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Tick Spotting: Using mannequins to evaluate individual efficacy at detecting *Ixodes scapularis* (Acari: Ixodidae)

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Abstract

Tick checks are a free and accessible personal protection measure used to prevent tick bites and are frequently recommended by public health institutions and vector-borne disease researchers. However, little is known about how successful people are at detecting ticks on themselves or others when using this method. We developed a tool for evaluating factors affecting the efficacy of tick checks using mannequins. In 2022 and 2023, we recruited 207 participants to complete a brief survey and perform a tick check on a mannequin, where dead *Ixodes scapularis* Say larvae, nymphs, and adults had been glued at various locations. None of the survey results (demographics, knowledge, attitude, and concerns about ticks and tick-borne disease) were associated with likelihood of tick detection. On average, participants detected 42% of nymphs on the mannequin. Adult females were 3 to 4 times more likely to be detected than nymphs. Ticks above the waistline were detected 3 times more frequently than ticks below. Ticks that were on white-colored clothing were 3 times more likely to be detected than those on dark-colored clothing. Ticks that were not covered by hair or clothing were 2 times more likely to be detected than covered ticks. These findings show that there are multiple factors that may limit tick detection during a tick check. Outreach should emphasize the importance of awareness of size variation between stages, completing a thorough whole-body examination including the lower limbs and covered locations, and wearing light-colored clothing.

Keywords

survey; blacklegged tick; prevention

Introduction

In the United States (US), ticks pose a major threat to public health due to the transmission of disease-causing pathogens that have a wide range of adverse health outcomes, including, in rare cases, mortality. Lyme disease (LD), caused by the bacteria *Borrelia burgdorferi* and *Borrelia mayonii* and primarily vectored by the bite of *Ixodes scapularis*, is the most common tick-borne disease (TBD) in the US (Burgdorfer et al. 1982, Pritt et al. 2016). An estimated 476,000 individuals are diagnosed and treated with Lyme disease annually (Kugeler et al. 2021). Although in most cases treatment options exist, acquiring LD or any TBD can be costly for both the afflicted individual and the healthcare system (Adrion et al. 2015, Mac et al. 2019).

Reducing TBD is currently primarily focused on preventing tick bites. Personal protection measures encompass changes in behaviors or actions designed to reduce the likelihood of encountering or being bitten by a tick (Eisen 2022). Examples include the application of repellents to clothing or skin, tucking in clothing to create a barrier against ticks, and conducting frequent but cursory tick checks while outdoors and thorough tick checks when coming home after outdoor activities.

Performing a tick check provides an opportunity for removal pre or post attachment, reducing the risk of pathogen exposure (Lantos et al. 2021). Tick checks are free of cost and easy to implement. They do not require the use of chemicals, including pesticides or repellents which some individuals prefer to avoid (Shelomi 2020). These benefits have led to tick checks being widely promoted by the Infectious Disease Society of America (IDSA) and public health agencies, especially in high TBD incidence areas (Lantos et al. 2021, Centers for Disease Control and Prevention 2020, Wisconsin Department of Health Services 2023). Surveys of residents in the LD-endemic states Connecticut, Maryland, Wisconsin, New York, and New Jersey revealed that checking for ticks was one of the most common personal protection measures taken (Herrington et al. 1997, Niesobecki et al. 2019, Bron et al. 2020, Beck et al. 2022). Nonetheless, evidence for the effectiveness of this widespread strategy for reducing TBD risk is mixed (Schwartz et al. 2022). Some studies found a positive correlation between the use of a range of personal protection measures including tick checks and reduced risk (Smith et al. 2001, Connally et al. 2009), while other studies found no correlation (Orloski et al. 1998, Phillips et al. 2001, Vázquez et al. 2008).

The effectiveness of a tick check relies on the ability to detect a tick. However, prior research suggests the public struggles to detect and identify ticks. Many patients that are diagnosed with LD have no recollection of being bitten by a tick (Strle et al. 1999, Nowakowski et al. 2001, Wormser et al. 2005). Detection may be difficult because ticks – especially immature life stages – are inconspicuous and hard to see due to their small size. It might also be harder to differentiate the dark-colored *I. scapularis* from dark-colored fabric. Evidence also shows that people often fail to even recognize the immature stages as ticks. In one study, 40% of the participants were unable to identify a nymphal *I. scapularis* as a tick when presented with an array of preserved specimens (Bron et al. 2021). The difficulty in detecting nymphs is also suggested by studies that have shown that adult *I. scapularis* make up most of the blacklegged ticks submitted to institutions for identification, despite nymphal

I. scapularis posing the greatest risk for tick-borne diseases (Falco et al. 1999, Schwartz et al. 2017, Kopsco et al. 2021, Kache et al. 2023). An inability to detect or recognize ticks would result in a non-thorough tick check engendering a false sense of security for the checker. A better understanding of the factors affecting the efficacy of this widespread personal protection measure could lead to improvements in education and outreach related to the practice.

In the study, we asked people to search a life-sized mannequin for *I. scapularis* ticks. In 2022, we aimed to evaluate the proficiency of participants in detecting ticks, identify key factors influencing tick detection, and determine the effectiveness of these mannequins as a research tool. In 2023, we conducted a follow-up study using the same methodology, with a particular focus on investigating the effect of clothing color on tick detection.

Materials and Methods

The University of Wisconsin – Madison Institutional Review Board (IRB) reviewed the survey protocol and deemed it exempt (IRB2022-1364).

Recruitment

The recruitment of participants was opportunistic. Surveys were conducted at three separate locations on the University of Wisconsin – Madison campus in November of 2022. Campus locations were near cafeterias, dorms, and/or parking lots. In November of 2023, participants were recruited at the East Bluff Woods trailhead at Devil’s Lake State Park, Baraboo, WI. For both years, we aimed to set up tents in areas with high foot traffic, near communal gathering spots, and had open, flat space for the tents and mannequins to remain level. Team members would inquire of passersby if they were interested in the survey, explaining its importance in tick bite prevention research as well as the prizes they would be entitled to with their enrollment. Participants were required to be at least 18 years of age to enroll in the study. We used incentives in the form of participation gifts (e.g. Playing cards, water bottles, tumblers, small plushies, etc.) valued between 1-6 US dollars. In 2022 we had an additional incentive by offering entry into a raffle where the winning entrant selected a prize from a pre-approved list of items valued between 120-200 US dollars. No personal identifiers were linked to the survey, and receiving gifts or prizes was independent of answers or results. In 2023 we had an additional incentive by offering entry into a raffle where the winning entrant selected a prize from a pre-approved list of items valued between 120-200 US dollars. No personal identifiers were linked to the survey, and receiving gifts or prizes was independent of answers or results.

Survey

In both years of the study, participants received a packet including an HRP-502(a) consent sheet, a screening sheet, a nine-part questionnaire, and images of mannequin silhouettes (Supplementary File S1). The questionnaire asked for the following demographic information: gender, age, occupation, state/region of residence, and country of origin. For analysis, participants were categorized as originating from a “high incidence” Lyme disease state if their given state of origin was classified as such by the CDC (Kugeler et al. 2024).

The CDC defines a region as high incidence if there are 10 or more confirmed cases per 100,000 individuals for three years. Participants from all other US states and territories, and participants originating from abroad were categorized together as originating from a low incidence region. Additionally, there were five questions about knowledge, attitudes, and behavior (KAB) related to ticks, TBDs, and outdoor activities. Participants reported their frequency of outdoor activities during May through November and then rated their agreement on a 5-point Likert scale with 1 equating to “strongly disagree” and 5 to “strongly agree” to the following four statements:

- “I am knowledgeable about ticks and tick-borne diseases.”
- “I am concerned about ticks and tick-borne diseases.”
- “I am confident in my ability to find and identify ticks on myself or another person.”
- “I always check myself and others for ticks after spending time outdoors.”

For descriptive statistics, we grouped Likert scale responses of 1 and 2 as “disagree” and 4 and 5 as “agree”.

Simulated tick checks

After completing the questionnaire, participants were informed that they would have up to 5 minutes to perform a tick check on a mannequin. Researchers told participants to do the check the way they would normally conduct one on a friend or relative at the end of a hike. They were instructed to place a 6.4-millimeter diameter sticker (Avery Products Corporation, Brea, California) on a paper sheet with the mannequin's silhouette, corresponding to where they detected a tick. They were not told how many ticks were on the mannequin.

Tick checks were performed in a partially enclosed tent to prevent those waiting from observing participants in the tent (Fig. 1). Only one participant was allowed in the tent at a time, and no member of the research team was present while a tick check occurred. The research team did not provide information or documentation to participants pre- or post-survey about life stages, species, or number of ticks that were on the mannequins. Research team members reset the poses, clothes, and hair of each mannequin and checked that ticks remained in place after each participant to standardize the initial presentation. Ticks used in this study were collected in 2019 in a city park in Eau Claire, Wisconsin, and preserved in 70% ethanol. Ticks were identified to species and life stages using standard keys (Clifford et al. 1961, Keirans and Litwak 1989, Keirans et al. 1996).

Mannequins were 175 centimeters tall, female presenting, and constructed out of polypropylene (model numbers MK-175 and MK-F61; Factory Direct Wholesales LLC, Duluth, Georgia). In 2022, the mannequins were dressed in an untucked plain, white cotton T-shirt (Fruit of the Loom, Inc. Bowling Green, Kentucky); ankle-length, dark blue denim jeans (Prana Company, Carlsbad, California); white running shoes (Athletic Works, Walmart Inc. Bentonville, Arkansas); and a shoulder-length brown hair wig that fell partially forward. In 2022, a total of 16 unfed (flat) *I. scapularis* – 2 larvae, 10 nymphs and 4 adults (2 females,

2 males) – were attached to clothing on each mannequin (at locations indicated by life stage in Fig. 2). To attach ticks, we used the end of a 2 millimeter diameter wooden dowel rod (Walmart Inc. Bentonville, Arkansas) to place a small dot of glue (Elmer's Products, Inc. Westerville, Ohio) to the clothes. Ticks were then placed dorsal side up on top of the glue dot with forceps. Ticks were equally distributed on light and dark clothing. All larvae, six nymphs, one adult male and one adult female were below the waistline of the mannequin. Four ticks, one adult male and three nymphs, were hidden from direct view by clothing or hair. Tick locations were identical on both mannequins. The location characteristics were above or below the waistline, clothing color, and covered or uncovered.

In 2023, mannequins were dressed either in an all-black or all-white outfit consisting of running shoes (Skechers USA Inc., Manhattan Beach, California), ankle socks (Hanes, Winston-Salem, North Carolina), a short sleeve shirt (Athletic Works, Walmart Inc., Bentonville, Arkansas), long athletic style pants (All In Motion, Target Corporation, Minneapolis, Minnesota), and a shoulder-length wig with the hair down. The clothing was identical apart from fabric color. Twenty ticks, 10 nymphs and 10 adults (5 females and 5 males), were in the same locations on both mannequins (Fig. 3). Six nymphs, three adult males and two adult females were attached below the waistline. Three nymphs, one adult male, and one adult female were obscured by the shirt or hair.

Scoring tick checks

Each tick was assigned an identifier (Fig. 2, 3, Table 1, 2) which was linked to location characteristics and life stage. A tick was scored as detected if a sticker was in the expected location of that tick. Locations on the sheets were graded independently by two members of the research team to prevent biases in the scoring. An intraclass correlation coefficient was calculated (Gamer et al. 2019), and we checked the overall agreement and the agreement on the detection of individual ticks. The overall scoring had a high level of agreement (2022: 0.93 ± 0.01 , $p < 0.001$; 2023: 0.88 ± 0.01 , $p < 0.001$), and the kappa values per tick showed substantial to almost perfect agreement depending on the tick (2022: 0.89 ± 0.02 ; 2023: 0.86 ± 0.02 ; Supplementary File 2). We interpreted the kappa values following Landis and Koch (1977). For the rest of the analysis, the scoring values by one research team member were used.

Model construction

The first generalized linear model was used to assess the relationship between the response variable (i.e. the number of ticks successfully detected), and the explanatory variables, including demographic characteristics, knowledge of ticks, origin from high- or low-incidence regions, and frequency of outdoor activities. When there were few responses to a particular question at a Likert scale level, participants were merged with levels of like agreement to avoid skewing the model. Therefore, we combined "Outdoors" 1 and 2, "Knowledge" 4 and 5, "Concern" 1 and 2, and "Confidence" 4 and 5. In the second generalized linear mixed-effect model, we investigated the location characteristics and life stage that predicted the likelihood that a tick was found, and we included participant (survey ID) as a random factor.

All models were checked for variance inflation factors (VIF; Belsley et al. 2005) and the levels of significance were established by log-likelihood ratio tests (Lewis et al. 2011). In 2023, the variables related to knowledge of ticks and confidence in tick checks showed elevated VIF values, raising concerns about multicollinearity. To assess the impact of this collinearity, we ran models with and without these variables and found no significant differences indicating that collinearity did not substantially affect the results. All analyses were conducted in R (4.4.1; R Core Team, 2024) using the packages broom (1.0.6 Robinson et al. 2024), broom.mixed (0.2.9; Bolker and Robinson, 2024), car (3.1-3; Fox et al. 2019), lme4 (1.1.35; Bates et al. 2015), lmttest (0.9.40; Zeileis and Hothorn 2002) and lsmeans (2.30; Lenth 2016).

Results

Demographics

In total, 207 people participated in our study, 96 in 2022 on the UW-Campus and 111 in 2023 at a state park (Table 3). Some participants (n = 6) did not answer all the questions on the survey. Most participants (92%, 190/207) were between the ages of 18 to 54. There was an almost even number of people, 100 and 101 respectively, who identified as male and female. Four participants identified as non-binary, and two preferred to not say. Eighteen nationalities were represented in the study, with the majority (184/206) originating from the US. Of the US participants, 65% (120/184) were from high incidence states. The high incidence states listed by participants in our survey were Connecticut, Maryland, Minnesota, New Jersey, New York, Pennsylvania, Washington DC, and Wisconsin.

Seventy-six percent (158/207) of participants said they spent time outdoors at least weekly during peak *I. scapularis* months. A little over half (114/201) of participants agreed with the statement that they were knowledgeable about ticks and TBD compared to 30% (60/201) who disagreed. Slightly under half (97/201) felt confident in their ability to find ticks and 23% (47/201) were not confident. Almost two-thirds of participants (135/201) indicated that they were concerned about ticks and TBD, however, of these 135 participants only 50% (68/135) agreed that they regularly performed tick checks. This was only slightly higher than the overall percentage of 42% (85/201) of participants who agreed that they performed tick checks regularly. Similarly, 43% (65/152) of participants that reported being outdoors at least weekly agreed that they performed tick checks regularly. Only 12% (7/60) of participants who disagreed with the statement about being knowledgeable about ticks and TBD agreed that they regularly check themselves for ticks, while those who considered themselves knowledgeable checked for ticks 60% (68/114) of the time.

There were some differences in responses between the two study years that were related to the different locations. Participants in 2022 in the campus study were younger with a median age of 19 compared to 34 in 2023. A larger percentage of participants originated from a high incidence state in 2022 (63%, 60/96) than in 2023 (39%, 43/110), where park visitors reported Illinois as the most frequent home state. Participants in 2023 agreed with the statements about knowledge (70%, 74/105), confidence (59%, 62/105), and frequency (51%, 54/105) of tick checks more often than their 2022 counterparts (41% 40/96; 36%, 35/96; 32%, 31/96).

Participant characteristics do not predict success of tick detection

Gender (2022: $\chi^2 = 0.13$, $df = 3$, $p = 0.988$; 2023: $\chi^2 = 2.30$, $df = 3$, $p = 0.513$), region of origin (2022: $\chi^2 = 1.12$, $df = 1$, $p = 0.290$; 2023: $\chi^2 = 1.22$, $df = 1$, $p = 0.269$), time outdoors (2022: $\chi^2 = 3.74$, $df = 3$, $p = 0.290$; 2023: $\chi^2 = 3.41$, $df = 3$, $p = 0.332$), knowledge (2022: $\chi^2 = 4.49$, $df = 3$, $p = 0.214$; 2023: $\chi^2 = 3.76$, $df = 3$, $p = 0.288$), concerns (2022: $\chi^2 = 1.30$, $df = 3$, $p = 0.729$; 2023: $\chi^2 = 0.32$, $df = 3$, $p = 0.955$), confidence (2022: $\chi^2 = 2.42$, $df = 3$, $p = 0.489$; 2023: $\chi^2 = 1.38$, $df = 3$, $p = 0.709$), or self-perceived experience at performing tick checks (2022: $\chi^2 = 2.88$, $df = 4$, $p = 0.579$; 2023: $\chi^2 = 0.92$, $df = 4$, $p = 0.922$) did not significantly predict the number of ticks a participant found. This remained true when results were stratified by tick life stage.

Life stage and location of tick impacts detection by participant

No participant detected all ticks on a mannequin. In 2022, the median number of ticks found by participants was seven (range = 0-13 out of 16). The median number of detections was zero larva (range = 0-2 out of 2), four nymphs (range = 0-8 out of 10), one adult male (range = 0-2 out of 2), and two adult females (range = 0-2 out of 2). Tick 14 (adult male) and Tick 2 (larva) were respectively the most and least commonly found ticks with 78% (75/96) and 4% (4/96) of the participants detecting them in 2022 (Table 1, Fig. 2). In 2023, the median number of ticks detected on the white and black clothed mannequins was 14 (range 4-14) and 10 (range 0-16) out of 20, respectively. The median number of nymphs ($n=10$), adult males ($n=5$), and adult females ($n=5$) on the white-clothed mannequin was 7, 4, and 4 (range 1-10, 1-5, 1-5) while the black-clothed mannequins had medians of 4, 3, and 3 (range 0-8, 0-5, 0-5). Tick T (nymph) was the least detected tick for both the white and black mannequins with 31% (17/55) and 11% (6/56) of participants detecting the tick, respectively (Table 2, Fig. 3). Tick D (adult male) (97%, 53/55) was found the most on the white-clothed mannequin and Tick O (adult female) (79%, 44/56) was found the most on the black-clothed mannequin (Table 2, Fig 3).

The life stage of the tick had a significant effect on the likelihood of being found by participants. Specifically, the likelihood was the lowest for larvae (2022: estimate = -1.76 ; p -value = <0.001) and the highest for adult females (2022: estimate = 1.39 ; p -value = <0.001 , 2023: estimate = 1.01 ; p -value = <0.001). Participants were 4 and 3 times more likely to detect an adult female than a nymph in 2022 and 2023, respectively. Nymphs were 6 times more likely to be detected than larvae.

Ticks above the waistline were more likely to be detected compared to ticks below in both 2022 (13-fold, estimate = 2.85 , $df = 1$, p -value < 0.001) and 2023 (3-fold, estimate = 1.32 , $df = 1$, p -value < 0.001). In 2022, two larvae were included, and both were glued to the shoes which may have biased this comparison since they are very small (no larvae were used in 2023). However, even when only nymphs were included in the 2022 model, participants were still much more likely to find those above the waistline than below (23-fold, estimate 3.12 , $df = 1$, p -value < 0.001). In 2022, mannequins were dressed in dark jeans and light-colored shirts. This additional variable may explain why the likelihood of detection of any tick above the waist was so much higher in 2022 (13-fold) when compared to 2023 (3-fold) when mannequins wore either all dark or all light clothing.

Ticks that were not covered by either clothing or hair were more likely to be found (2022: 2-fold, estimate = 0.57, df =1, p-value < 0.001; 2023: 2-fold, estimate = 0.71, df =1, p-value < 0.001) than those that were covered.

The color of the clothing was not significant in 2022 (estimate = -0.3, df = 1, p = 0.143). However, this year, the dark jeans were restricted to below the waistline, potentially confounding the model. In 2023, there was a significant increase in the likelihood of a tick being detected when on light-colored clothing (3-fold, estimate = 1.15, df = 1, p-value < 0.001). In 2023, 19 of the 20 ticks were detected more often on white-colored clothes than black-colored clothes (Table 2). Only Tick L was detected more often on the black-clothed mannequin.

Discussion

In this study, we simulated a tick check on an individual by using a life-sized mannequin and real tick specimens. Using this simulation tool, we identified several key factors that affected the likelihood a tick was detected. Specifically, *I. scapularis* ticks that were above the waistline, uncovered, or on light-colored clothing were more likely to be detected. Adult females were much more likely to be found compared to males and other life stages. Demographic and KAB responses by participants were not linked to the participant's ability to detect ticks on the mannequin.

The lack of relationship between the survey responses and the number of ticks detected highlights the discrepancy in the general public's perceived and actual ability in conducting tick checks. Interestingly, the factors that we predicted would be most important for detecting ticks, self-reported confidence in ability and experience with tick checks, did not lead to any significant improvements in detection. People may consider themselves knowledgeable but may not know the proper steps in conducting a tick check or may not possess a well-defined search image of an *I. scapularis* tick. When people conduct a tick check on themselves or others, they are unaware of how many ticks were acquired. After performing the check, they may believe they have detected all ticks, even if some were missed. This can lead to a false sense of confidence in their ability to detect ticks. A detection bias of what a tick looks like and where to check for ticks could occur when people are better at spotting adult females, ticks above the waist, on white clothing, and in uncovered locations. This in turn could skew their perception of where ticks are found and where to dedicate their time and effort looking for ticks. More research is needed to understand how people conduct tick checks, and the ways to bridge the self-perceived and actual knowledge gap we saw in our study.

Trouble detecting ticks, especially the nymphs, may explain why some studies that evaluate the practice of performing tick checks do not find an association between their use and lowered TBD risk (Ley et al. 1995, Klein et al. 1996, Orloski et al. 1998, Phillips et al. 2001, Vasquez et al. 2008, Finch et al. 2014). The association between a tick check and lowered TBD risk could be weakened if the check is ineffective in detecting ticks that are crawling on clothing or biting. Out of all 207 participants surveyed in both iterations of the current study, only one participant found all 10 nymphs. Depending on which mannequin was

inspected, participants detected a median of four to seven out of 10 nymphs, leaving three to six nymphs undetected. Nymphs have been implicated as the life stage of greatest concern from a human health perspective as the onset of most LD cases aligns with the phenological peak of nymphal activity (Falco et al. 1999, Schwartz et al. 2017). The timing of human outdoor activity and the difficulty of detecting nymphs contribute to this phenomenon. While participants did not find all nymphs, the results of our study indicate that a single tick check can be effective at detecting many ticks and conducting frequent tick checks while outdoors may increase the likelihood of detecting all ticks crawling.

The nymphs rarely detected were those below the waist, on dark-colored clothing, or covered by the shirt or hair. Fewer ticks detected on the lower half of the mannequin may indicate that participants either did not consider checking for ticks on the lower body or were more hesitant or physically unable to do so. This finding is troubling as immature *I. scapularis* are more frequently found attached below the waistline (Falco and Fish 1988, Xu et al. 2016, Hart et al. 2022). Ticks covered by clothing or hair were not visible and required an additional step by the participant to detect the tick. Additionally, we surmise that the dark blue jeans, black shoes, black socks, black pants, and black shirt provided less of a visual contrast to the dark *I. scapularis* nymph than white running shoes, white shoes, white pants, and white shirt.

People can manipulate some of these factors to increase their odds of tick detection. Showering after coming indoors, and tucking in shirts, socks, and pants, remove the refugia that clothes can provide a tick. Tucking in socks and shirts has the additional benefit of fewer attachment spots below or at the waistline. Wearing light or white colored clothing increases the odds of detection of all life stages and locations of the tick on the person. Comprehensively checking the lower body – by bending legs or lowering oneself – may be cumbersome, but is critical to increasing the odds of detecting a tick. However, physical limitations may complicate a thorough lower body evaluation. In this case, recruiting someone else's help or utilizing tools such as a mirror may aid in visibility in this critical search area.

There are special considerations for evaluating the efficacy of tick checks by using a mannequin as a human stand-in. This tool best simulates a cursory tick check performed on another person as participants are easily able to view the back of the mannequin, a scenario that would be impossible to replicate on themselves. Since the mannequins are inert, people may have performed a more thorough tick check than they would with a real person. Conversely, some participants may have felt uncomfortable and hesitant to interact with the mannequin. Thoroughly inspecting knees, ankles, groins, and waistbands of another person requires bending and crouching and may be socially awkward or physically challenging depending on the person and situation. Difficulty in detecting ticks on or below the waistline of a mannequin may suggest unrecognized social or physical barriers to proper implementation of the method. Additionally, the ticks that participants were searching for in our study were dead and therefore inanimate. In a real-life scenario, ticks that are unattached can move, a factor that might make them easier to detect and that should be investigated in future studies. We did not record time, but anecdotally, it was a rare occurrence for someone

to reach the five-minute maximum. Still, it is possible that some participants felt pressured by the time constraint and did not conduct a tick check to their normal standards.

Several questions remain that were not covered within the scope of this study, but we hope to answer with further research. We did not observe participants during tick checks and therefore are unable to determine how people allocated their search efforts. We also did not record the length of time participants took conducting a tick check. In the future measuring the quality and quantity of effort that goes into a tick check would be enlightening in learning where pitfalls and insights in tick detection strategies occur. Future studies could also be used to identify tools that aid in detection by comparing the scores of participants that receive devices like flashlights, mirrors, or magnifying glasses compared to a control group.

Tick checks are widely encouraged, but there are limitations in the ability to perform the method and to detect ticks effectively. The mannequin tick check simulation is a useful tool for quantification of additional factors that affect tick detection and for evaluation of different formats for educational approaches to improve personal protection from TBDs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

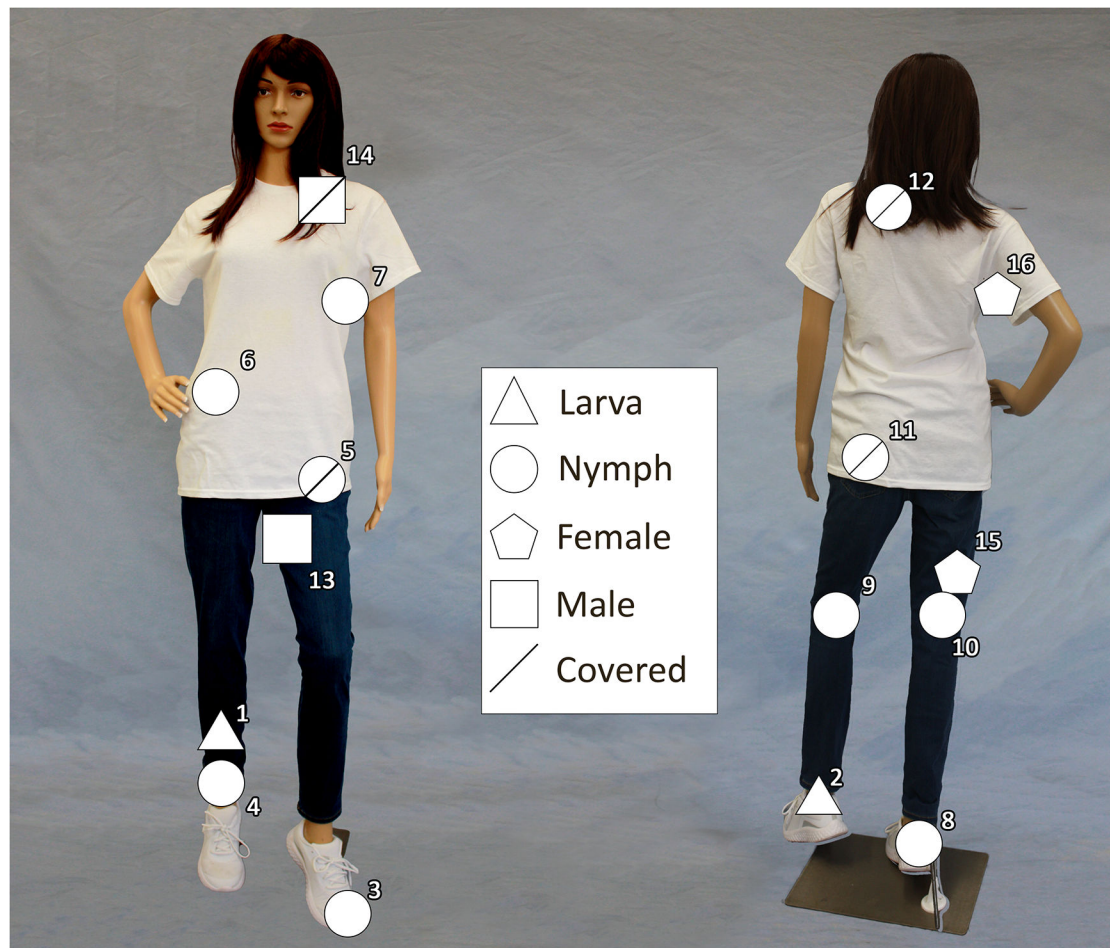


Figure 2.

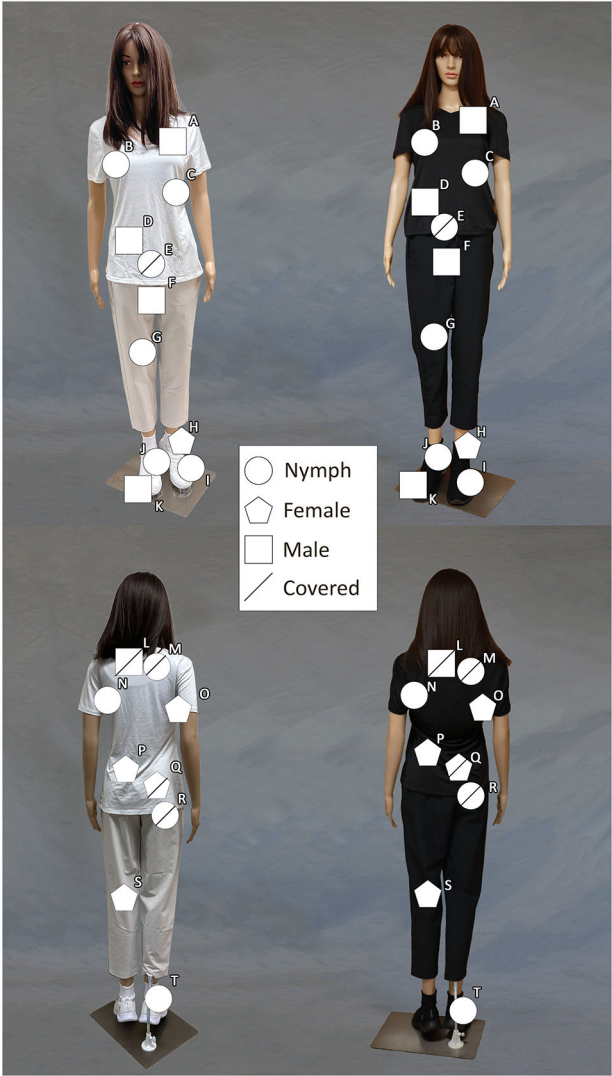


Figure 3.

Table 1.

Summary of 2022 *Ixodes scapularis* tick characteristics and successful detection events. Ticks could be detected once per participant for 96 detection opportunities per tick.

Tick ID	Tick life stage	Located above or below waistline	Tick covered or uncovered by hair or shirt	Located on light or dark clothing	Detected N (%)
1	Larva	Below	Uncovered	Dark	7 (7)
2	Larva	Below	Uncovered	Light	4 (4)
3	Nymph	Below	Uncovered	Light	29 (30)
4	Nymph	Below	Uncovered	Dark	7 (7)
5	Nymph	Below	Covered	Dark	12 (13)
6	Nymph	Above	Uncovered	Light	71 (74)
7	Nymph	Above	Uncovered	Light	70 (73)
8	Nymph	Below	Uncovered	Light	14 (15)
9	Nymph	Below	Uncovered	Dark	32 (33)
10	Nymph	Below	Uncovered	Dark	41 (43)
11	Nymph	Below	Covered	Dark	11 (11)
12	Nymph	Above	Covered	Light	63 (66)
13	Adult Male	Below	Uncovered	Dark	21 (22)
14	Adult Male	Above	Covered	Light	75 (78)
15	Adult Female	Below	Uncovered	Dark	74 (77)
16	Adult Female	Above	Uncovered	Light	69 (72)

Table 2.

Summary of 2023 *Ixodes scapularis* tick characteristics and successful detection events on the mannequins dressed in white or black. Ticks that were on the white and black mannequin had 55 and 56 detection opportunities, respectively.

Tick ID	Tick life stage	Located above or below waistline	Tick uncovered or covered by hair or shirt	Detected (%)	
				Located on white clothing	Located on black clothing
A	Adult male	Above	Uncovered	48 (88)	40 (72)
B	Nymph	Above	Uncovered	48 (88)	36 (65)
C	Nymph	Above	Uncovered	39 (71)	21 (38)
D	Adult male	Above	Uncovered	53 (97)	42 (75)
E	Nymph	Below	Covered	20 (37)	13 (24)
F	Adult male	Below	Uncovered	27 (50)	13 (24)
G	Nymph	Below	Uncovered	38 (70)	25 (45)
H	Adult female	Below	Uncovered	38 (70)	28 (50)
I	Nymph	Below	Uncovered	26 (48)	15 (27)
J	Nymph	Below	Uncovered	39 (71)	20 (36)
K	Adult male	Below	Uncovered	38 (70)	21 (38)
L	Adult male	Above	Covered	32 (59)	34 (61)
M	Nymph	Above	Covered	34 (62)	18 (33)
N	Nymph	Above	Uncovered	41 (75)	22 (40)
O	Adult female	Above	Uncovered	49 (90)	44 (79)
P	Adult female	Above	Uncovered	46 (84)	33 (59)
Q	Adult female	Below	Covered	21 (39)	8 (15)
R	Nymph	Below	Covered	21 (39)	13 (24)
S	Adult female	Below	Uncovered	45 (82)	38 (68)
T	Nymph	Below	Uncovered	17 (31)	6 (11)

Table 3.

Summary of survey responses. N = number of participants in each category.

Question	Answers	N (%)	
		2022	2023
Gender	Male	48 (50)	52 (47)
	Female	46 (48)	55 (50)
	Non-binary	1 (1)	3 (3)
	Prefer not to say	1 (1)	1 (1)
	Other	0 (0)	0 (0)
Age	18-54	94 (98)	96 (87)
	55-90	2 (2)	15 (14)
Region of origin	High incidence state	60 (63)	43 (39)
	Low incidence state	22 (23)	60 (55)
	Non-US	14 (15)	7 (7)
Time spent outdoors between May-November.	Never	3 (3)	0 (0)
	Few times	11 (11)	9 (8)
	Once a month	12 (13)	14 (13)
	Once a week	26 (27)	37 (34)
	Few times a week	44 (46)	51 (46)
I am knowledgeable about ticks and TBD.	Strongly disagree	13 (14)	5 (5)
	Disagree	26 (27)	16 (16)
	Neither A/D	17 (18)	10 (10)
	Agree	36 (38)	61 (59)
	Strongly agree	4 (4)	13 (13)
I am concerned about ticks and TBD.	Strongly disagree	2 (2)	1 (1)
	Disagree	17 (18)	5 (5)
	Neither A/D	20 (21)	21 (20)
	Agree	46 (48)	50 (48)
	Strongly agree	11 (11)	28 (27)
I am confident in my ability to find and identify ticks on myself or another person.	Strongly disagree	9 (9)	4 (4)
	Disagree	22 (23)	12 (12)
	Neither A/D	30 (31)	27 (26)
	Agree	31 (32)	53 (51)
	Strongly agree	4 (4)	9 (9)
I always check myself and others for ticks after spending time outdoors.	Strongly disagree	22 (23)	7 (7)
	Disagree	34 (35)	30 (29)
	Neither A/D	9 (9)	14 (14)
	Agree	23 (24)	47 (45)
	Strongly agree	8 (8)	7 (7)