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ORIGINAL PAPER

Associations Between Personal Protective Measures and Self-Reported Tick-Borne Disease Diagnosis in Indiana Residents

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Abstract

Several personal protective measures (PPMs) are recommended to prevent tick-borne diseases (TBD). We aimed to quantify the strength of seven PPMs and self-reported TBD diagnosis associations and to understand what variables modify these associations. In June–July 2018, with a cross-sectional study design, we surveyed a sample of adult Indiana state residents. Overall, 2927 participants were eligible for this analysis. All data were self-reported. We used the double robust approach of stabilized inverse probability weighting and propensity score adjustment to obtain ORs. Approximately 5% of participants (n = 142) self-reported TBD diagnosis. Practicing different PPMs ranged from 48% for treating outdoor clothing with special bug-spray to 83% for walking on established trails. Using insect repellent on exposed skin was protective against TBD diagnosis [OR (95% CI): 0.55 (0.35, 0.88)]. A thorough body/clothes check after being outdoors was also protective against TBD diagnosis [OR (95% CI): 0.40 (0.25, 0.67)]. In stratified analyses, TBD knowledge, safety worry because of ticks, avoiding outdoors because of ticks, and pet TBD risk modified the associations between different PPMs and self-reported TBD diagnosis. In the state of Indiana, thorough body/clothes check after being outdoors and use of insect repellent on exposed skin might be strongly effective in preventing TBD. The protective effect of different PPMs might be stronger among people with high TBD knowledge, high safety worry because of ticks, high avoidance of being outdoors because of ticks, and low pet TBD risk. These results might be useful in the design of intervention programs.

Keywords Tick-borne disease · TBD · Personal protective measure

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Introduction

In the United States, tick-borne diseases (TBD) are the most common vector-borne infectious diseases (Centers for Disease Control and Prevention [11]). TBD can cause various serious outcomes, such as brain inflammation, arthritis, uncontrolled bleeding, respiratory failure, and even death (CDC [13, 14]). The number of reported TBD cases to the CDC, such as Lyme disease (LD), anaplasmosis/ehrlichiosis, spotted fever rickettsiosis, and babesiosis have increased dramatically in recent years (CDC [16]). The total number of the mentioned TBD cases in 2017 had increased more than 22% compared to 2016, i.e. 59,349 vs. 48,610, and more than 160% compared to 2004, i.e. 59,349 vs. 22,527, though because of under-reporting, the actual number of cases is even higher (CDC [16]).

There are four tick species in Indiana state that are of public health concern, including *Dermacentor variabilis* (American dog tick), *Ixodes scapularis* (Blacklegged tick), *Amblyomma americanum* (Lone star tick), and *Rhipicephalus* *sanguineus* (brown dog tick) (CDC [15]). These species can carry different pathogens that cause different illnesses, such as LD, spotted fever rickettsiosis, tularemia, anaplasmosis, babesiosis, Powassan disease, and *Borrelia mayonii* and *Borrelia miyamotoi* infections [17, 42]. In 2017, The estimated total number of reported nationally notifiable TBDs (LD, undetermined ehrlichiosis/anaplasmosis, tularemia, babesiosis, and spotted fever rickettsiosis) was 278 TBD cases in Indiana (CDC [10]). For these TBD in Indiana, the incidence per 100,000 persons was 2.9 cases in 2016 and 4.2 cases in 2017 (CDC [10]). Despite the presence of ticks and TBD in Indiana state, the use of PPM and risk for TBD among residents of Indiana is not well understood. The life-threatening illnesses that TBD may cause advocate further research to better understand the protective magnitude of different PPMs and the factors that modify their effectiveness.

CDC recommends practicing a series of PPM that can be summarized as follows; walk on the trails, avoid contact with vegetation, use tick repellants on skin, clothing, and gear, shower immediately after being outdoors, wash the clothes with hot water and dry clothes on high heat, and conduct a thorough body check after being outdoors (CDC [12]). Other potential PPMs are wearing light-colored clothing and tucking shirts into pants and pants into socks [7, 18].

Despite their theoretical potential for preventing TBD, less research has been conducted to quantitatively evaluate the magnitude and strength of the above-mentioned PPMs in prevention of TBD [35]. Further, the results of such studies are mixed and sometimes contradictory. For instance, while some researchers found that checking body for ticks strongly lowers TBD [18] others found insignificant results in the opposing direction for this PPM [43]. Similarly, while a study in 2004 reported that none of the PPMs was associated to LD [32], others have found that showering after being outdoors [18], using tick repellents on skin or clothes [18, 43], wearing permethrin-treated uniforms [20], and spraying lemon eucalyptus extract to lower body extremities decrease tick bites [22].

Besides, many predictive factors for practicing PPMs have been identified. Formerly, exposure to ticks [39], region (Bartosik et al. [2]), TBD knowledge [4, 5], being concerned about ticks bites, having seen ticks, knowing a person with LD, perceived efficacy of a PPM [1], Herrington Jr. [26]), and risk perception [1] have been found to significantly predict the practice of different PPMs. However, learning about the predictors of different PPMs alone might not necessarily help us to understand how the mentioned predictors change the magnitude and direction for the measure of association between PPMs and TBD outcome. Fewer research has been conducted to study how the mentioned PPM predictive factors modify the effect of PPM on TBD outcome.

To this end, the aim of this study was to (1) quantify the magnitude and direction of personal protective measures in protecting individuals from acquiring a TBD in a sample of Indiana residents, and (2) to understand how different predictors of PPM modify the associations between PPMs and TBD outcome.

Methods

Study Population

The sampling frame for this study was Indiana state population. To select the study participants, in a cross-sectional study design, we used the existing online panels maintained by Qualtrics (Qualtrics, Provo, UT) [34]. The sampling was administered online. To ascertain that our sample is representative of Indiana population following quota were implemented for panel selection; Age (17–34 [33%], 35–54 [33%], 55 ≤ [33%]) and gender (Female 50%, Male 50%). The online survey was also designed on Qualtrics and responses were self-reported. Data collection took place over two weeks in June and July 2018. Inclusion criteria were; (1) age ≥ 18, and (2) Resident of the state of Indiana. There was an incentive of $6 for participation. This study was approved by the Indiana University IRB (Protocol No.: 1,806,808,759). Informed consent of participants was obtained before the start of the online survey.

Measures

Exposures

In this study, we used seven different exposures. The exposure variables were different types of PPM, including, (1) walk on established trails and avoid contact with adjacent vegetation, (2) wear light-colored clothing (long-sleeved), (3) tuck shirt into pants and pants into socks, (4) use insect repellent on exposed skin, (5) treat outdoor clothing with special bug-spray (insect repellent, e.g. permethrin), (6) thorough body/clothes check after being outdoors, and (7) shower immediately after being outdoors.

Outcome

The only outcome of interest was a self-reported TBD diagnosis, which was captured through the following question; "Have you ever been told by a healthcare provider (e.g. physician, nurse practitioner, or pharmacist) that you have a tick-borne disease (example tick-borne diseases include LD, ehrlichiosis, etc.)?".

Covariates for Propensity Score (PS) Models

We created separate PS models for each PPM (Hernán and Robins [25]). The PS models estimate the probability of reporting practice of a PPM given a set of covariates. The value of PS is close to 1 for those with a high probability of practicing the PPM in the PS model. Covariates in the PS models were selected based on the evidence from previous studies and statistical analysis [3, 19], Herrington Jr. [26], [30, 31]]. In the PS models, we included 24 categorical and 2 continuous covariates along with the quadratic terms for continuous covariates (Table 1).

Table 1 Demographics of the study population

Covariates	Total N (%)[a]
Gender	
Female	1491 (51%)
Male	1429 (49%)
Other	7 (less than 0.01%)
Race	
White	2549 (87%)
Other	378 (13%)
Education	
High school or less	694 (24%)
Some college/AA	1017 (35%)
College	713 (24%)
Grad/Professional degree	503 (17%)
Employment	
Employed by others	1552 (53%)
Self-employed	277 (9%)
Not employed	863 (30%)
Other	235 (8%)
Income	
First quartile	744 (25%)
Second quartile	753 (26%)
Third quartile	696 (24%)
Fourth quartile	734 (25%)
	(Mean + SD)
Age	45.7 + 16.8

[a]N = 2927

Specifically, to create the binomial variables of TBD knowledge, general perceived efficacy of PPMs, and pet TBD risk we first used a series of questions (Table 2) to make a score. Then, we made the binomial variables by dichotomizing the score variables. To create TBD knowledge index, we assessed participants' knowledge with six sets of TBD knowledge questions, including true/false and multiple-choice questions about diseases caused by ticks, ways of transmission, places that ticks are found, period of year with highest tick exposure, and a picture question that asked the participants to identify the tick picture out of six different insects/arachnoids pictures. This index ranged from 0 to 16 [mean ± SD: 10.8 ± 2.6]. Participants who correctly answered 80% of these questions were categorized as having high TBD knowledge. The general perceived efficacy of PPMs was created based on 14 items about the efficacy of different PPMs. The range of this index was from 1 to 14 [mean ± SD: 8.8 ± 2.4]. Similarly, participants who correctly answered 80% of these questions were categorized as having high general perceived efficacy for all the PPMs. Lastly, pet TBD risk was based on four questions. Pet owners were categorized as having high pet TBD risk if they reported that their pets regularly spend time outdoors in vegetation; or if they did not regularly check their pets for ticks; or if they reported finding ticks on their pets in the last 12 months.

Because practicing a PPM might affect practice of other PPMs, in the PS model for each PPM, we included a variable capturing the practice of the other PPMs. Additionally, we included a variable about PPM-specific perceived efficacy. This is different from the general perceived efficacy of PPMs. For example, for the PS model of the 1st PPM, i.e. walk on established trails and avoid contact with adjacent vegetation, we included a variable that equaled 1 if any of the other PPMs, i.e. PPMs 2 to 7, were practiced and 0 otherwise. Further, we included the general perceived efficacy for all PPMs and the 1st PPM-specific perceived efficacy, i.e. *is walking on the trails effective to protect you against diseases caused by tick?*. The PPM-specific perceived efficacy had three levels (yes, no, maybe).

Table 2 Frequency of personal protective measures (PPM)

PPM	Frequency N (%)[a]
1. Walk on established trails and avoid contact with adjacent vegetation	2418 (83%)
2. Wear light-colored clothing (long-sleeved)	1604 (55%)
3. Tuck shirt into pants and pants into socks	1524 (52%)
4. Use insect repellent on exposed skin	2296 (78%)
5. Treat outdoor clothing with special bug-spray (e.g. permethrin)	1409 (48%)
6. Thorough body/clothes check after being outdoors	2373 (81%)
7. Shower immediately after being outdoors	1833 (63%)
Participants who conducted at least one of the PPM	2852 (97%)

[a]N = 2927

Statistical Analysis

We performed bivariate two-sample t tests and Chi-Square tests, to evaluate the associations between the covariates with the exposures and outcome. In the PS models, we included two sets of covariates; (1) all the covariates that were associated with the outcome, regardless of their relationship with the exposure, (2) covariates that were only associated with the exposure and were deductively known to be related to the outcome [6], Rubin and Thomas [36]).

To predict the PS, we used logistic regression models. Overall, we fitted seven PS models, one for each PPM. To obtain the marginal effect estimates of PPMs on self-reported TBD diagnosis, we used stabilized Inverse Probability (IP) weighting along with PS adjustment, a double robust approach (Hernán [25]). Next, using interaction terms, we searched for potential effect modifiers in our data set, including TBD knowledge, pet TBD risk, safety worry because of ticks, exposure to TBD protective advertisements, region, know others with a TBD, avoid being outdoors because of ticks, and ability to identify a tick. A p value of less than 0.05 was considered statistically significant. We report Odds Ratios (OR) and 95% Wald confidence intervals.

Results

Response rate was high in this study (81%) (Omodior et al. [29]). Overall, 3003 participants were eligible to participate in the study. However, data on exposure or outcome was missing for 76 individuals. Correspondingly, 2927 participants were included in the analyses. Participants were from 91 of 92 Indiana counties (Supplementary figure). Counties with the most participants for this analysis were, Marion (n: 437), Lake (n: 226), Allen (n: 172), Hamilton (n: 139), St. Joseph (n: 131), and Porter (n: 99). These counties are also the most populated counties in Indiana. The sampling fraction for different counties (county's sample size divided by county's population) was almost equal (range: 0.001).

Participants were mostly female (51%) and white (87%) (Table 3). Five percent of participants ($n = 142$) self-reported TBD diagnosis. The frequency of practicing PPMs ranged from 48 to 83% (Table 4).

In bivariate statistical analyses, all covariates were associated with the outcome except the followings: PPM-specific perceived efficacy covariates, feeling that one can protect themselves against TBD, region, considering ticks to be a problem in Indiana, income quartiles, and hours of weekly outdoor activity. The first two were significantly associated with all the PPMs. Further, most of the mentioned covariates were previously reported to be associated with the outcome [21, 23]. Hence, we only excluded "considering ticks to be a problem in Indiana" from the final PS models since this

Table 3 Relationship between personal protective measure and self-reported tick-borne disease diagnosis

PPM (Exposure)[a]	Self-reported TBD diagnosis (Outcome)	
	Crude OR (95% CI)	Doubly robust adjusted results OR (95% CI)
1. Walk on established trails and avoid contact with adjacent vegetation	**1.98 (1.13, 3.46)****	1.88 (0.99, 3.59)
2. Wear light-colored clothing (long-sleeved)	1.04 (0.74, 1.45)	0.87 (0.58, 1.28)
3. Tuck shirt into pants and pants into socks	**2.20 (1.52, 3.17)******	1.30 (0.87, 1.95)
4. Use insect repellent on exposed skin	0.87 (0.58, 1.29)	**0.55 (0.35, 0.88)*****
5. Treat outdoor clothing with special bug-spray	**1.81 (1.28, 2.55)******	0.90 (0.61, 1.35)
6. Thorough body/clothes check after being outdoors	0.70 (0.47, 1.04)	**0.40 (0.25, 0.67)*****
7. Shower immediately after being outdoors	**2.41 (1.59, 3.65)******	1.17 (0.67, 2.06)

PPM personal protective measure, *TBD* tick-borne diseases

[a]Variables in the propensity score models: ability to identify ticks, practice of other PPMs, area where tick was seen, hours of outdoor activity (and hours of outdoor activity squared), reason for spending time outdoors, exposure to TBD protective advertisements, know others with a TBD, consider ticks a problem in Indiana, consider ticks a problem at home, take any measure to prevent ticks at residential area, safety-worry because of ticks, health-worry because of ticks, avoid being outdoors because of ticks, feeling that one can protect themselves against TBD, feel at risk because of TBD, region, gender, race, education, employment status, income quartiles, age (and age squared), PPM-specific perceived efficacy, TBD knowledge, general perceived efficacy for all PPMs, pet TBD risk

Boldface indicates statistical significance (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$)

Table 4 Relationship between personal protective measure (exposure) and self-reported tick-borne disease diagnosis (outcome), stratified by effect modifiers

PPM[a]	Strata of effect modifier		p value for interaction term
	High TBD Knowledge	Low TBD knowledge	
3rd PPM: Tuck shirt into pants and pants into socks	0.51 (0.22, 1.18)	**1.62 (1.02, 2.58)**	**0.0311**
	Safety worry because of ticks (High)	Safety worry because of ticks (Low)	
3rd PPM: Tuck shirt into pants and pants into socks	0.78 (0.43, 1.43)	**1.98 (1.16, 3.38)**	**0.0282**
5th PPM: Treat outdoor clothing with special bug-spray	**0.51 (0.29, 0.91)**	1.30 (0.75, 2.24)	**0.0346**
7th PPM: Shower immediately after being outdoors	0.52 (0.25, 1.08)	**3.45 (1.65, 7.21)**	**0.0024**
	Avoid being outdoors because of ticks (High)	Avoid being outdoors because of ticks (Low)	
6th PPM: Thorough body/clothes check after being outdoors	**0.21 (0.09, 0.49)**	0.65 (0.36, 1.18)	**0.0441**
	Pet TBD risk (High)	Pet TBD risk (Low)	
5th PPM: Treat outdoor clothing with special bug-spray	1.41 (0.88, 2.24)	**0.41 (0.19, 0.88)**	**0.0118**

PPM personal protective measure, *TBD* tick-borne diseases

[a]Models adjusted for the measured confounders via stabilized inverse probability weighting. Effect modifier variable was excluded from the propensity score model

Boldface indicates statistical significance ($p < 0.05$)

covariate was not significantly associated to the outcome or exposure.

After stabilized IP weighting using the PS, the balance in covariates between the two exposure groups notably improved for all PPMs. For instance, before stabilized IP weighting 18 out of 26 covariates were significantly associated to the 2nd PPM. After stabilized IP weighting, only one covariate remained significantly associated with the 2nd PPM.

In crude unadjusted analyses, five PPMs had ORs above 1, four of which were significant. After controlling for confounders by means of IP weighting and PS adjustment, all ORs turned either protective, i.e. fell below 1, or null and insignificant. Particularly, those who reported using insect repellent on exposed skin were 0.55 times less likely to self-report TBD diagnosis compared to those who did not practice this PPM [OR (95% CI): 0.55 (0.35, 0.88)]. Participants who reported practicing thorough body/clothes check after being outdoors were 0.40 times less likely to self-report TBD diagnosis, when compared to those who did not practice this PPM [OR (95% CI): 0.40 (0.25, 0.67)]. Treating outdoor clothing with special insect repellent and wearing light-colored clothing (long-sleeved) also reduced the odds of TBD diagnosis by 10% and 13%, respectively, though not significantly (Table 5).

In effect modification analysis, we stratified the data by potential effect modifiers (Table 6). TBD knowledge marginally significantly modified the association between the 3rd PPM, i.e. tucking shirt into pants and pants into socks, and the self-reported TBD diagnosis outcome. Among participants with high TBD knowledge, this PPM had a protective OR [OR (95% CI): 0.51 (0.22, 1.18)], though insignificant. The protective magnitude vanished among those with low TBD knowledge. Safety worry because of ticks was an effect modifier for most of the PPMs. Participants with high safety worry because of ticks were more likely to benefit from the protective effects of different PPMs. Specifically, among participants who had a high safety worry because of ticks, those who reported treating outdoor clothing with special bug-spray were 0.51 times less likely to self-report TBD diagnosis [OR (95% CI): 0.51 (0.29, 0.91)]. This protective effect turned away among those with low safety worry because of ticks. Further, among participants who highly avoid being outdoors because of ticks, thorough body/clothes check after being outdoors was strongly protective against self-reported TBD diagnosis [OR (95% CI): 0.21 (0.09 0.49)]. This strong association reduced and turned insignificant among the other stratum. Lastly, among participants with low pet TBD risk, respondents who reported treating outdoor clothing with special bug-spray were less likely to self-report TBD diagnosis [OR (95% CI): 0.41 (0.19, 0.88)].

This protective effect dissipated among the participants with high pet TBD risk.

Discussion

Comparative to northeastern states, Indiana has a lower incidence of TBD (CDC [9]). This could have influenced the disease awareness and consequently practicing of PPMs. After controlling for all the measured confounders, we found that two of the PPMs are strongly protective against TBD diagnosis in Indiana residents. People who used insect repellent on exposed skin when they were outdoors and those who conduct a thorough body/clothes check after being outdoors were notably and significantly less likely to report a TBD diagnosis. TBD knowledge, safety worry because of ticks, avoid being outdoors because of ticks, and pet TBD risk modified the associations between different PPMs and self-reported TBD diagnosis.

In our study sample of Indiana, 5% of participants self-reported TBD diagnosis. This is an estimate of lifetime TBD diagnosis prevalence in current Indiana adult residents. Based on the TBD reported cases to CDC, our finding is much higher than the current expected lifetime TBD diagnosis prevalence in Indiana adult residents (CDC [9]). The reason for this difference might be the underreported TBD cases to CDC [37]. However, the high prevalence might also relate to measurement error or other sources of bias discussed in the limitation section.

We found that use of insect repellent on exposed skin is protective against TBD. Our results are in concordance with that found in two matched case–control trials in Connecticut [18, 43]. A former case–control study in Chester County, Pennsylvania, also reported that applying insect repellents is protective against LD [40]. The protective magnitude of this PPM in these studies ranged from 0.7 to 0.8, weaker from that found in our study, i.e. 0.55 [18, 40, 43]. Moreover, other studies on insect repellents, e.g. Citriodiol, DEET, or permethrin-based products, have shown that these products can reduce the risk of a tick bite [22, 33].

We found that a thorough body/clothes check for ticks after being outdoors reduces the odds of a TBD. Two studies in Connecticut and Pennsylvania showed that checking for ticks can reduce the odds a TBD by around forty percent [18, 40]. Compared to our results, the protective magnitude was weaker in these studies. TBD knowledge, perceived likelihood of a tick bite, history of tick bites, self-efficacy for removing a tick, and lower tick disgust have been reported as predictive factors for performing a check for ticks [4, 5, 28]. A moderate to high level of concern is another predictor for practicing this PPM [4, 5]. We found that the protective effect of this PPM is higher among those with high concern, i.e. those who highly avoid being outdoors because of ticks. Because of their high concern, this subgroup might more thoroughly check their clothes/body for ticks. Hence, the mentioned PPM, checking body/clothes for ticks, might be more effective in this subgroup. Interventions that target to increase individuals' concern about ticks can leverage the protective magnitude of different PPMs (Herrington Jr. [26]), including tick checking.

TBD knowledge has been established as an important predictor for practicing different PPMs [1, 4, 5]. Researchers had found that higher levels of TBD knowledge can be a predictor for checking for ticks [28] and wearing protective clothing [4, 5]. In the current study, we found that tucking shirt into pants and pants into socks is also a strong protective measure among individuals with high TBD knowledge, though insignificantly.

Very few studies have evaluated the protective effect of showering after being outdoors against TBD [35]. Connally et al. found that showering within two hours after being outside is significantly protective against LD [18]. A study in suburban settings reported that those who shower after spending time outdoors are more likely to find ticks, perhaps because showering provides an opportunity to check for ticks [27]. In our study, we found that among individuals with low safety worry because of ticks showering after being outdoors significantly increases the risk of TBD. Participants with low safety worry might perceive that showering alone can protect them against ticks. However, showering might be efficiently protective when it is combined with a body check, especially for participants who have been outdoors for a longer time, since it takes some hours for ticks to attach to the body. Hence, showering alone might not suffice to remove the attached ticks. Showering alone, without body check, might be useful when the duration of being outdoors is shorter, for instance after being outdoors for a couple of hours in peri-domestic areas [18]. We suggest that public health interventions emphasize on a combination of tick checking and showering rather that showering alone.

Pets are susceptible to different TBD, e.g. LD and ehrlichiosis [38]. Pets can carry ticks indoors and increase TBD risk in humans. They can also act as reservoir for human TBD [38]. Pet TBD risk increases in different ways, e.g. when pets spend more time outdoors. In the current study, we observed that treating outdoor clothing with special bug-spray was not effective among households with high pet TBD risk. This finding highlights the importance of practicing both personal and pet protective measures against ticks. Interventions such as providing pamphlets regarding personal and pet TBD protective measures to pet owners, might be successful in reducing the TBD public health burden.

Limitations

This study has several limitations. Because of our cross-sectional study design, we are unable to assess the temporal relationship of the exposures and outcome variables. Participants might have started practicing the PPM as a result of a former TBD, which would bias the PPM protective magnitudes towards the null. Moreover, the data was collected by means of a self-reported survey, increasing the possibilities of measurement error. Recall bias is probable for PPMs. This could have changed the direction of true association in either an upward or a downward fashion. However, since any PPM is a routine practice, recall bias is less of a concern. As for the TBD diagnosis, it was also measured subjectively via self-reported responses and no validation procedure was implemented to lessen measurement error. For example, participants who had visited a physician and/or had taken prophylactic antibiotics following a tick bite may incorrectly report having been treated for a TBD. However, recall bias is less probable for the outcome measurement as any TBD diagnosis is an unforgettable event. Moreover, previous studies have successfully used self-reported outcome measures (CDC [8]; Social Research Center [41]). For instance, the Behavioral Risk Factor Surveillance System uses self-reported telephone surveys for data collection, yet, the dataset has been successfully used as for policy formulation (CDC [8]). Lastly, online respondents' characteristics usually departs from the population characteristics [24]. We tried to solve this limitation by use of Qualtrics specific survey panels [24].

Conclusions

The PPMs are the first line of defense against TBD. Different PPMs have been developed to protect populations that live in areas where ticks are prevalent. In the state of Indiana, we observed that using insect repellent on exposed skin and thorough body/clothes check after being outdoors were the most efficient PPMs. Participants knowledge of TBD, safety worry and avoiding outdoors because of ticks, and pet TBD risk modified the protective effect of different PPMs. The results of this study might be used when developing intervention programs against TBD.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix

See Tables 5 and 6.

Table 5 Exposure, outcome, and covariates in the propensity score models

Variable description	Values
Exposure	
Walk on established trails and avoid contact with adjacent vegetation	Yes, No
Wear light-colored clothing (long-sleeved)	Yes, No
Tuck shirt into pants and pants into socks	Yes, No
Use insect repellent on exposed skin	Yes, No
Treat outdoor clothing with special bug-spray	Yes, No
Thorough body/clothes check after being outdoors	Yes, No
Shower immediately after being outdoors	Yes, No
Outcome	
Self-reported TBD diagnosis	Yes, No
Propensity score models' covariates	
1. Ability to identify ticks	Yes, No, maybe
2. Practice of other PPMs	Yes, No
3. Area where tick was seen	Recreational, residential, employment, other, not seen a tick
4. Hours of outdoor activity	Continuous[a]
5. Reason for spending time outdoors	Employment, leisure/recreation, other, not spend time outdoors
6. Exposure to TBD protective advertisements	Yes, No
7. Know others with a TBD	Yes, No
8. Consider ticks a problem in Indiana	Yes, No, maybe
9. Consider ticks a problem at home	Yes, No, maybe
10. Take any measure to prevent ticks at residential area	Yes, No
11. Safety-worry because of ticks	High, Low
12. Health-worry because of ticks	High, Low
13. Avoid being outdoors because of ticks	High, Low
14. Feeling that one can protect themselves against TBD	High, Low
15. Feel at risk because of TBD	High, Low
16. Region	Urban, rural
17. Gender	Female, Male
18. Race	White, Other
19. Education	High school or less, some college/AA, College, Grad/Professional degree
20. Employment status	Employed by someone else, self-employed, other, not employed
21. Income quartiles	Quartiles
22. Age	Continuous[a]
23. PPM-specific perceived efficacy	Yes, maybe, No
24. TBD knowledge	High, Low
25. General perceived efficacy for all PPMs	High, Low
26. Pet TBD risk	High, Low

[a]We included both linear and quadratic terms in the propensity score models

Table 6 Survey questions and response options

Question[a]	Answers[b]
Questions about the exposure variables (Personal protective measures)	
Which of the Personal Protective Measures listed below, do you adopt when outdoors, or after spending time outdoors, during the summer months (April to October), specifically because you are concerned about tick exposure and tick-borne diseases (Questions 1 to 7)	
1. Walk on established trails and avoid contact with adjacent vegetation, such as grasses and low-shrubs when outdoors, specifically to prevent tick bites	Yes, No
2. Wear light-colored clothing (long-sleeved shirt and pants) to enable me identify and remove ticks when outdoors	Yes, No
3. Tuck shirt into pants, and the pants into socks when outdoors	Yes, No
4. Use bug spray (insect repellent) on exposed skin when outdoors	Yes, No
5. Treat outdoor clothing with special bug spray (insect repellent, e.g. Permethrin)	Yes, No
6. Conduct a thorough check of clothing and the body soon after returning from the outdoors	Yes, No
7. Shower immediately after returning from the outdoors, specifically because of concern for ticks	Yes, No
Question about the outcome variable (Self-reported TBD diagnosis)	
Have you ever been told by a healthcare provider (e.g. physician, nurse practitioner, or pharmacist) that you have a tick-borne disease (example tick-borne diseases include Lyme disease, ehrlichiosis, etc.)?	Yes, No
Questions used for making the covariates in propensity score models	
A. Demographics	
A1. Which of the following best describes you?	Female, Male, Other
A2. Which of the following best describes you?	White/European American, Black/African American, Latino/Latina, Asian, Native American, Other
A3. Which of the following best describes your highest level of education?	Less than High school, High school graduate, Some college, 2 year degree, 4 year degree, Professional degree, Masters degree, Docterate
A4. What is your current employment status?	Self-employed, Employed by someone else, Not employed, Other
A5. What was your total household income before taxes during the past 12 months?	Text box
A6. What is your age in years (please enter the number below)?	Text box
A7. Do you consider where you live in Indiana to be	Urban, rural
B. Assessment of outdoor level activity	
B1. Approximately how many hours per week do you spend outdoors during the summer months (April to October, [Provide your best estimate])?	Text box
B2. Which of the following explains the reason you spend time outdoors?	Leisure/recreation (e.g. hunting, gardening, lawn mowing, leisure walks, playing with the pets, etc.), Employment (e.g. natural resource employee, other outdoor-related employment, etc.), Other
C. Tick-borne disease Awareness	
C1. Can you identify a tick?	Yes, No, Maybe
C2. Within the past 12 months, have you seen a tick?	Yes, No, I don't know
C3. Where did you see a tick?	At my residential place, At place of employment, At a place of outdoor recreation, Other
D. Pet ownership and TBD Risk (used for making the pet TBD risk score)	
D1. Do you own a dog and/or a cat as a pet?	Yes, No
D2. Does your dog/cat regularly spend time outdoors in grassy shrubs, parks, wooded areas, or other places with vegetation?	Yes, No
D3. Do you regularly check your dog/cat for ticks?	Yes, No
D4. Within the past 12 months, have you found at least one tick on your dog/cat?	Yes, No
F. TBD knowledge questions (usef for making the TBD knowledge score)	
F1. Identify the tick from the pictures below	Images of; Fly, Mosquito, Silverfish, Tick, Cockroach, Earwig

Table 6 (continued)

Question[a]	Answers[b]
F2. Diseases transmitted by ticks in the U.S. mainly affect:	The health of animals, The health of humans, The health of animals and humans, I don't know
F3.1 Ticks can be found in grassy yards	True, False, I don't Know
F3.2 Ticks can be found on pets (e.g. Cats & Dogs)	True, False, I don't Know
F3.3 Ticks are present in grassy shrubs, or wooded vegetation, or leaf litter	True, False, I don't Know
F4. Diseases transmitted by ticks can be transmitted to humans:	Through a mosquito bite, by drinking contaminated water, through a tick bite, through close contact with an individual with a tick-borne disease
F5. Which of the following is a disease transmitted by ticks (Multiple True–False questions):	Zika disease, Lyme disease, Rocky Mountain Spotted Fever, West Nile disease, Chikungunya disease, Tularemia
F6. The period with the highest risk for tick exposure is:	May to October, November to April, I don't know
G. General knowledge of PPM (used for making the general perceived efficacy of PPMs score)[c] Are the following measures effective to protect you against diseases caused by ticks?	
G1. Examining yourself for ticks and removing them after you have been to a wooded area	Yes, Maybe, No
G2. Exercising regularly	Yes, Maybe, No
G3. Thoroughly washing your hands before eating	Yes, Maybe, No
G4. Wearing long clothing (such as long pants and long-sleeved shirts, wearing gaiters or tucking pants into socks) in wooded areas	Yes, Maybe, No
G5. Using bug spray (insect repellent containing DEET) on skin and clothes in wooded areas	Yes, Maybe, No
G6. Healthy eating habits	Yes, Maybe, No
G7. Avoiding wooded areas	Yes, Maybe, No
G8. Putting pesticides on residential property	Yes, Maybe, No
G9. Wearing sunscreen when spending time outside	Yes, Maybe, No
G10. Taking a shower or a bath after you have been to a wooded area	Yes, Maybe, No
G11. Regularly mowing the lawn on your property	Yes, Maybe, No
G12. Removing or sweeping the leaf litter on your property	Yes, Maybe, No
G13. Putting up barriers to exclude deer on your property	Yes, Maybe, No
G14. Staying on pathways in a wooded area	Yes, Maybe, No
H. Tick borne diseases concern	
H1. To what degree do you worry about your safety because of ticks?	Likert scale
H2. To what degree do you worry about your health because of ticks?	Likert scale
H3. To what degree do you avoid being outdoors because of ticks?	Likert scale
H4. To what degree do you feel you can protect yourself from tick-borne diseases?	Likert scale
H5. To what degree do you feel at risk for tick-borne diseases?	Likert scale
H6. Do you consider ticks to be a problem in Indiana?	Yes, Not Sure, No
H7. Do you consider ticks to be a problem where you live?	Yes, Not Sure, No
I. Other related questions	
I1. Do you know anyone who has been told by a healthcare provider (e.g. physician, nurse practitioner, pharmacist) that they have a tick-borne disease (example tick-borne diseases include Lyme disease, Ehrlichiosis, etc.)?	Yes, No
I2. Do you currently take any measures to prevent and control ticks at your primary residential property?	Yes, No
I3. Have you recently seen, heard or read an advertisement about tick-borne disease prevention?	Yes, No

Table 6 (continued)

[a]The numbering and the order of the questions differ from that in the actual survey. The order is based on how we used these questions in the current study, i.e. exposure, outcome, and covariates

[b]Response options are seperated by comma. They do not necessarily represent the values for the study variables. Please refer to the methods section and Table 1 for information about the values of each variable

[c]When making the PPM-specific perceived efficacy, we used single questions of this list. For instance, for the 7th PPM (taking shower after being outdoors) we used G10 to make the PPM-specific precieved efficacy

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