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Knowledge, attitudes, and practices of Illinois medical professionals related to ticks and tick-borne disease

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ABSTRACT

Background: The rising incidence of tick-borne disease (TBD) underscores the importance of proficiency in TBD diagnosis. Clinicians' knowledge about vector ticks and TBDs in their area may influence whether patients are questioned about potential tick exposure and the consideration of diagnostic testing for TBDs.
Objective: Our objective was to assess the knowledge, attitudes, and practices of Illinois clinicians towards ticks and TBDs. The study aimed to 1) identify predictors associated with knowledge, 2) identify knowledge gaps, and 3) evaluate attitudes and practices related to TBDs.
Methods: A web-based knowledge, attitudes, and practices survey about Illinois ticks and TBDs was disseminated to physicians, mid-level practitioners, and nurses between August 2020 and February 2022. Poisson regression analysis was conducted to identify predictors of higher scores.
Results: Of 346 respondents, 80% correctly identified Lyme disease as endemic to Illinois, and 95% were familiar with diagnostic testing for Lyme. Knowledge of other TBDs present in the state was highest among physicians, yet only 26% of physicians believed Rocky Mountain spotted fever (RMSF) to be present in Illinois, and only 17% believed ehrlichiosis to be endemic. Only 32% of physicians knew the cause of Alpha-gal syndrome and fewer than 18% were aware of available diagnostic testing. Tick or TBD-related education within the past two years was the most significant predictor of higher scores, increasing overall knowledge scores by 26% (RR 1.26, 95% CI 1.13–1.41) and increasing scores specific to TBDs by 42% (RR 1.42, 95% CI 1.19–1.69).
Conclusion: Illinois clinicians were informed about Lyme disease but lacked knowledge of other TBDs endemic to the state, including RMSF, ehrlichiosis, and Alpha-gal syndrome. The strongest predictor of knowledge was tick/TBD training in the previous two years, highlighting the importance of frequent region-specific training on ticks and TBDs.

1. Introduction

Tick-borne disease (TBD) incidence has been increasing in the United States, with reported cases more than doubling between 2004 and 2019 [1]. Lyme disease, comprising 82% of TBDs, has reached an estimated 476,000 cases per year [2,3]. In the North Central Region, which includes Illinois, the number of counties with high incidence of Lyme disease increased approximately 250% between 1993 and 2012 [4]. In Illinois, reportable TBDs, including Lyme disease, Rocky Mountain spotted fever (RMSF), ehrlichiosis and anaplasmosis, increased tenfold

Abbreviations: TBD, Tick-borne disease; KAP, Knowledge, attitudes, and practices; RMSF, Rocky Mountain spotted fever; SFGR, Spotted fever group rickettsiosis.

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between 2000 and 2020 [5,6]. The primary vectors for these diseases, *Ixodes scapularis*, *Amblyomma americanum*, and *Dermacentor variabilis*, increased their geographic range during this time [7,8] and are now established throughout Illinois [9,10]. *A. americanum* can also trigger mammalian meat allergy (Alpha-gal syndrome), an immune response to the carbohydrate galactose-α-1,3-galactose, which is transmitted from other mammals to humans by the tick [11–13].

TBDs present a diagnostic challenge as most symptoms are non-specific and similar to those of other illnesses; also, early serologic tests may lack sensitivity [14]. However, failure to promptly diagnose and treat TBDs can have serious consequences. Ehrlichiosis has a case fatality rate of 2.7% [15] and untreated RMSF is fatal in up to 30% of patients [16]. Lyme disease may present as disseminated disease with severe complications including neurological symptoms, carditis or meningitis [17,18]. Without a high index of suspicion and questioning patients about potential tick exposure, clinicians may underdiagnose these conditions.

In a national survey of the U.S. public in 2009, 21% of respondents indicated that a household member found a tick on themselves in the previous year, and 10% of those individuals consulted with a clinician [19]. In a national survey of physicians and nurse practitioners conducted the same year, 51.3% treated one or more patients for a TBD in the previous year [20]. Despite the increasing incidence of TBDs, there are few recent knowledge, attitudes, and practices (KAP) surveys of U.S. clinicians on this topic, and most focus primarily on Lyme disease [21]. Registered nurses have not typically participated in past KAP studies. Nurses play an important role in facilitating access to care, and therefore inclusion would be beneficial.

Previous TBD KAP studies have not addressed Alpha-gal syndrome. In a systematic sample of Alpha-gal patients in an allergy clinic in 2016, 75% rated their primary care physicians as lacking knowledge about the syndrome. Most of these patients learned about this condition from sources outside the health care system before seeking specialty care [22].

Our objective was to assess the knowledge, attitudes and practices of Illinois physicians, mid-level practitioners, and nurses towards ticks and tick-borne disease. The study aimed to 1) identify predictors associated with proficiency in this subject, 2) identify knowledge gaps, and 3) evaluate the attitudes and practices of clinicians related to TBDs.

2. Methods

2.1. Survey design and participant recruitment

A web-based survey was created using REDCap [23] tools hosted at the University of Illinois, Urbana-Champaign [24]. REDCap provided: 1) an interface for validated data entry; 2) audit trails for data manipulation and export; and 3) data download procedures, including automated de-identification.

Questions were developed by researchers with the Illinois - Tick Inventory Collaboration network (I-TICK) program [25], a multidisciplinary effort to improve surveillance of and response to ticks and TBDs in Illinois. Researchers are affiliated with the College of Veterinary Medicine, the Carle-Illinois College of Medicine, and the Illinois Natural History Survey-Prairie Research Institute. The program partners with the Illinois Department of Public Health, the University of Illinois Extension, the Midwest Center for Excellence for Vector Borne Diseases, and the Centers for Disease Control and Prevention to collect and share information about ticks of public health concern.

The questionnaire was divided into four categories: 1) Demographics: age, sex, clinician type, years in practice, practice type, county, and past training related to ticks or TBDs; 2) Knowledge: questions regarding ticks and TBDs in Illinois; 3) Attitudes: concern about ticks and TBDs, the importance of patient education on this topic, and interest in TBD training; and 4) Practices: questions about personal actions to reduce tick exposure, and professional practices such as assessing patients' risk for TBDs, diagnostic testing, and patient education practices. The questions were multiple choice, including "check all that apply" responses, and some short answer to allow for further elaboration. Answer choices were considered "correct" or "incorrect" based on information widely available through the CDC's website and the CDC's TBD Reference Manual for clinicians [26].

A convenience sampling strategy was employed, targeting physicians (MD/DO), advanced practice nurses (APN), physician associates/assistants (PA), and registered nurses (RN). The survey was disseminated by email through newsletters promoting the study or direct email messaging by: Illinois State Medical Society, Illinois Society for Advanced Practice Nurses, Illinois College of Emergency Physicians, Illinois Academy of Family Physicians, Illinois Critical Access Hospitals Network, county health departments, and a multi-hospital healthcare system. The questionnaire remained open from August 2020 to February 2022, with the widest dissemination occurring between September 2021 and February 2022. An educational poster on Illinois ticks was offered as incentive for participation.

This study was reviewed by the Office for the Protection of Research Subjects at the University of Illinois and the Johns Hopkins School of Public Health Institutional Review Board (IRB) and determined to be non-Human Subjects Research exempt from IRB approval (protocol #21099).

2.2. Statistical analysis

Data cleaning and analysis were performed in R Studio version 4.1.2 [27]. Respondent counties were grouped into three regions, based on U.S. Climate Divisions [28] for Illinois: northern (divisions 1–2), central (divisions 3–7) and southern (divisions 8–9) Illinois. For modeling, central and southern Illinois were combined due to the small number of responses in the south. Practice types were grouped according to specialties likely to encounter early vs. later clinical presentations of tick-borne illness [18,29]: 1) First-line: primary care, urgent care, emergency medicine, critical care, and dermatology 2) Second-line: infectious disease, rheumatology, neurology, cardiology, gastroenterology, allergy/immunology, and sleep medicine; and 3) Unrelated: specialties not expected to encounter TBDs. Scores for tick knowledge and TBD knowledge were calculated by assigning one point for each correct response and summing the points. Overall knowledge score was calculated by summing the tick score (29 possible points) and TBD score (33 possible points), for a total potential score of 62 points.

Descriptive statistics were generated for each survey section, stratified by clinician type; Chi-square tests were conducted to assess differences by provider type. *t*-tests were performed to compare knowledge scores by clinician type and Pearson's r was calculated to measure correlation between knowledge subcategories.

Poisson regression was performed to identify predictors of overall knowledge score and sub scores. Prior to model building, a directed acyclic graph was created to portray hypothesized causal associations [30,31]. Potential predictors evaluated included age, gender, practitioner type, years in practice, practice type, past tick training, and region. Akaike Information Criterion (AIC) scores were compared to select a final model. Goodness of fit testing and negative binomial regression identified no overdispersion in the selected models.

3. Results

The survey received 362 responses, with 349 (96.4%) responding between September 2021 and February 2022. Sixteen respondents who selected provider type "Other" were excluded, leaving 346 full responses for analysis.

3.1. Demographics

Among respondents, 212 (61.3%) were RNs, 74 (21.4%) were

physicians, and 60 (17.3%) were APNs/PAs (Table 1). Over 93% of RN and APN/PA respondents were female, while 56.8% of physicians were male. A greater proportion of physicians (27.0%) were 65 or above, while only 3.3% of APNs/NPs or RNs were in this age category. A larger percentage (63.3%) of APN/PA's had practiced ten years or less, compared to physicians (21.6%) or RNs (42.0%). Most physician (68.9%) and APN/PA (60.0%) respondents represented practices involved in first-line treatment of TBDs. For RNs, 48.6% worked in first-line treatment practices, while 45.8% worked in areas not directly relevant to TBDs. Most practices (75.1%) were in the central region (Fig. 1). Overall, 78.0% had never received tick training, however, more physicians (52.7%) had training than APNs/PAs or RNs. Short answer responses specifying the type of tick training received predominantly described clinical training during medical school, residency or continuing medical education.

Table 1
Demographics of respondents with *P* values from tests for differences by clinician type.

Question	Answer	Number (%)				
		Overall	MD/DO	APN/PA	RN	P Value
		346 (100.0)	74 (21.4)	60 (17.3)	212 (61.3)	
Age	18–25	8 (2.3)	0 (0.0)	0 (0.0)	8 (3.8)	<0.001
	26–34	65 (18.8)	5 (6.8)	17 (28.3)	43 (20.3)	
	35–44	92 (26.6)	17 (23.0)	16 (26.7)	59 (27.8)	
	45–54	68 (19.7)	15 (20.3)	17 (28.3)	36 (17.0)	
	55–64	84 (24.3)	17 (23.0)	8 (13.3)	59 (27.8)	
	65+	29 (8.4)	20 (27.0)	2 (3.3)	7 (3.3)	
Gender	Female	282 (81.5)	27 (36.5)	57 (95.0)	198 (93.4)	<0.001
	Male	56 (16.2)	42 (56.8)	3 (5.0)	11 (5.2)	
	Nonbinary	1 (0.3)	1 (1.4)	0 (0.0)	0 (0.0)	
	No answer	7 (2.0)	4 (5.4)	0 (0.0)	3 (1.4)	
Years in Practice	1–10	143 (41.3)	16 (21.6)	38 (63.3)	89 (42.0)	<0.001
	11–20	82 (23.7)	16 (21.6)	11 (18.3)	55 (25.9)	
	> 20	120 (34.7)	41 (55.4)	11 (18.3)	68 (32.1)	
	No answer	1 (0.3)	1 (1.4)	0 (0.0)	0 (0.0)	
Practice Type: Specialties Treating Tick-Borne Disease	First-line treatment	190 (54.9)	51 (68.9)	36 (60.0)	103 (48.6)	0.015
	Second-line treatment	21 (6.1)	4 (5.4)	5 (8.3)	12 (5.7)	
	Other	135 (39.0)	19 (25.7)	19 (31.7)	97 (45.8)	
Practice Region	Central IL	260 (75.1)	45 (60.8)	43 (71.7)	172 (81.1)	<0.001
	Northern IL	28 (8.1)	16 (21.6)	5 (8.3)	7 (3.3)	
	Southern IL*	10 (2.9)	2 (2.7)	4 (6.7)	4 (1.9)	
	No answer	50 (14.5)	11 (14.9)	8 (13.3)	29 (13.7)	
Previous Tick Training	1–2 years ago	10 (2.9)	5 (6.8)	3 (5.0)	2 (0.9)	<0.001
	3–4 years ago	10 (2.9)	3 (4.1)	5 (8.3)	2 (0.9)	
	5 or more years ago	56 (16.2)	31 (41.9)	4 (6.7)	21 (9.9)	
	None	270 (78.0)	35 (47.3)	48 (80.0)	187 (88.2)	

* Two respondents practiced in both Central and Southern IL.

3.2. Knowledge

There were no significant differences in knowledge of Illinois ticks by clinician type (Table 2), however there were differences in TBD knowledge ($p < 0.001$). Tick knowledge scores were moderately correlated with TBD knowledge, with a correlation coefficient of 0.38 ($p < 0.001$).

Regarding Illinois ticks, respondents were aware of Lyme disease risks, with 85.3% responding that the blacklegged tick (*I. scapularis*) is present in Illinois and 91.3% specifying that it spreads disease to humans. However, only 21.4% responded that the Lone star tick (*A. americanum*) is present in Illinois, while 51.4% knew that it transmits disease. Less than half of respondents were aware that the American dog tick (*D. variabilis*) and brown dog tick (*Rhicephalus sanguineus*) vector disease to humans. Most were able to identify tick habitats and risk factors associated with TBDs.

On the TBD section, knowledge regarding diagnostic testing varied widely by disease. Among physicians, 97.3% were familiar with Lyme disease testing, but fewer were aware of testing for anaplasmosis (35.3%), *B. miyamotoi* (28.4%), *B. mayonii* (27.0%), and Powassan disease (8.1%). Lyme disease was the only TBD that most respondents (79.5%) reported as endemic to Illinois. The diseases physicians most frequently reported as present were Lyme disease (77.0%), RMSF (25.7%), tularemia (17.6%), ehrlichiosis (16.2%), and rickettsiosis (12.5%). Among treating practitioners, 74.3% of physicians and 71.7% of APNs/PAs identified antibiotics as an available treatment for many TBDs. Among physicians, 32.4% knew that exposure to saliva from *A. americanum* can trigger Alpha-gal syndrome, while 17.6% knew of diagnostic testing for Alpha-gal, and 13.5% correctly stated that no treatment is currently available.

Despite smaller sample sizes in the southern ($n = 10$) and northern ($n = 28$) regions, some differences consistent with regional patterns in TBDs and their vectors [32] (Fig. 1) were observed. In the south, 63% reported the presence of *A. americanum* compared to 18% of central and 29% of northern respondents ($p < 0.001$); 38% of southern respondents stated that ehrlichiosis was endemic, in contrast to 9% of central and 11% of northern clinicians ($p = 0.03$). No regional differences were detected in familiarity with RMSF or rickettsiosis. Knowledge of Lyme disease was universal with no differences observed by region despite higher incidence in the north.

Results of Poisson regression of knowledge scores on multiple predictors are presented in Table 3. For overall knowledge, the strongest predictor of a higher score was tick or TBD training one to two years ago, with a relative risk (RR) of 1.26 (1.14–1.41) compared to no training, and training three to four years ago yielding a RR of 1.12 (1.01–1.25). Training five or more years ago had no significant association with overall knowledge. Physicians scored higher than RNs, with a RR of 1.12 (1.05–1.20). In the subcategory analysis, only tick training one to two years ago was significantly associated with knowledge of Illinois ticks. For the TBD subcategory, the same predictors were significant as for overall knowledge, but with greater effect sizes, suggesting the overall score results are primarily explained by differences in knowledge regarding TBDs. Tick training one to two years ago was the strongest predictor of TBD knowledge, with a RR of 1.42 (1.19–1.69) (Fig. 2). Age and practice type were included as co-variates in the model selection process, but neither were significant, nor did they contribute to the performance of the model and were not retained in the final analysis.

3.3. Attitudes

Overall, 68.8% of clinicians reported that TBDs were a concern in their area, and 92.8% stated patient education regarding TBDs was important. Most (77.5%) expressed interest in tick-related training. Of those, 81.0% preferred web-based rather than in-person or written instruction. Preferred training topics were TBDs/treatment (97.0%), tick removal (83.6%) and identification (83.2%). Most (82.7%) indicated

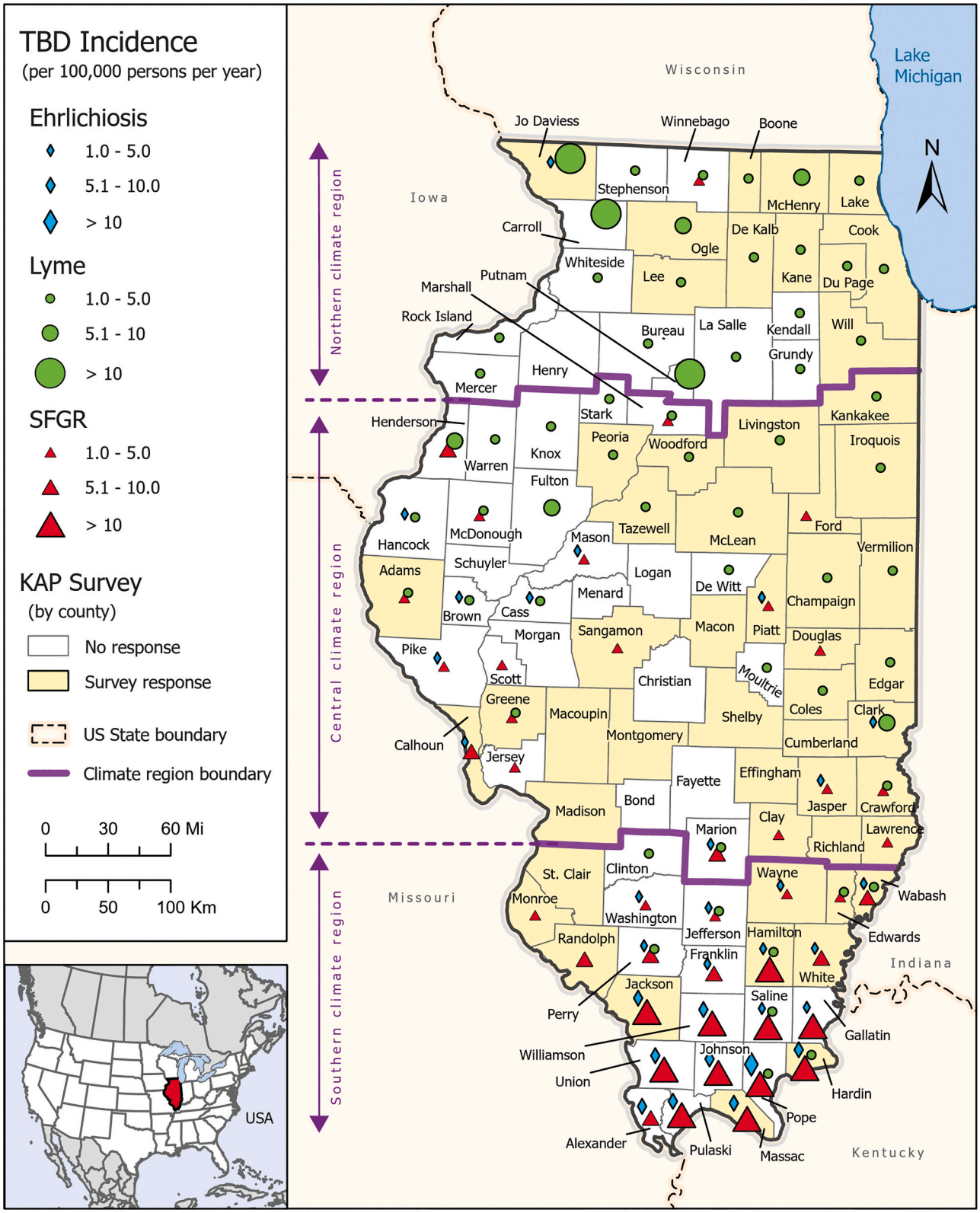

Fig. 1. Survey responses and reported TBD incidence in Illinois counties. Counties were grouped into three regions, based on U.S. Climate Divisions (National Oceanic and Atmospheric Administration, 2022): northern (divisions 1–2), central (divisions 3–7) and southern (divisions 8–9). Counties where survey respondents practice are depicted in yellow, with symbols to indicate the average reported annual incidence of Illinois's top three TBDs (Lyme, Spotted Fever Group Rickettsiosis, Ehrlichiosis) between 2010 and 2019 (Illinois Department of Public Health, Illinois Tickborne Disease Incidence, 2010–2019). Counties without a TBD symbol reported average annual incidence <1.0 per 100,000. Cases are reported by county of residence, which may not be where infection was acquired. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
Percent of correct responses by survey knowledge category and for the survey overall. Results include percent correct (range), and P values from tests to assess differences in score by clinician type.

Knowledge category	Percent correct: mean (range)			
	MD/DO	APN/PA	RN	P Value
N				
Tick Knowledge	69.9 (41.4–89.7)	69.6 (48.3–82.8)	67.9 (27.6–93.1)	0.282
Tick-borne Disease Knowledge	43.9 (21.2–72.7)	35.9 (21.2–57.6)	31.5 (12.1–72.7)	<0.001
Overall (Total Score)	56.1 (35.5–79.0)	51.6 (35.5–67.7)	48.5 (19.4–77.4)	<0.001

Table 3
Results from Poisson regression models of predictors related to tick knowledge, tick-borne disease knowledge and overall knowledge.

Predictor	Relative risk (95% CI) of a higher score		
	Overall knowledge	Tick knowledge	TBD knowledge
Practitioner type: MD/DO	1.12 (1.05–1.20)***	1.03 (0.94–1.12)	1.30 (1.16–1.44)***
Practitioner type: APN/PA	1.03 (0.97–1.09)	1.00 (0.93–1.08)	1.08 (0.98–1.19)
Northern IL Region	1.05 (0.98–1.13)	1.01 (0.92–1.11)	1.11 (0.99–1.24)
Tick training 1–2 years ago	1.26 (1.13–1.41)***	1.17 (1.01–1.36)*	1.42 (1.19–1.69)***
Tick training 3–4 years ago	1.12 (1.01–1.25)*	0.98 (0.85–1.14)	1.36 (1.16–1.61)***
Tick training 5 or more years ago	1.04 (0.98–1.10)	1.04 (0.97–1.13)	1.03 (0.93–1.14)
Years in practice: 11–20	1.06 (1.01–1.12)*	1.04 (0.97–1.11)	1.10 (1.01–1.20)*
Years in practice: 20+	0.99 (0.94–1.04)	0.96 (0.90–1.03)	1.04 (0.96–1.13)
Gender: Male	0.98 (0.92–1.05)	0.97 (0.90–1.07)	0.98 (0.88–1.09)

*** $p < 0.001$.
* $p < 0.05$.

that more public health outreach on this topic would be beneficial.

3.4. Practices

Physicians reported they would test for TBDs: when patient symptoms are consistent with TBD (87.8%), to rule out TBD (74.3%), or when a patient has traveled to a high-risk area (33.8%). However, only 31.1% of physicians and 23.3% of mid-level practitioners stated they routinely ask about potential tick exposure. Regarding patient education, 36.5% of physicians and 31.7% of APNs/PAs reported they provide information on TBD to patients.

Responses to questions on knowledge, attitudes and practices are summarized in Supplement Tables 1–3.

4. Discussion

In this survey most respondents were knowledgeable about Lyme disease. These results are consistent with findings in other states where Lyme is endemic [20,21,33,34]. While physicians were generally familiar with diagnostic testing for RMSF and ehrlichiosis, most did not believe either disease to be endemic to Illinois. Spotted fever group rickettsiosis (SFGR), which includes RMSF, is the second most frequently reported TBD in Illinois and has increased substantially since 2009 [5,6]. Ehrlichiosis cases have also increased rapidly with the range expansion of *A. americanum*, and unawareness of the presence of these diseases can lead to underdiagnosis and undertreatment [15].

Knowledge about Alpha-gal syndrome was low across all clinician types. The allergic response in Alpha-gal syndrome is typically delayed by hours after consuming meat, and over 51% of cases involve anaphylaxis, making this condition both challenging to diagnose and life-threatening [12]. While the prevalence of Alpha-gal in the U.S. is unknown, the range of *A. americanum* is expanding [7,8] and now includes all of Illinois [9,10]. There is a need for more research on clinicians' knowledge of Alpha-gal syndrome as this condition may become more widespread with increased exposure to the Lone star tick. TBD training for clinicians should address Alpha-gal syndrome in regions where *A. americanum* is present, particularly now that the Council of State and Territorial Epidemiologists have approved an Alpha-gal surveillance case definition, and the CDC is awaiting approval to begin formally receiving data on the condition [35].

Although physicians scored higher than APN/PAs or RNs in knowledge regarding TBDs, they correctly answered only 44% of questions on average, suggesting knowledge gaps across all clinician types. All practitioner types were proficient in identifying tick habitats and risks for exposure to tick bites. While clinicians may not be skilled in tick identification [36], these results suggest they have the knowledge to screen for potential exposure to TBDs. Although 72% of physicians reported concern about TBDs, only 34% of those with concern routinely ask patients about tick exposure, and only 43% of those concerned (37% of physicians overall) educate patients about TBDs. Clinical guidelines recommend that patients presenting with fever, rash, or flu-like symptoms, especially during spring or summer, be screened for potential tick exposure and evaluated for endemic TBDs [37].

Registered nurses performed as well as physicians and mid-level providers on questions related to ticks in Illinois and the diseases they carry, tick habitats, and risk factors for exposure to TBD. Nurses can play an important role in identifying TBD exposure and facilitating access to care. A team-based approach to care with nurses assessing potential exposure to ticks and providing patient education would help address the gap in screening and educating patients on this topic [38].

The strongest predictor of knowledge about ticks and TBDs was tick-related education, with recent training having the strongest effect. The impact diminished over time, with training five or more years ago having no significant effect. As the range of vector ticks and the incidence of TBDs are increasing and region-specific, recurrent training specific to the practice region is recommended. Tick training materials for health care professionals have been developed by the CDC and are publicly available on their web site [39]. Given the knowledge gaps regarding non-Lyme TBDs, it is also recommended that education focused on Lyme disease be broadened to include all TBDs relevant to a given area.

Access to information improves the diagnosis and prevention of tick-borne disease [40]. Also, training has been shown to significantly increase knowledge related to ticks and TBDs for public health [41] and veterinary [42] professionals in Illinois. The Tick-borne Disease Working Group recommends a One Health approach to training and TBD control [14,43], targeting TBDs in both humans and animals, as well as addressing environmental factors. In our study, only 51% of clinicians knew that dog ticks transmit disease to humans, suggesting that collaboration with veterinarians would be beneficial. People living with dogs or cats have almost twice the risk of finding ticks on themselves [44], reinforcing the need for veterinarians to counsel pet owners about TBD risks. An interprofessional educational approach including the medical and veterinary community and public health professionals would enhance collaboration among these stakeholders.

This study is limited by the use of a convenience sample rather than a random sampling methodology, due both to the lack of a comprehensive sampling universe of Illinois clinician email addresses and the difficulty of obtaining high response rates in this population. Recruitment of physicians and other clinicians for surveys has historically been

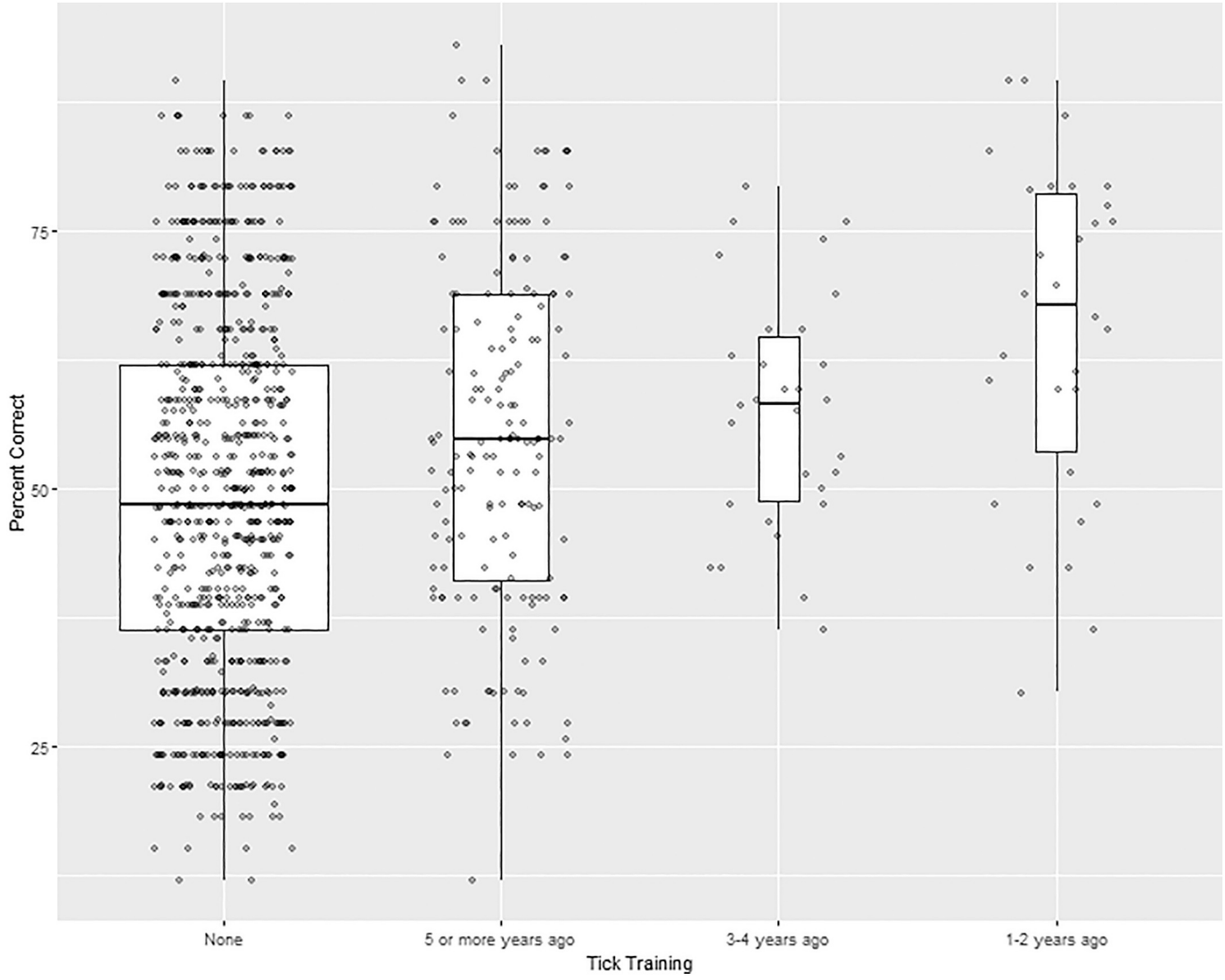

Fig. 2. Distribution of overall knowledge scores (percent of correct responses) by training experience. Boxes depict the interquartile range (IQR), with the median indicated by the bold horizontal line and whiskers drawn to the largest and smallest observations within 1.5*IQR.

challenging, and response rates in this group are declining [45]. This study experienced similar challenges and relied on survey dissemination by medical societies, hospitals, and health departments. Respondents represented 53 of 102 Illinois counties as well as a wide range of experience and specialties. However, clinicians with interest in TBDs may have been more likely to participate, potentially overestimating knowledge related to ticks and interest in related education. Also, recruitment during the COVID-19 pandemic may have reduced participation by practice settings disproportionately impacted by the pandemic. These considerations may affect the generalizability of the results. Our study did not include clinicians across state borders where some Illinois patients may seek care. Finally, we acknowledge that there is the potential for subjective differences in respondent interpretation of survey questions

5. Conclusion

In our study, Illinois clinicians were knowledgeable about Lyme disease; however, there were substantial gaps in awareness of other endemic TBDs. These findings suggest that TBDs may be underdiagnosed and undertreated in Illinois, though further study is warranted both on a state and national level. The strongest predictor of knowledge related to ticks and TBDs was tick or TBD training in the previous two years. Based on our results, frequent training for clinicians highlighting TBDs endemic to their region is critical to address this growing public health issue.

CRediT authorship contribution statement

Dawn A. Carson: Methodology, Formal analysis, Investigation, Data curation, Writing – original draft. **Heather Kopsco:** Conceptualization, Methodology, Writing – review & editing. **Peg Gronemeyer:** Visualization, Writing – review & editing. **Nohra Mateus-Pinilla:** Conceptualization, Methodology, Writing – review & editing. **Genee S. Smith:** Methodology, Writing – review & editing. **Emma N. Sandstrom:** Conceptualization, Investigation. **Rebecca L. Smith:** Conceptualization, Methodology, Formal analysis, Data curation, Visualization.

Declaration of Competing Interest

The authors declare that there were no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2022.100424.

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