Brief Report

PUBLIC HEALTH REPORTS

Public Health Reports
00(0) 1-5

DOI: 10.1177/00333549211026777
journals.sagepub.com/home/phr
SAGE

Changing Trends in Age and Sex Distributions of Lyme Disease—United States, 1992-2016

Kiersten J. Kugeler, PhD, MPH[1]; Paul S. Mead, MD, MPH[1]; Amy M. Schwartz, MPH[1]; and Alison F. Hinckley, PhD[1]

Abstract

Lyme disease is the most common vector-borne disease in the United States and is characterized by a bimodal age distribution and male predominance. We examined trends in reported cases during a 25-year period to describe changes in the populations most affected by Lyme disease in the United States. We examined demographic characteristics of people with confirmed cases of Lyme disease reported to the Centers for Disease Control and Prevention during 1992-2016 through the National Notifiable Diseases Surveillance System. We grouped cases into 5-year periods (1992-1996, 1997-2001, 2002-2006, 2007-2011, 2012-2016). We calculated the average annual incidence by age and sex and used incidence rate ratios (IRRs) to describe changes in Lyme disease incidence by age and sex over time. We converted patient age at time of illness into patient birth year to ascertain disease patterns according to birth cohorts. The incidence of Lyme disease in the United States doubled from 1992-1996 to 2012-2016 (IRR = 1.74; 95% CI, 1.70-1.78) and increased disproportionately among males; IRRs were 39%-89% higher among males than among females for most age groups. During the study period, children aged 5-9 years were most frequently and consistently affected. In contrast, the average age of adults with Lyme disease increased over time; of all adults, people born during 1950-1964 were the most affected by Lyme disease. Our findings suggest that age-related behaviors and susceptibilities may drive infections among children, and the shifting peak among adults likely reflects a probability proportional to the relative size of the baby boom population. These findings can inform targeted and efficient public health education and intervention efforts.

Keywords

Lyme disease, epidemiology, surveillance, demographic

Lyme disease is a tickborne illness caused by certain genospecies of *Borrelia burgdorferi* sensu lato.[1] Since the inception of standardized public health surveillance for Lyme disease in the United States in the early 1990s, information has accumulated about the relative frequency, geographic distribution, and demographic characteristics of people most affected.[2,3] Lyme disease is not only the most common vector-borne disease in the United States but often is the second or third most common of all notifiable conditions in highly affected states.[4] The geographic distribution is focal, with more than 95% of all cases reported from 15 states in the Northeast, mid-Atlantic, and upper Midwest, areas characterized by an abundance of infected *Ixodes scapularis* ticks.[3,5] The geographic distribution of areas with a high risk of Lyme disease has expanded over time.[6]

The age of patients with Lyme disease in the United States is consistently bimodal, with peaks among children and older adults; overall, males are affected more often than females.[3,5] Nevertheless, subtle changes in the relative frequency of cases across age groups and sex are apparent. We examined trends in reported cases and disease incidence during a 25-year period to ascertain whether changes have occurred in the populations most affected by Lyme disease in the United States. Our objectives were to describe (1) changes in the age and sex distribution of Lyme disease, (2) birth-cohort effects

[1] Division of Vector-Borne Diseases, Centers for Disease Control and Prevention, Fort Collins, CO, USA

Corresponding Author:
Kiersten J. Kugeler, PhD, MPH, Centers for Disease Control and Prevention, Division of Vector-Borne Diseases, 3156 Rampart Rd, Fort Collins, CO 80521, USA.
Email: kkugeler@cdc.gov

among reported cases, and (3) changes in incidence rates according to patient age and sex.

Methods

Lyme disease reports are submitted by health care providers and clinical laboratories to state and local health officials, who in turn classify available information according to standardized surveillance case definitions and transmit data to the Centers for Disease Control and Prevention (CDC) through the National Notifiable Diseases Surveillance System.[2,7] For this analysis, we included records submitted to CDC during 1992-2016 that met the confirmed surveillance case definition in effect during the year of report.[7] The criteria for a confirmed Lyme disease case changed during the 25-year period. In brief, confirmed Lyme disease for surveillance purposes includes clinician-diagnosed erythema migrans rash >5 cm in diameter or at least 1 discrete later manifestation (eg, carditis, facial palsy, arthritis) with accompanying laboratory evidence of infection. In 1997 and 2008, the laboratory criteria were updated to reflect improvements in available testing.[7] We grouped reported cases into five 5-year periods (1992-1996, 1997-2001, 2002-2006, 2007-2011, 2012-2016). We calculated the average annual incidence by age and sex using the mean number of cases in each subgroup per 5-year period per 100 000 population. We grouped patient age at time of illness onset into 5-year age categories. In addition, we converted patient age at the time of illness into patient birth year and grouped patients into 5-year birth cohorts. We qualitatively compared patterns of reported Lyme disease among birth cohorts with the age structure of the US population over time. We used decadal census and mid-decade intercensal population estimates to approximate the population at risk during each 5-year period, specifically 1995, 2000, 2005, 2010, and 2015.[8] We calculated incidence rate ratios (IRRs) and associated 95% CIs to compare Lyme disease incidence during the most recent 5-year period (2012-2016) with the earliest 5-year period (1992-1996). In addition, we conducted a sensitivity analysis using only case and population data from 14 states with a high incidence of Lyme disease (Connecticut, Delaware, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, and Wisconsin) to assess whether trends differed when restricted to the population most at risk of Lyme disease rather than the US population at large. We used Microsoft Excel and SAS version 9.4 (SAS Institute, Inc) for analysis. This analysis of public health surveillance data was considered part of routine public health surveillance activity and not subject to institutional review board review at CDC.

Results

A total of 510 555 case records of confirmed Lyme disease were transmitted to CDC during the 25-year period, of which 474 218 (93%) contained information on patient age and sex (Table). From 1992-1996 to 2012-2016, the number of confirmed cases of Lyme disease doubled from 56 075 to 117 588, and the proportion of reported cases among males increased from 51% to 58%. The mode of the age distribution of all cases ranged from 6 to 8 years during the study period (Table; Figure 1). The most common 5-year age group of people aged <20 with reported Lyme disease was consistently 5-9 years (Figure 1). The most common age group among adults with reported Lyme disease increased over time, shifting about 20 years older during the study period, from age 35-40 to age 55-60.

When we examined patient age at the time of illness according to the year of patient birth, the birth years of children with reported Lyme disease shifted incrementally with the passage of time. Specifically, people born during 1990-1994 accounted for the incidence peak among children in the earliest period (1992-1996), and people born during 2010-2014 accounted for the incidence peak among children in the most recent period (2012-2016; Table). Adults with Lyme

Table. Characteristics of Lyme disease cases reported through national surveillance—United States, 1992-2016[a]

Characteristic	Year				
	1992-1996	1997-2001	2002-2006	2007-2011	2012-2016
No. of confirmed cases	56 075	79 427	104 348	116 780	117 588
Male sex, %	51	53	55	55	58
Age, mode (median), y	6 (39)	7 (39)	8 (41)	8 (43)	7 (45)
Most common birth years[b] among children with Lyme disease	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014
Most common 5-year period of birth years[c] among adults with Lyme disease	1960-1964	1960-1964	1960-1964	1960-1964	1960-1964
Total cases among people born during 1950-1964, %	25.5	24.8	24.9	24.7	23.8

[a]Data source: Centers for Disease Control and Prevention, National Notifiable Diseases Surveillance System.[4]
[b]According to 5-year cohorts constructed based on year of birth.
[c]Children were defined as people aged <20, and adults were defined as people aged ≥20.

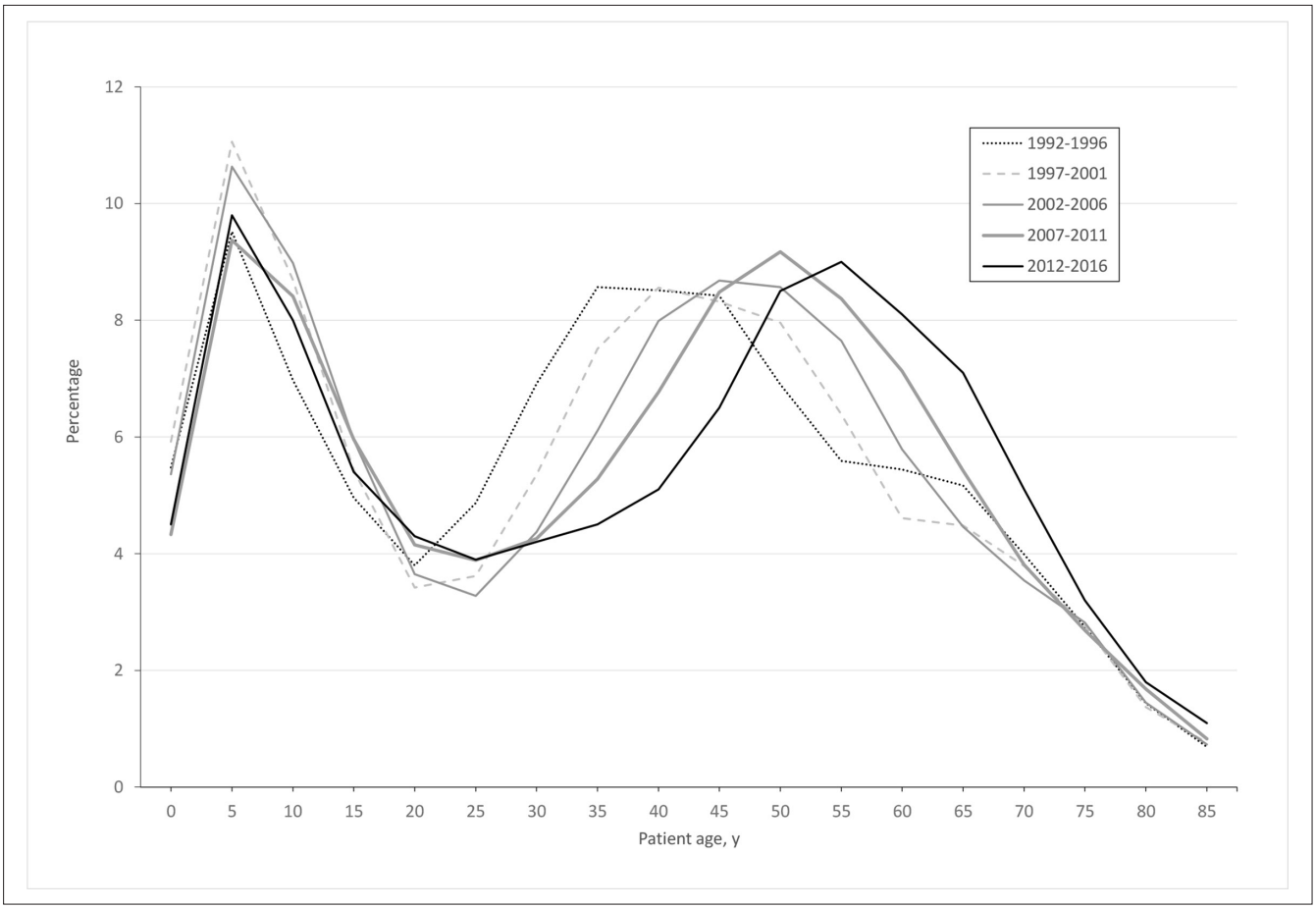

Figure 1. Percentage of confirmed Lyme disease cases, by patient age, United States, 1992-2016. Data were based on surveillance reports meeting the confirmed case classification in the surveillance case definition that was in effect during the year of report. Data source: Centers for Disease Control and Prevention, National Notifiable Diseases Surveillance System.[4]

disease were most commonly born during 1950-1964 regardless of the period of disease acquisition. During the 25-year study period, people born during 1950-1964 comprised approximately one-quarter of all reported Lyme disease cases.

The overall incidence of confirmed Lyme disease increased nearly 2-fold from 1992-1996 to 2012-2016 (IRR = 1.74; 95% CI, 1.70-1.78; Figure 2). However, the temporal increase in incidence was nonuniform between sexes and across age groups. The greatest incidence rate increases occurred among children and adolescents aged 10-14 (IRR = 2.23; 95% CI, 2.05-2.42) and older adults aged ≥70 (IRR = 2.01; 95% CI, 1.87-2.16). The incidence of confirmed Lyme disease increased disproportionately among males; the IRRs among males aged 2-69 were 39%-89% higher than the IRRs for females. The same trends existed when we examined data with a restricted population denominator of the 14 states with a high incidence of Lyme disease. Lyme disease case data for 2017 and 2018 demonstrate patterns comparable with case data for 2012-2016. The median patient age was older than during 2012-2016 (48 years), 58% of cases were among males, and 26% of all confirmed cases were among people born during 1950-1964.

Discussion

Using data from 25 years of Lyme disease surveillance in the United States, we found subtle changes in the bimodal age distribution of reported cases and disproportionate increases in incidence among several segments of the population. The consistent peak in the number of Lyme disease cases among children aged 5-9 during the study period suggests that disease risk in this group is driven by age-related behavior and interaction with tick habitat, possibly compounded by age-related developmental susceptibility. In contrast, the average age of adults with reported Lyme disease increased. The baby boom population comprised one-quarter of the US population during the study period.[9] Thus, the age distribution of Lyme disease cases among adults likely reflects the probability of encountering infected ticks that is proportional to the relative size of the baby boom population rather than any

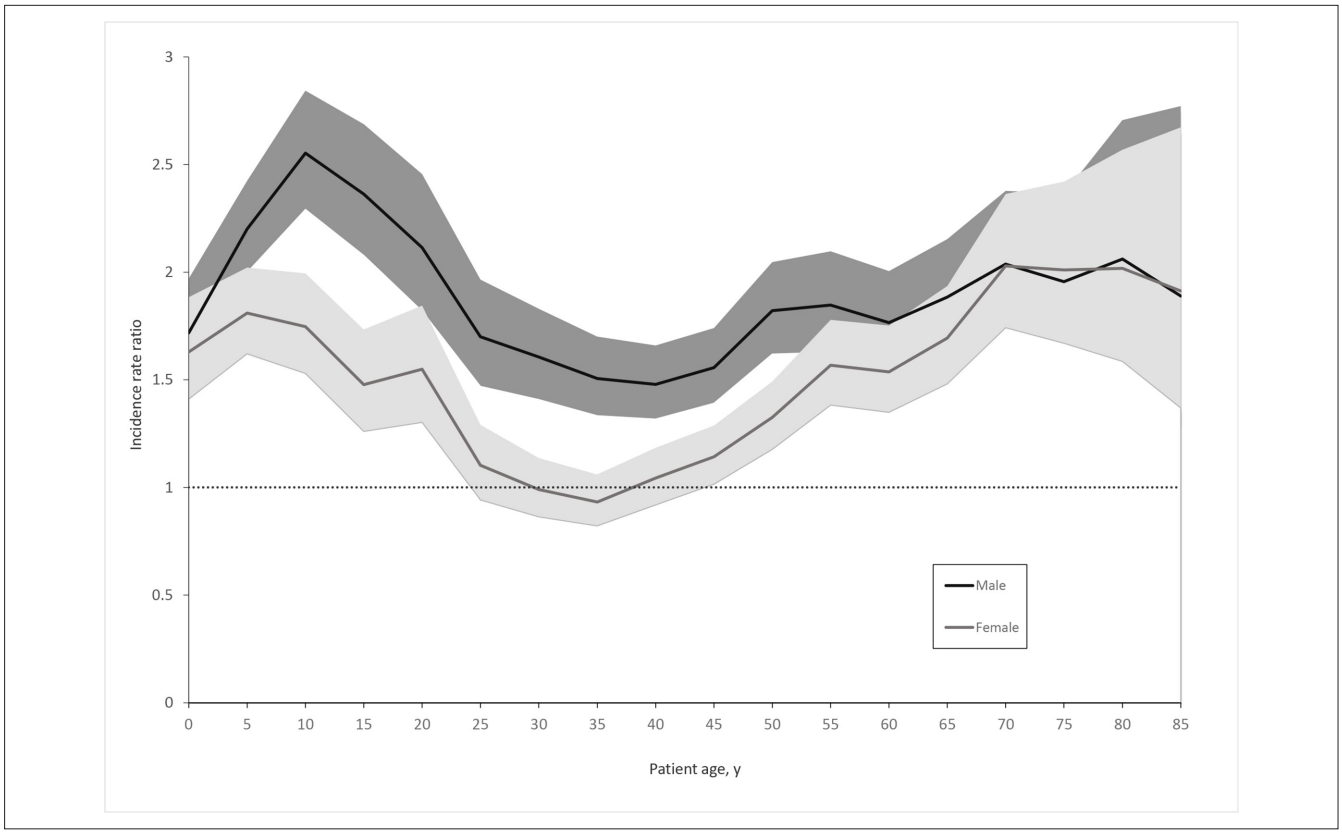

Figure 2. Proportional changes in reported Lyme disease incidence, by patient age and sex, United States, 2012-2016 vs 1992-1996. Ratio of incidence rates in the most recent period compared with the first period. Ratio of 1 (dotted line) reflects no change in incidence rate over time. The gray shading indicates 95% CIs. Data source: Centers for Disease Control and Prevention, National Notifiable Diseases Surveillance System. The gray shading indciates 95% CIs around male and female incidence rate ratios, with the lighter shading corresponding to lighter line for females as noted in legend.[4]

specific age-related behavior or susceptibility to infection. As the population structure in the United States shifts during the next several decades, further change in the peak age of adults most affected by Lyme disease is inevitable.

Overall, case counts and disease incidence doubled from 1992-1996 to 2012-2016, with increases occurring across most age groups and disproportionately among males. The reasons for differential increases in rates among certain groups are unknown but could be associated with differences in the composition of populations at risk as the disease expands into new areas, sex-associated differences in prevention behaviors, or sex- and age-based differences in clinical manifestations. Analyses from the United States and Europe suggest that clinical manifestations may differ according to patient sex and age, including a preponderance of Lyme disease–associated arthritis in children.[3,10-12] The approach to Lyme disease surveillance is increasingly dependent on laboratory-based reporting, introducing bias toward more disseminated Lyme disease manifestations; sex or age-based differences in clinical manifestations may affect the likelihood of capturing data through national surveillance. Although anaplasmosis and babesiosis are transmitted by the same tick vector, the age and sex distributions of reported cases in the United States are distinctly different from those for Lyme disease.[4] For anaplasmosis and babesiosis, reported illness frequency increases with age and may be related to an increased likelihood of clinically apparent illness rather than risk of tick bite.

Efforts to estimate the true number of Lyme disease cases in the United States suggest that national surveillance data may reflect one-tenth of the number of Lyme disease diagnoses in the United States.[13,14] Nevertheless, analyses of commercial health insurance claims for Lyme disease found that the age and sex distribution among diagnosed patients was similar to that reported through national surveillance, except for proportionally more clinician-diagnosed Lyme disease among women.[13,15] Underreporting in surveillance data could account for some of the patterns described in this analysis, and a disproportionate increase in incidence among males and certain age groups demonstrated here may not reflect trends among all people diagnosed with Lyme disease in the United States.

Over time, the human and economic resources needed to conduct Lyme disease surveillance have grown, and many

jurisdictions have been forced to modify their practices in a way that may affect comparability of data.[3,14] Nevertheless, the sheer volume of available data collected to date still offers clues to help us better understand who is most affected by the disease and why. Given the lack of proven effective and acceptable environmental controls or a commercially available vaccine, education on other means of personal prevention, such as repellent use and tick removal, are essential.

Conclusions

This analysis found disproportionate increases in Lyme disease incidence among certain segments of the US population and yielded novel insight into discordant epidemiologic patterns between children and adults. Our findings underscore the importance of using incidence rates when describing populations at risk of Lyme disease and using case counts to provide information on populations to target for potential intervention so that the maximum number of cases can be averted. A deeper understanding of the populations most affected by Lyme disease can inform targeted and efficient public health education efforts.

Acknowledgments

The authors thank the public health professionals who diligently collect and voluntarily transmit surveillance data to the Centers for Disease Control and Prevention to allow for analysis from the national perspective.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Kiersten J. Kugeler, PhD, MPH https://orcid.org/0000-0002-5702-6688

References

1. Steere A. Lyme disease (Lyme borreliosis) due to *Borrelia burgdorferi*. In: Bennett JE, Dolin R, Blaser MJ, eds. *Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases*. 9th ed. Elsevier; 2020:2911-2922.
2. Centers for Disease Control and Prevention. National Notifiable Diseases Surveillance System (NNDSS). 2019. Accessed November 15, 2020. https://wwwn.cdc.gov/nndss/
3. Schwartz AM, Hinckley AF, Mead PS, Hook SA, Kugeler KJ. Surveillance for Lyme disease—United States, 2008-2015. *MMWR Surveill Summ*. 2017;66(22):1-12. doi:10.15585/mmwr.ss6622a1
4. Centers for Disease Control and Prevention. Notifiable infectious diseases and conditions data tables. 2019. Accessed October 1, 2019. https://wwwn.cdc.gov/nndss/infectious-tables.html
5. Bacon RM, Kugeler KJ, Mead PS. Surveillance for Lyme disease—United States, 1992-2006. *MMWR Surveill Summ*. 2008;57(10):1-9.
6. Kugeler KJ, Farley GM, Forrester JD, Mead PS. Geographic distribution and expansion of human Lyme disease, United States. *Emerg Infect Dis*. 2015;21(8):1455-1457. doi:10.3201/eid2108.141878
7. Centers for Disease Control and Prevention. National Notifiable Diseases Surveillance System (NNDSS): Lyme disease case definitions. Accessed November 15, 2020. https://wwwn.cdc.gov/nndss/conditions/lyme-disease/
8. US Census Bureau. Population and housing unit estimates. 2020. Accessed December 4, 2019. https://www.census.gov/programs-surveys/popest.html
9. Colby SL, Ortman JM. *The Baby Boom Cohort in the United States: 2012-2060. Population Estimates and Projections*. Current Population Reports. US Census Bureau; 2014. Accessed November 15, 2020. https://www.census.gov/prod/2014pubs/p25-1141.pdf
10. Mead PS. Epidemiology of Lyme disease. *Infect Dis Clin North Am*. 2015;29(2):187-210. doi:10.1016/j.idc.2015.02.010
11. Kwit NA, Nelson CA, Max R, Mead PS. Risk factors for clinician-diagnosed Lyme arthritis, facial palsy, carditis, and meningitis in patients from high-incidence states. *Open Forum Infect Dis*. 2018;5(1):ofx254. doi:10.1093/ofid/ofx254
12. Strle F, Wormser GP, Mead P, et al. Gender disparity between cutaneous and non-cutaneous manifestations of Lyme borreliosis. *PLoS One*. 2013;8(5):e64110. doi:10.1371/journal.pone.0064110
13. Nelson CA, Saha S, Kugeler KJ, et al. Incidence of clinician-diagnosed Lyme disease, United States, 2005-2010. *Emerg Infect Dis*. 2015;21(9):1625-1631. doi:10.3201/eid2109.150417
14. Cartter ML, Lynfield R, Feldman KA, Hook SA, Hinckley AF. Lyme disease surveillance in the United States: looking for ways to cut the Gordian knot. *Zoonoses Public Health*. 2018;65(2):227-229. doi:10.1111/zph.12448
15. Schwartz AM, Kugeler KJ, Nelson CA, Marx GE, Hinckley AF. Use of commercial claims data for evaluating trends in Lyme disease diagnoses, United States, 2010-2018. *Emerg Infect Dis*. 2021;27(2):499-507. doi:10.3201/eid2702.202728