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# Risk factors for tick exposure in suburban settings in the Northeastern United States

P. Mead[a,*], S. Hook[a], S. Niesobecki[b], J. Ray[c], J. Meek[b], M. Delorey[a], C. Prue[d], A. Hinckley[a]

[a] Bacterial Diseases Branch, Division of Vector-borne Diseases, Centers for Disease Control and Prevention, Fort Collins, CO, USA
[b] Connecticut Emerging Infections Program, Yale School of Public Health, New Haven, CT, USA
[c] Mayo Clinic, 200 First Street SW, Rochester, MN, USA
[d] Office of the Director, National Center for Emerging and Zoonotic Infectious Diseases, Centers for Disease Control and Prevention, Atlanta, GA, USA

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ABSTRACT

Prevention of tick-borne diseases requires an understanding of when and where exposure to ticks is most likely. We used an epidemiologic approach to define these parameters for residents of a Lyme-endemic region. Two persons in each of 500 Connecticut households were asked to complete a log each night for one week during June, 2013. Participants recorded their whereabouts in 15 min increments (indoors, outdoors in their yard, outdoors on others' private property, or outdoors in public spaces) and noted each day whether they found a tick on themselves. Demographic and household information was also collected. Logs were completed for 934 participants in 471 households yielding 51,895 time-place observations. Median participant age was 49 years (range 2–91 years); 52% were female. Ninety-one participants (9.8%) reported finding a tick during the week, with slightly higher rates among females and minors. Household factors positively associated with finding a tick included having indoor/outdoor pets (odds ratio (OR) = 1.7; 95% confidence interval (CI): 1.1–2.9), the presence of a bird feeder in the yard (OR = 1.9; CI:1.2–3.2), and presence of an outdoor dining area (OR = 2.2; CI:1.1–4.3). Individual factors associated with finding a tick on a given day were bathing or showering (OR = 3.7; CI:1.3–10.3) and hours spent in one's own yard (OR = 1.2, CI:1.1–1.3). Nineteen participants found ticks on multiple days, more than expected assuming independence ($p < 0.001$). Participants who found ticks on multiple days did not spend more time outdoors but were significantly more likely to be male than those finding ticks on a single day ($p < 0.03$). Our findings suggest that most tick exposures in the study area occurred on private property controlled by the respective homeowner. Interventions that target private yards are a logical focus for prevention efforts.

## 1. Introduction

Each year an estimated 300,000 Americans develop Lyme disease, a multi-system tick-borne illness caused by *Borrelia burgdorferi* sensu lato (Hinckley et al., 2014; Nelson et al., 2015). Most of these infections occur among residents of the northeastern, mid-Atlantic, and north-central states. The principal vector in these regions is the blacklegged tick, *Ixodes scapularis* (Bacon et al., 2008), which also transmits the human pathogens *Anaplasma phagocytophilum, Babesia microti*, and Powassan virus (Piesman and Gern, 2004). Although Lyme disease can be cured with appropriate antibiotics, long term symptoms and occasional deaths due to cardiac involvement have been reported (Wormser et al., 2006; Centers for Disease Control and Prevention, 2013).

In the absence of an effective vaccine, prevention of Lyme disease rests on reducing human exposure to infected ticks (Hayes and Piesman, 2003). Tick-bite prevention measures can be grouped into three general categories: personal protective measures (e.g., repellents, tick checks, and protective clothing), household-based interventions (e.g., yard pesticide treatments, landscaping, deer fencing), and community-wide interventions (e.g., deer control, wide scale pesticide applications) (Stafford, 2007). While each approach has advantages and limitations, the utility of any method ultimately depends on when and where human exposure to ticks is most common.

Current understanding of risk for tick exposure is based primarily on entomologic studies. Flagging yards of New York patients with Lyme disease, Falco and Fish detected *Ixodes* ticks in 10 of 11 yards, demonstrating the potential for exposure in the peridomestic environment (Falco and Fish, 1988a,b). Subsequent studies of residential settings have further defined wooded areas of the yard, followed by ecotone, as locations of greatest entomologic risk (Maupin et al., 1991; Carroll

* Corresponding author at: 3156, Rampart Road, Fort Collins, CO, 80521, USA.
*E-mail address:* pmead@cdc.gov (P. Mead).

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et al., 1992; Stafford and Magnarelli, 1993; Duffy et al., 1994). *Ixodes* ticks are also abundant, however, in recreational parks and other non-peridomestic habitat in Lyme disease endemic areas (Falco and Fish, 1989), suggesting that these areas may also be an important source of human exposure.

While entomological studies can define areas of potential tick exposure, actual risk of human-tick contact depends on human activity, which is less easily studied (Connally et al., 2009; Finch et al., 2014). Consequently, the proportion of human disease due to peridomestic versus non-peridomestic exposures is poorly defined. Further, it is not known what proportion of peridomestic exposure occurs on property controlled by a homeowner and what proportion occurs on nearby property controlled by a neighbor. This distinction is critical when assessing the potential utility of household-level, yard-based interventions.

To better define the contribution of different settings to human tick exposure in a Lyme disease endemic region, we asked Connecticut residents to record for 1 week the amount of time they spent in different settings each day and whether they found a tick on their body. The specific study objectives were to assess the relationship between finding a tick, household characteristics (e.g., yard size), and time spent in different locations.

## 2. Methods

As part of a larger tick-borne disease prevention study, a total of 500 households were recruited from among eligible residents of Fairfield and Litchfield counties, Connecticut. Fairfield County, located in southwestern Connecticut, has a population of approximately 900,000 residents living in mostly suburban communities intermingled with deciduous and coniferous forest. Litchfield County, located in northwestern Connecticut, is more heavily wooded, more rural, and has a population of approximately 190,000. In 2013, the reported incidence of Lyme disease was 48.2 and 98.5 cases per 100,000 population in the two counties, respectively (Connecticut Department of Health, 2013).

Households were recruited through targeted mailings. Eligible households had 3 or more residents living in freestanding homes on wooded or partially wooded properties ½ to 5 acres in size. Participants were excluded if they did not speak English, had an intact deer fence (≥5 ft in height) around the entire perimeter of their yard, or reported using acaricidal products on their yard for any reason in the previous year, including mosquito control. Within each household, two individuals were selected for participation: an adult > 18 years of age with authority to make decisions regarding the property ("head of household"), and a second household member whose birthday occurred closest to June 1st and was at least 2 years of age. Background information on household demographics, property characteristics (e.g., lot size, percent forested, rock walls) was collected from the head of household via a phone survey. Informed consent was obtained for study participation from all heads of household, and participants were compensated for their time with a gift card. All households were provided with basic information on tick-borne diseases and standard means of preventing tick bites such as use of repellents; participants were reminded to perform tick checks daily. The study was approved by the relevant institutional review boards at CDC and Connecticut.

During the week of June 5–11, 2013, the two household participants were asked to complete each night a daily log detailing their whereabouts between the hours of 4 am and midnight in 15 min increments (Appendix A). This week is historically a time of high *Ixodes scapularis* nymphal tick activity in Connecticut (Stafford and Magnarelli, 1993). Participants could delay onset of logging for up to 4 weeks to accommodate vacations and travel away from home. Locations were recorded as one of four options: indoors (e.g., inside any building or form of transportation, such as home, school, work, car, bus, train, etc.), in their own yard (any outdoor area on their private property), in someone else's yard (any outdoor area on someone else's private property), and outdoor public spaces (e.g, parks, school playgrounds, athletic fields, sidewalks, golf courses, or hiking trails). If the second person was a child or otherwise unable to complete the log, the head of household completed their log for them according to their activities. Along with location, participants recorded whether they bathed that day, and whether they found a tick attached to or crawling on them on that day.

Risk factors for finding a tick were assessed at both the level of the household and the individual. At the household level, data were aggregated into one record for each household. A generalized, linear, mixed-effects model with an assumed binomial distribution was used to evaluate the effect of fixed factors (e.g., lot size, presence of a bird feeder) on whether a household member found a tick during the week. For individuals, a generalized, linear, mixed-effects model was fit to daily activity data. The response was whether or not a participant found a tick on that day. Predictors included hours spent in one's own yard, hours spent in neighbors' yards, time spent in other outdoor locations, sex, age group ($<= 18$ and $> 18$), the interaction between sex and age and with each of the location categories, and bathing. Household identifier and individual within the family were included as random effects to account for clustering within households and repeated measures for the individual. Factors associated with risk at the household level were also included in the individual-level model. Because the total time of observation for an individual is fixed, the amount of time he or she spent outdoors is not independent of the amount of time spent indoors. Accordingly, time spent indoors (which was protective overall) was not included in the models. Standard diagnostics were performed to ensure model assumptions were reasonable.

## 3. Results

Logs were completed for 934 participants in 471 households accounting for over 35,000 person-hours of observation and 51,895 distinct time-place observations. Ninety-seven percent of participants recorded time for the week of June 5–11; the remaining 3% recorded for a subsequent week, the latest being July 3–9. Median participant age was 49 years (range 2–91 years); 52% were female. Among heads of household, 95% self-identified as white, 97% as non-Hispanic, and 76% had completed 4 years of college or more. Median household income was between $100,000 and $150,000 for the 79% of households providing income information; median property size was 1–2 acres (range 1/2–5 acres). Ninety-seven percent of properties were described as at least partially wooded, and 37% as half or more-than-half wooded. Other common property features included a wood pile (76%), a stone wall (72%), flower gardens (63%), a bird feeder (47%), a vegetable garden (38%), and a compost pile (37%).

Overall, 66% of respondents reported that at least one family member found a tick on them in the previous year, and 215 (23%) reported that at least one family member had been diagnosed at some time with a tick-borne infection, including 191 (20%) with Lyme disease, 17 (1.8%) with anaplasmosis or ehrlichiosis, and 5 (0.5%) with babesiosis. Only 5% of respondents reported having a job that regularly involved outdoor work. Overall during the week of observation, respondents spent 80% of their recorded time indoors, 8% in their own yard, 2% in a neighbor's yard, and 10% in another outdoor area.

Ninety-one participants (9.8%) reported finding a tick during the week. There was no clear trend by day of the week, although the number that found ticks was greatest on Sunday (n = 23) and least on Monday (n = 9). Median age of those finding ticks was 50 years, and overall 57% were female, which is not significantly different from the overall population of respondents ($p = 0.34$). Among the 91 participants who found ticks, 72 found ticks on only one of the 7 days, and 19 found ticks on two or more days (Table 1). The number of participants finding ticks on multiple days was significantly greater than would be expected if the events were independent of one another, ($p < 0.001$), suggesting that certain individuals were more likely than others to acquire or find ticks. Participants finding ticks on multiple days were