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Human-tick encounters as a measure of tickborne disease risk in lyme disease endemic areas

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Abstract

Entomological measures have long served as proxies for human risk of Lyme disease (LD) and other tickborne diseases (TBDs) in endemic areas of the United States, despite conflicting results regarding the correlation between these measures and human disease outcomes. Using data from a previous TBD intervention study in Connecticut, Maryland and New York, we evaluated whether human-tick encounters can serve as an accurate proxy for risk of TBDs in areas where LD and other *Ixodes scapularis*-transmitted infections are common. Among 2,590 households consisting of 4,210 individuals, experiencing a tick encounter was associated with an increased risk of both self-reported (RR = 3.17, 95% CI: 2.05, 4.91) and verified TBD (RR = 2.60, 95% CI: 1.39, 4.84) at the household level. Household characteristics associated with experiencing any tick encounter were residence in Connecticut (aOR = 1.86, 95% CI: 1.38, 2.51) or New York (aOR = 1.66, 95% CI: 1.25, 2.22), head of household having a graduate level education (aOR = 1.46, 95% CI: 1.04, 2.08), owning a pet (aOR = 1.80, 95% CI: 1.46, 2.23) and a property size of 2 acres or larger (aOR = 2.30, 95% CI: 1.42, 3.70). Results for individual characteristics were similar to those for households. Future prevention studies in LD endemic areas should consider using human-tick encounters as a robust proxy for TBD risk.

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CONFLICT OF INTEREST
The authors do not have any conflicts of interest to report.

ETHICAL STATEMENT
All participants provided informed consent. The study protocol was reviewed and approved by the human subjects research committees at the Centers for Disease Control and Prevention, Yale University, Connecticut Department of Public Health, Maryland Department of Health and New York State Department of Health. This study conforms to the Declaration of Helsinki.

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

SUPPORTING INFORMATION
Additional supporting information may be found online in the Supporting Information section.

Keywords

lyme disease; tickborne disease; tickborne diseases; ticks

1 | INTRODUCTION

The burden of Lyme disease (LD) and other diseases transmitted by *Ixodes spp.* ticks is increasing in the United States (Adams et al., 2017; Schwartz et al., 2017). With no vaccines currently available, prevention relies on use of personal protective measures (e.g. tick checks, repellent use) and environmental controls (e.g. yard-based acaricide sprays, host-targeted acaricide treatments; Shen et al., 2011; Wormser, 2005). However, because of a relatively low disease incidence, well-powered studies designed to measure the efficacy of specific prevention approaches on human tickborne disease (TBD) outcomes are exceptionally time- and resource-intensive. Therefore, in studies evaluating environmental controls for the prevention of LD, the primary outcomes have been measures of nymphal *Ixodes scapularis* abundance and infection prevalence with *Borrelia burgdorferi* (e.g. nymphal density, nymphal infection prevalence, density of infected nymphs; Curran et al., 1993; Dolan et al., 2009; Dolan et al., 2004; Eisen & Dolan, 2016; Falco & Fish, 1992; Rand et al., 2010; Schulze et al., 1995; Schulze et al., 2001; Stafford, 1991). For decades, these entomological measures have functioned as proxies for human LD risk.

Studies evaluating the relationship between entomological measures and human disease risk have shown inconsistent results (Connally et al., 2006; Pepin et al., 2012; Falco et al., 1999; Mather et al., 1996), indicating that entomological measures may not accurately represent human risk of becoming infected with tickborne pathogens. In addition to the fact that tick abundance can be highly variable even at a fine spatial scale (e.g. within a single yard), entomological indices do not account for human behaviour (Feldman et al., 2015; Pardanani & Mather, 2004). For example, the presence of nymphal *I. scapularis* ticks indicates some LD risk in an endemic area, and even more so if the vectors are shown to be infected with *B. burgdorferi*. However, if humans rarely venture into *I. scapularis* habitat, the risk of acquiring LD is low (Eisen & Eisen, 2018). On the other hand, human-tick encounters, that is finding ticks crawling or attached, provide direct evidence of tick exposure. Even for those who only noticed ticks crawling on themselves, this is a potential marker for having attached ticks that went undetected. This scenario is especially likely with encounters with *I. scapularis* nymphs, which are very small in size and can be difficult to see. While human-tick encounters do not indicate 100% probability of acquiring LD, the relationship between TBDs and tick encounters, which account for both tick abundance and human behaviour, is potentially stronger than that with entomological measures alone. However, this relationship has never been quantified.

In the first intervention study that prospectively measured human disease outcomes to evaluate the effectiveness of a yard-based acaricide application in LD endemic areas, *I. scapularis* density did not correlate with the occurrence of human-tick encounters (ticks found crawling on or attached to study household members) or with reported TBDs among household members (Hinckley et al., 2016). Using data from this study, we sought to answer the question of whether human-tick encounters may better capture risk of LD and other TBDs associated with *I. scapularis* in endemic areas. The specific objectives of this analysis were to (a) evaluate whether human-tick encounters can serve as an accurate measure of LD risk and (b) to identify demographic and property characteristics associated with human-tick encounters.

2 | MATERIALS AND METHODS

As described in Hinckley et al., households in counties highly endemic for LD in Connecticut, Maryland and New York were enrolled in a randomized controlled trial to determine the effectiveness of a single, yard-based, spring-time barrier application of acaricide in preventing LD and other TBDs (Feldman et al., 2015; Hinckley et al., 2016). Enrolment criteria included the presence of certain property characteristics known to be favourable to *I. scapularis* populations and a household size of two or more people. The study was conducted from late April to October in 2011 and 2012; households participated in only one of the two years. Because the randomized controlled trial found no difference in human-tick encounters or human TBD between treated and placebo properties, participants from both groups were treated as a single cohort in our analysis.

Household property characteristics and demographic information were collected via phone-based, introductory surveys at the time of study enrolment during April and May of each study year. Human-tick encounters were self-reported in four web-based surveys conducted approximately monthly during the treatment period, June – September. Designated heads of household answered all questions for the household surveys, including the number of ticks found crawling on or attached to household members. In 2011, human-tick encounters were reported in aggregate for each household; in 2012, these were also reported individually for each household member. Participants in CT and MD were also offered the opportunity in both 2011 and 2012 to send ticks to study investigators for species identification. Self-reported TBD diagnoses were collected in a final, phone-based survey at the end of each study year in October. Self-reported diagnoses were verified by chart review by two physicians and one doctoral-level epidemiologist. Participants who did not complete any monthly surveys were excluded from all analyses, and those who did not complete a final survey at the end of the study year were excluded when assessing relationships between tick encounters and development of a TBD. Participant information that was collected only at the household level was assumed to apply to all members of the household (e.g. race, pet ownership).

Human-tick encounters reported during the study period at either the household or individual level were categorized into the following three groups: experienced any tick encounter (i.e. found at least one tick crawling or attached), found at least one tick crawling and found at least one tick attached. Descriptive statistics were conducted for household (2011, 2012) and individual (2012) level tick encounters, with Pearson's chi-square tests used to compare tick encounters by household and individual characteristics. To evaluate the association between human-tick encounters and TBD diagnoses at both the household and individual levels, relative risk ratios with 95% confidence intervals and attributable risk per cent were calculated. Multivariable logistic regression models were used to evaluate whether certain demographic and property characteristics were risk factors for human-tick encounters at the household level, while adjusting for covariates. Alpha was set at .05 for all statistical tests of significance. Responses of 'don't know', 'not sure' or 'prefer not to answer' were classified as missing data for all analyses. All analyses were conducted in R 3.5.1 (R Core Team, 2018). Tidyverse packages (Grolemund & Wicham, 2011; Wickham, 2017, 2018; Wickham, Francois et al., 2018; Wickham, Hester et al., 2018) were used to clean, organize and analyse data. The FMSB package (Nakazawa, 2018) was used to calculate odds ratios and risk ratios.

The study protocol was reviewed and approved by human subjects research committees at the Centers for Disease Control and Prevention, Yale University, Connecticut Department of Public Health, Maryland Department of Health and New York State Department of Health.

3 | RESULTS

3.1 | Study population

As reported in Hinckley et al., a total of 2,727 households were enrolled in the study from 2011 to 2012 (Hinckley et a., 2016). Of these, 2,590 (95.0%) households completed at least one monthly survey, and 2,541 (93.2%) completed a final survey. In 2012, 4,210 (95.2%) of 4,421 individual household members answered at least one monthly survey, and 94.1% of household members completed the final survey. The majority of households were white (92.9%) and had an annual household income of $70,000 or higher (66.9%).

3.2 | Household tick encounters and associations with tickborne disease

Across both years, tick encounters were reported for 31.0% of households; finding a tick crawling was reported for 26.4% of households, and finding a tick attached was reported for 17.1% of households. Table 1 shows reported tick encounters by household characteristic. Experiencing any tick encounter was associated with self-reported disease (RR = 3.17, 95% CI: 2.05, 4.91) and verified disease (RR = 2.60, 95% CI: 1.39, 4.84). Similarly, finding a tick crawling and finding a tick attached were also associated with both self-reported and verified disease (Table 2). Overall, the attributable risk per cent of any tick encounter for self-reported and verified TBD was 69% and 61%, respectively.

3.3 | Risk factors for household tick encounters

Unadjusted and adjusted odds ratios for household characteristics and human-tick encounters are shown in Table 3. In univariate analyses, the following characteristics were associated with both experiencing any tick encounter and finding a tick crawling: state, white race, Hispanic ethnicity, owning a pet, property size and having forested areas on property. After adjusting for each covariate, residing in CT or NY, owning a pet and having a property size ≥2 acres were associated with increased odds of experiencing both outcomes. Head of household having a graduate level education was associated with increased odds of any tick encounter, while having at least some college was associated with increased odds of finding a tick crawling. The following characteristics were associated with finding a tick attached in the univariate analyses: state, white race, ethnicity, education level of head of household and pet ownership. After adjusting for each covariate, residing in CT or NY, head of household having a graduate level education and owning a pet were associated with increased odds of finding a tick attached. Those who were Hispanic were less likely to find a tick attached than non-Hispanics, and participants had less risk of finding a tick attached in 2012 compared to 2011.

3.4 | Summary of individual tick encounters, associations with tickborne disease and risk factors

Tick encounters by individual characteristic are shown in Appendix S1. In 2012, tick encounters of any kind were reported by 483 individuals (11.0%), and self-reported and verified TBD were experienced by 9 (1.9%) and 4 (0.82%) individuals, respectively. Experiencing any tick encounter and finding a tick crawling were significantly associated with both self-reported (RR = 3.65, 95% CI: 1.66, 8.01; RR = 4.34, 95% CI: 1.98, 9.53, respectively) and verified (RR = 3.42, 95% CI: 1.06, 11.07; RR = 4.07, 95% CI: 1.26, 13.17, respectively) TBD (Appendix S2). While finding a tick attached was not significantly associated with TBD, some with tick attachment did report TBD ($n = 3$, Appendix S2). Being from CT or NY, being male, white, having a past TBD, owning a pet and having a property size >1 acre were associated with increased odds of experiencing a tick encounter at the individual level. Individuals 0–9 years of age had the highest odds of experiencing a tick encounter (Appendix S3). Six individuals reported experiencing more than 10 tick encounters on any monthly survey in 2012. All reports of experiencing more than 10 tick encounters occurred in the first two monthly surveys, typically June and July.

3.5 | Identification of ticks submitted by participants from CT and MD

The majority (64.2%) of the 123 ticks from human hosts submitted by CT participants for identification were identified as *I. scapularis*, followed by *Dermacentor variabilis* (34.2%); 2 submissions were not ticks. Of 73 ticks from human hosts submitted by MD participants, 45.2% were identified as *D. variabilis* followed by 34.2% *I. scapularis* and 12.3% *Amblyomma americanum*; 3 submissions were not ticks.

4 | DISCUSSION

The primary objective of this analysis was to evaluate whether human-tick encounters can serve as an accurate proxy for LD risk in endemic areas by measuring the association between human-tick encounters and TBD using a prospective design. We found that, at both the household and individual levels, experiencing any tick encounter and finding a tick crawling on oneself was associated with a three- to four-fold increase in risk of TBD. This relationship is further strengthened by the alignment between demographic and property characteristics associated with human-tick encounters found in this study and those commonly associated with LD in other studies (Jones et al., 2018; Ley et al., 1995; Nadelman & Wormser, 2007; Schwartz et al., 2017). Our findings suggest that tick encounters can serve as a robust proxy for LD and other TBDs associated with *I. scapularis* in prevention studies in endemic areas. Using any tick encounter (i.e. at least one tick found crawling or attached) as an outcome in future prevention studies would reduce sample size requirements as well as participant follow-up time compared to using TBDs as an outcome. An additional advantage is that using tick encounters as an outcome measure can account for human behaviour, which purely entomological outcomes cannot.

Risk factors for reported tick encounters were concordant with those typically associated with LD. For example, trends in national surveillance data from 2008 to 2015 indicate that confirmed and probable cases of LD tended to be white, male and follow a bimodal age distribution with peaks seen among younger children and older adults [2]. We saw similar trends for tick encounters at the individual level. Being white and male were both associated with experiencing any tick encounter, and those 9 years of age and younger had especially high odds of experiencing any tick encounter, though all age groups had higher odds of experiencing a tick encounter than those 20–29 years of age. Further, studies have shown that previous history of LD is a risk factor for current LD (Nadelman & Wormser, 2007). Similarly, our results suggest that those with a previous history of TBD were at an increased risk for experiencing tick encounters.

We found that higher proportions of households and individuals with properties ≥2 acres experienced tick encounters compared to those with smaller properties. Having a property size >0.5 acre has commonly been considered a risk factor for human exposure to *I. scapularis* (Maupin et al., 1991). However, this is the first study we are aware of that has quantified the relationship between property size and tick encounters. Interestingly, those with forested areas on their properties did not have increased odds of experiencing tick encounters at the household or individual level, though other studies have documented a positive relationship between forested properties and entomological indices (Carroll et al., 1992; Dister et al., 1997; Duffy et al., 1994; Maupin et al., 1991; Stafford & Magnarelli, 1993) as well as LD diagnoses (Smith et al., 2001). Forested area may be a better indicator of viable tick habitat and entomological risk, rather than human risk.

It is certainly possible that participants in CT and NY had a higher likelihood of experiencing tick encounters than those in MD. Additional risk for LD in CT and NY is supported by public health surveillance data. In 2009, before the intervention study was initiated, all but one of the five counties targeted for recruitment in MD had lower LD incidences (with 4.0, 37.2, 43.3, 52.4 and 95.1 reported cases per 100,000 population) than the one targeted county in CT (79 reported cases per 100,000 population), and all had lower LD incidence rates than the two targeted counties in NY (927.6 and 333.5 reported cases per 100,000 population).

Owning a pet was also associated with increased odds of all forms of tick encounters. Pet ownership has long been considered a risk factor for tick exposure (Fischhoff et al., 2019; Hojgaard et al., 2014; Mead et al., 2018; de Wet et al., 2020) and TBD (Drexler et al., 2014; Jones et al., 2018; Lane & Lavoie, 1988; Ley et al., 1995; Rabinowitz et al., 2007; Steere et al., 1978). Recent evidence suggests increased risk may come from activities pet owners engage in with their pets that expose them to tick habitat rather than pets transporting ticks into the home or through direct contact (e.g. sleeping with pets; de Wet et al., 2020).

D. variabilis represented notable proportions of ticks from human hosts submitted by participants for identification in both CT (64.2%) and MD (45.2%). While these submitted ticks do not represent all tick encounters reported for CT and MD during the study, they do confirm that not all tick encounters reported by participants in these two states were with *I. scapularis*. Nonetheless, we found that all forms of tick encounters were correlated with both self-reported and verified disease, providing confidence that in regions of the United States where LD is the most commonly reported TBD (e.g. the northeast), and especially in states where *I. scapularis* is the predominant tick species (e.g. CT), tick encounters may serve as an accurate proxy for LD and other TBDs associated with *I. scapularis*.

4.1 | Limitations

These results are subject to several limitations. First, tick exposures and all other survey data were self-reported and not verified by study staff; therefore, our outcomes and covariates of interest may be subject to measurement error. However, more than 95% of tick submissions for identification from CT and MD were truly ticks, suggesting little error by participants in distinguishing between ticks and other insects. A second limitation may result from the possibility that those who experienced tick encounters may have been more likely to self-report TBD than those who did not, potentially biasing results away from the null. Similarly, those who had a past TBD may have had more interest in and knowledge of TBDs and prevention compared to the general population and therefore may have been more likely to enrol in this study and complete monthly surveys than those without a past TBD. Additionally, some variables that were collected at the household level only, such as race of the head of household, were applied to the entire household when making estimates at the individual level. This may have resulted in misclassification of these factors and should be kept in mind when interpreting these results. Lastly, the analysis of tick encounters and verified disease had low power due to a small number of participants with verified TBD, and similarly so for the analysis of individual tick attachment and TBD.

In terms of generalizability, we cannot draw conclusions for use of tick encounters as a correlate of disease risk beyond LD and other TBDs transmitted by *I. scapularis* in the northeastern United States. More research is needed to assess the relationship between tick encounters and TBDs in areas that have higher populations of other tick vectors, such as *A. americanum*. In addition, because our study population came from a cohort enrolled in a TBD intervention study, our participants may have been more aware of and knowledgeable about ticks than the general population. Future studies should evaluate the ability of the general public to correctly identify ticks of various species, as this would strengthen the validity of using self-reported tick encounters as proxy for TBDs. Lastly, these findings that human-tick encounters can serve as a proxy for TBD in LD prevention studies should not be extrapolated to influence clinical recommendations for individual human-tick encounters. Rather, infection risk should be assessed on an individual basis per clinical guidelines (Lantos et al., 2020).

5 | CONCLUSIONS

We sought to quantify the relationship between human-tick encounters and TBDs associated with *I. scapularis*. Human-tick encounters, at both the household and individual levels, are a robust measure of disease risk and inherently account for human behaviour, which entomological measure cannot. We recommend that future LD prevention research consider using tick encounters as an outcome and as a proxy for LD diagnoses, in addition to offering professional identification of tick species encountered to validate results.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Impacts

- In Lyme disease endemic areas, self-reported human-tick encounters are a robust surrogate for human tickborne disease associated with *Ixodes scapularis* at the household and individual levels.
- Use of human-tick encounters should be considered as a proxy for disease in tickborne disease intervention studies in Lyme disease endemic areas to reduce study costs, time and sample sizes.
- Use of human-tick encounters as a proxy for tickborne disease outcomes in intervention studies in Lyme disease endemic areas inherently accounts for human behaviour, which entomological outcomes cannot.

TABLE 1

Household-level demographic and property characteristics and reported tick encounters (2011–2012)

Household Characteristic *N* = 2,590	***N* (%)**	**Reported tick encounter[a] *N* = 802**	**No reported tick encounter *N* = 1788**	***p*-value[b]**
Study year				
2011	1531 (59.1)	470 (30.7)	1,061 (69.3)	.76
2012	1,059 (40.9)	332 (31.4)	727 (68.6)	
State				
CT	965 (37.3)	335 (34.7)	630 (65.3)	<.0001
MD	608 (23.5)	145 (23.8)	463 (76.2)	
NY	1,017 (39.3)	322 (31.7)	695 (68.3)	
Race[c]				
White	2,407 (92.9)	765 (31.8)	1,642 (68.2)	.009
Black/African American	27 (1.0)	3 (11.1)	24 (88.9)	
Asian	62 (2.4)	12 (19.4)	50 (80.6)	
Other	69 (2.7)	16 (23.2)	53 (76.8)	
Hispanic[c]				
Yes	106 (4.1)	22 (20.8)	84 (79.2)	.03
No	2,474 (95.5)	779 (31.5)	1,695 (68.5)	
Household Income				
<$70,000	856 (33.1)	253 (29.6)	603 (70.4)	.30
≥$70,000	1734 (66.9)	549 (31.7)	1,185 (68.3)	
Education level[c]				
High school or less	345 (13.3)	94 (27.2)	251 (72.8)	.26
At least some college	1,439 (55.6)	451 (31.3)	988 (68.7)	
Graduate school	799 (30.8)	255 (31.9)	544 (68.1)	
Owns pet				
Yes	1,464 (56.5)	530 (36.2)	934 (63.8)	<.0001
No	1,126 (43.5)	272 (24.2)	854 (75.8)	
Found tick on pet[d]				
Yes	309 (21.1)	175 (56.6)	134 (43.3)	<.0001
No	1,103 (75.3)	340 (30.8)	763 (69.2)	
Property size (acres)				
≤1	1,025 (39.6)	273 (26.6)	752 (73.4)	.001
1.1–1.9	857 (33.1)	256 (29.9)	601 (70.1)	
≥2	82 (3.2)	37 (45.1)	45 (54.9)	
Forested areas on property				
Yes	2,222 (85.8)	708 (31.9)	1514 (68.1)	.02
No	363 (14.0)	93 (25.6)	270 (74.4)	

[a]A tick encounter is considered any event where one or more ticks were found crawling, attached or crawling and attached.

[b]Evaluated using Pearson's chi-square test.

[c]Pertains to head of household only.

[d]Of those who reported owning a pet (N = 1,464).

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TABLE 2

Self-reported and verified tickborne disease risk by household-level tick encounters (2011–2012; *N* = 2,541)

	Self-reported disease			Verified disease		
	N **(%)**	**Relative RR (95% CI)**	**Attributable risk %**	***N*** **(%)**	**Relative RR (95% CI)**	**Attributable risk %**
Any tick encounter	47 (5.9)	3.17(2.05–4.91)	68.5	21 (2.6)	2.60(1.39–4.84)	61.3
Ticks crawling	45 (6.6)	3.58(2.32–5.52)	72.1	19 (2.8)	2.65 (1.42–4.93)	62.2
Ticks attached	36 (8.1)	3.99 (2.60–6.13)	74.9	17 (3.8)	3.77 (2.02–7.04)	73.6

Abbreviation: RR: risk ratio.

TABLE 3

Unadjusted and adjusted odds ratios measuring associations between tick encounters and household-level demographic and property characteristics (2011–2012)

	Any tick encounter		Crawling		Attached	
Household characteristic	**OR**	**aOR**	**OR**	**aOR**	**OR**	**aOR**
Year						
2011	reference	reference	reference	reference	reference	-
2012	1.03 (0.87–1.22)	0.93 (0.75–1.15)	1.08 (0.91–1.29)	1.01 (0.81–1.26)	0.89 (0.72–1.09)	0.74 (0.57–0.96)
State						
CT	1.70 (1.35–2.14)	1.86 (1.38–2.51)	1.61 (1.27–2.05)	1.69 (1.24–2.32)	1.93 (1.43–2.63)	1.91 (1.31–2.85)
MD	reference	reference	reference	reference	reference	reference
NY	1.48 (1.18–1.86)	1.66 (1.25–2.22)	1.32 (1.04–1.68)	1.50 (1.12–2.04)	1.99 (1.48–2.71)	2.05 (1.43–3.00)
White race						
Yes	1.91 (1.29–2.90)	1.56 (0.95–2.67)	1.98 (1.30–3.13)	1.59 (0.93–2.86)	2.03 (1.22–3.63)	1.68 (0.86–3.69)
Hispanic						
Yes	0.57 (0.35–0.90)	0.58 (0.31–1.02)	0.56 (0.32–0.91)	0.57 (0.29–1.04)	0.33 (0.14–0.67)	0.27 (0.08–0.69)
Household income						
<$70,000	reference	reference	reference	reference	reference	-
≥$70,000	1.10 (0.93–1.32)	0.97 (0.78–1.22)	1.06 (0.88–1.28)	0.91 (0.72–1.16)	1.13 (0.91–1.42)	0.99 (0.75–1.31)
Education level						
High school or less	reference	-	reference	-	reference	reference
At least some college	1.22 (0.94–1.59)	1.28 (0.94–1.76)	1.26 (0.96–1.67)	1.41 (1.02–1.99)	1.30 (0.94–1.84)	1.36 (0.92–2.06)
Graduate school	1.25 (0.95–1.66)	1.46 (1.04–2.08)	1.27 (0.95–1.71)	1.60 (1.11–2.32)	1.44 (1.02–2.07)	1.74 (1.13–2.73)
Owns pet						
Yes	1.78 (1.50–2.12)	1.80 (1.46–2.23)	1.84 (1.53–2.21)	1.89 (1.51–2.37)	1.49 (1.21–1.85)	1.57 (1.21–2.05)
Property size						
≤1 acre	reference	reference	reference	reference	reference	-
1.1–1.9 acre	1.17 (0.96–1.44)	1.15 (0.93–1.41)	1.14 (0.92–1.41)	1.11 (0.89–1.39)	1.18 (0.92–1.51)	1.14 (0.88–1.47)
≥2 acres	2.26 (1.43–3.57)	2.30 (1.42–3.70)	2.55 (1.60–4.03)	2.60 (1.60–4.21)	1.31 (0.70–2.29)	1.28 (0.68–2.29)
Forested areas on property						
Yes	1.35 (1.06–1.75)	1.02 (0.76–1.38)	1.39 (1.07–1.83)	1.09 (0.80–1.51)	1.27 (0.94–1.75)	1.01 (0.70–1.48)

Abbreviation: aOR: adjusted odds ratio.