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Research article

Assessing knowledge gaps and empowering Extension workers in Illinois with information on ticks and tickborne diseases through KAP surveys

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ABSTRACT

Tickborne diseases (TBDs) are increasingly prevalent in Illinois and the Upper Midwest region. People who work in occupations that require time outdoors in agricultural or natural settings, such as some Extension workers, are at risk of tick bites and TBDs. Additionally, Extension workers are often a primary source of information about ticks and TBDs in rural communities. However, there is limited information on the level of awareness about ticks and TBDs in the Extension community. The goals of this study were to sequentially i) determine the baseline awareness of Extension workers in Illinois about ticks and TBDs using a knowledge, attitudes, and practices (KAP) survey tool, ii) provide comprehensive training on ticks and TBDs to this demographic, and iii) measure the uptake of knowledge after the training intervention through a post-training survey. The study period was from June 2022 until May 2023. We received 233 pre-training and 93 paired post-training survey responses. Most survey respondents were Extension volunteers, identified as women, and were over 50 years old. Knowledge about ticks and TBDs varied. We identified several gaps in their current tick awareness, most importantly, in tick prevention measures, tick identification, and TBDs in general. TBD knowledge, attitude, and practice scores all significantly improved after training ($p < 0.001$), with a mean difference of 10.47, 1.49, and 2.64 points, respectively. Additionally, both Extension professionals (79.2 %) and Extension volunteers (66.7 %) were more likely to feel confident in engaging with their stakeholders on ticks and TBDs after participating in training. Poisson models revealed that higher attitude and practice scores and greater self-reported knowledge were the factors most significantly associated with higher TBD knowledge. We found that greater concern for ticks and TBD (attitudes) and adherence to science-based prevention and management methods (practices) were also associated with higher knowledge scores. To our knowledge, this is the first study in Illinois to capture Extension workers' awareness of ticks and TBDs. The results highlight Extension workers' interest in filling knowledge gaps through learning, and the importance of training

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Extension workers to disseminate reliable and updated information on ticks and TBDs to their constituents, a critical step in preventing TBDs.

1. Introduction

Tickborne diseases (TBDs) have become increasingly prevalent in the United States, with nearly 476,000 diagnosed and treated Lyme disease cases estimated to occur annually [1,2]. The prevalence of tickborne diseases, especially Lyme disease, in Illinois and in the Upper Midwest region has also increased [3,4]. Other TBDs in Illinois include ehrlichiosis, anaplasmosis, Rocky Mountain spotted fever, and tularemia [5,6]. The increase in TBD cases has coincided with the geographic range expansion of the medically important vector tick species *Ixodes scapularis*, *Amblyomma americanum*, *Amblyomma maculatum* and *Dermacentor variabilis* [7]. Previous research found that factors associated with climate change, such as maximum average temperature and total precipitation [8], presence of forest cover in metropolitan areas [9] and wetlands [10], open habitats with minimal canopy cover [11] are associated with distribution and abundance of various tick species in Illinois. Thus, the number of tick species and cases of TBDs in the Upper Midwest region is likely to follow an upward trend in the coming decades.

Increasing numbers of studies indicate that outdoor workers such as farmers, agriculturists, and forest workers are at a high risk of exposure to tick bites and TBDs due to their occupations, and often do not have current or adequate information on tick prevention [12–16], including university Extension personnel [17]. Extension workers serve as liaisons between the public interest in natural systems, the scientific and agricultural communities; they help to disseminate information to farmers and other stakeholders [18]. Extension volunteers work with Extension professionals on projects of community interest, such as Master Gardeners and Master Naturalists. Depending on the subject area or discipline, Extension volunteers receive various trainings so that they can impart that information to their local communities, thus delineating them from citizen scientists [19], who have already been shown to be helpful in monitoring vector-borne diseases [20]. The University of Illinois Extension focuses on disseminating information on various disciplines such as agriculture, financial wellness, health, gardening, youth development, and livestock health [21] to stakeholders within the state.

Ticks have been identified among diverse habitats, including natural areas in Illinois [22], where Extension workers often spend time in the course of their work, putting them at risk of tick bites and TBDs. However, the few studies in the scientific literature involving Extension officers and their knowledge of TBDs or other vector-borne diseases are concentrated in African countries [23–25], with only one study in the United States [17]. By understanding the behaviors and perceptions of Extension officers in Illinois, we can identify gaps and misinformation in their knowledge of TBDs, and we can use the identified gaps to train Extension workers on important aspects of ticks and TBDs, empowering them to engage confidently with their constituents on this critical issue.

Therefore, the objectives of this study were to i) evaluate the current knowledge, attitudes and, prevention practices of Extension workers in Illinois regarding ticks and TBDs by using a frequently used socio-behavioral tool called a Knowledge, Attitudes and Practices (KAP) survey, ii) provide educational training to Extension workers on ticks and TBDs, iii) assess their level of knowledge uptake through a pre- and post-training survey. The goal of this work is to provide a framework of knowledge that can empower Extension workers to share important information on ticks and TBDs with the citizens of Illinois.

2. Methods

This study was conducted between June 1, 2022, and May 30, 2023, and it had three main phases: the pre-training survey, which measured the baseline knowledge and awareness of Extension workers on ticks and TBDs; an online educational training course on ticks and TBDs, which participants were asked to complete; and the post-training survey, which measured the uptake of knowledge following the training (Fig. 1).

2.1. Surveys

We developed a knowledge, attitudes, and practices (KAP) survey using existing tools and questionnaires from the literature [12, 26–29]. The pre- and post-training surveys used in this study contained the same assessment questions in the same order (supplemental file 1). The surveys had 46 questions on i) demographics (n = 9), ii) knowledge regarding ticks and TBDs (n = 22; 68 possible points),

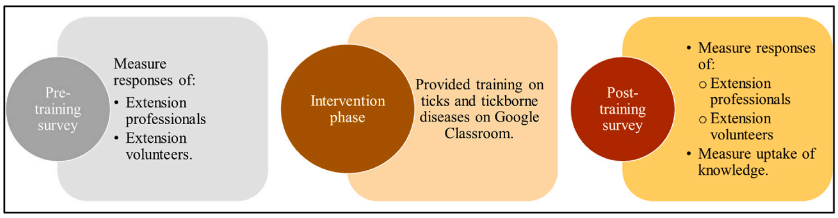

Fig. 1. Visual representation of the three phases of the study.

iii) attitudes towards ticks and TBDs (n = 6; 15 possible points), and iv) prevention practices (n = 4; 16 possible points). The surveys were developed and disseminated via REDCap (Research Electronic Data Capture), a secure online platform that is hosted by the University of Illinois Urbana Champaign [30,31] with the help of the Interdisciplinary Health Sciences Institute and Research IT – Technology Services. REDCap provides 1) an intuitive interface for validated data capture; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for data integration and interoperability with external sources [30,31]. The survey was beta-tested for logistical or technical issues by subject matter experts. The University of Illinois Institutional Review Board (UIUC IRB) ruled the study (protocol #22170) to be exempt (not human subjects research, see supplement). Informed consent was sought from each participant prior to both the pre-training and post-training surveys. A non-probability convenience sampling strategy was used for recruiting participants.

Inclusion criteria for the study respondents were: i) affiliation with the University of Illinois Extension as a volunteer or as an officer/employee in Illinois, ii) 18 years of age or older, and iii) self-reported English proficiency. Extension collaborators and partners conducted recruitment efforts in June 2022 and February 2023 using electronic flyers and newsletter postings linking to the survey and study information among their networks. Extension participants who took the study were also asked to distribute the survey link to their Extension colleagues. An incentive in the form of an electronic certificate of completion on official University of Illinois letterhead was offered to all participants who completed all 3 phases of the study. The certificates were emailed to those participants (n = 55) who requested them at the end of the post-training survey.

2.2. Training materials

Comprehensive training and educational materials on ticks and TBDs were created specifically for this study and modified from content previously developed for the Midwest Center for Excellence in Vector borne Disease. The training consisted of six modules which had information on 1) tick biology/anatomy, 2) tick species identification, 3) feeding signs used by ticks, 4) tick geographic range, life cycle, and phenology, 5) tick control and tick-bite/TBD prevention methods, and 6) public health implications of TBDs. The information was presented in Google Slides, housed in Google Classroom, and participants had the option to review these slides with or without audio narration. The Instructional Media Resources team within the Center for Innovation in Teaching and Learning (CITL) at the University of Illinois Urbana Champaign provided logistical and technical support. Once participants finished the online pre-training survey, REDCap would automatically redirect them to Google Classroom, where participants could log in using an existing Gmail account or create a free account to access the training materials. Fifteen days after completing the pre-training survey, REDCap would automatically send the link to the post-training survey to each participant. Reminders for the post-training survey were sent every alternate day for a maximum of five times if the participants still needed to complete the post-training survey. After completion of the study, the training materials were uploaded to YouTube for accessibility https://www.youtube.com/playlist?list=PLfi_IIiboMJMy113i5uHHgZaZqcj5ROCz.

2.3. Analysis

Data were cleaned (*tidyverse* package) [32] and survey responses were analyzed using R 4.2.0 via R Studio [33,34]. Analysis was divided into two main components: 1) pre-survey responses served as the "baseline" population, and 2) pre- and post-intervention responses matched by individuals, as a measure of training program impact on knowledge, attitude, and practice scores. Baseline (n = 234) and intervention (n = 93) scores were calculated for each respondent regarding ticks and TBD knowledge (total possible score = 68), attitudes (total possible score = 15), and prevention practices (total possible score = 16). Points were assigned to answer choices that reflected established scientific knowledge, general awareness, and concern for the impacts of ticks and TBD, and the use of recommended prevention methods. Baseline analysis consisted of associations between self-reported knowledge and questions such as Extension affiliation, TBD experience, tick exposure, time spent outdoors for recreation and Extension duties analyzed using Pearson's Chi-square test. Paired t-tests were used to determine the impact of training on participants' knowledge, attitudes, and prevention practices in the pre-training and post-training survey responses, combined and across affiliations. Poisson regression was used to identify significant factors that contributed to overall knowledge, attitude, and prevention practice scores. Models were evaluated using Bayesian Information Criterion (BIC), mean square error, mean absolute error, and a check for overdispersion and goodness of fit. Graphs and figures were generated using *ggplot* in the *tidyverse* package [32]. We followed the US Department of Interior's [35] standards on presenting data on race and ethnicity while reporting the demographics information of our study participants.

3. Results

3.1. Demographics

We received 282 raw pre-training survey responses and 105 post-training survey responses, including a small number of respondents who were not affiliated with Extension (10 pre-training, 3 post-training) through REDCap. After excluding incomplete, ineligible (non-affiliated), and duplicated responses, we received 233 pre-training (baseline KAP) survey responses, and 93 paired pre- and post-training survey responses. Loss to attrition between pre- and post-training surveys was 60.1 % (140/233). Most of the survey respondents were Extension volunteers (171/233 pre-training, 69/93 post-training). Supplemental Fig. 1 illustrates the participant recruitment process. Demographic information for both the baseline and paired post-training surveys is provided in Table 1.

3.2. Baseline knowledge

More than half of respondents (51.9 %) reported possessing 'some knowledge' regarding ticks in the pre-training survey. More Extension professionals (11.3 %) reported knowing 'a lot about ticks' than volunteers (3.5 %). But there was no significant difference in the overall baseline knowledge between Extension professionals and volunteers (p = 0.17).

At baseline, 22.6 % of Extension professionals reported confidence in engaging with the community on ticks and tickborne diseases,

Table 1
Demographic information of pre-training (baseline) and post-training respondents of the surveys offered to Extension workers regarding ticks and tick-borne diseases in Illinois.

Items	Pre-training survey (n = 233)		Post-training survey (n = 93)	
	Extension Professional (n = 62)	Extension volunteer (n = 171)	Extension professional (n = 24)	Extension volunteer (n = 69)
Age (years):				
18–20	0 (0.0 %)	0 (0.0 %)	0 (0.0 %)	0 (0.0 %)
21–30	7 (11.3 %)	4 (2.3 %)	2 (8.3 %)	0 (0.0 %)
31–40	14 (22.6 %)	8 (4.7 %)	7 (29.2 %)	5 (7.2 %)
41–50	8 (12.9 %)	13 (7.6 %)	3 (12.5 %)	4 (5.8 %)
51–60	27 (43.5 %)	29 (17.0 %)	8 (33.3 %)	8 (11.6)
61–64	1 (1.6 %)	11 (6.4 %)	1 (4.2 %)	13 (18.8 %)
65 and up	5 (8.1 %)	104 (60.8 %)	3 (12.5 %)	39 (56.5 %)
No answer	0 (0.0 %)	2 (1.2 %)	0 (0.0 %)	0 (0.0 %)
Gender:				
Male	11 (17.7 %)	33 (19.3 %)	6 (25 %)	13 (18.8 %)
Female	50 (80.6 %)	132 (77.2 %)	18 (75 %)	55 (79.7 %)
Non-binary	1 (1.6 %)	1 (0.6 %)	0 (0.0 %)	0 (0.0 %)
Other/Prefer not to answer	0 (0.0 %)	5 (2.9 %)	0 (0.0 %)	1 (1.4 %)
Race:				
White/Caucasian	57 (91.9 %)	150 (87.7 %)	24 (100 %)	61 (88.4 %)
Black/African American	0 (0.0 %)	1 (0.6 %)	0 (0.0 %)	1 (1.4 %)
American Indian/Alaska native	1 (1.6 %)	1 (0.6 %)	0 (0.0 %)	0 (0.0 %)
Asian American/Asian	0 (0.0 %)	3 (1.7 %)	0 (0.0 %)	1 (1.4 %)
Pacific Islander	0 (0.0 %)	0 (0.0 %)	0 (0.0 %)	0 (0.0 %)
Mixed	0 (0.0 %)	2 (1.2 %)	0 (0.0 %)	2 (2.9 %)
Prefer to not answer	4 (6.5 %)	14 (8.2 %)	0 (0.0 %)	4 (5.8 %)
Spanish or Latin origin:				
Yes	5 (8.1 %)	1 (0.6 %)	0 (0.0 %)	0 (0.0 %)
No	57 (91.9 %)	166 (97.1 %)	24 (100.0 %)	68 (98.6 %)
Prefer to not answer	0 (0.0 %)	4 (2.3 %)	0 (0.0 %)	1 (1.4 %)
Level of education:				
High school diploma	0 (0.0 %)	1 (0.6 %)	0 (0.0 %)	1 (1.4 %)
Technical, trade or some college	11 (17.7 %)	18 (10.5 %)	2 (8.4 %)	4 (5.8 %)
Bachelor's degree (BA, BS)	16 (25.8 %)	52 (30.4 %)	5 (20.8 %)	22 (31.9 %)
Master's degree or higher (MS, MS, or PhD)	33 (53.2 %)	97 (56.7 %)	17 (70.8 %)	40 (58 %)
Prefer to not answer	2 (3.2 %)	3 (1.7 %)	0 (0.0 %)	2 (2.9 %)
Practice farming:				
Yes, commercial farming	5 (8.1 %)	5 (2.9 %)	1 (4.2 %)	2 (2.9 %)
Yes, non-commercial farming	14 (22.6 %)	23 (13.5 %)	9 (37.5 %)	7 (10.1 %)
No	42 (67.7 %)	139 (81.3 %)	14 (58.3 %)	59 (85.5 %)
Prefer to not answer	1 (1.6 %)	4 (2.3 %)	0 (0.0 %)	1 (1.4 %)
Practice hunting:				
Yes	14 (22.6 %)	12 (7.0 %)	6 (25 %)	6 (8.7 %)
No	45 (72.6 %)	156 (91.2 %)	18 (75 %)	62 (89.9 %)
Prefer to not answer	3 (4.8 %)	3 (1.7 %)	0 (0.0 %)	1 (1.4 %)
Hours spent outdoors on a non-winter day for outdoor recreation				
Less than 1 h	0 (0.0 %)	2 (1.2 %)	1 (4.2 %)	1 (1.4 %)
1–3 h	41 (66.1 %)	87 (50.9 %)	14 (58.3 %)	41 (59.4 %)
4–6 h	14 (22.6 %)	62 (36.2 %)	8 (33.3 %)	21 (30.4 %)
7–9 h	3 (4.8 %)	8 (4.7 %)	1 (4.2 %)	3 (4.3 %)
More than 10 h	3 (4.8 %)	4 (2.3 %)	0 (0.0 %)	0 (0.0 %)
NA	1 (1.6 %)	8 (4.7 %)	0 (0.0 %)	3 (4.3 %)
Hours spent outdoors on a non-winter day for Extension duties				
Less than 1 h	34 (54.8 %)	50 (29.2 %)	13 (54.2 %)	19 (27.5 %)
1–3 h	21 (33.9 %)	98 (57.3 %)	9 (37.5 %)	41 (59.4 %)
4–6 h	3 (4.8 %)	10 (5.8 %)	2 (8.3 %)	6 (8.7 %)
7–9 h	1 (1.6 %)	1 (0.6 %)	0 (0.0 %)	1 (1.4 %)
More than 10 h	2 (3.2 %)	3 (1.7 %)	0 (0.0 %)	0 (0.0 %)
NA	1 (1.6 %)	9 (5.3 %)	0 (0.0 %)	2 (2.9 %)

compared to 19.3 % of Extension volunteers. Extension professionals were more likely to classify ticks as arachnids and not insects (correct = 53.2.0 %) than volunteers (correct = 43.9 %) in the pre-training survey. We asked participants if they were able to distinguish between the adult stage of the different tick species present in Illinois i.e., lone star tick (*Amblyomma americanum*), blacklegged tick (*Ixodes scapularis*), American dog tick (*Dermacentor variabilis*), brown dog tick (*Rhipicephalus sanguineus*), and rabbit tick (*Haemaphysalis leporispalustris*). Pre-training, most participants could not distinguish among these tick species, and only 26.2 % (n = 61) of respondents reported knowing which ticks were present in their counties. About half of respondents (54.1 %) indicated an understanding that ownership of animals increases the likelihood of TBD risk at baseline.

Most respondents knew that ticks could spread diseases to humans (97.9 %) and about 70.4 % of respondents at baseline agreed that TBDs can be potentially fatal. Participants' knowledge of diseases spread by ticks in Illinois was very low in the pre-training survey, with the exception of Lyme disease (98.7 %) and Rocky Mountain Spotted fever (78.5 %). Among the correct TBDs listed, only 17.2 % indicated anaplasmosis, 38.2 % alpha-gal syndrome, 15.9 % babesiosis, 13.7 % ehrlichiosis, and 5.1 % bartonella. About 61.8 % of participants indicated knowing someone with a TBD, but this was not significantly associated with their knowledge scores. There was moderate baseline awareness about possible symptoms that TBDs can cause among the participants, with most correctly identifying rash, lesions, ulcers, or other skin reactions (89.7 %), pain in the joints/aches and muscle pain (84.9 %), fever and chills (82.4 %), fatigue (78.1 %), and headache and/or stiff neck (72.5 %). Respondents were aware of TBD transmission via 'bite of an infected tick' in the pre-training (100 %), but not TBD transmission via consumption of infected meat or animal by-products. The main baseline sources of information for Extension professionals were the internet (33.9 %), Extension resource materials (24.2 %), and friends and family (17.7 %), followed by conventional media (12.9 %). For volunteers, the main information sources were the internet (32.7 %), conventional media (16.4 %), Extension resource materials (17.5 %) and friends and family (14 %).

At baseline, participants indicated they wanted to learn more about tick removal (89.7 %), ideas and support for community outreach or communication about ticks and diseases (80.7 %), treatment of TBDs (79 %), and testing for TBDs (76.8 %). After training, respondents reported learning most about tick species identification (73.1 %), tick removal (63.4 %), TBDs in their area (56 %), ideas and support for community outreach or communication about ticks and diseases (42 %), treatment of TBDs (24.7 %), and testing of TBDs (19.4 %), indicating the alignment of the training with participant goals.

3.3. Post-intervention knowledge status and paired responses to knowledge questions

After the intervention, self-reported knowledge increased across both groups, although professionals (25 %) were still more likely than volunteers (11.6 %) to report knowing 'a lot about ticks' ($\chi 2 = 9.33$, df = 4, p = 0.01)(Fig. 2A and B).

Self-reported knowledge was positively associated with daily hours spent outdoors for general recreation in the post-training survey ($\chi 2 = 24.68$, df = 12, p-value = 0.01), and specifically for Extension duties pre- and post-intervention (pre: $\chi 2 = 23.82$, df

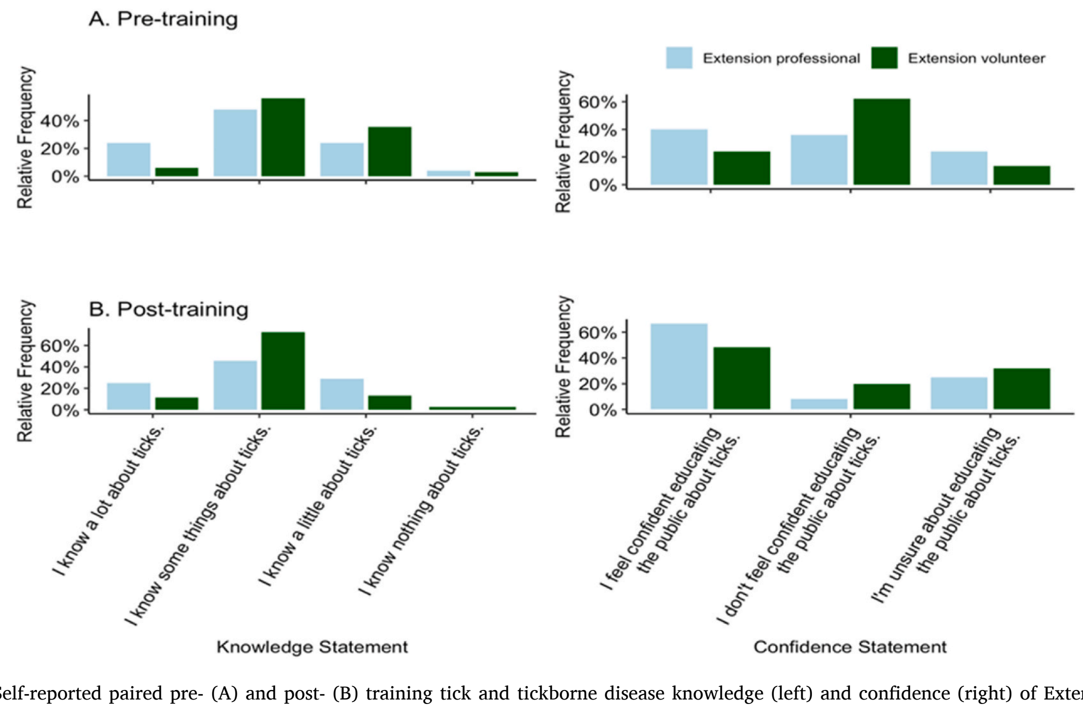

Fig. 2. Self-reported paired pre- (A) and post- (B) training tick and tickborne disease knowledge (left) and confidence (right) of Extension professionals (n = 24) and volunteers (n = 69). There was no difference between affiliations in the pre-training survey self-reported knowledge (p = 0.09), but Extension professionals and volunteers reported significantly different knowledge ($\chi 2 = 9.33$, df = 9, p = 0.01) in the post-training survey.

= 4, p-value = 0.004; post: $\chi2 = 28.91$, df = 9, p-value = 0.0006). However, time spent outdoors did not contribute to the final best fit model predicting knowledge, attitude, or practice scores.

One critical goal of this study was to measure participant confidence in educating the public on ticks and TBDs after training. Both groups reported significantly increased confidence following the intervention, with Extension professionals (from 41.7 % pre-training to 79.2 % post-training) reporting higher confidence than volunteers (from 23.2 % pre-training to 66.7 % post-training) ($\chi2 = 13.47$, df = 4, p = 0.009; Fig. 2A and B).

After training, all Extension professionals and 77 % of Extension volunteers correctly classified ticks as arachnids. Participants predominantly felt confident in being able to identify the lone star tick, blacklegged tick, and American dog tick, but were less confident about identifying the brown dog tick and still had difficulty identifying the rabbit tick (Fig. 3A and B).

While most respondents reported a personal connection to tickborne disease (61.8 %), or a previous tick encounter (83.3 %), neither (p = 0.4 and p = 0.3, respectively) was associated with self-reported knowledge pre- or post-training. Knowledge about TBD risk associated with animal ownership significantly increased to 80.6 % post-training survey ($\chi2 = 15.31$, df = 4, p = 0.004).

After training, all respondents indicated that ticks could spread diseases to humans and 89.2 % indicated that TBDs could be fatal. The majority of respondents (97.8 %) chose the bite of an infected tick as the main TBD transmission pathway after training, but still had low knowledge about other transmission mechanisms.

The main sources of information for Extension professionals and volunteers varied pre-training, but after the intervention both groups chose Extension resource materials as their main source of information on ticks and TBDs (Extension professionals 70.8 %, Extension volunteers 53.6 %) (Fig. 4A and B). Before training, we found significant difference between the knowledge scores of Extension employees and volunteers (t = 2.286, df = 42.24, p-value = 0.027, 95 % CI: [0.56–9.11], with employees scoring 4.85 points higher than volunteers on average. In the post-training survey, employees only scored slightly higher than volunteers on average (2.88 points) for the knowledge portion of the survey (t = 2.058, df = 36.76, p-value = 0.047, 95 % CI: [0.04–5.72]).

Combined mean knowledge scores significantly increased from the pre-training to the post-training survey (t = 12.61, df = 92, $p < 0.001$, 95 % CI: [8.82–12.12]) with a mean difference between tests of 10.47 points (Fig. 5A).

3.4. Baseline attitudes

At baseline, there was no significant difference between Extension professionals and volunteers in their attitudes toward ticks and tickborne diseases (p = 0.22).

Slightly more participants considered ticks a risk to humans (81.5 %) than to animals (72.1 %) at baseline. Top baseline participant concerns regarding ticks, were human health (97.4 %), animal health (73.8 %), the economic impact of human tickborne disease treatment in the US (41.2 %), nuisance (39.5 %), and economic impact of ticks on livestock (26.6 %). 1.3 % said nothing about ticks concerns them. Few respondents at baseline (12.9 %) said their local county public health district was doing enough to raise awareness about ticks and TBDs; most said they did not know if their local county public health was doing enough research and surveillance on this topic (51.1 %).

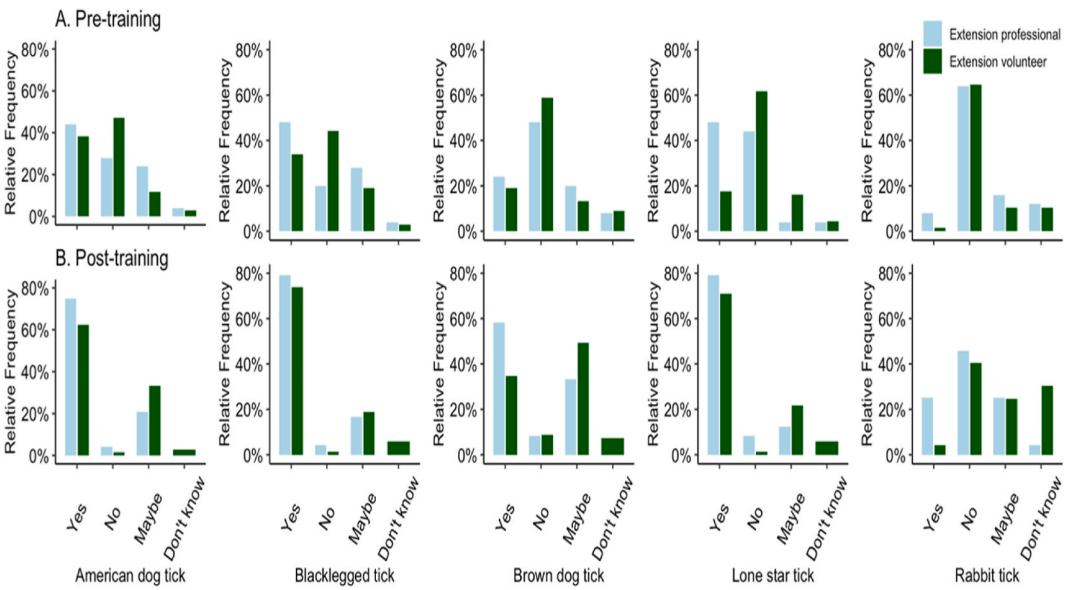

Fig. 3. Extension professionals (n = 24) and volunteers (n = 69) identification response percentages from paired pre- (A) and post- (B) training surveys (n = 93) to the question 'can you identify the respective tick species?' The common name of the tick species shown in a photo to participants is indicated in the x-axis label.

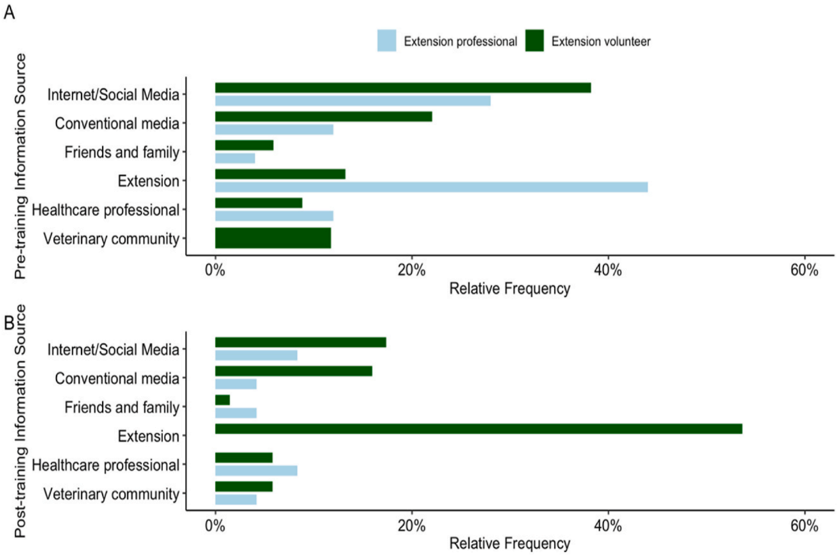

Fig. 4. Comparison of self-reported sources of tick and TBD information in the paired pre- (A) and post-training (B) among Extension professionals (n = 24) and volunteers (n = 69).

3.5. Post-intervention attitude status and paired responses to attitude questions

Neither pre-intervention ($p = 0.91$) nor post-intervention attitude scores ($p = 0.52$) differed between Extension professionals and volunteers. After the training, mean attitude score significantly increased for both Extension professionals and volunteers with a mean difference of 1.49 points ($t = 5.57$, $df = 92$, $p < 0.001$, 95 % CI: [0.962–2.027]) (Fig. 5B). Attitudes towards ticks being a risk for both humans and animals increased post-training (90.3 %, and 81.7 %, respectively). However, some respondents were still unsure or felt that ticks were not a risk to human and animal health.

Post-training concerns regarding ticks, were higher across all answer choices, with top choices being human health (95.7 %), followed by animal health (79.6 %), economic impact of human tickborne disease treatment in the US (70.9 %), nuisance (52.7 %), and economic impact of ticks on livestock (49.5 %); some respondents still reported no concerns (1.1 %). Training did not shift attitudes toward local public health districts' actions on ticks and TBD prevention; 10.7 % said their local county public health district was raising awareness about ticks and TBDs, and many still did not know if their local county public health was doing enough research and surveillance on this topic (48.4 %).

3.6. Baseline tick bite prevention and management practices

Baseline practice scores did not differ between Extension professionals and volunteers ($p = 0.48$). Nearly all participants pre- (98.7 %) and post-training (98.9 %) agreed that preventive behaviors can help protect against TBDs in Illinois. Most participants (97 %) reported taking at least one preventive measure against tick bites at baseline.

The most used prevention measures reported by respondents were applying a tick repellent on themselves (75.9 %), wearing long-sleeved shirts and long pants (85.8 %), tucking pants into socks/boots (71.7 %), wearing light-colored clothing (53.6 %), and wearing permethrin-treated clothing (33.9 %) (Table 2). Few (3.4 %) respondents reported no prevention measures (Table 2). Most participants reported using tools such as tweezers to remove an attached tick (82.0 %) (Table 2). However, some reported removal methods that are discouraged, such as bare hands (6.9 %) or using alcohol or another substance to smother or kill an attached tick (6.0 %). After removal, many at baseline reported taking a photo of the tick (43.8 %), storing the tick in a container with alcohol (36.9 %), flushing the tick in a toilet (32.2 %) and freezing the tick (18.0 %) (Table 2).

3.7. Post-intervention tick bite prevention and management practices

Pre- ($p = 0.46$) and post-training ($p = 0.99$) survey practice scores did not differ between Extension professionals and volunteers. Post-training, practice scores increased significantly (mean 2.64 points, $t = 10.06$, $df = 92$, $p < 0.001$, 95 % CI: [2.12–3.17]) (Fig. 5C). Use of several recommended tick prevention measures increased in the post-training survey: application of tick repellent (86.0 %), wearing long-sleeved shirts and long pants (91.4 %), tucking pants into socks/boots (82.8 %), wearing light colored clothing (68.8 %), and wearing permethrin-treated clothing (51.6 %), but the proportion reporting no preventive measures did not significantly change (Table 2). Reported use of a hat or a cap to prevent tick encounters did not change (68 %, pre- and post-training) (Table 2).

After training, participants self-reported use of tools such as tweezers to remove attached ticks increased (96.8 %) and reports of non-approved methods of tick removal decreased (using bare hands: 2.1 %, using alcohol or another substance to smother or kill an

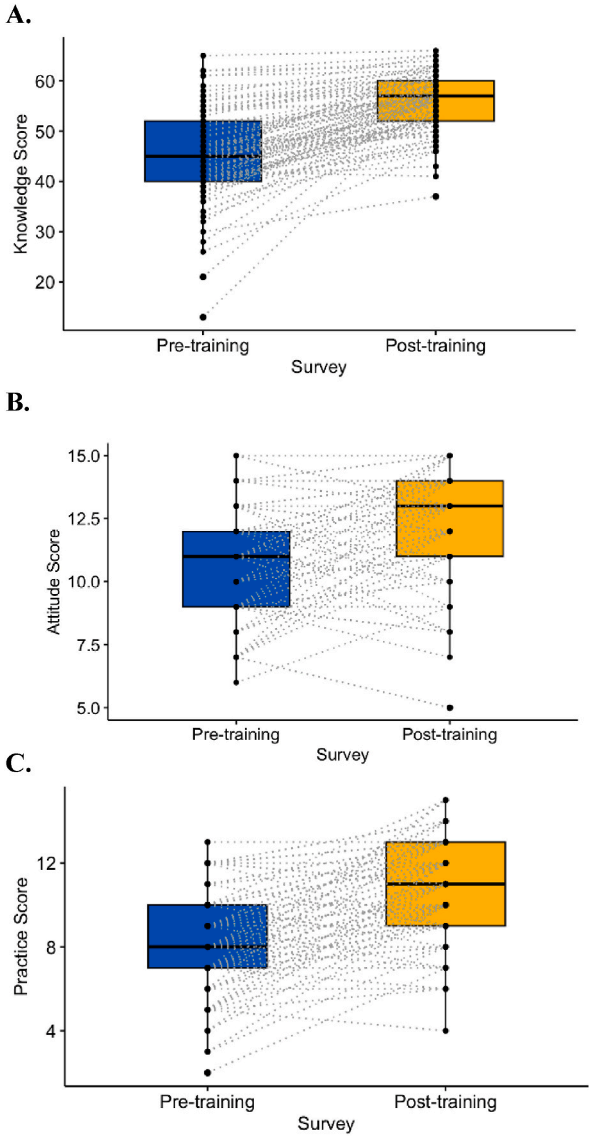

Fig. 5. Boxplots comparing paired pre-training (left) and post-training (right) scores on tick and TBD knowledge; A: knowledge (total possible points = 68), B: attitudes (total possible points = 15), and C: prevention practices (total possible points = 22) (n = 93).

attached tick: 1.1 %) (Table 2). Recommended behaviors following tick removal increased post-training (taking a photo of the tick: 64.5 %, storing the tick in a container with alcohol: 30.1 %, and freezing the tick: 80.6 %), while discouraged behaviors decreased (flushing the tick in a toilet: 4.3 %) (Table 2).

3.8. Factors predicting knowledge, attitude, and prevention practice scores

The best-fit model to predict overall knowledge scores from the pre-training survey population included self-reported knowledge ($p < 0.001$) and both attitude ($p < 0.001$) and practice scores ($p < 0.01$). Respondents who reported that they knew "nothing" or only "a little" about ticks had significantly lower knowledge scores ($p < 0.001$) (Table 3). Participants whose attitude and practice scores were higher (reflecting concern for ticks and TBDs, and information on preventative practice methods) were more likely to score higher in the knowledge section of the survey. The only significant predictor for attitude scores was the knowledge score ($p < 0.05$); those with higher knowledge scores were more likely to have attitude scores that reflected greater concern about ticks and TBDs (Table 3; $p < 0.01$). Prevention practice scores were also only predicted by the knowledge score (Table 3; $p < 0.001$); those with higher knowledge scores were associated with significantly higher prevention practice scores.

Table 2
Reported tick encounter management practices (% of respondents) in the pre-training (n = 233), paired pre-training (n = 93)) and post-training (n = 93) surveys.

Method	Baseline survey (n = 233)	Paired pre-survey (n = 93)	Paired post-survey (n = 93)
Encounter prevention			
Use a tick repellent	75.9 %	72.0 %	86.0 %
Wear light-colored clothing	53.6 %	59.1 %	68.8 %
Wear long-sleeved shirts/long pants	85.8 %	83.9 %	91.4 %
Wear a hat/cap	68.6 %	67.7 %	68.8 %
Tuck pants into socks/boots	71.7 %	71.0 %	82.8 %
Wear permethrin-treated clothing	33.9 %	33.3 %	51.6 %
No prevention method	3.4 %	6.4 %	4.3 %
Encounter management			
Crush or burn attached tick off	2.1 %	1.1 %	0.0 %
Remove attached tick with fingers	6.9 %	9.7 %	2.1 %
Use a tool to remove tick (e.g., tweezers)	82.0 %	81.7 %	96.8 %
Apply alcohol or other substance to attached tick	6.0 %	4.3 %	1.1 %
Consult a medical professional for tick removal	2.1 %	3.2 %	0.0 %
Do nothing to remove attached tick	0.0 %	0.0 %	0.0 %
Take a photograph of removed tick	43.8 %	44.1 %	64.5 %
Throw removed tick away	16.3 %	19.4 %	1.1 %
Flush tick in toilet	32.2 %	34.4 %	4.3 %
Burn removed tick	12.4 %	5.4 %	3.2 %
Store removed tick in container with alcohol	36.9 %	38.7 %	30.1 %
Freeze removed tick	18.0 %	21.5 %	80.6 %

Table 3
Predictors with respective estimates and standard errors included in best fit Poisson models evaluating factors associated with baseline knowledge, attitude, and practice scores.

Predictor		Knowledge score		Attitude score		Practice score	
		Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Self-reported knowledge	A lot of tick knowledge	*Reference*		–	–	–	–
	Some tick knowledge	−0.125**	0.047	–	–	–	–
	Little tick knowledge	−0.214***	0.049	–	–	–	–
	No tick knowledge	−0.351***	0.096	–	–	–	–
KAP Score	Knowledge Score	–	–	0.008*	0.002	0.015***	0.004
	Attitude Score	0.020*	0.005	–	–	–	–
	Practice score	0.010***	0.005	–	–	–	–

P < 0.001***, P < 0.01**, *P < 0.05.

4. Discussion

The geographic expansion of numerous tick species and their associated pathogens is a concern for the Upper Midwest and for many regions of the United States. Hence, it is important to pursue research and scientific communication to increase awareness about ticks and TBDs among citizens [36,37]. In this study, we assessed awareness among the Extension workforce in Illinois of ticks and TBDs through a KAP survey, provided participants with an online training course on ticks and TBDs, and evaluated their uptake of knowledge on this topic through a post-training survey.

4.1. Effect of demographics on knowledge, attitudes, and prevention behaviors of extension workers

The majority of the participants in this study identified as women, over 50 years old, white, and had a Bachelor's or Master's degree. This reflects the demographic makeup of both Extension professionals and volunteers as of 2021–2022 and 2022–2023 (data provided by the University of Illinois Extension, personal communications); however, we acknowledge that our survey may not reflect the experiences of younger, non-female, and non-white Extension workers. Utilizing the information learned through educational programs like ours and creating opportunities where our participants can train in-house other Extension workers and disseminating that knowledge into the community would be highly beneficial and help reduce TBD prevalence in the state.

4.2. Interpretation of main findings

Since half of the participants reported some knowledge of ticks and TBDs at baseline, we consider there to be a moderate level of knowledge in the Extension community. However, knowledge of ticks and TBDs varied among Extension professionals and volunteers. Self-reported knowledge was significantly associated with Extension affiliation post-training, and time spent outdoors for both recreational activities (post-training) and Extension duties (pre-and post-training). However, we did not find any significant difference in knowledge scores ($p = 0.18$), attitude scores ($p = 0.17$) and practice scores ($p = 0.93$) between Extension professionals and volunteers. This may indicate that exposure to tick habitat was a more important driver in learning about ticks than profession.

Many participants reported encountering ticks on themselves and were moderately aware of the risks posed by ticks. However, those who self-reported low knowledge of ticks had low knowledge scores ($p < 0.004$). The amount of time spent outdoors and the specific duties that Extension workers were involved in, might be a reason behind the variability in knowledge among Extension workers.

Some areas of knowledge were commonly answered correctly even in the pre-training survey, indicating a broad existing knowledge base in this population that may be the result of other communication programs. For instance, Extension workers were generally aware of various outdoor activities that could be risk factors for contracting TBDs, such as hiking, gardening, playing with pets outside, and mushroom hunting. Overall, participants also had high to moderate knowledge about areas in the body where ticks could attach themselves to, and most participants at baseline knew the recommended method for tick removal. Extension workers also predominantly believed that following tick prevention measures can protect them against tick bites and TBDs.

4.3. Identified gaps

Certain points of concern in this study were respondents' lack of knowledge about ticks spreading diseases to companion and domesticated animals, and lack of concern about the negative consequences of TBDs, such as impacts on animal health and economic impact of TBDs. While most respondents were aware of the risk ticks posed to human health in their counties, few participants believed at baseline, that TBDs affecting humans and animals can largely impact the economy, and about half indicated TBDs have little impact on the economy. This is concerning considering the importance of agriculture in the economy of Illinois [38] and the potential for TBDs to have sizeable economic impacts [39,40]. The low concern over the risk ticks pose to livestock was previously reported among Illinois farmers [12], who take minimal tick prevention measures for their livestock animals [12]; these farmers reported Extension professionals as one of their preferred sources for tick and TBD information. The low concern among Extension participants about impacts on livestock and companion animals could, therefore, have serious consequences on health, including animal health, in rural communities. In addition, about 68.2 % of the respondents understood pre-training that ticks like to feed on livestock animals, and slightly more than half of the respondents at baseline (54.1 %) believed ownership of companion animals could put them at risk for tick bites and TBDs. This again relates to respondents being unaware of or less concerned about ticks' impact on domestic animals and, in turn, their impact on humans. Insufficient tick prevention measures for livestock and companion animals can negatively impact human health and the economy [41], as domestic animals may increase tick populations in the vicinity of humans and bring ticks into human environments, such as houses and barns [41].

A common mistake among our survey respondents was misidentifying ticks as insects, although this improved after training and was less common among Extension professionals compared to volunteers. Participants' knowledge of TBDs was limited as observed from the baseline survey results except for Lyme disease and RMSF. We believe that knowledge of Lyme disease might have led to participant awareness of its most common symptoms [42]. The lack of knowledge about many other endemic TBDs in Illinois [5], especially those that can affect both humans and animals, is a concerning gap that has also been reported in the medical professional community in Illinois [6]. It is essential for frontline demographics to know about the various TBDs present in Illinois, in order to promote disease prevention and reduce disease incidence. Although knowledge regarding all these diseases increased after training, additional outreach is needed to raise awareness of these TBDs. At baseline, most thought that summer (70.4 %) and spring (59.2 %) months were the only seasons in which ticks are a concern, and only 12.9 % correctly indicated ticks could be active throughout the year. After training, this slightly increased to 23.7 % respondents indicating ticks are a concern all year. At baseline, 23.2 % did not know if TBDs were fatal, highlighting the lack of awareness about the negative consequences of TBDs on health. All of these results indicate major knowledge gaps to be addressed around TBDs.

4.4. Study implications

We also observed the use of unreliable sources of information for ticks and TBDs by the Extension community, particularly volunteers, prior to training. Similar findings have been reported among Illinois farmers [12]. After training, most participants reported relying on Extension for information on ticks and TBDs, likely referring to the training itself. This may indicate that these training courses could play an important role in improving the quality of information available to those interested. Extension workers were not aware of research, surveillance, and tick prevention efforts by local public health departments to reduce ticks and TBDs in the community. This gap can be fixed by promoting better communication between the various state agencies (such as Extension, public health departments, universities etc.) and increased information sharing to reduce the burden of TBDs in the community.

We observed some dissonance between knowledge and actual adoption of recommended tick prevention measures among the Extension community, as reported in other studies [43,44]. For example, 67.4 % identified 'wearing permethrin-treated clothing' as a recommended tick prevention measure but only 33.9 % reported personal use of permethrin-treated clothing at baseline, although this increased to 51.6 % after training. While permethrin's use as an agricultural pesticide is restricted in numerous countries, the EPA states that permethrin is an acceptable and effective clothing treatment to protect against insect bites [45,46]. This should be an important action point in future education and training programming: determining what motivates people to adopt proper tick prevention measures, and bridging the gap between knowledge of tick prevention measures, and following these measures to protect both humans and animals.

4.5. Observations and assessment of the training intervention

Our training course on ticks and TBDs, the main intervention of this study, was associated with an increase in knowledge, attitudes, and practice scores among the participants in the post-training survey ($p < 0.001$). However, Extension professionals had slightly more knowledge uptake than volunteers. The predictors associated with higher knowledge scores were higher attitude score ($p = 0.0003$), higher practices score ($p = 0.006$), and participant self-reported knowledge ($p < 0.001$). There were some aspects that the training did not improve on, such as ticks being a concern throughout the year as opposed to specific months, knowing which sources of information to trust on for ticks and TBDs (apart from the training provided by this study, which we assume participants categorized as Extension training), treatment of TBDs, testing for TBDs, and some tick prevention behaviors. For instance, wearing a hat/cap to protect against tick bites did not change from baseline to post-intervention, indicating that the training did not address the myth that ticks fall from trees. Wearing a hat/cap might be suitable behavior in general while one is outdoors, but it should not be the sole prevention measure against exposure to tick bites.

Another area where the training can improve is the varied TBD transmission pathways other than the bite of an infected tick. Since, the training did not include information on other TBD transmission pathways such as consumption of infected meat [41,47], infected dairy or other animal by-products [41,47], and since this pathway of TBD transmission is not that common in the U.S., it makes sense that participants were less familiar with this pathway and that knowledge did not improve after the training. However, this aspect of TBD transmission could be more important in rural areas and among farmers, for whom Extension is an important source of information. Seasonality of ticks and TBDs can also be further improved in the training. Our training intervention significantly increased participants' practices scores in the post-training survey ($p < 0.001$) and higher knowledge scores were predictive of higher practice scores ($p < 0.001$).

The goal of the training was to increase participants' knowledge of the main vector ticks of medical concern in Illinois so that they can learn to recognize them if they encounter them and follow proper tick prevention measures. Participants reported difficulty distinguishing between the five tick species i.e., *Amblyomma americanum*, *Ixodes scapularis*, *Dermacentor variabilis*, *Rhipicephalus sanguineus*, *Haemaphysalis leporispalustris*. Their reported knowledge of tick species increased in the post-training survey, but many participants still felt they could not identify the latter two tick species. This is an important knowledge gap that should be further incorporated into the training as well as in outreach efforts. With the rise of TBDs in the Midwest and across the US [2,3,48], awareness of the various tick species present and the pathogens that these ticks can carry is critical in reducing the burden of TBDs [44,49,50]. In the baseline survey, 89.3 % of participants indicated that tick species identification was a topic they would like to learn about if they participated in tick-training, and 95.7 % wanted to learn about TBDs in their area, indicating that this lack of knowledge may be due more to lack of prior training than to lack of interest. Over a quarter of participants (29.0 %) felt they had learned about all the topics mentioned. This demonstrates that the instructional materials provided successfully met the self-identified needs of the participants.

4.6. Public health impact of our study

We found that confidence in engaging with community members on ticks and TBDs among the participants significantly increased after the training ($p = 0.009$), with Extension professionals reporting more confidence than volunteers. This may be due to professionals having more experience conducting outreach and scientific communication to the public [51,52] than volunteers, and that communication with the public is one of the reasons why Extension professionals like and do these jobs. Several respondents commented in the free responses section indicating that this kind of tick training should be added to Master Naturalist and Master Gardener training and that more information, such as signage and resources on tick prevention measures, should be provided in parks, trails, and natural areas. Additionally, the level of information on ticks and TBDs might vary depending on the number of 'outreach' or 'training' hours volunteers may have undertaken prior to participating in our study. We also acknowledge that there might be selection bias on the part of participants; respondents who may know more about this topic may have been more likely to participate and complete the pre-training and post-training surveys than those with less information. In addition, as the results of this study are based on self-reported survey responses, we acknowledge the role of self-reported bias as well as social desirability bias, which might impact the results obtained.

The study intervention increased the overall KAP of respondents; however, some individuals' attitude and prevention scores decreased while their knowledge scores increased. This may indicate that in addition to training modules such as this, additional educational resources and communication between researchers, Extension workers, and other state agencies can help drive the awareness of ticks and TBDs. Our study successfully demonstrates the critical importance of providing tick and TBD training to the Extension community as well as illustrates the increased confidence of Extension workers in engaging with various stakeholders on ticks and TBDs with the goal of reducing tick encounters and TBD incidence in Illinois. We also recommend more investment in outreach and communication on vector-borne diseases with key members of the local government and public to enhance public health and prevention efforts.

4.7. Limitations

We acknowledge that the training course that we created for this study lacked information on non-vector tick species present in Illinois and in the Upper Midwest and did not sufficiently stress the need to adopt effective tick prevention measures for humans, companion animals, and livestock animals. We also believe that we may have needed to provide more information on TBDs, their symptoms, TBD transmission pathways, testing, diagnosis, and treatment options. The training program was kept brief to ensure participants completed it and did not lose interest while participating in the study, which necessitated cutting material that may have been of interest or use. We did not collect information regarding how long participants had been working for Extension, which would have been an important piece of information for analyzing the survey responses of Extension professionals and volunteers.

Four baseline respondents reported they would not complete the intervention and post-training survey phases of the study as they were uncomfortable with using Google/Gmail, a requirement of Google Classroom. Since the training materials were built on Google slides and had narration, at the time Google Classroom was the best option available to us. In the future, exploring other media and communication formats and outlets to better disseminate information would be conducive. The training materials are now available on YouTube ((https://www.youtube.com/playlist?list=PLfi_IIiboMJMy113i5uHHgZaZqcj5ROCz), which may be more accessible for future trainings.

5. Conclusion

This KAP study had three main objectives: i) to assess the current understanding of Extension workers in Illinois on ticks and TBDs, ii) to provide training intervention to this group on ticks and TBDs, so that they can work on transferring the knowledge back to the Illinois community, and iii) evaluate the ability of the training intervention in increasing knowledge in this population. We used a pre-test post-test methodology, where we used a KAP survey to assess knowledge and an online, asynchronous training module on ticks and TBDs served as the intervention of this study. We successfully increased uptake in knowledge and increased confidence in engaging with the community on ticks and TBDs among Extension participants. Empowering Extension workers and providing them with the necessary tools and resources so that they can effectively disseminate proper tick prevention measures and tick information to the public is a crucial step in the fight against ticks and TBDs. Since, the Extension plays an important role in the community particularly in rural areas, providing the correct information on ticks and TBDs to Extension workers who have extended contacts and interactions with Illinois residents can help reduce tick bites and TBDs. The survey also demonstrates a desire by Extension professionals to increase their knowledge about ticks and TBD and the opportunity to empower these colleagues to assist in the fight against TBDs. Our KAP pre-post training study can also be used among other outdoor workers to raise awareness about ticks and tickborne diseases.

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Data availability statement

Data will be made available upon request.

CRediT authorship contribution statement

S. Chakraborty: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **H. Kopsco:** Writing – review & editing, Visualization, Methodology, Formal analysis, Conceptualization. **C. Evans:** Writing – review & editing, Validation, Resources, Methodology, Investigation. **N. Mateus-Pinilla:** Writing – review & editing, Writing – original draft, Visualization, Resources, Project administration, Methodology, Investigation. **R.L. Smith:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Rebecca Lee Smith reports financial support was provided by University of Illinois Urbana Champaign Extension. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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