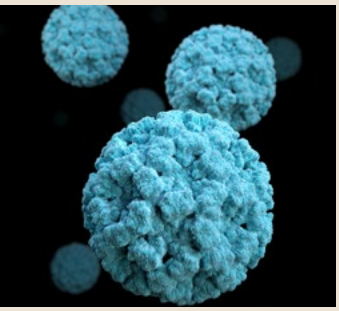

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Incidence of *Campylobacter* Intestinal Infections, Active Component, U.S. Armed Forces, 2007–2016

Francis L. O'Donnell, MD, MPH (COL, USA, Ret); Shauna Stahlman, PhD, MPH; Gi-Taik Oh, MS

During 2007–2016, there were 1,753 diagnosed cases of *Campylobacter* intestinal infection among active component service members. The overall rate for the period was 14.1 cases per 100,000 person-years (p-yrs), but the annual incidence rates steadily increased from 7.6 cases per 100,000 p-yrs in 2007 to 22.1 cases per 100,000 p-yrs in 2016. Overall rates were higher in females, those aged 45 years or older, members of the Air Force and Army, officers, and those in military healthcare occupations. Incidence rates were lowest among service members who were recruit trainees, younger than 20 years of age, non-Hispanic blacks, and Marines. For the entire 10-year surveillance period, more cases were diagnosed in the warmer months of the year. Only eight cases were diagnosed in deployment settings during the 10-year period. Discussion of the recognized risk factors for *Campylobacter* infections reviewed the hazards of undercooked meats (especially poultry), unpasteurized milk, and untreated surface water in the environment. The limitations of the study methodology were described.

The bacterial genus *Campylobacter* includes at least a half-dozen species that have been well documented to cause illness in humans.[1] *Campylobacter jejuni* is the species most commonly associated with gastrointestinal infections that are characterized by fever, diarrhea, and abdominal pain, although systemic spread of the bacterium may affect other organ systems. The species *C. coli* and *C. fetus* are better known for their association with extra-intestinal disease, but they may produce typical gastroenteritis. *Campylobacter* species, predominantly *C. jejuni*, are among the most common causes of symptomatic intestinal infections in the U.S. and around the world. Humans acquire these infections most often by ingesting contaminated food or water. The principal reservoirs of *Campylobacter* are cattle, sheep, pigs, goats, dogs, cats, and birds, especially poultry. Animals who acquire the infection early in life may become lifelong carriers of the organism and may serve as continuing sources of contamination of soil and water through their feces. Although the bacteria are located in the animals' intestinal tracts, the production of meat for human consumption often results in contamination of the meat by intestinal organisms. In particular, chicken and turkey meat should be presumed to be contaminated by *Campylobacter* and other enteric pathogens. Cases and outbreaks of campylobacteriosis have also been associated with consumption of untreated surface waters (rivers, lakes), contaminated community water supplies, and unpasteurized milk.[1-7]

In the U.S., *Campylobacter* and *Salmonella* species and *Clostridium perfringens* are the most commonly identified bacterial causes of foodborne illness.[2] Among active component service members of the U.S. Armed Forces diagnosed with gastrointestinal infections due to specific bacterial pathogens, the incidence rates of diagnoses of *Campylobacter* and *Salmonella* infections are higher than rates for other identified bacterial pathogens. Recent *MSMR* studies have indicated that the annual incidence rates for diagnoses of *Campylobacter* infections among active component service members have steadily increased since 2007 and have exceeded those of nontyphoidal *Salmonella* infections in the most recent years studied, 2012 and 2013.[8,9]

This report documents the incidence of diagnoses of *Campylobacter* intestinal infections in active component service members during the 10-year period 2007–2016. Other reports in this issue of the *MSMR* describe the incidence of diagnoses of the other leading causes of gastrointestinal infections during the same period.

METHODS

The surveillance period was 1 January 2007 through 31 December 2016. The surveillance population consisted of all active component service members of the U.S. Armed Forces who served at any time during the 10-year surveillance period. Diagnoses of *Campylobacter* infection were ascertained from records of reports of notifiable medical events and from administrative records of all medical encounters of individuals who received care in fixed (i.e., not deployed or at sea) medical facilities of the MHS or civilian facilities in the purchased care system. All such records are maintained in the electronic database of the Defense Medical Surveillance System (DMSS). In addition, cases were ascertained from Navy and Marine Corps Public Health Center (NMCPHC) records of laboratory identification of *Campylobacter* in stool or rectal samples tested in laboratories of the MHS. Because laboratory results had not been used in the previous report on

the incidence of *Campylobacter* infections, the contribution of laboratory results to the final case counts was determined.

For surveillance purposes, an incident case of *Campylobacter* infection was defined as a service member associated with any one of the following: 1) a laboratory-confirmed identification of *Campylobacter* in a stool or rectal sample, 2) a reportable medical event record of "confirmed" *Campylobacter* infection, 3) a single hospitalization with any of the defining diagnoses for *Campylobacter* in any diagnostic position (ICD-9: 008.43; ICD-10: A04.5), or 4) a single outpatient encounter with any of the defining diagnoses for *Campylobacter* in any diagnostic position. An individual could be considered a case once every 180 days. The incidence date was considered the date of the earliest rectal or fecal sample that was confirmed positive for *Campylobacter*, the date documented in a reportable medical event report, or the date of the first hospitalization or outpatient medical encounter that included the defining diagnosis of *Campylobacter*. Incidence rates were calculated as the number of cases per 100,000 person-years (p-yrs).

Campylobacter infections occurring during deployments (e.g., to Southwest Asia, Haiti) were analyzed separately. These cases were identified from the medical records of deployed service members whose healthcare encounters were documented in the Theater Medical Data Store (TMDS). TMDS data were available from 2008 through 2016 (9 years). An incident case during deployment was based on a single medical encounter with a diagnosis of *Campylobacter* infection recorded in TMDS that occurred between the start and end dates of a service member's deployment record.

RESULTS

During the surveillance period of 2007–2016, there were 1,753 diagnosed cases of *Campylobacter* infections among active component service members. Approximately one-fourth (n=455, 26%) of all cases would not have been identified as such if the positive laboratory confirmation data from NMCPHC had not been included in the case definition. The overall incidence rate was 14.1 cases per 100,000 p-yrs. The total numbers of cases, overall incidence rates, and distribution by various demographic characteristics are shown in the **Table**. Compared to their respective counterparts, overall rates were higher in females, those aged 45 years or older, members of the Air Force and Army, officers, and those in military healthcare occupations. Incidence rates were lowest among service members who were recruit trainees, younger than 20 years of age, non-Hispanic blacks, and Marines **(Table)**.

Annual numbers of diagnosed cases and annual incidence rates of *Campylobacter* infections increased during the 10-year surveillance period **(Figure 1)**. The 2016 incidence rate for all active component service members (22.1 cases per 100,000 p-yrs) was the highest of the period and was nearly three times the 2007 rate (7.6 per 100,000 p-yrs). Among the demographic categories shown in the **Table**, the only subcategories for which the rates did not greatly increase during the surveillance period were service members who were younger than 20 years of age, recruit trainees, and those whose military occupational category was armor/motor transport. For the latter, annual rates actually declined during the period **(data not shown)**.

Among the 1,753 diagnosed cases of *Campylobacter* infection during the 10-year period, the distribution of cases by calendar month was examined to assess seasonality. Although at least 100 cases were identified in each of the 12 calendar months for the whole period, April–September had the highest numbers of cases (n=1,035; 59.0% of all cases) and October–March had the lowest counts of cases (n=718; 41.0%) **(Figure 2)**.

When the 242 medical facilities associated with diagnoses of *Campylobacter* infection were aggregated by geographic location (foreign country or state), six countries accounted for 28.5% of cases and 11 states were associated with another 55.1% of all cases **(data not shown)**. Locations associated with 5% or more of the total number of cases (n=1,753) were the countries of Germany (181 cases) and South Korea (109), and the states of Hawaii

TABLE. Incident cases and incidence rates of *Campylobacter* infection, active component, U.S. Armed Forces, 2007–2016

	Total 2007–2016	
	No.	Rate[a]
Total	1,753	14.1
Sex		
Male	1,451	13.8
Female	302	16.1
Age group		
<20	36	4.3
20–24	464	11.8
25–29	517	17.6
30–34	269	14.0
35–39	217	14.9
40–44	139	15.9
45–49	69	19.8
50+	42	33.4
Race/ethnicity		
Non-Hispanic white	1,133	15.0
Non-Hispanic black	194	9.7
Hispanic	224	14.5
Other/unknown	202	15.3
Service		
Army	714	15.7
Navy	388	12.9
Air Force	542	17.6
Marine Corps	109	6.1
Rank/grade		
Junior enlisted (E1–E4)	595	11.1
Senior enlisted (E5–E9)	707	14.4
Junior officer (O1–O4)	320	20.3
Senior officer (O5–O10)	96	24.6
Warrant officer (WO1–WO5)	35	21.1
Status		
Recruit	8	3.1
Nonrecruit	1,745	14.4
Military occupation		
Combat-specific	175	10.7
Armor/motor transport	41	9.2
Pilot/air crew	90	19.3
Repair/engineering	434	12.0
Communications/ intelligence	419	15.3
Health care	265	23.8
Other	329	13.7

[a]Rate per 100,000 person-years

FIGURE 1. Annual numbers of incident cases and incidence rates of *Campylobacter* infection, active component, U.S. Armed Forces, 2007–2016

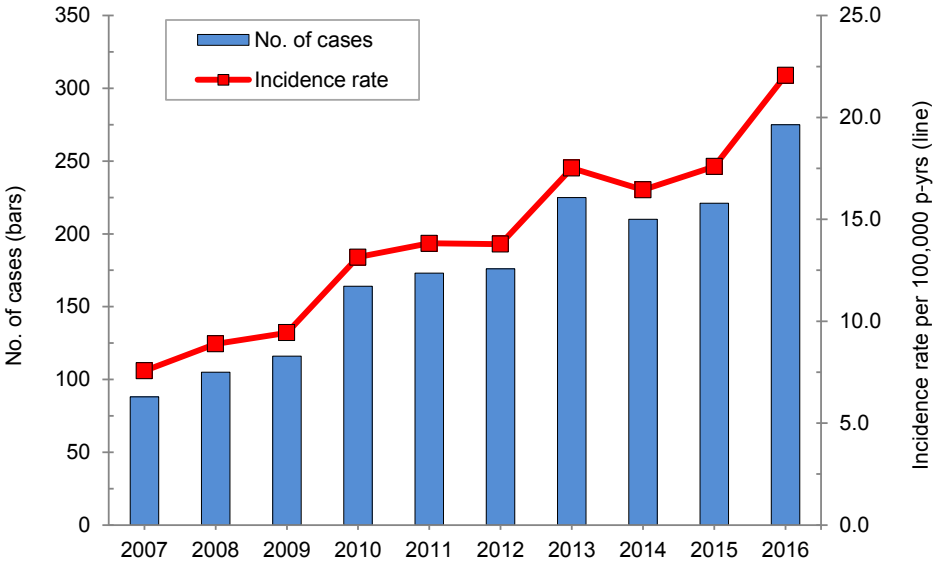
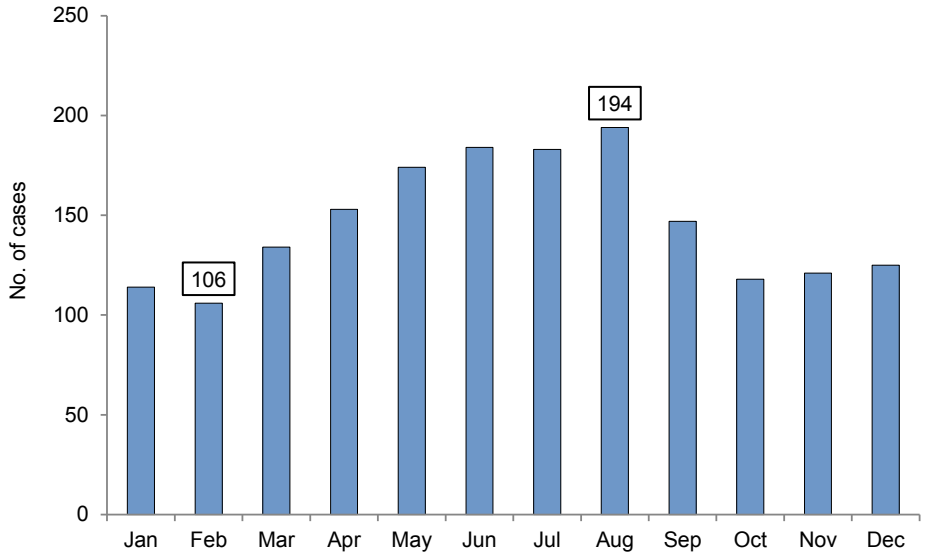


FIGURE 2. Cumulative numbers of incident cases of *Campylobacter* infection, by calendar month, active component, U.S. Armed Forces, 2007–2016



(203), Florida (149), North Carolina (144), Texas (111), and California (111).

The separate analysis of diagnoses of *Campylobacter* infections among deployed members of the active component identified only eight cases during the 9-year surveillance period. Four cases were documented in TMDS in 2008, two in 2011, and one each in 2014 and 2016. The paucity of cases precluded any attempt to identify demographic patterns of infection occurring during deployment.

EDITORIAL COMMENT

This analysis documented that the annual incidence rates of diagnoses of *Campylobacter* infections among active component service members have been steadily increasing from 2007 through 2016. This finding confirms the results of the 2014 *MSMR* report that indicated that the annual incidence rates had begun to increase after 2007, before which the rates had been slowly declining.[8] The rate for 2016 (22.1 cases per 100,000 p-yrs) was the highest in the past decade.

With respect to the demographic patterns of cases, the findings of this analysis are similar to the earlier study. Higher rates of *Campylobacter* infections were associated with female gender, the older age groups, service in the Air Force and Army, and officer ranks. As before, rates among non-Hispanic blacks were notably lower when compared to rates among service members of other racial/ethnic groups.

Other findings that replicated those of the earlier study pertain to seasonality of diagnoses of *Campylobacter* infection and the relatively high numbers of cases diagnosed in the state of Hawaii. The numbers of cases diagnosed during the warmer part of the year—at least in the northern hemisphere—were clearly higher than during the colder months. This observation has been made by others, but the reasons for the increased summer incidence are unclear.[1] As noted in the 2014 *MSMR* report, Hawaii has been reported to have the highest incidence rates of *Campylobacter* infections in the U.S.[8] There are hypotheses suggesting reasons for the increased incidence in Hawaii, but clear evidence is lacking.

The use of TMDS records of deployed service members' healthcare encounters uncovered few diagnoses of *Campylobacter* infections. It is unclear whether the risks of acquiring such infections differ much from the risks in nondeployed settings. It is plausible that the limitations of medical laboratory support in the austere environment of the theater of combat operations simply precluded the identification of *Campylobacter*.

Although this analysis documents a trend since 2007 of increasing rates of diagnoses of *Campylobacter* intestinal infections among active component service members, the results should be interpreted in the context of several considerations. It should be noted that the annual rates in this report are higher than those found in the 2014 *MSMR* article.[8] The principal reason for the difference is that this update was able to ascertain cases from not only electronic records of diagnoses and reportable medical events but also the laboratory results provided by the NMCPHC. The latter were not available in 2014.

In this report, the numbers of cases and the incidence rates should be regarded

as underestimates of the true incidence of *Campylobacter* infections in the population of active component service members. First, not all affected service members seek care for episodes of acute gastroenteritis. Second, some cases may not be tested for *Campylobacter* infection. Third, even when stool or rectal specimens are collected, the sensitivity of the laboratory testing for *Campylobacter* may vary according to the type of test (culture vs. culture-independent diagnostic tests) and the laboratory performing the test.[10] Last, results of laboratory tests performed in the civilian purchased care system are not available to the NMCPHC, so positive tests in that system are not reflected in this report. Unless the diagnosis of *Campylobacter* infection was documented in the purchased care record for a service member, the fact of a positive laboratory test in the purchased care network would not result in that case being identified in this analysis.

It should be noted that the ICD-9 and ICD-10 codes used to ascertain cases refer only to *Campylobacter* intestinal infections irrespective of the species. Similarly, the NMCPHC laboratory data do not provide species identification. However, the laboratory results were restricted to specimens of stool or rectal swabs, and instances of finding *Campylobacter* bacteria in other bodily fluids (e.g., blood, urine) were not counted as cases if no other criteria of the case definition were met. This analysis was unable to determine the extent to which cases of *Campylobacter* infection were sporadic in occurrence or were associated with outbreaks.

The Centers for Disease Control and Prevention (CDC) has noted that ongoing efforts to reduce the incidence of foodborne diseases, including those caused by *Campylobacter* bacteria, must be enhanced to meet the national target levels of *Healthy People 2020*.[10] Much of the emphasis has been placed on regulating and monitoring the poultry industry in the U.S. as well as imported foods. It is estimated that more than half of sporadic cases of *Campylobacter* infections are attributable to consumption of undercooked poultry in developed nations such as the U.S.[1]

The findings of this analysis are not directly comparable to CDC surveillance data for the U.S. population. The active component military population comprises young and middle-aged adults but not children. *Campylobacter* infections in the U.S. civilian population are most common in children younger than 5 years old.[1] It should be noted that a portion of the 2014 *MSMR* report on *Campylobacter* infections included counts of cases in the nonmilitary beneficiary population of the MHS.[8] The data in that report showed that the largest numbers of cases were diagnosed in children younger than 5 years of age and in adults aged 75 years or older. Rates were not presented in that report. It is of interest that the counts of cases among the nonmilitary beneficiaries during the surveillance period (2000–2013) showed steady increases after 2009. The case count in 2013 was more than twice that of 2009. That trend is comparable to the increases among active component service members described in this report.

For the individual who seeks to avoid disease due to *Campylobacter* and other enteric pathogens, several reminders of risk factors are mentioned here. Meat of all types (but especially chicken and turkey) should be cleaned and thoroughly cooked before consumption. Food preparation surfaces and equipment (e.g., knives) used on possibly contaminated meats should be cleaned before they are used for other menu items not destined to be cooked (e.g., salads).[1] Another prevalent risk factor for *Campylobacter* infections is consumption of unpasteurized milk. Numerous outbreaks in this country have been reported, and have especially been associated with dairies in states that permit the sale of unpasteurized milk.[6,7,11] Lastly, drinking surface water (e.g., mountain streams, waterfalls, lakes) should be avoided unless steps are taken to disinfect the water before ingestion.[4,12] The bacterial hazards in surface water are due to its contamination by the feces of livestock, poultry, or wild birds.

A surveillance snapshot on page 26 of this issue of the *MSMR* provides context for the findings of this analysis. The snapshot compares the incidence rates of *Campylobacter* gastrointestinal infections with the incidence rates of the other common gastrointestinal pathogens among active component service members.[13]

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REFERENCES

1. Allos BM, Iovine NM, Blaser MJ. *Campylobacter jejuni* and related species. In: Bennett JE, Dolin R, Blaser MJ, eds. *Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases*. 8th ed. Philadelphia: PA: Elsevier Saunders; 2015:2485–2493.
2. Scallan E, Hoekstra RM, Angulo FJ, et al. Foodborne illness acquired in the United States—major pathogens. *Emerg Inf Dis*. 2011;17(1):7–15.
3. Centers for Disease Control and Prevention. Incidence and trends of infection with pathogens transmitted commonly through food—foodborne diseases active surveillance network, 10 U.S. sites, 1996–2012. *MMWR*. 2013;62(15):283–287.
4. Centers for Disease Control and Prevention. Surveillance for waterborne disease outbreaks associated with drinking water and other nonrecreational water—United States, 2009–2010. *MMWR*. 2013;62(35):714–720.
5. DeFraites RF, Sanchez JL, Brandt C, et al. An outbreak of *Campylobacter* enteritis associated with a community water supply on a U.S. military installation. *MSMR*. 2014;21(11):10–15.
6. Mungai EA, Behravesh CB, Gould LH. Increased outbreaks associated with nonpasteurized milk, United States, 2007–2012. *Emerg Inf Dis*. 2015;21(1):119–122.
7. Davis KR, Dunn AC, Burnett C, et al. *Campylobacter jejuni* infections associated with raw milk consumption—Utah, 2014. *MMWR*. 2016;65(12):301–305.
8. Armed Forces Health Surveillance Center. Incidence of *Campylobacter* infections among service members of the active and reserve components of the U.S. Armed Forces and among other beneficiaries of the Military Health System, 2000–2013. *MSMR*. 2014;21(12):11–16.
9. Clark LL, Daniele DO, O'Donnell FL. Incidence of *Salmonella* infections among service members of the active and reserve components of the U.S. Armed Forces and among other beneficiaries of the Military Health System, 2000–2013. *MSMR*. 2015;22(1):11–15.
10. Crim SM, Iwamoto M, Huang JY, et al. Incidence and trends of infection with pathogens transmitted commonly through food—Foodborne Diseases Active Surveillance Network, 10 U.S. sites, 2006–2013. *MMWR*. 2014;63(15):328–332.
11. Centers for Disease Control and Prevention. Recurrent outbreak of *Campylobacter jejuni* infections associated with a raw milk dairy—Pennsylvania, April–May 2013. *MMWR*. 2013;62(34):702.
12. Hlavsa MC, Roberts VA, Kahler AM, et al. Recreational water-associated disease outbreaks—United States, 2009–2010. *MMWR*. 2014;63(1):6–10.
13. Armed Forces Health Surveillance Branch. Surveillance snapshot: Annual incidence rates and monthly distribution of cases of gastrointestinal infection, active component, U.S. Armed Forces, 2007–2016. *MSMR*. 2017;24(6):26.

Incidence of Nontyphoidal *Salmonella* Intestinal Infections, Active Component, U.S. Armed Forces, 2007–2016

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During 2007–2016, there were 1,536 incident cases of nontyphoidal *Salmonella* infection among active component service members, with an overall crude incidence rate of 12.4 cases per 100,000 person-years (p-yrs). The overall rate for the period was higher among female service members than males. Service members aged 50 years or older and those aged 25–29 years had the highest rates of nontyphoidal *Salmonella* infection. Compared to their respective counterparts, overall rates were highest among non-Hispanic white service members, members of the Air Force, junior officers, recruits, and service members in healthcare occupations. Annual incidence rates were relatively stable during the first 9 years of the surveillance period. Rates peaked in 2016 at 15.9 cases per 100,000 p-yrs. The monthly distribution of the cumulative number of cases during the period showed a pattern of seasonality with a summer peak and the largest number of infections in July. During 2008–2016, a total of 132 cases were diagnosed in deployment settings, with an overall crude incidence rate of 12.6 cases per 100,000 p-yrs. Standard measures for the prevention of salmonellosis are reviewed.

Salmonella is a group of gram-negative bacteria that cause a wide spectrum of disease in a range of mammalian hosts. In humans, they cause a number of characteristic clinical infections, including gastroenteritis, enteric fever (caused by typhoid and paratyphoid serotypes), bacteremia, focal metastatic infections (e.g., osteomyelitis, abscess), and an asymptomatic chronic carrier state.[1] The genus *Salmonella* consists of two species, *S. enterica* and *S. bongori*; the former is the species most often associated with human disease.[2,3] Most clinically important salmonellae are formally classified within a single subspecies, *S. enterica*, subspecies *enterica*.[2,3] *Salmonella* serotypes other than *S. typhi* and *S. paratyphi* are collectively known as nontyphoidal salmonellae. In the U.S., *S. enterica* serotypes Enteritidis (17%), Newport (11%), and Typhimurium (9%) account for more than one-third of the human isolates from nontyphoidal *Salmonella* infection.[4]

Nontyphoidal salmonellae are a leading cause of foodborne illness in the U.S.[5] Although *Salmonella* has been superseded by norovirus as the leading cause of foodborne outbreaks and illness in the U.S., nontyphoidal salmonellae are still responsible for the largest numbers of hospitalizations and deaths.[6-8] Among members of the active component of the U.S. Armed Forces, nontyphoidal *Salmonella* is a top cause of acute gastrointestinal illness.[9,10]

Gastroenteritis is the most common clinical presentation of nontyphoidal *Salmonella* infection. Gastroenteritis due to nontyphoidal salmonellae is typically self-limiting and is usually characterized by acute onset of fever, abdominal pain/cramping, diarrhea, nausea, and sometimes vomiting.[11] The organism is spread primarily via contaminated food products, but it can also be transmitted through animal contact (e.g., turtles, frogs, lizards, chickens). In developed countries, the main reservoir of nontyphoidal *Salmonella* is the intestinal tract of food-producing animals, and this widespread distribution readily leads to contamination of a broad range of food products.[12-14] Therefore, foods of animal origin, particularly contaminated poultry products (eggs and poultry meat), have been considered major vehicles of nontyphoidal *Salmonella* infection.[5,13-16] Contaminated water, milk, milk products, beef, fruit, and vegetables are also common sources of infection.[17] Recently, multistate human outbreaks have been associated with contaminated alfalfa sprouts and cucumbers.[18-20]

Antimicrobial resistance in nontyphoidal *Salmonella* has been increasing both in the U.S. and worldwide. The incidence of clinically important antimicrobial drug–resistant *Salmonella* infections (culture-confirmed) in the U.S. between 2004 and 2012 was estimated at 2 per 100,000 person-years (p-yrs).[21] Antimicrobial resistance was found in approximately 12% of the nontyphoidal isolates overall.[21] In 2014, approximately 4% of nontyphoidal *Salmonella* isolates in the U.S. were resistant to five or more antimicrobial agents.[22] Antimicrobial resistance in foodborne human pathogens is thought to be due, in part, to antibiotic overuse and development of resistance by organisms in animals.[23] A recent study that linked outbreaks reported to the U.S. Foodborne Disease Outbreak Surveillance System between 2003 and 2012 to isolate susceptibility data in the National Antimicrobial Resistance Monitoring System found that resistant nontyphoidal

Salmonella infections were more common in outbreaks attributed to foods from land animals than outbreaks linked to food from plants or aquatic animals.[24]

This report summarizes the counts, rates, and trends of nontyphoidal *Salmonella* infections in active component service members over the past 10 years.

METHODS

The surveillance period was 1 January 2007 through 31 December 2016. The surveillance population consisted of all active component service members of the U.S. Armed Forces who served at any time during the surveillance period. Diagnoses of nontyphoidal *Salmonella* infection were derived from records of reports of notifiable medical events and from administrative records of all medical encounters of individuals who received care in fixed (i.e., not deployed or at sea) medical facilities of the Military Health System (MHS) or civilian facilities in the purchased care system. All such records are maintained in the electronic databases of the Defense Medical Surveillance System (DMSS). In addition, laboratory-confirmed cases of nontyphoidal *Salmonella* infection were identified from Navy and Marine Corps Public Health Center (NMCPHC) records of tested stool or rectal samples. Because laboratory results were not used in the previous report on the incidence of *Salmonella* infections, the contribution of laboratory results to the final case counts was determined.

For surveillance purposes, an incident case of nontyphoidal *Salmonella* infection was defined as a service member having any one of the following: 1) a laboratory-confirmed identification of nontyphoidal *Salmonella* in a stool or rectal sample, 2) a reportable medical event (RME) record of "confirmed" nontyphoidal *Salmonella* infection, 3) a single hospitalization with any of the defining diagnoses for nontyphoidal *Salmonella* in any diagnostic position (ICD-9: 003.0, 003.1, 003.2, 003.20, 003.29, 003.8, 003.9; ICD-10: A02.0, A02.1, A02.2, A02.20, A02.29, A02.8, A02.9), or 4) a single outpatient encounter with any of the defining diagnoses for nontyphoidal *Salmonella* in any diagnostic position. An individual could be considered a case once every 180 days. The incidence date was considered the first sample collection date for a laboratory-confirmed positive rectal or fecal sample, the date documented in an RME report, or the first hospitalization or outpatient medical encounter that included the defining diagnosis of nontyphoidal *Salmonella*. Incidence rates were calculated as the number of cases per 100,000 p-yrs.

Nontyphoidal *Salmonella* infections that occurred during deployments (e.g., to Southwest Asia, Haiti) were analyzed separately. These cases were identified from the medical records of deployed service members that are documented in the Theater Medical Data Store (TMDS). TMDS data were available from 2008 to 2016. To qualify as an incident case during deployment, an individual needed a single medical encounter with a diagnosis of nontyphoidal *Salmonella* infection in TMDS that occurred between the start and end dates of a deployment.

RESULTS

During the 10-year surveillance period, there were 1,536 incident cases of nontyphoidal *Salmonella* infection among active component service members, with an overall crude incidence rate of 12.4 cases per 100,000 p-yrs **(Table)**. Of the total count of cases, 313 cases (20.4%) were based on laboratory results alone. The overall incidence rate of nontyphoidal salmonellosis was higher among female service members than males (15.0 cases per 100,000 p-yrs and 11.9 cases per 100,000 p-yrs, respectively). Across age groups, service members aged 50 years or older and those aged 25–29 years had the highest rates of nontyphoidal *Salmonella* infection. Compared to their respective counterparts, members of the Air Force, junior officers, and recruits had the highest rates of nontyphoidal salmonellosis **(Table)**. Crude overall incidence rates were highest among non-Hispanic white service members and lowest among non-Hispanic black service members (13.8 cases per 100,000 p-yrs and 9.5 cases per 100,000 p-yrs, respectively). Service members in

TABLE. Incident cases and incidence rates of nontyphoidal *Salmonella* infection, active component, U.S. Armed Forces, 2007–2016

	Total 2007–2016	
	No.	Rate[a]
Total	1,536	12.4
Sex		
Male	1,255	11.9
Female	281	15.0
Age group		
<20	100	12.0
20–24	511	13.0
25–29	415	14.1
30–34	210	11.0
35–39	150	10.3
40–44	105	12.0
45–49	28	8.0
50+	17	13.5
Race/ethnicity		
Non-Hispanic white	1,041	13.8
Non-Hispanic black	190	9.5
Hispanic	159	10.3
Other/unknown	146	11.1
Service		
Army	598	13.1
Navy	293	9.8
Air Force	417	13.5
Marine Corps	228	12.8
Rank/grade		
Junior enlisted (E1–E4)	688	12.8
Senior enlisted (E5–E9)	554	11.3
Junior officer (O1–O4)	226	14.3
Senior officer (O5–O10)	50	12.8
Warrant officer (WO1–WO5)	18	10.9
Status		
Recruit	41	15.8
Nonrecruit	1,495	12.3
Military occupation		
Combat-specific	190	11.6
Armor/motor transport	41	9.2
Pilot/air crew	59	12.6
Repair/engineering	402	11.1
Communications/ intelligence	340	12.4
Health care	187	16.8
Other	317	13.2

[a]Rate per 100,000 person-years

healthcare occupations had the highest overall incidence rate of nontyphoidal salmonellosis, compared to service members in other occupational groups **(Table)**.

Annual incidence rates of nontyphoidal *Salmonella* infection were relatively stable during the first 9 years of the surveillance period and ranged from 10.5 cases per 100,000 p-years in 2010 to 13.9 cases per 100,000 p-yrs in 2007. Rates peaked in 2016 at 15.9 cases per 100,000 p-yrs (an increase of 23.9% between 2015 and 2016) **(Figure 1)**.

Between 2008 and 2016, a total of 132 incident cases of nontyphoidal *Salmonella* infection were identified among active component service members during deployment (e.g., to Southwest Asia, Haiti), with an overall crude incidence rate of 12.6 cases per 100,000 p-yrs **(data not shown)**. In the analysis of cases among deployed members of the active component, many of the subgroup-specific incidence rates were based on small numbers of cases (e.g., overall rate among Hispanic service members was based on 10 cases; overall rate among Marine Corps members was based on 10 cases). These small group sizes did not allow for the identification of demographic patterns of nontyphoidal *Salmonella* infection that occurred during deployment.

The monthly distribution of the cumulative number of incident cases of nontyphoidal *Salmonella* during the 10-year surveillance period showed a pattern of seasonality with a summer peak and the largest number of infections in July (n=218) **(Figure 2)**. In 2016, 58.7% of nontyphoidal salmonellosis cases among U.S. active component service members were diagnosed during June–October.

During the 10-year surveillance period, 1,212 (81.4% of total cases with available location information) diagnoses of nontyphoidal *Salmonella* infection were associated with U.S. facilities **(data not shown)**. Seven states accounted for almost two-thirds (65.7%) of the cases associated with U.S. locations and included North Carolina (n=160; 13.2%), California (n=140; 11.6%), Texas (n=126; 10.4%), Georgia (n=115; 9.5%), Florida (n=115; 9.5%), Virginia (n=71; 5.9%), and Hawaii (n=68; 5.6%) **(data not shown)**. Facilities at 15 locations outside of the U.S. contributed 277 cases (18.6% of total cases with available location information). Five countries accounted for 87.7% of these cases and included Germany (n=87; 31.4%), Japan (n=76; 27.4%), South Korea (n=41; 14.8%), Italy (n=24; 8.7%), and Spain (n=15; 5.4%) **(data not shown)**.

FIGURE 1. Annual numbers of incident cases and incidence rates of nontyphoidal salmonellosis, active component, U.S. Armed Forces, 2007–2016

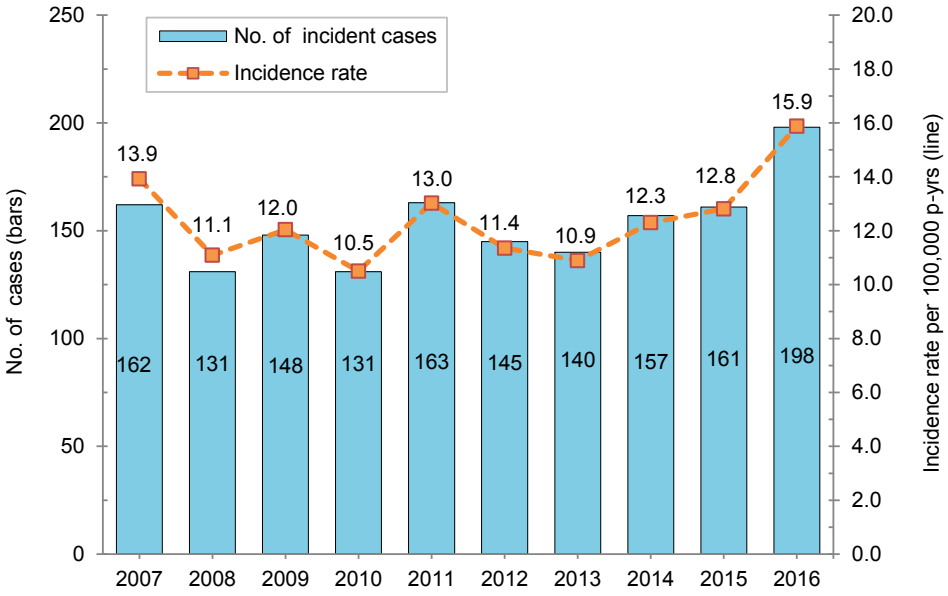
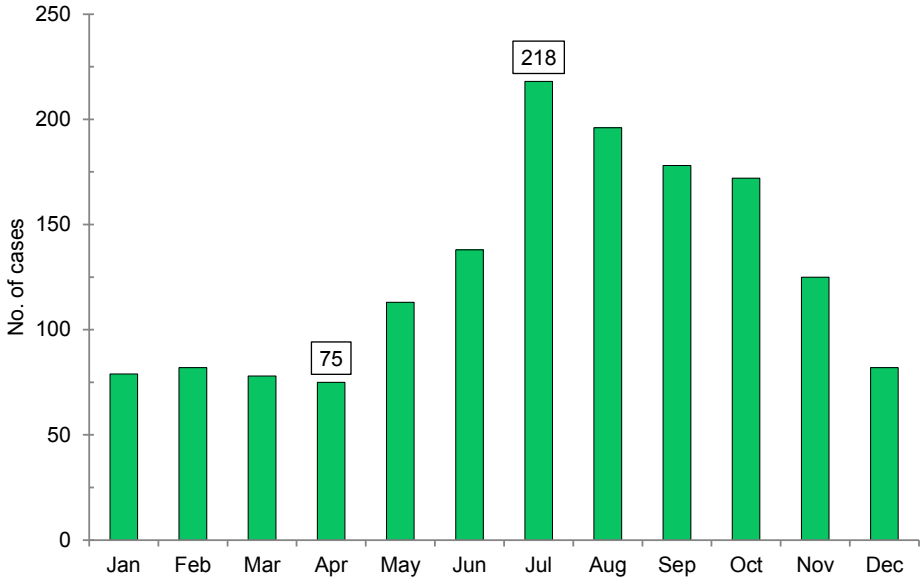


FIGURE 2. Cumulative number of incident cases of nontyphoidal salmonellosis, by calendar month, active component, U.S. Armed Forces, 2007–2016



EDITORIAL COMMENT

This report represents an update to the January 2015 *MSMR* article on the incidence of *Salmonella* infections among active component service members from

2000 through 2013.[10] Since 2013, the annual incidence rates of nontyphoidal *Salmonella* infection have increased 29.2% with the rate for 2016 (15.9 cases per 100,000 p-yrs) the highest in the past decade.

The vast majority of cases of nontyphoidal *Salmonella* infection go undiagnosed.[8] The Centers for Disease Control and Prevention (CDC) estimated that as many as 29 undetected infections occur for every culture-confirmed case.[8] For 2016, the CDC estimated incidence rates of nontyphoidal *Salmonella* based on two measures: numbers of confirmed (culture-positive) cases only; and numbers of positive culture-independent diagnostic tests (CIDTs) that were not confirmed by culture. These two methods yielded incidence rates of 15.4 cases per 100,000 persons and 16.7, respectively.[4] Both of these estimates are well above the national *Healthy People 2020* incidence goal of 11.4 cases per 100,000 people. The CDC estimates that additional efforts will be needed to reach this target.[25,26]

Although the 2016 crude overall incidence rate for nontyphoidal *Salmonella* infection among active component service members falls within the range of the estimates for the general U.S. population, the results are not directly comparable. The active component military population comprises young and middle-aged adults and includes a smaller proportion of females than the general U.S. population. Salmonellosis in the general U.S. population is most prevalent among children and adolescents less than 15 years old.[27] The 2015 *MSMR* report on *Salmonella* infections included counts of cases among other beneficiaries (family members and retirees) of the MHS.[10] In the earlier report, the age groups with the largest numbers of cases were the youngest and the oldest (children younger than 5 years old and adults aged 75 years or older).[10]

Many of the demographic patterns of nontyphoidal salmonellosis during the surveillance period are similar to those reported in 2015. As in the earlier report, crude overall incidence rates of nontyphoidal *Salmonella* infections were higher among female service members, non-Hispanic whites, those aged 25–29 years, and junior officers. Examination of the numbers of cases and incidence rates by occupational group in the current analysis showed that service members in healthcare occupations had the highest overall incidence rate of nontyphoidal salmonellosis, compared to service members in other occupational groups. State-level surveillance studies within the U.S. (MD, VA, OH) have demonstrated that healthcare workers are at increased risk of salmonellosis.[28]

Consistent with existing literature on temporal patterns of nontyphoidal *Salmonella* infections in the U.S., results of the current analysis showed a pattern of seasonality, with more cases diagnosed during the summer months than the winter months.[28-33] Higher temperatures in the summer could boost proliferation and survival of nontyphoidal salmonellae, potentially increasing pathogen load in animal reservoirs.[30,34,35] However, studies of temporal patterns in the occurrence of nontyphoidal *Salmonella* in livestock, raw meat, and poultry products and their relationship to human illnesses in the U.S. and Canada indicate that the seasonal increase in human cases precedes the seasonal increase in meat and poultry products.[30,34] Such results suggest that, even though contaminated meat and poultry products may be key vehicles of nontyphoidal *Salmonella* for humans, seasonal variations in the levels of animal infections are not necessarily the primary driver of the seasonality in human nontyphoidal salmonellosis.[32,36] For a predominantly foodborne illness such as salmonellosis, higher temperatures and their association with certain human activities (e.g., summer barbecuing) could enhance opportunities for food handling errors that contribute to seasonal enteric disease outbreaks.[29,36]

Review of TMDS records of deployed service members' medical encounters identified a total of 132 incident cases of nontyphoidal *Salmonella* infection. It is possible that the risks of infection in deployed settings differ from the risks in nondeployed settings and/or that the level of medical laboratory support during operations in austere environments may have limited the identification of nontyphoidal *Salmonella*.

This analysis has certain limitations that should be considered when interpreting the results. First, it should be noted that the annual rates presented in this report for 2007–2013 are slightly higher than those presented in the 2015 *MSMR* article.[10] This difference is primarily due to the fact that the current analysis included cases identified not just from RME records and records of inpatient and outpatient medical encounters but also from laboratory results provided by the NMCPHC. Laboratory results were not available for inclusion in the 2015 analysis.

Although the case-finding approach for this report was broad (administrative data from medical encounters, RME system, laboratory data), the actual number of cases of nontyphoidal salmonellosis during the surveillance period among active component service members was undoubtedly underestimated. Many individuals with acute gastrointestinal illnesses do not seek medical care and, of those who do seek care, many are not tested to determine the etiologies. Even when samples are collected, the sensitivity of the laboratory testing for nontyphoidal *Salmonella* may vary according to the type of test (culture vs. CIDTs) employed.[4] In addition, because NMCPHC does not have access to results of laboratory tests carried out in the civilian purchased care system, data on positive tests in that system were not available for this analysis. Finally, the diagnosis codes used to identify cases refer only to nontyphoidal *Salmonella* intestinal infections and do not provide information on species identified. The NMCPHC laboratory data also lacked information on species identified. Based on the data available for the current analysis, it was not possible to determine the extent to which cases of nontyphoidal *Salmonella* infection were outbreak-associated or sporadic (nonoutbreak) illnesses.

Many foodborne *Salmonella* infections can be prevented through standard measures (e.g., hand washing; thorough cleaning of cooking surfaces and utensils; appropriate storage and handling of food; thorough cooking of poultry, ground beef, and eggs). It is important to follow these standard prevention measures, especially during the summer months. Another common risk factor for salmonellosis is consumption of unpasteurized milk or other raw dairy products. In addition, in the U.S., outbreaks linked to contact with live

poultry have increased in recent years as more people maintain backyard flocks.[37] These outbreaks are a reminder of the importance of washing hands with soap and water after handling pets (especially reptiles and birds) and after contact with pet feces.

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REFERENCES

1. Coburn B, Grassl GA, Finlay BB. *Salmonella*, the host and disease: a brief review. *Immunol Cell Biol.* 2007;85(2):112–118.
2. Tindall BJ, Grimont PA, Garrity GM, Euzéby JP. Nomenclature and taxonomy of the genus *Salmonella*. *Int J Syst Evol Microbiol.* 2005;55(Pt 1):521–524.
3. Kumar S. *Essentials of Microbiology*. London, England: JP Medical Ltd.; 2015:277.
4. Marder EP, Cieslak PR, Cronquist AB, et al. Incidence and trends of infections with pathogens transmitted commonly through food and the effect of increasing use of culture-independent diagnostic tests on surveillance—Foodborne Diseases Active Surveillance Network, 10 U.S. sites, 2013–2016. *MMWR*. 2017;66(15):397–403.
5. Linam WM, Gerber MA. Changing epidemiology and prevention of *Salmonella* infections. *Pediatr Infect Dis J.* 2007;26(8):747–748.
6. Kennedy M, Villar R, Vugia DJ, et al. Hospitalizations and deaths due to *Salmonella* infections, FoodNet, 1996–1999. *Clin Infect Dis.* 2004;38(Suppl 3):S142.
7. Khabbaz RF, Moseley RR, Steiner RJ, et al. Challenges of infectious diseases in the USA. *Lancet*. 2014;384(9937):53–63.
8. Scallan E, Hoekstra RM, Angulo FJ, et al. Foodborne illness acquired in the United States—major pathogens. *Emerg Infect Dis.* 2011;17(1):7–15.
9. Armed Forces Health Surveillance Center. Gastrointestinal infections, active component, U.S. Armed Forces, 2002–2012. *MSMR*. 2013;20(10):7–11.
10. Clark LL, Daniele DO, O'Donnell FL. Incidence of *Salmonella* infections among service members of the active and reserve components of the U.S. Armed Forces and among other beneficiaries of the Military Health System, 2000–2013. *MSMR*. 2015;22(1):11–15.
11. Chen HM, Wang Y, Su LH, Chiu CH. Nontyphoid *Salmonella* infection: microbiology, clinical features, and antimicrobial therapy. *Pediatr Neonatol*. 2013;54(3):147–152.
12. Crump JA, Sjolund-Karlsson M, Gordon MA, Parry CM. Epidemiology, clinical presentation, laboratory diagnosis, antimicrobial resistance, and antimicrobial management of invasive *Salmonella* infections. *Clin Microbiol Rev.* 2015;28(4):901–937.
13. Barrow PA, Jones MA, Smith AL, Wigley P. The long view: *Salmonella* the last forty years. *Avian Pathol.* 2012;41(5):413–420.
14. Cosby DE, Cox NA, Harrison MA, Wilson JL, Buhr RJ, Fedorka-Cray PJ. *Salmonella* and antimicrobial resistance in broilers: a review. *J Appl Poultry Res.* 2015;24(3):408–426.
15. Braden CR. *Salmonella enterica* serotype Enteritidis and eggs: a national epidemic in the United States. *Clin Infect Dis*. 2006;43(4):512–517.
16. Foley SL, Nayak R, Hanning IB, et al. Population dynamics of *Salmonella enterica* serotypes in commercial egg and poultry production. *Appl Environ Microbiol.* 2011;77(13):4273–42799.
17. Centers for Disease Control and Prevention, National Outbreak Reporting System 2004-2008. www.cdc.gov/vitalsigns/pdf/2011-06-vitalsigns.pdf. Accessed on 6 June 2017.
18. Centers for Disease Control and Prevention, Multistate Outbreak of *Salmonella* Reading and *Salmonella* Abony Infections Linked to Alfalfa Sprouts, 2016. www.cdc.gov/salmonella/reading-08-16/index.html. Accessed on 6 June 2017.
19. Centers for Disease Control and Prevention, Multistate Outbreak of Salmonella Infections Linked to Alfalfa Sprouts from One Contaminated Seed Lot, 2016. www.cdc.gov/salmonella/muenchen-02-16/index.html. Accessed on 6 June 2017.
20. Centers for Disease Control and Prevention, Multistate Outbreak of *Salmonella* Poona Infections Linked to Imported Cucumbers, 2015. www.cdc.gov/salmonella/poona-09-15/. Accessed on 6 June 2017.
21. Medalla F, Gu W, Mahon BE, et al. Estimated incidence of antimicrobial drug-resistant nontyphoidal *Salmonella* infections, United States, 2004–2012. *Emerg Infect Dis.* 2016;23(1):29–37.
22. Centers for Disease Control and Prevention. National Antimicrobial Resistance Monitoring System for Enteric Bacteria (NARMS): Human Isolates Surveillance Report for 2014 (Final Report). U.S. Department of Health and Human Services, Atlanta, GA. 2016. www.cdc.gov/narms/reports/annual-human-isolates-report-2014.html. Accessed on 2 June 2017.
23. Marshall BM, Levy SB. Food animals and antimicrobials: impacts on human health. *Clin Microbiol Rev*. 2011;24(4):718–733.
24. Brown AC, Grass JE, Richardson LC, et al. Antimicrobial resistance in *Salmonella* that caused foodborne disease outbreaks: United States, 2003-2012. *Epidemiol Infect.* 2017;145(4):766–774.
25. U.S. Department of Health and Human Services. Office of the Assistant Secretary of Health. Office of Disease Prevention and Health Promotion. Healthy People 2020, Food Safety. www.healthypeople.gov/2020/topics-objectives/topic/food-safety/objectives. Accessed on 5 June 2017.
26. Crim SM, Iwamoto M, Huang JY, et al. Incidence and trends of infection with pathogens transmitted commonly through food—Foodborne Diseases Active Surveillance Network, 10 U.S. sites, 2006–2013. *MMWR*. 2014;63(15):328–332.
27. Adams D, Fullerton K, Jajosky R, et al. Summary of notifiable infectious diseases and conditions–United States, 2013. *MMWR*. 2015; 62(53):1–122.
28. Su C, de Perio M, Fagan K, et al. Occupational Distribution of Campylobacteriosis and Salmonellosis Cases–Maryland, Ohio and Virginia, 2014. Council of State and Territorial Epidemiologists. Annual conference, 2014. https://cste.confex.com/cste/2017/webprogram/Paper8266.html. Accessed on 13 June 2017.
29. Naumova EN, Jagai JS, Matyas B, et al. Seasonality in six enterically transmitted diseases and ambient temperature. *Epidemiol Infect*. 2007;135(2):281–292.
30. Lal A, Hales S, French N, Baker MG. Seasonality in human zoonotic enteric diseases: a systematic review. *PLoS One*. 2012;7(4):e31883.
31. Nesbitt A, Ravel A, Murray R, et al. Integrated surveillance and potential sources of *Salmonella* enteritidis in human cases in Canada from 2003 to 2009. *Epidemiol Inf.* 2012;140(10):1757–1772.
32. Williams MS, Ebel ED, Golden NJ, Schlosser WD. Temporal patterns in the occurrence of *Salmonella* in raw meat and poultry products and their relationship to human illnesses in the United States. *Food Control.* 2014;35(1):267–273.
33. Yun J, Greiner M, Höller C, Messelhäusser U, et al. Association between the ambient temperature and the occurrence of human *Salmonella* and *Campylobacter* infections. *Sci Rep*. 2016;Jun 21;6:28442.
34. Kovats RS, Edwards SJ, Hajat S, et al. The effect of temperature on food poisoning: a time-series analysis of salmonellosis in ten European countries. *Epidemiol Inf.* 2004;132(3):443–453.
35. D'Souza RM, Beeker NG, Hall G, Moodie KBA. Does ambient temperature affect foodborne disease? *Epidemiology.*2004;15(1):86–92.
36. Ravel A, Smolina E, Sargeant JM, et al. Seasonality in human salmonellosis: assessment of human activities and chicken contamination as driving factors. *Foodborne Pathog Dis.* 2010;7(7):785–794.
37. Centers for Disease Control and Prevention. Eight Multistate Outbreaks of Human Salmonella Infections Linked to Live Poultry in Backyard Flocks (Final Update). October 6, 2016. www.cdc.gov/salmonella/live-poultry-05-16/index.html. Accessed on 5 June 2017.

Incidence of *Shigella* Intestinal Infections, Active Component, U.S. Armed Forces, 2007–2016

Valerie F. Williams, MA, MS; Shauna Stahlman, PhD, MPH; Gi-Taik Oh, MS

During 2007–2016, there were 428 incident cases of *Shigella* infection among active component service members, with an overall crude incidence rate of 3.4 cases per 100,000 person-years (p-yrs). Compared to their respective counterparts, overall incidence rates were highest among females, non-Hispanic black service members, those aged 35–39 years, members of the Army, and those in military healthcare occupations. With the exception of 2015, the annual incidence rates of shigellosis from 2007 through 2016 were relatively stable. The annual incidence rate in 2015 was twice that of the rate in 2014 (6.4 cases per 100,000 p-yrs and 3.1 cases per 100,000 p-yrs, respectively). This peak was followed by a decrease to 3.4 cases per 100,000 p-yrs in 2016. There was no marked pattern of seasonality of *Shigella* infections during the 10-year surveillance period. During 2008–2016, a total of 23 cases of *Shigella* infection were diagnosed in deployment settings. Risk factors for *Shigella* infection and standard measures for the prevention of shigellosis are reviewed.

Diarrhea caused by bacteria of the *Shigella* genus is a major cause of morbidity and mortality worldwide, especially in developing countries.[1] In the U.S., *Shigella* is the third most commonly isolated bacterial enteric pathogen.[2] The genus *Shigella* includes four species: *S. dysenteriae*, *S. flexneri*, *S. boydii*, and *S. sonnei*.[1] Most cases of shigellosis in the U.S. are caused by *S. sonnei* followed by *S. flexneri*.[3] Now rare, *S. dysenteriae* type 1 was the most common isolate both in Europe and the U.S. in the early 1900s.[4] In the U.S, *S. dysenteriae* type 1 infection is generally limited to imported cases from Mexico and Central America or from confined populations such as in refugee camps.[4,5]

Shigella organisms can survive passage through the stomach because they are more resistant to acid than other bacteria.[6,7] Because of their relative acid resistance, as few as 10–100 *Shigella* organisms can produce disease.[8,9] After passing into the small intestine, *Shigella* bacteria multiply; large numbers of bacteria then pass into the colon, where they colonize the colonic mucosa.[9] *Shigella* transmission is through the fecal-oral route and can occur via direct person-to-person contact or indirectly through contaminated food, water, or fomites.[3] An infected person can be the source of infection for others from the time of illness onset until *Shigella* bacteria are no longer shed in the infected individual's feces.[3] Humans are the primary reservoir of *Shigella* species.[10]

Shigella gastroenteritis is generally characterized by high fever, abdominal cramps, and bloody, mucoid diarrhea (dysentery).[10] The range of illness severity varies depending on the serogroup of the infecting organism. *S. sonnei* commonly causes mild disease with a relatively short clinical course (5–7 days), which may be limited to watery diarrhea, while *S. dysenteriae* type 1 or *S. flexneri* commonly cause dysenteric symptoms.[2] *Shigella* species (particularly *S. flexneri* and *S. sonnei*) are among the most common causes of diarrheal disease among adults and children who live in the developing world as well as among U.S. military personnel deployed to these areas.[11-15] Several large outbreaks of severe gastroenteritis attributed to *Shigella* infection were reported among both American and British military personnel during the early phases of operations in Afghanistan and Iraq.[16-18]

In the U.S. and other developed countries, shigellosis is most common among children in daycare centers or elementary schools and their caretakers and teachers.[19] Secondary transmission has been estimated to exceed 30% in households with young children.[20] Others at increased risk of *Shigella* intestinal infection include people who have contact with recreational water,[21] international travelers,[22] and men who have sex with men.[23,24]

The Centers for Disease Control and Prevention (CDC) has estimated that approximately 130,000 cases of shigellosis result from foodborne transmission in the U.S. each year.[25] Although recognized outbreaks of foodborne shigellosis make a relatively small contribution to the overall burden of shigellosis in the U.S., foodborne transmission is likely responsible for many more sporadic cases that are not detected by outbreak surveillance.[25] It has been estimated that one-third of sporadic cases of shigellosis could be attributed to foodborne exposure after eliminating exposure to other select risk factors.[26] Foodborne shigellosis outbreaks have been associated with many types of raw and cooked foods including produce (e.g., lettuce-based salads) and commercially prepared/pre-cooked products (e.g., salsa, potato salad).[27,28] Infected food handlers and improper food-handling practices have been frequently shown to contribute to *Shigella* transmission. The broad range of foods implicated suggests that handling and preparation practices contribute to contamination across an array of food

products.[29] Because mixed transmission (transmission by direct and indirect routes) is likely in most shigellosis outbreaks, it can be difficult to attribute *Shigella* transmission to specific foods or other vehicles.[30]

The increasing antimicrobial resistance of *Shigella* species is a major problem in the treatment of *Shigella* gastroenteritis both in the U.S. and globally.[31] Among the *Shigella* isolates tested by the National Antimicrobial Resistance Monitoring System for Enteric Bacteria during 2014 (predominantly *S. flexneri* and *S. sonnei*), approximately 42% were resistant to three or more antimicrobial classes.[32]

This report summarizes the counts, rates, and trends of *Shigella* infections in active component service members over the past 10 years.

METHODS

The surveillance period was 1 January 2007 through 31 December 2016. The surveillance population consisted of all active component service members of the U.S. Armed Forces who served at any time during the surveillance period. Diagnoses of *Shigella* infection were derived from records of reports of notifiable medical events and from administrative records of all medical encounters of individuals who received care in fixed (i.e., not deployed or at sea) medical facilities of the Military Health System (MHS) or civilian facilities in the purchased care system. All such records are maintained in the electronic databases of the Defense Medical Surveillance System (DMSS). In addition, laboratory-confirmed cases of *Shigella* infection were identified from Navy and Marine Corps Public Health Center (NMCPHC) records of tested stool or rectal samples. Because laboratory results were not used in a previous *MSMR* report on the incidence of gastrointestinal infections attributed to *Shigella*, the contribution of laboratory results to the final case counts was determined.[14]

For surveillance purposes, an incident case of *Shigella* infection was defined as a service member having any one of the following: 1) a laboratory-confirmed identification of *Shigella* in a stool or rectal sample; 2) a reportable medical event (RME) record of "confirmed" *Shigella* infection; 3) a single hospitalization with any of the defining diagnoses for *Shigella* in any diagnostic position (ICD-9: 004.0–004.3, 004.8; ICD-10: A03.0–A03.3, A03.8); or 4) a single outpatient encounter with any of the defining diagnoses for *Shigella* in any diagnostic position. An individual could be considered a case once every 180 days. The incidence date was considered the first sample collection date for a laboratory-confirmed positive rectal or fecal sample, the date documented in an RME report, or the first hospitalization or outpatient medical encounter that included a defining diagnosis of *Shigella*. Incidence rates were calculated as the number of cases per 100,000 person-years (p-yrs).

Shigella infections that occurred during deployments (e.g., to Southwest Asia, Haiti) were analyzed separately. These cases were identified from the medical records of deployed service members that are documented in the Theater Medical Data Store (TMDS). TMDS data were available from 2008 through 2016. To qualify as an incident case during deployment, an individual needed a single medical encounter with a diagnosis of *Shigella* infection in TMDS that occurred between the start and end dates of a deployment.

RESULTS

During the 10-year surveillance period, there were 428 incident cases of *Shigella* infection among active component service members, with an overall crude incidence of 3.4 cases per 100,000 p-yrs **(Table)**. Of the total count of cases, 80 cases (18.7%) were based on laboratory results alone. The overall incidence rate of shigellosis was higher among female service members than males (5.5 cases per 100,000 p-yrs and 3.1 cases per 100,000 p-yrs, respectively). Compared to their respective counterparts, service members aged 35–39 years and Army members had the highest overall rates of shigellosis **(Table)**. Crude overall incidence rates were highest among non-Hispanic black service members and lowest among service members of other or unknown race/ethnicity (5.1

TABLE. Incident cases and incidence rates of *Shigella* infection, active component, U.S. Armed Forces, 2007–2016

	Total	
	No.	Rate[a]
Total	428	3.4
Sex		
Male	324	3.1
Female	104	5.5
Age group		
<20	9	1.1
20–24	88	2.2
25–29	118	4.0
30–34	91	4.7
35–39	79	5.4
40–44	32	3.7
45–49	8	2.3
50+	3	2.4
Race/ethnicity		
Non-Hispanic white	229	3.0
Non-Hispanic black	103	5.1
Hispanic	58	3.8
Other/unknown	38	2.9
Service		
Army	193	4.2
Navy	88	2.9
Air Force	121	3.9
Marine Corps	26	1.5
Rank/grade		
Junior enlisted (E1–E4)	132	2.5
Senior enlisted (E5–E9)	197	4.0
Junior officer (O1–O4)	76	4.8
Senior officer (O5–O10)	14	3.6
Warrant officer (WO1–WO5)	9	5.4
Status		
Recruit	3	1.2
Nonrecruit	425	3.5
Military occupation		
Combat-specific	44	2.7
Armor/motor transport	4	0.9
Pilot/air crew	18	3.9
Repair/engineering	113	3.1
Communications/ intelligence	108	3.9
Health care	70	6.3
Other	71	3.0

[a]Rate per 100,000 person-years

cases per 100,000 p-yrs and 2.9 cases per 100,000 p-yrs, respectively). Service members in healthcare occupations had the highest overall incidence rate of shigellosis (6.3 cases per 100,000 p-yrs), compared to service members in other occupational groups **(Table)**.

Annual incidence rates of *Shigella* infection decreased from 4.1 cases per 100,000 p-yrs in 2008 to 2.8 cases per 100,000 p-yrs in 2009 (33.3% decrease). Rates were relatively stable during 2009–2014 and ranged from 2.3 cases per 100,000 p-years in 2013 to 3.1 cases per 100,000 p-yrs in 2011. Rates peaked in 2015 at 6.4 cases per 100,000 p-yrs (approximately twice the rate for 2014) **(Figure 1)**. This peak was followed by a 45.8% decrease to 3.4 cases per 100,000 p-yrs in 2016.

During 2008–2016, a total of 23 incident cases of *Shigella* infection were identified among active component service members during deployment (e.g., to Southwest Asia, Haiti). Seven cases were documented in 2008, three in 2009, two in 2010, five in 2011, three in 2012, one in 2013, two in 2014, and zero in 2015 and 2016. The low number of cases did not allow for the identification of demographic patterns of *Shigella* infection during deployment.

The monthly distribution of the cumulative number of incident cases of *Shigella* infections during the 10-year surveillance period showed no pronounced pattern of seasonality. The largest number of infections was reported in June (n=55) **(Figure 2)**.

During the 10-year surveillance period, 376 (90.6% of total cases with available location information) diagnoses of *Shigella* infection were associated with U.S. medical facilities **(data not shown)**. Seven states accounted for slightly more than two-thirds (67.3%) of the cases associated with U.S. locations: Texas (n=79; 21.0%), California (n=40; 10.6%), Georgia (n=39; 10.4%), Florida (n=33; 8.8%), Maryland (n=22; 5.9%), Kentucky (n=20; 5.3%), and Virginia (n=20; 5.3%) **(data not shown)**. Medical facilities at 15 locations outside of the U.S. contributed 39 cases (9.4% of total cases with available location information). Three countries accounted for approximately two-thirds (66.6%) of these cases: Germany (n=16; 41.0%), South Korea (n=5; 12.8%), and Afghanistan (n=5; 12.8%) **(data not shown)**.

FIGURE 1. Annual numbers of incident cases and incidence rates of shigellosis, active component, U.S. Armed Forces, 2007–2016

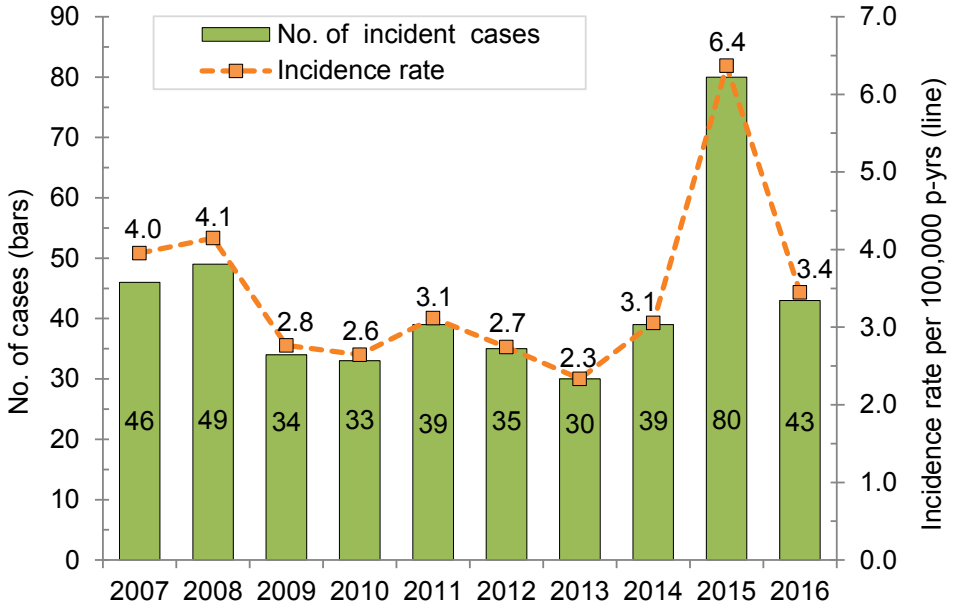
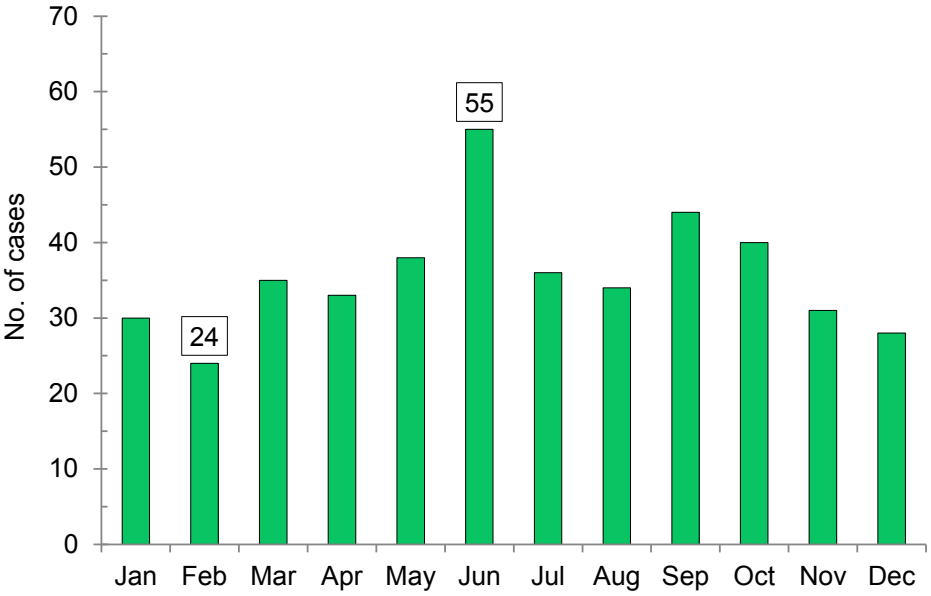


FIGURE 2. Cumulative number of incident cases of shigellosis, by calendar month, active component, U.S. Armed Forces, 2007–2016



EDITORIAL COMMENT

This report documents that, with the exception of 2015, the crude annual incidence rates of *Shigella* infections among active component service members from 2007 through 2016 were relatively stable. The annual incidence rate in 2015 was twice that of the rate in 2014 (6.4 cases per 100,000 p-yrs and 3.1 cases per 100,000 p-yrs, respectively).

Estimation of the burden of shigellosis is, for the most part, speculative because only a fraction of infected individuals seek medical care and are subsequently diagnosed.[23,24]

The CDC has estimated that the true burden of *Shigella* infections in the U.S. is almost nine times higher than reported case counts.[23] Results of time-series modeling that incorporated underreporting suggest that the shigellosis burden in the U.S. may be more than 10 times the number of laboratory-confirmed cases.[33] For 2016, two incidence rates of shigellosis were reported for the general U.S. population. One rate was based on numbers of cases confirmed by culture only and the other rate was based on numbers of cases identified using diagnostic tests other than culture (culture-independent diagnostic tests; CIDTs). These two laboratory methods yielded incidence rates of 4.6 cases per 100,000 persons and 5.9, respectively.[2] It is important to note that the crude incidence estimates generated by the current analysis are not directly comparable to CDC surveillance data for the general U.S. population. The active component military population comprises young and middle-aged adults. Shigellosis in the general U.S. population is most prevalent among children 2–4 years of age.[34,35]

There was no marked pattern of seasonality of *Shigella* infections during the 10-year surveillance period. Studies of shigellosis outbreaks in the U.S. generally report more pronounced seasonal variations with more cases occurring during the warmer months (June/July through October) than during the colder months.[29,33,36-38] The lack of a pronounced pattern of seasonality in the current analysis may reflect the importance of person-to-person transmission.[39]

Analysis of TMDS records of deployed service members' healthcare encounters during 2008–2016 identified relatively few diagnoses (n=23) of *Shigella* infections. It is possible that the risks of *Shigella* infection in deployed settings differ from the risks in non-deployed settings. It is also possible that, in an austere deployed environment, logistical barriers may have limited the availability of laboratory equipment and supplies as well as the transport of specimens sent from theater for analysis elsewhere.

The results of this report should be interpreted in light of several limitations. First, the findings presented here most certainly underestimate, to some degree, the true numbers and rates of *Shigella* infection during the surveillance period. For the current analysis, cases were identified from administrative data from medical encounters, the RME system, and laboratory data of confirmed *Shigella* infections. However, many individuals with acute gastrointestinal illnesses (particularly mild cases) do not seek medical care and thus go undiagnosed. Even if affected individuals do seek medical attention, some cases may not have stool or rectal swab samples tested for *Shigella* infection. For samples that are collected and tested, the sensitivity of the laboratory testing for *Shigella* may vary according to the type of test (culture vs. CIDTs) used. In addition, because NMCPHC does not have access to results of laboratory tests carried out in the civilian purchased care system, data on positive tests in that system were not available for this analysis. Finally, the diagnosis codes used to identify cases refer only to *Shigella* intestinal infections and do not provide information on species identified. The NMCPHC laboratory data also lacked information on species identified. The current analysis was unable to determine the extent to which cases of shigellosis were associated with outbreaks or were sporadic illnesses.

Strict compliance with human hygiene practices is the cornerstone of prevention of transmission of *Shigella*. Frequent and thorough hand washing with soap and water is an effective way to stop the spread of this and other enteric pathogens. Another common risk factor for shigellosis is swallowing water from ponds, lakes, or untreated swimming pools. International travelers should be aware of the risks for infection by multidrug-resistant *Shigella*, adhere to food and water precautions (e.g., drink only treated or boiled water, avoid uncooked foods), and wash hands with soap frequently.[40] High numbers of pre-prepared foods consumed raw or partially raw (e.g., salads, salsas) have been implicated in foodborne outbreaks of shigellosis.[29] Given increasing consumer preferences for ready-to-eat products and demand for fresh produce year-round, these foods deserve special attention with regard to control measures. Clinicians should request stool specimens or rectal swab cultures when they suspect *Shigella* infection and advise infected individuals to follow meticulous hygiene practices particularly while they are ill.

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REFERENCES

1. Zaidi MB, Estrada-García T. *Shigella*: A highly virulent and elusive pathogen. *Curr Trop Med Rep*. 2014;1(2):81–87.
2. Marder EP, Cieslak PR, Cronquist AB, et al. Incidence and trends of infections with pathogens transmitted commonly through food and the effect of increasing use of culture-independent diagnostic tests on surveillance—Foodborne Diseases Active surveillance network, 10 U.S. sites, 20132016. *MMWR*. 2017;66(15):397–403
3. Dekker J, Frank K. *Salmonella, Shigella*, and *Yersinia*. *Clin Lab Med*. 2015;35(2):255–256.
4. Parsonnet J, Greene KD, Gerber AR, Tauxe RV, Vallejo Aguilar OJ, Blake PA. *Shigella dysenteriae* type 1 infections in US travellers to Mexico, 1988. *Lancet*.1989;2(8662):543–545.
5. Department of Immunization, Vaccines, and Biologicals, World Health Organization. State of the art of new vaccine research and development. 2006. http://apps.who.int/iris/bitstream/10665/69348/1/WHO_IVB_06.01_eng.pdf. Accessed on 7 June 2017.
6. Zhao B, Houry WA. Acid stress response in enteropathogenic gammaproteobacteria: an aptitude for survival. *Biochem Cell Biol*. 2010;88(2):301–314
7. Phalipon A, Sansonetti PJ. *Shigella*'s ways of manipulating the host intestinal innate and adaptive immune system: a tool box for survival? *Immunol Cell Biol*. 2007;85(2):119–129.
8. DuPont HL, Levine MM, Hornick RB, Formal SB. Inoculum size in shigellosis and implications for expected mode of transmission. *J Infect Dis*. 1989;159(6):1126–1128.
9. Levinson WE. Review of Medical Microbiology and Immunology.11th ed. New York, NY: McGraw-Hill Companies, Inc.; 2010:30.
10. Hale TL, Keusch GT. Chapter 22: *Shigella*. *Medical Microbiology*. 4th ed. Baron S, ed. Galveston, TX: University of Texas Medical Branch at Galveston; 1996.
11. Hyams KC, Bourgeois AL, Merrell BR, et al. Diarrheal disease during Operation Desert Shield. *N Engl J Med*. 1991;325(20):1423–1428.
12. World Health Organization. Guidelines for the control of shigellosis, including epidemics due to *Shigella dysenteriae* type 1. Geneva: World Health Organization; 2005.
13. Kasper MR, Lescano AG, Lucas C, et al. Diarrhea outbreak during U.S. military training in El Salvador. *PloS One*. 2012;7(7):e40404.
14. Armed Forces Health Surveillance Center. Gastrointestinal infections, active component, U.S. Armed Forces, 2002–2012. *MSMR*. 2013;20(10):7–11.
15. Connor P, Porter CK, Swierczewski B, Riddle MS. Diarrhoea during military deployment: current concepts and future directions. *Curr Opin Infect Dis*. 2012;25(5):546–554.
16. Thornton S, Sherman S, Farkas T, et al.

Gastroenteritis in U.S. marines during Operation Iraqi Freedom. *Clin Infect Dis*. 2005;40(4):519–525.
17. Sanders JW, Putnam SD, Antosek LE, et al. A cross-sectional, case finding study of traveler's diarrhea among US military personnel deployed to Iraq [Abstract 697]. Annual Meeting of the American Society of Tropical Medicine and Hygiene. 2005. Washington, DC: American Society of Tropical Medicine and Hygiene.
18. Monteville MR, Riddle MS, Baht U, et al. Incidence, etiology, and impact of diarrhea among deployed U.S. military personnel in support of Operation Iraqi Freedom and Operation Enduring Freedom. *Am J Trop Med Hyg*. 2006;75(4):762–767.
19. Khan WA, Griffiths JK, Bennish ML. Gastrointestinal and extra-intestinal manifestations of childhood shigellosis in a region where all four species of *Shigella* are endemic. *PLoS One.* 2013;8(5):e64097.
20. Shane AL, Tucker NA, Crump JA, Mint ED, Painter JA. Sharing *Shigella:* risk factors of a multi-community outbreak of shigellosis. *Arch Pediatr Adolesc Med.* 2003;157(6):601–603.
21. Rosenberg ML, Hazlet KK, Schaefer J, Wells JG, Pruneda RC. Shigellosis from swimming. *JAMA*. 1976;236(16):1849–1852.
22. Toro C, Arroyo A, Sarria A, et al. Shigellosis in subjects with traveler's diarrhea versus domestically acquired diarrhea: implications for antimicrobial therapy and human immunodeficiency virus surveillance. *Am J Trop Med Hyg.* 2015;93(3):491.
23. Centers for Disease Control and Prevention. *Shigella flexneri* serotype 3 infections among men who have sex with men–Chicago, Illinois, 2003–2004. *MMWR.* 2005;54(33):820–822.
24. Hines JZ, Pinsent T, Rees K, et al. Notes from the field: Shigellosis outbreak among men who have sex with men and homeless persons–Oregon, 2015–2016. *MMWR*. 2016;65(31):812–813.
25. Scallan E, Hoekstra RM, Angulo FJ, et al. Foodborne illness acquired in the United States—major pathogens. *Emerg Infect Dis.* 2011;17(1):7–15.
26. Haley CC, Ong KL, Hedberg K, et al. Risk factors for sporadic shigellosis. FoodNet 2005. *Foodborne Pathog Dis.* 2010;7(7):741–747.
27. Agle ME, Martin SE, Blaschek HP. Survival of *Shigella boydii* 18 in bean salad. *J Food Prot*. 2005;68(4):838–840.
28. Warren BR, Yuk HG, Schneider KR. Survival of *Shigella sonnei* on smooth tomato surfaces, in potato salad and in raw ground beef. *Int J Food Microbiol*. 2007;116(3):400–404.
29. Nygren BL, Schilling KA, Blanton EM, Silk BJ, Cole DJ, Mintz ED. Foodborne outbreaks of shigellosis in the USA, 1998–2008. *Epidemiol Infect*. 2013;141(2):233–241.
30. Nygren B, Bowen A. Ch. 12—*Shigella*. Morris G, Jr., Potter M, eds. In: *Foodborne Infections and Intoxications.* 4th ed. Cambridge, MA: Academic Press;2013:217–222.
31. Klontz KC, Singh N. Treatment of drug-resistant *Shigella* infections. *Expert Rev Anti Infect Ther*. 2015;13(1):69–80.
32. Centers for Disease Control and Prevention. National Antimicrobial Resistance Monitoring System for Enteric Bacteria (NARMS): Human Isolates Surveillance Report for 2014 (Final Report). U.S. Department of Health and Human Services: Atlanta, GA 2016. www.cdc.gov/narms/reports/annual-human-isolates-report-2014.html. Accessed on 9 June 2017.
33. Joh RI, Hoekstra RM, Barzilay EJ, et al. Dynamics of shigellosis epidemics: estimating individual-level transmission and reporting rates from national epidemiologic data sets. *Am J Epidemiol*. 2013;178(8):1319–1326.
34. Lee LA, et al. Hyperendemic Shigellosis in the United States: A Review of Surveillance Data for 1967–1988. *J Infect Dis.* 1991;164(5):894–900.
35. Centers for Disease Control and Prevention. Preliminary FoodNet Data on the Incidence of Infection with Pathogens Transmitted Commonly Through Food—10 States, United States, 2005. *MMWR*. 2006;55(14):392–395.
36. Gupta A, Polyak CS, Bishop RD, Sobel J, Mintz ED. Laboratory-confirmed shigellosis in the United States, 1989–2002: epidemiologic trends and patterns. *Clin Infect Dis*. 2004;38(10):1372–1377.
37. Naumova EN, Jagai JS, Matyas B, DeMaria A Jr, MacNeill IB, Griffiths JK. Seasonality in six enterically transmitted diseases and ambient temperature. *Epidemiol Infect*. 2007;135(2):281–292.
38. Wikswo ME, Hall AJ, Centers for Disease Control and Prevention. Outbreaks of acute gastroenteritis transmitted by person-to-person contact—United States, 2009–2010. *MMWR*. 2012;61(9):1–12.
39. Bowman C, Flint J, Pollari F. Canadian integrated surveillance report: *Salmonella*, *Campylobacter*, pathogenic *E. coli* and *Shigella*, from 1996 to 1999. *Can Comm Dis Rep*. 2003;29(Suppl 1):1–6.
40. American Public Health Association. Shigellosis. Heymann DL, ed. In: *Control of Communicable Diseases Manual.* 20th ed. Washington, DC: American Public Health Association;2015:488–489.

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Using Records of Diagnoses from Healthcare Encounters and Laboratory Test Results to Estimate the Incidence of Norovirus Infections, Active Component, U.S. Armed Forces, 2007–2016: Limitations to This Approach

Leslie L. Clark, PhD, MS; Shauna Stahlman, PhD, MPH; Gi-Taik Oh, MS

During the 10-year surveillance period, there were 709 incident cases of norovirus (NoV) infection identified among active component service members, with an overall crude incidence rate of 5.7 cases per 100,000 person-years (p-yrs). The overall incidence rate of NoV infection was slightly higher among female service members than males. Compared to their respective counterparts, service members aged 24 years or younger, members of the Army, junior enlisted, and recruits had the highest rates of NoV infection. Overall rates were similar across all race/ethnicity groups. Service members in "other" occupations had the highest overall incidence rate, compared to service members in other occupational groups. Annual incidence rates of NoV infection ranged from a low of 2.5 cases per 100,000 p-yrs in 2008 to 11.2 cases per 100,000 p-yrs in 2010. The monthly distribution of the cumulative number of incident cases of NoV infection during the surveillance period showed a pattern of seasonality with higher numbers of diagnosed cases from November through March. Comparing the results of this analysis to modeled estimates of the underreported incidence of NoV infections demonstrated the limited utility of using only medical encounter diagnoses, reportable events, and laboratory data to report on NoV incidence. The disparity between such estimates highlights the importance of developing and using other methodologies to derive estimates of norovirus incidence and burden in future analyses.

Norovirus (NoV) is a highly infective and easily transmitted pathogen that imposes a significant public health burden across geographic regions and in all age groups. It is estimated to be the causative pathogen in almost one-fifth (18%) of all diarrhea cases worldwide.[1,2] In the U.S., NoV is the most common cause of acute gastroenteritis (AGE) outbreaks, hospitalizations, and deaths.[3] In active component U.S. military members, NoV has been estimated to cause 31% of all in-garrison AGE-related medical encounters and has also been responsible for numerous outbreaks in deployed troops.[4,5]

NoV symptoms (e.g., vomiting, diarrhea) usually occur within 24–48 hours after ingestion of contaminated food or water or contact with an infected individual. Symptoms generally are self-limiting in healthy individuals and resolve within 2–3 days. There are currently no specific treatments approved for NoV infections except supportive care.

Noroviruses (NoV) are nonenveloped, single-stranded, positive-sense ribonucleic acid (RNA) viruses belonging to the Caliciviridae family. The NoV genus comprises dozens of genetically diverse strains that are divided into at least six genogroups (G). Three of these genogroups infect humans (GI, GII, and GIV) and genogroup II genotype 4 (GII.4) noroviruses are the most prevalent and clinically significant. Immunity to NoV is of limited duration and is strain- or genotype-specific.[6] Although significant advances have been made toward the development of a NoV vaccine, the genetic diversity and rate of antigenic evolution of NoV have proven to be major complicating factors in vaccine development.[6,7]

This report estimates the incidence of NoV diagnoses among active component service members during a 10-year surveillance period using medical record documentation of diagnoses of NoV infection and of positive laboratory tests for the virus. The limitations of this methodology are discussed.

METHODS

The surveillance period was 1 January 2007 through 31 December 2016. The surveillance population consisted of all active component service members of the U.S. Armed Forces who served at any time during the surveillance period. Diagnoses of NoV infection were derived from records of reports of notifiable medical events and from administrative records of all medical encounters of individuals who received care in fixed (i.e., not deployed or at sea) medical facilities of the Military Health System (MHS) or civilian facilities in the purchased care system. All such records are maintained in the electronic databases of the Defense Medical Surveillance System (DMSS). In addition, laboratory-confirmed cases of NoV infection were identified from Navy and Marine Corps Public Health Center

(NMCPHC) records of tested stool or rectal samples. The contribution of laboratory results to the final case counts was determined.

For surveillance purposes, an incident case of NoV infection was defined as a service member having any one of the following: 1) a laboratory-confirmed identification of NoV in a stool or rectal sample, 2) an RME record of "confirmed" NoV infection, 3) a single hospitalization with any of the defining diagnoses for NoV infection in any diagnostic position (ICD-9: 008.63; ICD-10: A08.11), or 4) a single outpatient encounter with any of the defining diagnoses for NoV infection in any diagnostic position. An individual could be considered a case once every 180 days. The incidence date was considered the first sample collection date for a laboratory-confirmed positive rectal or fecal sample, the date documented in a reportable medical event report, or the first hospitalization or outpatient medical encounter that included a defining diagnosis of NoV infection. Incidence rates were calculated as the number of cases per 100,000 person-years (p-yrs).

NoV infections that occurred during deployments (e.g., to Southwest Asia, Haiti) were analyzed separately. These cases were identified from the medical records of deployed service members that are documented in the Theater Medical Data Store (TMDS). TMDS data were available from 2008 through 2016. To qualify as an incident case during deployment, an individual needed a single medical encounter with a diagnosis of NoV infection in TMDS that occurred between the start and end dates of a deployment.

RESULTS

During the 10-year surveillance period, there were 709 incident cases of NoV infection identified among active component service members, with an overall crude incidence rate of 5.7 cases per 100,000 p-yrs **(Table)**. Of the total count of cases, 56 cases (7.9%) were based on laboratory results alone. The overall incidence rate of NoV infection was slightly higher among female service members than males (6.0 cases per 100,000 p-yrs and 5.7 cases per 100,000 p-yrs, respectively). Service members aged 24 years or younger had higher rates of NoV infection than any of the other age groups. Compared to their respective counterparts, members of the Army, junior enlisted, and recruits had the highest rates of NoV infection **(Table)**. Crude overall incidence rates were similar across all race/ethnicity groups. Service members in "other" occupations (which include those in training) had the highest overall incidence rate, compared to service members in other occupational groups **(Table)**.

Annual incidence rates of NoV infection ranged from a low of 2.5 cases per 100,000 p-years in 2008 to a high of 11.2 cases per 100,000 p-yrs in 2010 **(Figure 1)**.

Between 2008 and 2016, a total of 20 incident cases of NoV infection were identified among active component service members during deployment (e.g., to Southwest Asia, Haiti), with an overall crude incidence rate of 1.9 cases per 100,000 p-yrs. Half of the total number of cases (n=10) were diagnosed in 2011 while the number of diagnoses in other years ranged from zero to three **(data not shown)**.

The monthly distribution of the cumulative number of incident cases of NoV infection during the 10-year surveillance period demonstrated a pattern of seasonality with higher numbers of diagnosed cases from November through March and the largest number of infections in March (n=145) **(Figure 2)**.

EDITORIAL COMMENT

This report represents the first time the *MSMR* has reported on diagnoses of norovirus infection in the entire population of active component service members. During the 10-year surveillance period, the total number of incident NoV diagnoses identified through ICD-9 and ICD-10 diagnostic codes was 709. This is undoubtedly a significant underestimate of the true number of NoV cases in the

TABLE. Incident cases and incidence rates of norovirus infection, active component, U.S. Armed Forces, 2007–2016

	Total 2007–2016	
	No.	Rate[a]
Total	709	5.7
Sex		
Male	596	5.7
Female	113	6.0
Age group		
<20	63	7.5
20–24	275	7.0
25–29	177	6.0
30–34	94	4.9
35–39	61	4.2
40–44	23	2.6
45–49	12	3.4
50+	4	3.2
Race/ethnicity		
Non-Hispanic white	451	6.0
Non-Hispanic black	109	5.4
Hispanic	88	5.7
Other/unknown	61	4.6
Service		
Army	321	7.1
Navy	137	4.6
Air Force	169	5.5
Marine Corps	82	4.6
Rank/grade		
Junior enlisted (E1–E4)	387	7.2
Senior enlisted (E5–E9)	252	5.1
Junior officer (O1–O4)	56	3.6
Senior officer (O5–O10)	10	2.6
Warrant officer (WO1–WO5)	4	2.4
Status		
Recruit	18	7.0
Nonrecruit	691	5.7
Military occupation		
Combat-specific	92	5.6
Armor/motor transport	23	5.1
Pilot/air crew	14	3.0
Repair/engineering	178	4.9
Communications/ intelligence	164	6.0
Health care	65	5.8
Other	173	7.2

[a]Rate per 100,000 person-years

FIGURE 1. Annual numbers of incident cases and incidence rates of norovirus infection, active component, U.S. Armed Forces, 2007–2016

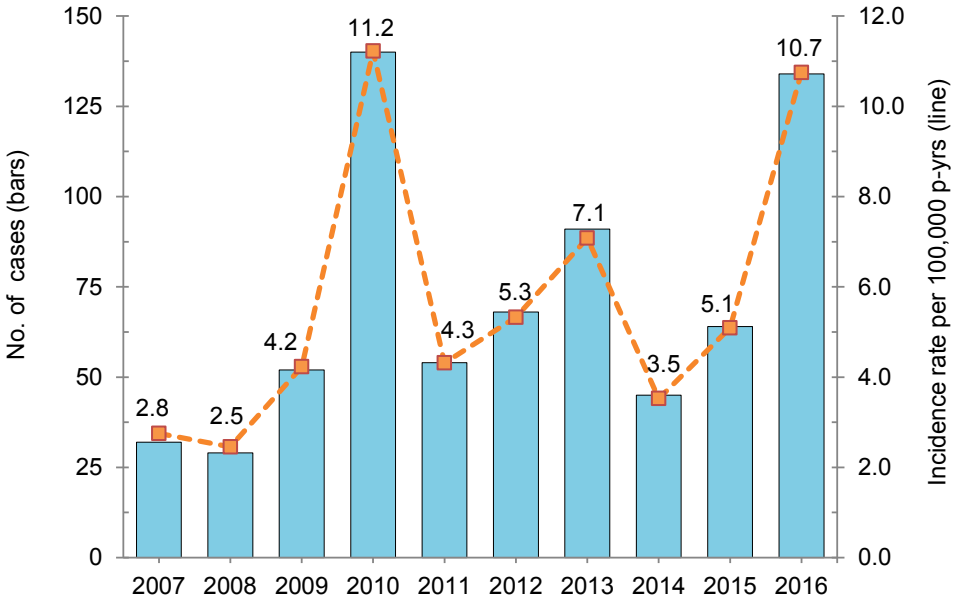
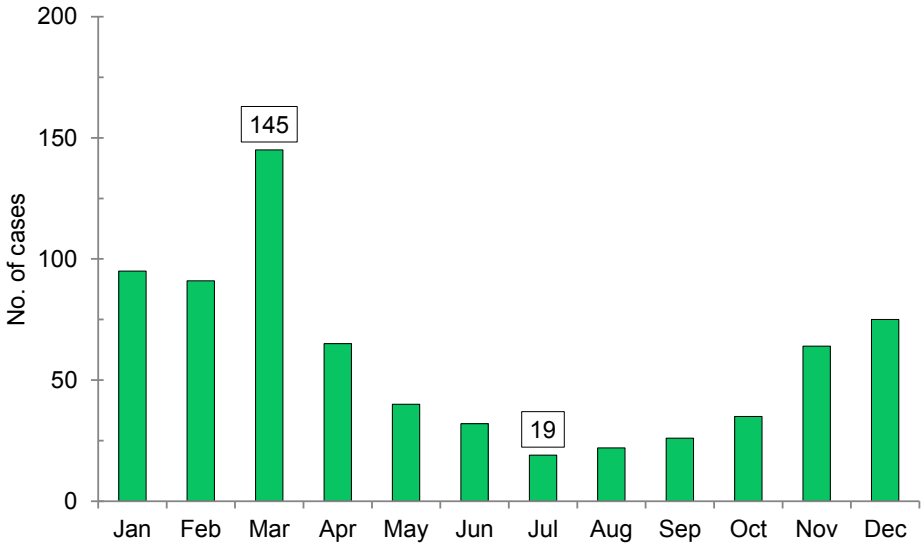


FIGURE 2. Cumulative number of incident cases of norovirus infection, by calendar month, active component, U.S. Armed Forces, 2007–2016



active component population during this time period. There are several reasons why underestimation likely occurred. A significant percentage of individuals with NoV infection may not seek medical care and, therefore, go undiagnosed. In addition, NoV infection is unlikely to be laboratory-confirmed at the same time as a healthcare encounter for clinical assessment of a patient experiencing an AGE episode. Even during an outbreak, a limited number of specimens are tested to identify the presumed causative agent. Thus, a majority of records of health care for AGE episodes are coded using a non-specific diagnosis (e.g. "unspecified diarrhea" and/or "vomiting") without attributing the episode to a specific pathogen.

In 2016, Rha and colleagues utilized diagnostic codes from AGE-related medical encounters of active component military members and beneficiaries to develop a model to estimate norovirus-attributable medical encounters from nonspecific encounters in the data.[4] This approach estimated that approximately 42,000 norovirus-attributable medical encounters occurred per year in active component military members. This is equivalent to a rate of 292 encounters per 10,000 p-yrs.[4] This estimated rate is four to five times higher than reported rates in U.S. civilian populations using similar modeling strategies and the difference may be a result of model assumptions. However, the higher rates may also reflect a real increased risk of contracting NoV infection among military members. Military members are often placed in settings that are likely to increase their risk of NoV infection, including recruit training and housing, aboard ship, and austere deployment locations.

Relatively few NoV cases were ascertained in theater through the use of TMDS data. Of note, the greatest number of TMDS NoV diagnoses occurred during 2011, which corresponds to reported norovirus outbreaks in two camps in Kuwait that occurred while a preventive medicine detachment with enhanced laboratory capabilities was deployed. These enhanced capabilities provided access to real-time PCR diagnostic testing for specimens which significantly reduced turnaround times for test results and may have contributed to the increased numbers of NoV diagnoses during 2011.[8]

Despite the clear underascertainment of total NoV cases, the counts and rates of NoV infection reported for subsets of the surveillance population in this analysis represent findings consistent with known NoV epidemiology. For example, a clear pattern of seasonality (with increased numbers of diagnoses during winter months) was demonstrated. The finding that younger enlisted service members had the highest crude NoV infection rates may be attributable to the increased likelihood that these service members were living and working together in closer proximity than their more senior counterparts.

This analysis demonstrated the limited utility of using only medical encounter diagnoses, reportable events, and laboratory data to report on NoV incidence, and highlights the importance of developing and using other methodologies (e.g., modeling, attributable proportion methods) to derive estimates of norovirus incidence and burden in future analyses.

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REFERENCES

1. Ahmed SM, Hall AJ, Robinson AE, et al. Global prevalence of norovirus in cases of gastroenteritis: a systematic review and meta-analysis. *Lancet Infect Dis.* 2014;14(8):725–730.
2. Lopman BA, Steele D, Kirkwood CD, Parashar UD. The vast and varied global burden of norovirus: prospects for prevention and control. *PLoS Med.* 2016;13(4):e1001999.
3. Hall AJ, Lopman BA, Payne DC, et al. Norovirus disease in the United States. *Emer Infect Dis.* 2013;19(8):1198–1205.
4. Rha B, Lopman BA, Alcala AN, Riddle MS, Porter CK. Incidence of norovirus-associated medical encounters among active duty United States military personnel and their dependents. *PLOS One.* 2016;11(4):1–14.
5. Armed Forces Health Surveillance Center. Historical perspective: norovirus gastroenteritis outbreaks in military forces. *MSMR.* 2011;18(11):7–8.
6. De Graaf M, Van Beek J, Koopmans MP. Human norovirus transmission and evolution in a changing world. *Nat Rev Microbiol.* 2016;14:421–433.
7. Riddle MS, Walker RI. Status of vaccine research and development for norovirus. *Vaccine.* 2016;34(26):2895–2899.
8. Thompson KR, Mossel EC, Federman B, Claborn DM. Does reducing time to identification of infectious agents reduce incidence rates of norovirus in a population deployed to Southwest Asia? *US Army Med Dep J.* 2016;(3–16):42–51.

Incidence of *Escherichia coli* Intestinal Infections, Active Component, U.S. Armed Forces, 2007–2016

Valerie F. Williams, MA, MS; Shauna Stahlman, PhD, MPH; Gi-Taik Oh, MS

During 2007–2016, there were 290 incident cases of *Escherichia coli* infection among active component service members, with an overall crude incidence rate of 2.3 cases per 100,000 person-years (p-yrs). Subgroup-specific rates were higher among service members aged 50 years or older and those aged 25–29 years than those in other age groups. Compared to their respective counterparts, females, non-Hispanic white service members, members of the Air Force, and service members in healthcare occupations had the highest rates of *E. coli* infection. Crude overall incidence rates were highest among senior enlisted service members and junior officers, compared to those in other ranks/grades. Annual incidence rates of *E. coli* infection among active component service members peaked in 2011(3.4 cases per 100,000 p-yrs) and in 2016 (4.7 cases per 100,000 p-yrs) but otherwise were relatively stable. The monthly distribution of the cumulative number of incident cases of infections during the 10-year period showed a modest pattern of seasonality. During 2008–2016, a total of 14 incident cases of *E. coli* infection were identified among active component service members during deployments. Standard measures for the prevention of intestinal *E. coli* infection are reviewed.

Escherichia coli are members of the normal microbiota of the lower intestines of humans and other mammals and certain types of *E. coli* are among the most frequent bacterial causes of diarrhea.[1] Diarrheagenic *E. coli* can be classified into five major groups or pathotypes according to virulence mechanisms, serologic characteristics, and the clinical syndrome they produce*:* enterotoxigenic (ETEC), enteropathogenic (EPEC), enterohemorrhagic (EHEC), enteroinvasive (EIEC), and enteroaggregative (EAEC).[1,2] Other groups are recognized but are less well described as pathogens (e.g., diffusely adherent [enteroadherent] *E. coli*).[1]

ETEC bacteria are noninvasive, colonizing the mucosal surface of the small intestine.[2] ETEC strains are associated with two main clinical syndromes: diarrhea among children under two years of age in the developing world and traveler's diarrhea.[1,3-6] In addition, ETEC is emerging as a significant diarrheal pathogen in developed regions.[7,8] Contaminated food and water have been implicated as the most common vehicles for ETEC infection.[7,9,10] The presence of ETEC in rivers, untreated drinking water, irrigation water, and sea water has been demonstrated repeatedly.[11-13] ETEC's ability to adhere firmly to fresh vegetables increases risk for its transmission.[9,14,15] Illness due to ETEC has a short incubation period with a rapid onset of symptoms.[1] Infected individuals may report nausea, but vomiting is uncommon.[2] ETEC causes profuse watery diarrhea that may be mild, brief (1–5 days), and self-limiting or may include severe purging.[1,2] Most patients recover with supportive measures alone and do not require hospitalization or antibiotics.[2]

EPEC strains are defined by their hallmark attaching-and-effacing histopathology (changes they elicit when they interact with epithelial cells) and by the fact that they do not produce Shiga toxin.[1] EPEC have been associated with sporadic diarrheal illness as well as outbreaks of diarrhea, usually among children younger than 6 months old in developing countries.[16,17] As with other diarrheagenic *E. coli* strains, transmission of EPEC occurs via the fecal-oral route, with contaminated hands, contaminated baby foods, or contaminated fomites acting as vehicles.[1,2] The spread of EPEC infection through nurseries, daycare centers, and hospitals from an index case has been reported in numerous studies.[18-20] EPEC diarrhea in children may be severe and accompanied by vomiting and dehydration.[19] Protracted illness may result in weight loss, malnutrition, and death, particularly in regions of the developing world where resources for supportive care may be limited.[21]

EHEC are a subset of Shiga toxin-producing *E. coli* (STEC) that cause hemorrhagic colitis and are often associated with hemolytic uremic syndrome (microangiopathic anemia, renal failure, and thrombocytopenia).[1] The prototype strain, *E. coli* O157:H7, is associated with both outbreaks and sporadic cases of severe disease.[1,2] The most common route of transmission of EHEC is ingestion of undercooked ground beef.[1] However, spread through consumption of other food products has been documented (e.g., unpasteurized apple cider).[22] Many of the largest outbreaks have occurred in the U.S., Canada, Europe, and Japan.[1] EHEC is also an important pathogen in some countries in the southern hemisphere including Argentina, Australia, Chile, and South Africa.[1] In the northern hemisphere, there is a pronounced seasonality to EHEC infection, with most cases reported in the summer.[23]

EIEC strains are closely related to

shigellae and cause dysenteric illness similar to shigellosis.[2] EIEC bacteria invade the interstitial epithelial cells of the large intestine, multiply within them, and extend into adjacent intestinal cells.[2] EIEC illness is self-limiting and typically begins as watery diarrhea and may or may not progress to bloody mucoid diarrhea.[1] Prior to outbreaks in Europe in 2012 (Italy) and 2014 (U.K.), reports of EIEC outbreaks were uncommon in developed regions.[24-26] The occurrence of these outbreaks may suggest a possible undocumented increase in this pathogen in Europe.[26] Clinicians and laboratories may not be aware of EIEC as a potential pathogen for diarrhea, particularly when affected individuals seem to have contracted the illness within the U.K. Frontline diagnostic tests are often unable to differentiate EIEC from nonpathogenic *E. coli*.[24]

EAEC is the most recently recognized diarrheagenic *E. coli* pathotype and represents a heterogeneous group of *E. coli* strains.[1,2] EAEC bacteria have been identified as a top cause of persistent and acute diarrheal illness among many demographic groups in both developing and developed regions and have been associated with both outbreaks and sporadic cases of diarrhea.[1,2,27] The transmission of EAEC most often is described as being foodborne, and as such, it is most likely spread by the fecal-oral route.[2,27] Contaminated water, baby formula, bean sprouts, and unpasteurized dairy products have been implicated in outbreaks in industrialized countries.[27] Diarrhea caused by EAEC is often watery but can be accompanied by blood or mucus.[28] EAEC illness is most frequently reported as self-limiting and as typically being associated with mild symptoms.[27]

Infectious diarrhea among deployed military forces remains an important cause of morbidity and can threaten the operational efficiency of affected units.[29] Epidemiologic investigations identified ETEC and EAEC as primary pathogens isolated from U.S. troops deployed to Iraq and Afghanistan (OIF/OEF).[30,31] According to Riddle and colleagues' review of studies of diarrhea prevalence among U.S. military and similar populations, ETEC and EAEC were identified as causing 22% and 13% of diarrheal illness, respectively, with regional differences.[32]

This report summarizes the counts, rates, and trends of *E. coli* gastrointestinal infections in active component service members over the past 10 years.

METHODS

The surveillance period was 1 January 2007 through 31 December 2016. The surveillance population consisted of all active component service members of the U.S. Armed Forces who served at any time during the surveillance period. Diagnoses of *E. coli* infection were derived from records of reports of notifiable medical events and from administrative records of all medical encounters of individuals who received care in fixed (i.e., not deployed or at sea) medical facilities of the Military Health System (MHS) or civilian facilities in the purchased care system. All such records are maintained in the electronic databases of the Defense Medical Surveillance System (DMSS). In addition, laboratory-confirmed cases of *E. coli* infection were identified from Navy and Marine Corps Public Health Center (NMCPHC) records of tested stool or rectal samples. Because laboratory results were not used in a previous *MSMR* report on the incidence of gastrointestinal infections attributed to *E. coli,* the contribution of laboratory results to the final case counts was determined.[33]

For surveillance purposes, an incident case of *E. coli* infection was defined as a service member having any one of the following: 1) a laboratory-confirmed identification of *E. coli* in a stool or rectal sample, 2) a reportable medical event (RME) record of "confirmed" *E. coli* infection, 3) a single hospitalization with any of the defining diagnoses for *E. coli* in any diagnostic position (ICD-9: 008.00–008.09; ICD-10: A04.0–A04.4), or, 4) a single outpatient encounter with any of the defining diagnoses for *E. coli* in any diagnostic position. An individual could be considered a case once every 180 days. The incidence date was considered the first sample collection date for a laboratory-confirmed positive rectal or fecal sample, the date documented in a reportable medical event report, or the first hospitalization or outpatient medical encounter that included a defining diagnosis of *E. coli*. Incidence rates were calculated as the number of cases per 100,000 person-years (p-yrs). In addition, incident cases of *E. coli* gastrointestinal infection were summarized by data source and pathotype.

E. coli infections that occurred during deployments (e.g., to Southwest Asia, Haiti) were analyzed separately. These cases were identified from the medical records of deployed service members that are documented in the Theater Medical Data Store (TMDS). TMDS data were available from 2008 through 2016. To qualify as an incident case during deployment, an individual needed a single medical encounter with a diagnosis of *E. coli* infection in TMDS that occurred between the start and end dates of a deployment.

RESULTS

During 2007–2016, there were 290 incident cases of *E. coli* infection among active component service members **(Table)**. Only nine cases (3.1% of total) would not have been identified as such without the NMCPHC laboratory data. The overall crude incidence rate for the 10-year period was 2.3 cases per 100,000 p-yrs **(Table)**. The overall incidence rate of *E. coli* infection among female service members was two times that of males (4.0 cases per 100,000 p-yrs and 2.0 cases per 100,000 p-yrs, respectively). Subgroup-specific rates were higher among service members aged 50 years or older and those aged 25–29 years than those in other age groups. Compared to their respective counterparts, non-Hispanic white service members and members of the Air Force had the highest rates of *E. coli* infection **(Table)**. Crude overall incidence rates were highest among senior enlisted service members and junior officers, compared to those in other ranks/grades. Service members in healthcare occupations had the highest overall incidence rate of *E. coli* infection, compared to service members in other occupational groups **(Table)**.

TABLE. Incident cases and incidence rates of *Escherichia coli* infection, active component, U.S. Armed Forces, 2007–2016

	Total 2007–2016	
	No.	Rate[a]
Total	290	2.3
Sex		
Male	214	2.0
Female	76	4.0
Age group		
<20	14	1.7
20–24	73	1.9
25–29	90	3.1
30–34	48	2.5
35–39	33	2.3
40–44	19	2.2
45–49	9	2.6
50+	4	3.2
Race/ethnicity		
Non-Hispanic white	191	2.5
Non-Hispanic black	38	1.9
Hispanic	30	1.9
Other/unknown	31	2.4
Service		
Army	121	2.7
Navy	51	1.7
Air Force	96	3.1
Marine Corps	22	1.2
Rank/grade		
Junior enlisted (E1–E4)	115	2.1
Senior enlisted (E5–E9)	128	2.6
Junior officer (O1–O4)	41	2.6
Senior officer (O5–O10)	2	0.5
Warrant officer (WO1–WO5)	4	2.4
Status		
Recruit	3	1.2
Nonrecruit	287	2.4
Military occupation		
Combat-specific	24	1.5
Armor/motor transport	8	1.8
Pilot/air crew	10	2.1
Repair/engineering	75	2.1
Communications/intelligence	79	2.9
Health care	40	3.6
Other	54	2.2

[a]Rate per 100,000 person-years

Annual incidence rates of *E. coli* infection were relatively stable during the first 4 years of the surveillance period and ranged from 1.6 cases per 100,000 p-years in 2010 to 2.1 cases per 100,000 p-yrs in 2007. The annual rate increased to 3.4 cases per 100,000 p-yrs in 2011 and then decreased to 2.0 cases per 100,000 p-yrs in 2012. Annual incidence rates of *E. coli* infection remained relatively low between 2012 and 2015 and then peaked in 2016 at 4.7 cases per 100,000 p-yrs (an increase of 94.8% between 2015 and 2016) **(Figure 1)**.

The monthly distribution of the cumulative number of incident cases of *E. coli* infections during the 10-year surveillance period showed a modest pattern of seasonality. The 7 months from May through November (58.6% of the year) accounted for 69.3% of all cases during the 10-year period. The counts of cases in each of the 5 cooler months (December–April) were lower than the monthly counts for every one of the other 7 months **(Figure 2)**.

During the 10-year surveillance period, 116 medical facilities were associated with diagnoses of *E. coli* infection. Facilities at U.S. locations accounted for more than four-fifths (81.4%; n=192) of the cases with valid location information **(data not shown)**. Six states accounted for 45.2% of the these cases and included Texas (n=35; 18.4%), California (n=25; 13.2%), Maryland (n=9; 4.7%), New York (n=9; 4.7%), Hawaii (n=8; 4.2%), and Mississippi (n=8; 4.2%) **(data not shown)**. Facilities at six locations outside of the U.S. accounted for 18.6% (n=44) of cases with valid location information **(data not shown)** and included Germany (n=30; 68.2%), Japan (n=5; 11.4%), Turkey (n=4; 9.1%), Italy (n=2; 4.5%), South Korea (n=2; 4.5%), and the U.K. (n=1; 2.3%).

During 2008–2016, a total of 14 incident cases of *E. coli* infection were identified among active component service members during deployments (e.g., to Southwest Asia, Haiti) **(data not shown)**. Two cases were documented in 2008, three in 2009, one in 2010, 0 in 2011, one in 2012, zero in 2013 and 2014, three in 2015, and four in 2016. The very low number of cases did not allow for the identification of demographic patterns of *E. coli* infection during deployment.

Examination by data source and pathotype showed that the majority of *E. coli* infections ascertained from medical encounter records (n=222) were categorized as "intestinal infection due to *E. coli* unspecified" (n=97; 43.7%) or "intestinal infection due to other *E. coli* infections" (n=74; 33.3%) **(data not shown)**. Incident infections identified from medical encounter records with pathotype information accounted for the remaining cases and included EPEC (n=22; 9.9%), ETEC (n=13; 5.9%), EHEC (n=12; 5.4%), and EIEC (n=4; 1.8%). For the majority (n=11; 84.6%) of the 13 cases ascertained from laboratory results, STEC was recorded as the causative agent. Six of these cases were labeled as O157:H7, one as O157:H16, and one as "O157 PCR" **(data not shown)**. For three of the STEC cases, "Shiga toxin 1/2" was recorded as the causative agent. "Shiga-like toxin producing *E. coli*" was recorded as the causative agent for the remaining case identified from laboratory results. For all of the 55 cases ascertained from RME records, STEC was recorded as the causative agent **(data not shown)**. STEC infections are the only *E. coli* infections considered an RME.

EDITORIAL COMMENT

This report documents that, during 2007–2016, annual incidence rates of *E. coli* infection among active component service members peaked in 2011(3.4 cases per 100,000 p-yrs) and in 2016 (4.7 cases per 100,000 p-yrs). During 2007–2010 and 2012–2015, rates were relatively stable.

The burden of *E. coli* intestinal infections is extremely difficult to ascertain. Because few diarrheagenic *E. coli* pathotypes can be identified using technology that is widely (or even currently) available, a significant proportion of outbreaks and sporadic infections undoubtedly go undetected. Several major challenges limit the detection of diarrheagenic *E. coli*. First, diagnosis at clinical presentation is seldom possible because, except for O157:H7 and non-OH157:H7 STEC, diarrhea-causing *E. coli* have no readily

FIGURE 1. Annual numbers of incident cases and incidence rates of *Escherichia coli* infection, active component, U.S. Armed Forces, 2007–2016

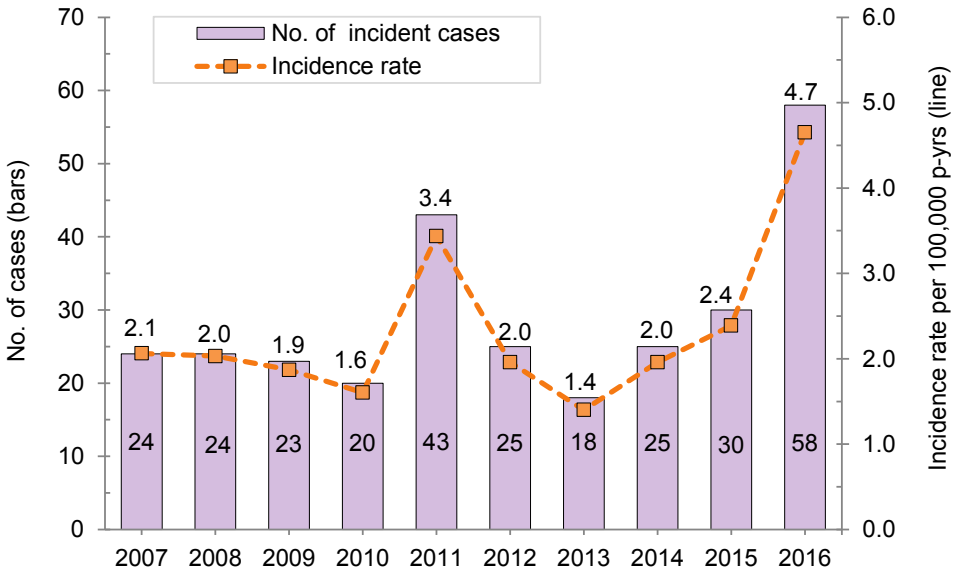
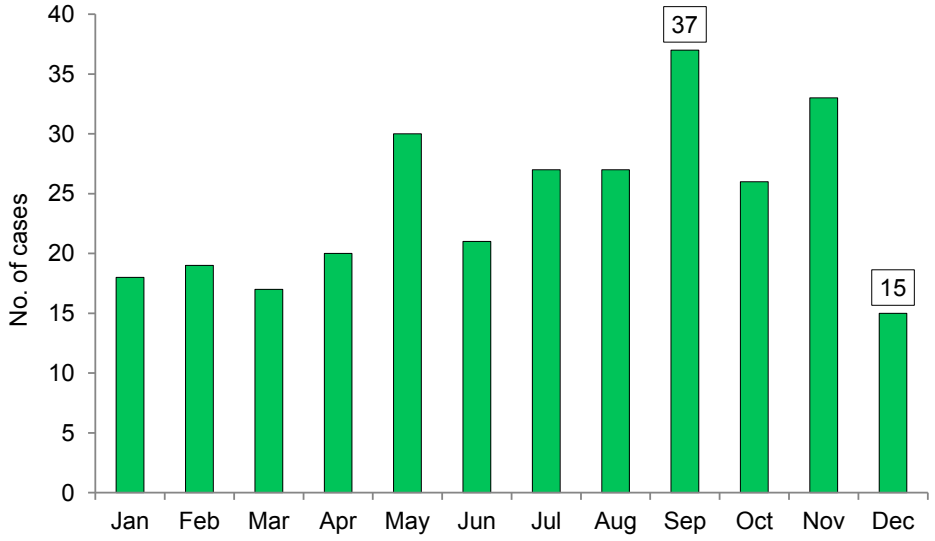


FIGURE 2. Cumulative number of incident cases of *Escherichia coli* infection by calendar month, active component, U.S. Armed Forces, 2007–2016



identifiable observable features that distinguish them from other *E. coli* (or even *Shigella* spp.) present in stool samples.[34] The detection and differentiation of diarrheagenic *E. coli* depends, for the most part, on complex phenotypic determinations (e.g., patterns of adherence to cells, toxicity assays) and/or molecular diagnostic techniques, which may not be widely available.[34] In addition, with the exception of EHEC, most illnesses caused by diarrheagenic *E. coli* are self-limiting and resolve without causing major injury to the host.[2] Individuals affected by mild diarrheal illness may not seek medical care allowing no opportunity for clinical assessment. Finally, even during an outbreak, a limited number of specimens are tested to identify the presumed causative agent. Thus, a majority of records for diarrhea are coded using non-specific diagnoses (e.g., "intestinal infection due to *E. coli*, unspecified" or "intestinal infection due to other *E. coli* infections") without attributing the illness to a specific *E. coli* pathotype.

STEC is the only pathogenic *E. coli* monitored by the Centers for Disease Control and Prevention's (CDC's) Foodborne Diseases Active Surveillance Network. For 2016, the CDC estimated incidence rates of STEC based on two measures: numbers of confirmed (culture-positive) cases only; and, numbers of positive culture-independent diagnostic tests (CIDTs) that were not confirmed by culture. These two methods yielded incidence rates of 2.85 and 3.76 cases per 100,000 persons, respectively.[35] Both of these estimates are well above the national *Healthy People 2020* STEC incidence goal of 0.6 cases per 100,000 people and the CDC has noted that additional efforts are needed to reach this target.[36,37]

During 2008–2016, relatively few cases of *E. coli* infection were identified in theater using TMDS data. It is possible that the risks of acquiring *E. coli* infections in deployed settings are different from the risks in non-deployed settings. It is important to note that the molecular diagnostic techniques and toxin assays needed to identify certain pathotypes of diarrheagenic *E. coli* may not be available in an austere forward deployed environment. Given these constraints, it is likely that the low number of total cases ascertained from TMDS data is due, at least in part, to a limited ability to identify and differentiate pathogenic *E. coli*.

The monthly counts of cases of *E. coli* infections during the 10-year surveillance period tended to be modestly higher in the warmer months of the year. However, other studies of diarrheagenic *E. coli* infection have demonstrated more marked seasonality with the highest incidence in warmer months (June–August in the northern hemisphere) and lower incidence in cooler months.[38] Modest increases also have been seen in months with higher than average rainfall.[38] An increase of 1.8°F in mean temperature is associated with an 8% increase in the incidence of diarrheagenic *E. coli*, not controlling for

precipitation.[38] Higher temperatures can boost replication rates and survival of bacteria in the environment and can result in alterations in *E. coli* gene expression.[39] Research on *E. coli* O157 has shown both greater transmission at warmer ambient temperatures and decreased survival of bacteria during periods of temperature variability.[40] In addition, during warmer months, human exposure may be higher and increased pathogen loading from animal reservoirs may also occur.[41]

As previously noted, it is not unexpected that the majority (77.9%) of medical encounter records for *E. coli* intestinal infection were coded using non-specific diagnoses ("intestinal infection due to *E. coli*, unspecified" or "intestinal infection due to other *E. coli* infections"). The distribution of pathotypes ascertained from medical encounter records and laboratory results likely reflects, at least in part, the availability of diagnostic techniques for identifying and differentiating diarrheagenic *E. coli*.

This analysis has additional limitations that should be considered when interpreting the results. First, results of laboratory tests performed in the civilian purchased care system are not available to the NMCPHC, so positive tests in that system were not available for this analysis. Also, this analysis was unable to determine the extent to which cases of *E. coli* intestinal infection were associated with outbreaks or were sporadic illnesses.

Prevention of *E. coli* intestinal infections, in general, depends on sanitary measures to prevent fecal-oral transmission. Hands should be washed thoroughly with soap and water after using the bathroom, after changing diapers, and after any contact with animals or their living environments (e.g., at farms, petting zoos, fairs).[1,2] Frequent and thorough handwashing is also important before and after preparing or eating food. Food preparation surfaces and utensils should be washed after each use. Washing fruits and vegetables can remove dirt and reduce the amount of bacteria on the surface of the produce. It is important to note, however, that rinsing may not be sufficient to remove adherent bacteria because pathogenic *E. coli*, including ETEC, adheres firmly to leafy vegetables (e.g., lettuce, spinach).[15,34] To prevent cross-contamination, meat, poultry, seafood and eggs should be kept separate from all other foods during shopping and while refrigerated. Perishable foods should be refrigerated promptly. All meat and meat products should be cooked thoroughly before consumption. Beef steaks and roasts should be cooked to an internal temperature of at least 145°F and allowed to rest for several minutes after removing from the stove or grill. Ground beef and pork should be cooked to a minimum internal temperature of 160°F.[42] Use of a food thermometer is recommended to verify that meat has reached a safe internal temperature. Other common risk factors for *E. coli* intestinal infection include consumption of unpasteurized milk or other raw dairy products, unpasteurized fruit juices, and water from recreational sources (e.g., swimming pool, lakes, ponds, streams). International travelers should adhere to food and water precautions (e.g., drink treated or boiled water only, avoid uncooked foods), and wash hands with soap frequently.[43]

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REFERENCES

1. Nataro JP, Kaper JB. Diarrheagenic *Escherichia coli*. *Clin Microbiol Rev*. 1998;1(2):142.
2. Parija SC. *Textbook of Microbiology and Immunology*. 2nd ed. New Delhi, India: Reed Elsevier India Private Ltd; 2012:254–256.
3. Qadri F, Svennerholm AM, Faruque AS, Sack RB. Enterotoxigenic *Escherichia coli* in developing countries: epidemiology, microbiology, clinical features, treatment, and prevention. *Clin Microbiol Rev.* 2005;18(3):465–483.
4. Fischer Walker CL, Sack D, Black RE. Etiology of diarrhea in older children, adolescents and adults: a systematic review. *PLoS Negl Trop Dis.* 2010;4(8):e768.
5. Kotloff KL, Nataro JP, Blackwelder WC, et al. Burden and aetiology of diarrhoeal disease in infants and young children in developing countries (the Global Enteric Multicenter Study, GEMS): a prospective, case-control study. *Lancet.* 2013;382(9888):209–222.
6. Lamberti LM, Bourgeois AL, Fischer Walker CL, Black RE, Sack D. Estimating diarrheal illness and deaths attributable to Shigellae and enterotoxigenic *Escherichia coli* among older children, adolescents, and adults in South Asia and Africa. *PLoS Negl Trop Dis.* 2014;8(2):e2705.
7. Beatty ME, Adcock PM, Smith SW, et al. Epidemic diarrhea due to enterotoxigenic *Escherichia coli. Clin Infect Dis.* 2006;42(3):329–334.
8. Devasia RA, Jones TF, Ward J, et al. Endemically acquired foodborne outbreak of enterotoxin-producing *Escherichia coli* serotype O169:H41. *Am J Med*. 2006;119(2):168.e7–168.e10.
9. Gonzales-Siles L, Sjoling A. The different ecological niches of enterotoxigenic *Escherichia coli. Environ Microbiol*. 2015;18(3):741–751.
10. MacDonald E, Moller KE, Wester AL, et al. An outbreak of enterotoxigenic *Escherichia coli* (ETEC) infection in Norway, 2012: a reminder to consider uncommon pathogens in outbreaks involving imported products. *Epidemiol Infect.* 2015;143(3):486–493.
11. Lothigius A, Janzon A, Begum Y, et al. Enterotoxigenic *Escherichia coli* is detectable in water samples from an endemic area by real-time PCR. *J Appl Microbiol.* 2008;104(4):1128–1136.
12. Lothigius A, Sjoling A, Svennerholm AM, Bolin I. Survival and gene expression of enterotoxigenic *Escherichia coli* during long-term incubation in sea water and freshwater. *J Appl Microbiol.* 2010;108(4):1441–1449.
13. Cabral JP. Water microbiology. Bacterial pathogens and water. *Int J Environ Res Public Health*. 2010;7(10):3657–3703.
14. Ethelberg S, Lisby M, Bottiger B, et al. Outbreaks of gastroenteritis linked to lettuce, Denmark, January 2010. *Euro Surveill.* 2010;15(6):pii 19484.
15. Shaw RK, Berger CN, Pallen MJ, Sjoling A, Frankel G. Flagella mediate attachment of enterotoxigenic *Escherichia coli* to fresh salad leaves. *Environ Microbiol Rep.* 2011;3(1):112–117.
16. Rothbaum R, McAdams AJ, Giannella R, Partin JC. A clinicopathologic study of enterocyte-adherent *Escherichia coli*: a cause of protracted diarrhea in infants. *Gastroenterology.* 1982;83(2):441–454.
17. Ulshen MH, Rollo JL. Pathogenesis of *Escherichia coli* gastroenteritis in man—another mechanism. *N Engl J Med.* 1980;302(2):99–101.
18. Bower JR, Congeni BL, Cleary TG, et al. *Escherichia coli* O114: nonmotile as a pathogen in an outbreak of severe diarrhea associated with a day care center. *J. Infect. Dis*. 1989;160(2):243–247.
19. Levine MM, Edelman R. Enteropathogenic *Escherichia coli* of classic serotypes associated with infant diarrhea: epidemiology and pathogenesis. *Epidemiol Rev*. 1984;6:31–51.
20. Wu SX, Peng RQ. Studies on an outbreak of neonatal diarrhea caused by EPEC O127:H6 with plasmid analysis restriction analysis and outer membrane protein determination. *Acta Paediat.* 1992;81(3):217–221.
21. Ciccarelli S, Stolfi I, Caramia G. Management strategies in the treatment of neonatal and pediatric gastroenteritis. *Infect Drug Resist*. 2013;6:133–161.
22. Besser RE, Lett SM, Weber JT, et al. An outbreak of diarrhea and hemolytic uremic syndrome from *Escherichia coli* O157H7 in fresh-pressed apple cider. *JAMA*. 1993;269(17):2217–2220.
23. Ferens WA, Hoyde CJ. *Escherichia coli* O157:H7: animal reservoir and sources of human infection. *Foodborne Pathog Dis*. 2011;8(4):465–487.
24. Escher M, Scavia G, Morabito S, et al. A severe foodborne outbreak of diarrhoea linked to a canteen in Italy caused by enteroinvasive *Escherichia coli*, an uncommon agent. *Epidemiol Infect*. 2014;142(12):2559–2566.
25. Michelacci V, Prosseda G, Maugliani A, et

al. Characterization of an emergent clone of enteroinvasive *Escherichia coli* circulating in Europe. *Clin Microbiol Infect*. 2016;22(3):287.e11-9.
26. Newitt S, MacGregor V, Robbins V, et al. Two linked enteroinvasive *Escherichia coli* outbreaks, Nottingham, UK, June 2014. *Emerg Infect Dis*. 2016;22(7):1178–1184.
27. Hebbelstrup Jensen B, Olsen KE, Struve C, Krogfelt KA. Epidemiology and clinical manifestations of enteroaggregative *Escherichia coli. Clin Microbiol Rev*. 2014;27(3):614–630.
28. Huang DB, Mohamed JA, Nataro JP, DuPont HL, Jiang ZD, Okhuysen PC. Virulence characteristics and the molecular epidemiology of enteroaggregative *Escherichia coli* isolates from travelers to developing countries. *J Med Microbiol*. 2007;56(Pt 10):1386–1392.
29. Connor P, Porter CK, Swierczewski B, Riddle MS. Diarrhoea during military deployment: current concepts and future directions. *Curr Opin Infect Dis*. 2006;25(5):546–554.
30. Monteville MR, Riddle MS, Baht U, et al. Incidence, etiology, and impact of diarrhea among deployed U.S. military personnel in support of Operation Iraqi Freedom and Operation Enduring Freedom. *Am J Trop Med Hyg*. 2006;75(4):762–767.
31. Sanders JW, Putnam SD, Antosek LE, et al. A cross-sectional, case finding study of traveler's diarrhea among U.S. military personnel deployed to Iraq [Abstract 697]. Annual Meeting of the American Society of Tropical Medicine and Hygiene. 2005. Washington, DC: American Society of Tropical Medicine and Hygiene.
32. Riddle MS, Sanders JW, Putnam SD, Tribble DR. Incidence, etiology and impact of diarrhea among long-term travelers (U.S. military and similar populations): a systematic review. *Am J Trop Med Hyg*. 2006;74(5): 891–900.
33. Armed Forces Health Surveillance Center. Gastrointestinal infections, active component, U.S. Armed Forces, 2002–2012. *MSMR*. 2013;20(10):7–11.
34. Estrada-Garcia T, Hodeges K, Hecht GA, Tarr PL. Ch. 8—*Escherichia coli.* Morris G, Jr., Potter M, eds. In: *Foodborne Infections and Intoxications*. 4th ed. Cambridge, MA: Academic Press;2013:129–164.
35. Marder EP, Cieslak PR, Cronquist AB, et al. Incidence and trends of infections with pathogens transmitted commonly through food and the effect of increasing use of culture-independent diagnostic tests on surveillance—foodborne diseases active surveillance network, 10 U.S. sites, 2013–2016. *MMWR*. 2017;66(15):397–403.
36. U.S. Department of Health and Human Services. Office of the Assistant Secretary of Health. Office of Disease Prevention and Health Promotion. Healthy People 2020, Food Safety. www.healthypeople.gov/2020/topics-objectives/topic/food-safety/objectives. Accessed on 5 June 2017.
37. Crim SM, Iwamoto M, Huang JY, et al. Incidence and trends of infection with pathogens transmitted commonly through food—Foodborne Diseases Active Surveillance Network, 10 U.S. sites, 2006–2013. *MMWR*. 2014;63(15):328–332.
38. Philipsborn R, Ahmed SM, Brosi BJ, Levy K. Climatic drivers of diarrheagenic *Escherichi coli i*ncidence: a systematic review and meta-analysis. *J Infect Dis*. 2016;214(1):6–15.
39. van Elsas JD, Semenov AV, Costa R, Trevors JT. Survival of *Escherichia coli* in the environment: fundamental and public health aspects. *ISME J*. 2011;5(2):173–183.
40. Semenov AV, van Bruggen AH, van Overbeek L, Termorshuizen AJ, Semenov AM. Influence of temperature fluctuations on *Escherichia coli* O157:H7 and *Salmonella enterica* serovar Typhimurium in cow manure. *FEMS Microbiol Ecol*. 2007;60(3):419–428.
41. Lal A, Hales S, French N, Baker MG. Seasonality in human zoonotic enteric diseases: a systematic review. *PLoS One*. 2012;7(4):e31883.
42. Centers for Disease Control and Prevention. Shiga Toxin-Producing *E. coli* & Food Safety. https://www.cdc.gov/features/ecoliinfection/index.html. Accessed on 19 June 2017.
43. Centers for Disease Control and Prevention. Enterotoxigenic *E. coli* (ETEC). https://www.cdc.gov/ecoli/etec.html. Accessed on 19 June 2017.

(Source: U.S. Department of Agriculture)

Surveillance Snapshot: Annual Incidence Rates and Monthly Distribution of Cases of Gastrointestinal Infection, Active Component, U.S. Armed Forces, 2007–2016

FIGURE 1. Annual incidence rates of five most common diagnoses of gastrointestinal infection (*solid lines*) and of unspecified gastroenteritis/diarrhea (*dashed line*), active component, U.S. Armed Forces, 2007–2016

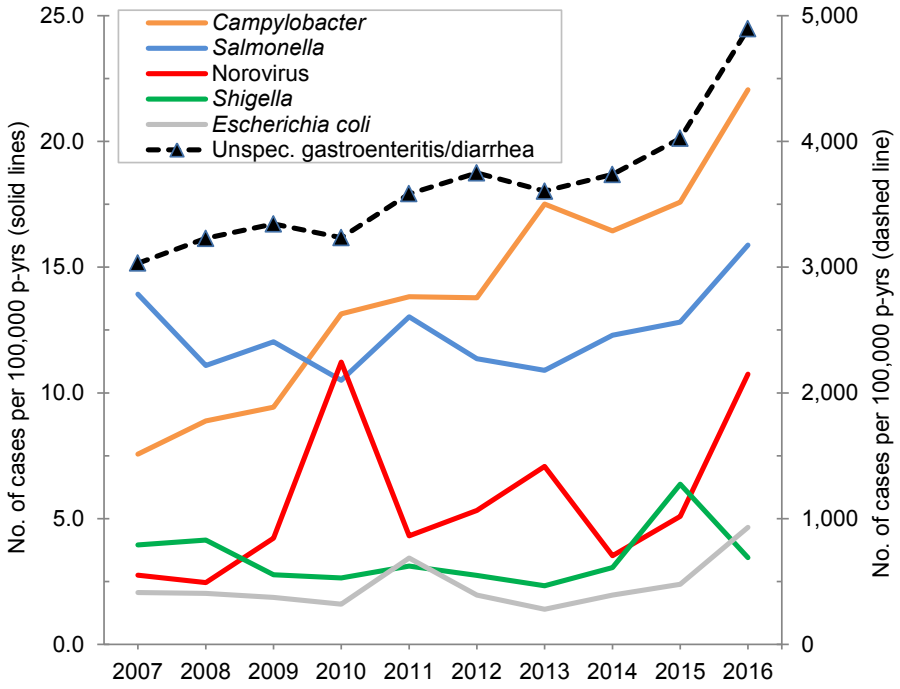
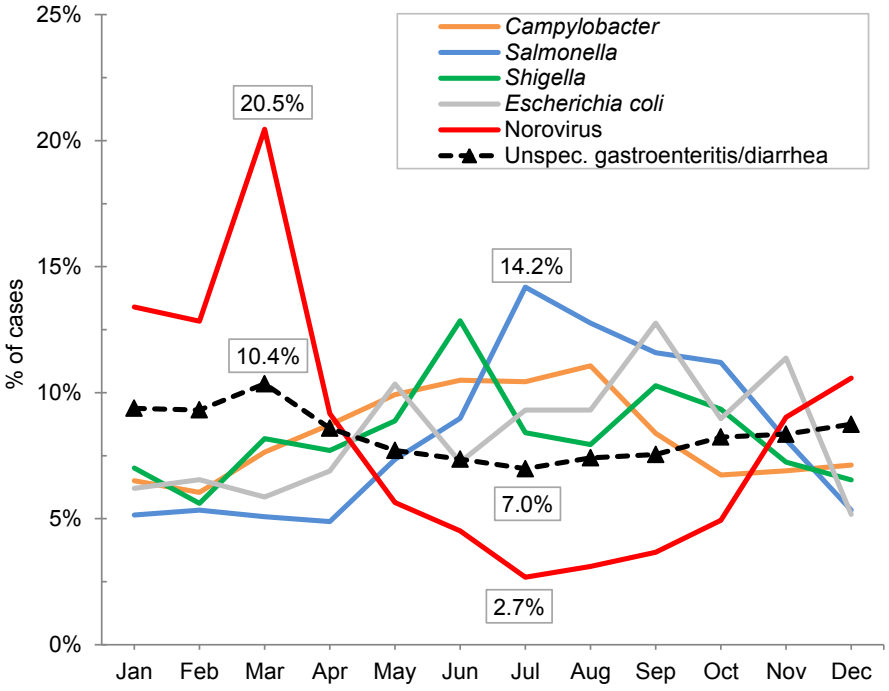


FIGURE 2. Percentage distribution, by month of diagnoses, for each of the five most common types of gastrointestinal infection and for unspecified gastroenteritis/diarrhea, active component, U.S. Armed Forces, 2007–2016



The five preceding articles in the June 2017 *MSMR* examined the incidence rates and other epidemiologic characteristics of the five most common diagnoses of gastrointestinal infections among active component service members.

Figure 1 compares the annual incidence rates of the five gastrointestinal diagnoses during the surveillance period of 2007–2016. In addition, the figure shows another line depicting the annual incidence rates of diagnoses of unspecified gastroenteritis/diarrhea. A noteworthy finding is that the annual rates of diagnosed *Campylobacter* infections have steadily increased since 2007 and have surpassed those of *Salmonella* infections in every year after 2009. Annual incidence rates have remained relatively stable for diagnoses of *Shigella* and *Escherichia coli* infections and have risen slightly for *Salmonella* and norovirus. Rates for unspecified diarrhea were more than 80 times the combined rates of the specific pathogens, and have steadily increased during the period. It should be noted that the Centers for Disease Control and Prevention estimates that norovirus infections are by far the most common cause of gastroenteritis in the U.S. It is highly likely that the data on norovirus infections among active component service members are significant underestimates of the actual incidence because the data in this report reflect only diagnosed cases and laboratory confirmations of norovirus infections.

Figure 2 uses the distribution of cases by calendar month to illustrate the variations in the proportions of cases that occur by month throughout the years 2007–2016. Most dramatic is the observation that cases of norovirus infections are diagnosed much more often in the winter months than the summer months. For example, of all norovirus infections diagnosed during the 10-year surveillance period, 20.5% were detected during the month of March. For the bacterial pathogens shown, cases are more often diagnosed during the warmer months of the year, although cases are detected year round for every organism depicted. For the diagnoses of unspecified gastroenteritis/diarrhea, November–April had the highest proportions of the total for the period, and May–October had the lowest proportions.

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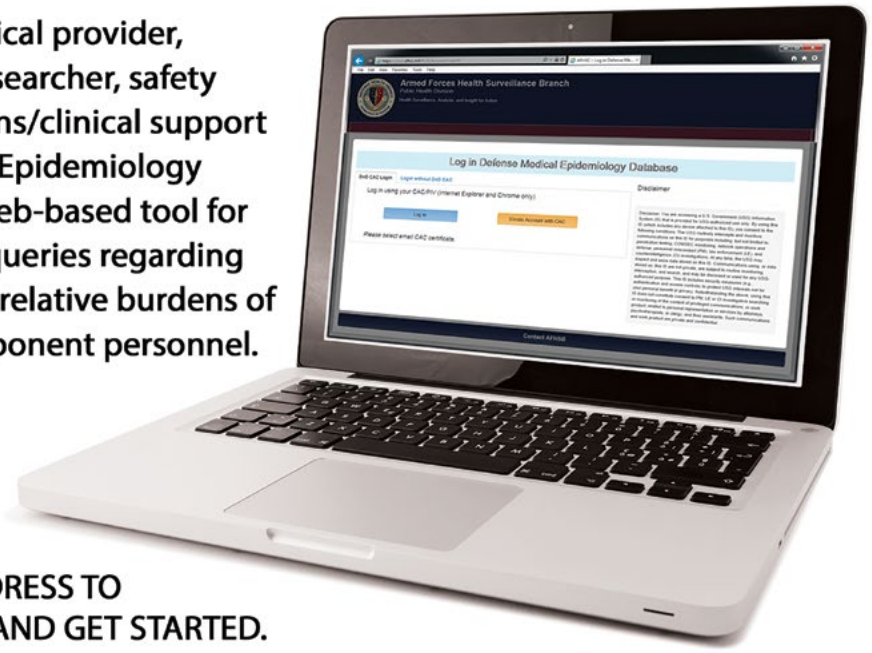

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