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Original article

Living with ticks: Results of an online survey of the knowledge, attitudes and practices (KAP) regarding ticks and tick-borne pathogens in academic environments across Europe

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ABSTRACT

We prepared a digital questionnaire to capture knowledge, attitudes and practices (KAP) regarding ticks and tick-borne pathogens (TBPs) in 20 languages. The questionnaire was distributed to 21 universities and research institutions in 22 European countries and 9401 valid responses were collected. Most survey participants identified ticks correctly and regarded ticks as a serious health risk. There was also a good level of knowledge regarding tick

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Questionnaire survey
Europe

activity, habitats and the predominant TBPs in the country or region. Moreover, most respondents were familiar with effective tick protection and removal measures. Over 75 % of respondents had been bitten by ticks and up to 12 % of participants had been diagnosed with a tick-borne infection in the past. Respondents from northern and central European countries who reported engaging in outdoor activities more frequently, reported increased frequencies of tick bites and infection with TBPs compared to respondents from southern Europe. Awareness of national information campaigns on ticks and TBPs was also greater among respondents from northern and central European countries than among Mediterranean countries.

This study identified knowledge gaps among respondents from some European countries where TBPs have not been prioritised historically. These knowledge gaps should be addressed by reputable bodies to encourage personal protective behaviours without causing alarm and to forestall the spreading of incorrect and unreliable information propagated by some social media sources.

1. Introduction

The most common human tick-borne pathogens (TBPs) in Europe are spirochaetes belonging to the *Borrelia burgdorferi* sensu lato complex and the tick-borne encephalitis virus (TBEV). The former is the agent of Lyme borreliosis, which can lead to mild or asymptomatic infections in some patients and severe multisystem disease in others (Stanek et al., 2012). The other is a flavivirus which infects the central nervous system resulting in serious, long-term cognitive and neuropsychiatric impairments in about 40 % of infected individuals (Haglund and Günther, 2003). In addition, there are several other, less common TBPs that infect humans in Europe, including *Babesia* spp., *Anaplasma phagocytophilum, Borrelia miyamotoi, Ehrlichia* spp., *Francisella* spp., *Neoehrlichia mikurensis, Rickettsia* spp. and the Crimean Congo Haemorrhagic Fever virus (CCHFV) (Monsalve Arteaga et al., 2021; Pustijanac et al., 2024). The main tick vector in central and northern Europe is *Ixodes ricinus*. In addition, there are a number of tick species that have a patchier distribution such as *Dermacentor reticulatus* and *Dermacentor marginatus* (Estrada-Peña et al., 2017) and some that are of lesser importance as vectors or have a more restricted range in Europe, such as *Haemaphysalis punctata* or *Ixodes persulcatus*. In southern European countries the climate is more suitable for tick species such *as Hyalomma marginatum, Rhipicephalus sanguineus* s.l., and *Rhipicephalus bursa* and some of these species can be found sympatrically with *I. ricinus* in the southern fringes of its distribution (Estrada-Peña et al., 2017). All of these tick species have different affinities for humans and the range of pathogens they can transmit is highly specific (Slunge and Boman, 2018).

It is expected that changes in climate and land use will lead to shifts in the geographical spread of ticks with some areas becoming more and others becoming less suitable for the ticks' or their hosts' survival (García-Vozmediano et al., 2020; Estrada-Peña and Fernández-Ruiz, 2023). As a result, the risk of being exposed to unexpected, 'exotic' ticks and TBPs, may be increasing for both, humans and animals. A case in point is CCHFV which is transmitted by *H. marginatum* and was first reported in Spain in 2013. It has since spread across Spain (Sánchez-Seco et al., 2022), with isolated cases also reported from Portugal and France, including Corsica. In the short to medium term CCHFV is predicted to expand along the Mediterranean coastlines, including France, Italy and the southern Balkans (Messina et al., 2023).

Having said this it is important to stress that the risk of developing a tick-borne disease after a tick bite is still relatively low in Europe with figures suggesting that even in endemic areas only 2 % of those that are bitten by a tick develop Lyme borreliosis (Wilhelmsson et al., 2016). Nevertheless, public concern about TBPs is growing in many countries.

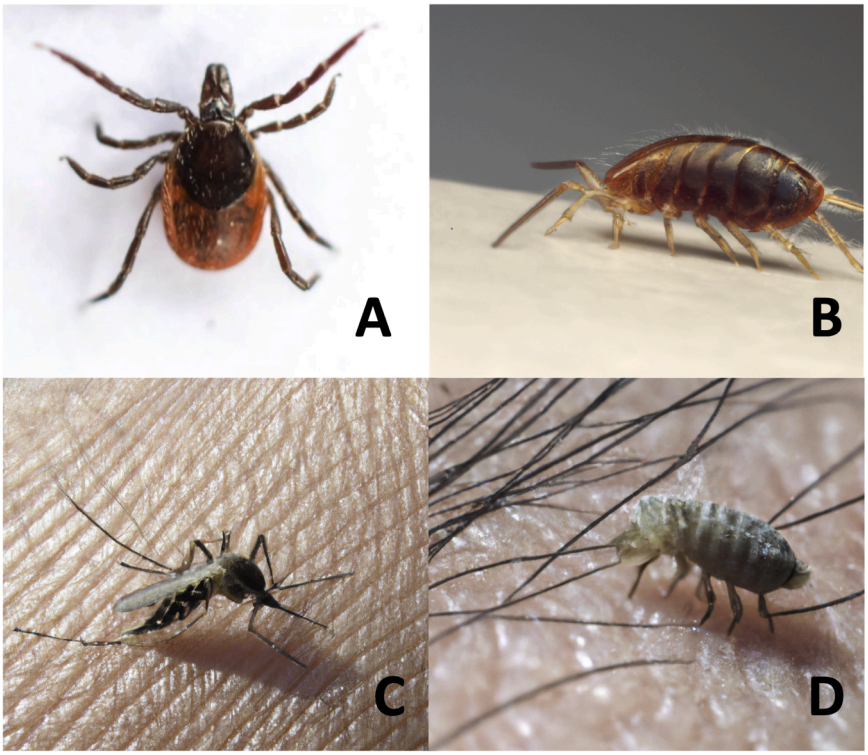

Fig. 1. Panel of images used as a prompt in survey question 6. (A) image of an unfed female *Ixodes ricinus* tick, B to D artificially generated images using openjnart.ai (accessed October 2022).

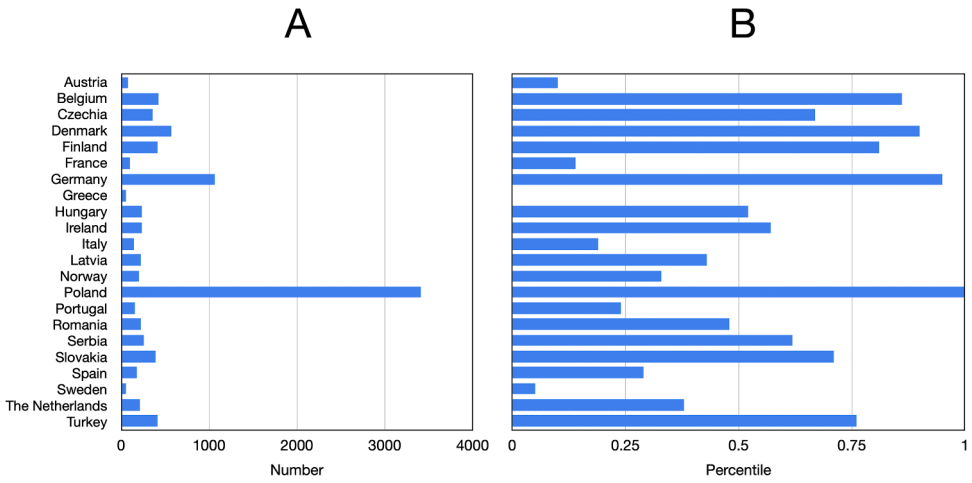

Fig. 2. Number (A) and percentile (B) of valid questionnaires received per country.

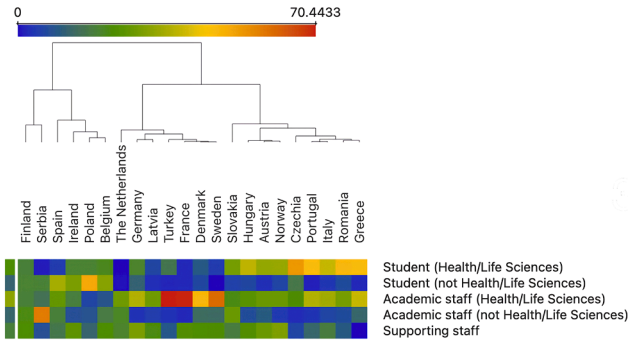

Fig. 3. Survey participation separated by category, i.e. university support staff (e.g., technical, administrative), student (health/life sciences or 'other'), and support staff (health/life sciences or 'other'). Countries are clustered using a k-means algorithm based on the percentage distribution of responses (shown at the top of the chart).

This is partially driven by relatively recent arrivals of some zoonotic TBPs into Europe (e.g. CCHFV) and the spread of others into new areas, but also partially by social media and patient activist groups which do not always take the specific epidemiology of different tick species and TBPs into account.

It is therefore essential to provide evidence-based, reliable information to the public without causing alarm. This is even more important as previous studies have highlighted the importance of public awareness in mitigating the health risks associated with tick bites. In fact, it has been suggested that public awareness of the potential risks associated with ticks has a greater effect on the likelihood of becoming infected with LB than actual exposure to ticks (Shadick et al., 1997). However, anecdotal evidence suggests that the importance ascribed to ticks and TBPs by health care professionals and the public varies across Europe, largely reflecting the historical clinical importance of ticks and the pathogens they carry. For example, for centuries the main focus in many Mediterranean countries has been on mosquitoes and sandflies, as the most important vectors of pathogens (Slunge et al., 2019).

To evaluate whether there is a need to improve public knowledge, awareness and practices regarding ticks and TBPs in some European regions or countries, a questionnaire was designed, translated into 20 languages and circulated to staff and students in universities across 22 European countries. In order to facilitate a broad spectrum of participation, students enrolled in any programme, academic and non-academic staff were included. The questionnaire explored the level of knowledge regarding ticks and TBPs and personal experiences with ticks. We hypothesized that there would be a degree of heterogeneity in the perceived relative importance TBPs roughly reflecting the latitudinal distribution of tick species and TBPs across Europe.

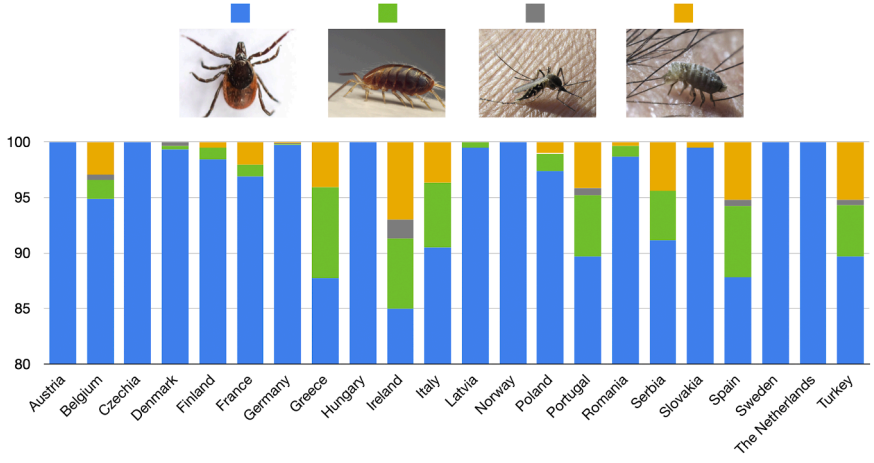

Fig. 4. Percentage of correct identifications of the tick image (option A) versus wrong identifications of other 'plausible' arthropods (options B to D).

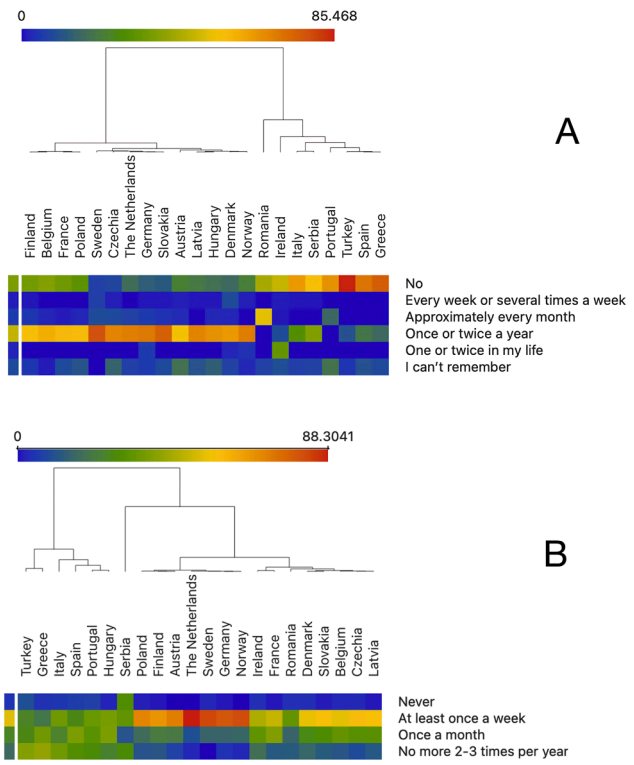

Fig. 5. (A) reported frequency of tick bites and (B) Reported frequency of outdoor activities (e.g., sports, leisure). Countries are clustered using a k-means algorithm based on the percentage distribution of responses (shown at the top of the charts).

2. Materials and methods

2.1. Survey design and distribution

A questionnaire consisting of 19 questions was designed in English (Supplementary Material S1) and following approval by all co-authors, translated into 20 languages representing the national languages of all participating countries. In countries with more than one national language, such as Belgium, translations were provided in each of the official languages. Translations were conducted by one or more co-authors and care was taken to use country-specific terminology. As a part of the survey, respondents were offered four images, one of them depicting an unfed female *Ixodes ricinus* tick, with the other three showing other arthropods (Fig. 1) and asked to identify the image showing a tick. To avoid using pictures of well-known arthropods (e.g., bee, ant, spider, scorpion), the non-tick images were generated using artificial intelligence (openjnart.ai, free version, accessed October 2022) and the prompt, 'draw a realistic parasitic arthropod crawling on human skin, over a human arm or leg with a few hairs on the skin.' For the tick itself a real image was used with sufficient detail for easy identification.

The survey was created and disseminated using Microsoft Forms. Participants were recruited from students, teaching and support staff in the affiliated universities or research institutes of the co-authors. The questionnaire explicitly stated that the questions should be answered regarding the country of current residence rather than the home country (where the two were different). Invitations to participate, hyperlinks and QR codes were disseminated via e-zines, intranet, and similar electronic means. Participation was anonymous and no personal data such as gender, age, postal or email address were collected (the email address, that is sometimes requested by online services to login, was not linked to the generated reports of responses and was unavailable to the researchers). The survey was open for responses from June to December 2023. Upon closing, the results were downloaded, and the questionnaire taken offline.

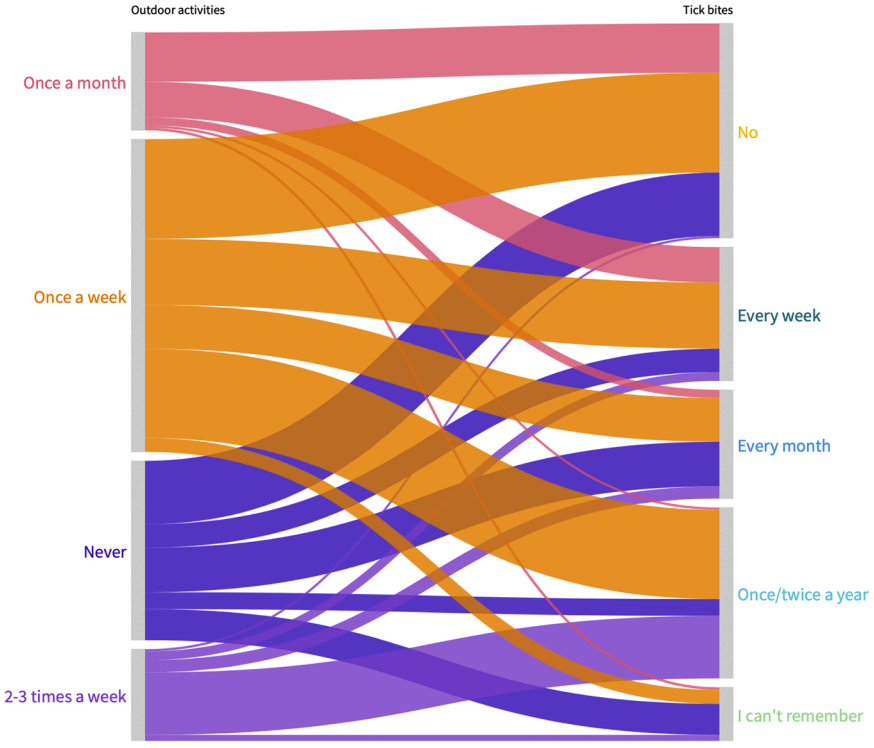

Fig. 6. Association of the reported frequency of outdoor activities (left) with the reported frequency of tick bites (right). The width of the bands connecting responses on the left to those on the right is proportional to the percentage of responses.

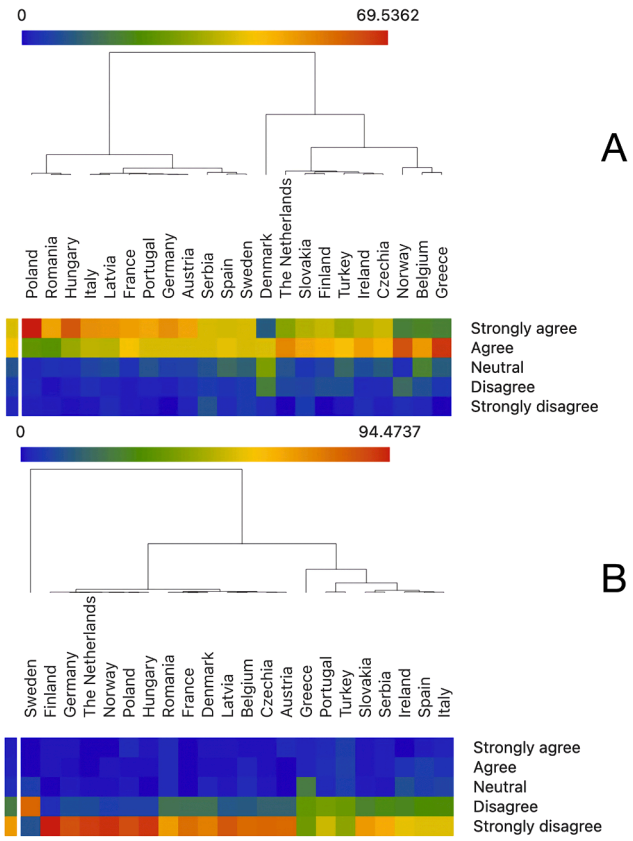

Fig. 7. Likert scale responses to the statement (A) 'Ticks represent a serious health issue for humans and/or animals' and (B) 'Ticks only infest livestock, pets, and/or wildlife, not humans'. Countries are clustered using a k-means algorithm based on the percentage distribution of responses (shown at the top of the charts).

2.2. Data analysis

Questionnaires were manually reviewed for completeness and processed by country. Using Chi-squared analysis, initial checks were undertaken to determine whether there were significant differences in the proportion of responses from each country.

Results were visualized using histograms and heat maps with simultaneous cluster analyses of the participating countries. Clustering of countries to check for patterns of responses was performed using the percentage of responses for each option/question and applying a k-means clustering algorithm using scripts developed in the Orange Data Mining environment (https://orangedatamining.com, accessed June 2023). Where appropriate, results were presented using alluvial charts or maps of Europe with histograms for each country. Associations between responses to selected questions (e.g. frequency of outdoor activity and tick bites) were also assessed.

The 'KAP index' for each country was summarized by averaging the responses to questions relating to (i) the recognition of ticks, (ii) perceptions as to the importance of ticks and TBPs, (iii) methods of personal protection and (iv) tick removal resulting in a mapped index ranging between 0 and 100.

3. Results

3.1. Response rate and representation

A total of 10,108 questionnaires were received, of which 9401 were complete and valid. Most questionnaires (almost 50 % of the total) were received from Poland and Germany (Fig. 2A). Generally, participation was higher in northern and central European regions than in Mediterranean countries, although this trend did not apply to Austria, France, and Sweden (Fig. 2B). There was no significant difference in the professional background of the respondents (Fig. 3, chi-square = 29.22, DF = 84, $p = 0.779$) and we concluded that the sample was homogeneous across countries. Notably, there was a high level of participation among support staff (technicians, administrative personnel) and academic staff not involved in the health/life sciences.

3.2. Ability to recognize ticks and reported tick bite frequency

The ability to correctly identify the tick image was generally very high (equal to or greater than 85 % in all participating countries), but somewhat lower among respondents from Belgium, France, Greece, Ireland, Italy, Portugal, Serbia, Spain, and Turkey (Fig. 4). Regarding tick bite frequency, the majority of respondents from Mediterranean countries, Romania, Ireland, and Serbia primarily reported never having been bitten (63 %), while 65 % of respondents from other countries selected 'once or twice a year' (Fig. 5A). It is of note that <25 % of participants from 14 countries (Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Hungary, Latvia, Norway, Poland, Slovakia, Sweden, and The Netherlands) reported they had never been bitten by a tick; in other words, 77 % of respondents from these countries had been bitten at least once by ticks in the past. Overall, there was a north (higher) to south (lower) gradient of reported frequency of tick bites. There was also a weak association between reporting a low tick bite frequency and the failure to correctly identify the tick image (chi-square=71.04, DF=84, $p = 0.089$).

Patterns of outdoor activity (hiking, biking, camping, etc., excluding winter sports) are shown in Fig. 5B Nearly 50 % of respondents reported engaging in outdoor activities at least weekly with the highest values recorded in The Netherlands (88 %), Germany (87 %), Sweden (82 %), Austria (71 %), Poland (70 %), Finland (66 %), Czechia (58 %), and Latvia (56 %). Lowest rates of outdoor activity were reported in Mediterranean countries (Italy, Spain, Portugal, and Turkey), along with Hungary. While there was a weak association between outdoor activity rates and tick bite frequency (chi-square = 31.56, DF=12, $p = 0.079$), several points are noteworthy: (a) lack of outdoor activity was not correlated with a complete absence of tick bites, (b) weekly outdoor activity was correlated with a higher frequency of tick bites, and (c) respondents who reported no outdoor activities displayed the highest percentage of forgotten bites (i.e. 'can't remember') (Fig. 6).

3.3. Perception of the importance of ticks and TBPs and awareness of tick habitats and seasonality

<70–80 % of respondents from Belgium, Denmark, Romania, Serbia, and Turkey agreed or strongly agreed with the statement 'ticks represent a serious health issue for humans and/or animals' compared to over 80 % from other countries (Fig. 7A). In all but two countries (Greece and Turkey) over 80 % disagreed or strongly disagreed with the statement 'ticks only infest livestock, pets, and/or wildlife, not humans' (Fig. 7B).

Regarding suitable tick habitats, participants from central and northern countries (Austria, Finland, France, Germany, Hungary, Latvia, The Netherlands, Norway and Sweden) mainly listed deciduous forests (Fig. 8A) while coniferous forests were highlighted by respondents from most Mediterranean countries (Fig. 8B). With regard to pastures, responses were more varied, with respondents from most countries (except for Czechia, Finland and Greece) suggesting that they can serve as suitable habitats for ticks (Fig. 8C). Similarly, regarding private or public gardens, opinions were divided, resulting in two clusters of countries (Fig. 8D), indicating that the suitability of both habitat types may vary between countries or regions.

Fig. 9 shows the time of year indicated by respondents when tick bites are likely. The pattern is consistent across the region, with peak activity during late-spring and the summer months and reduced activity

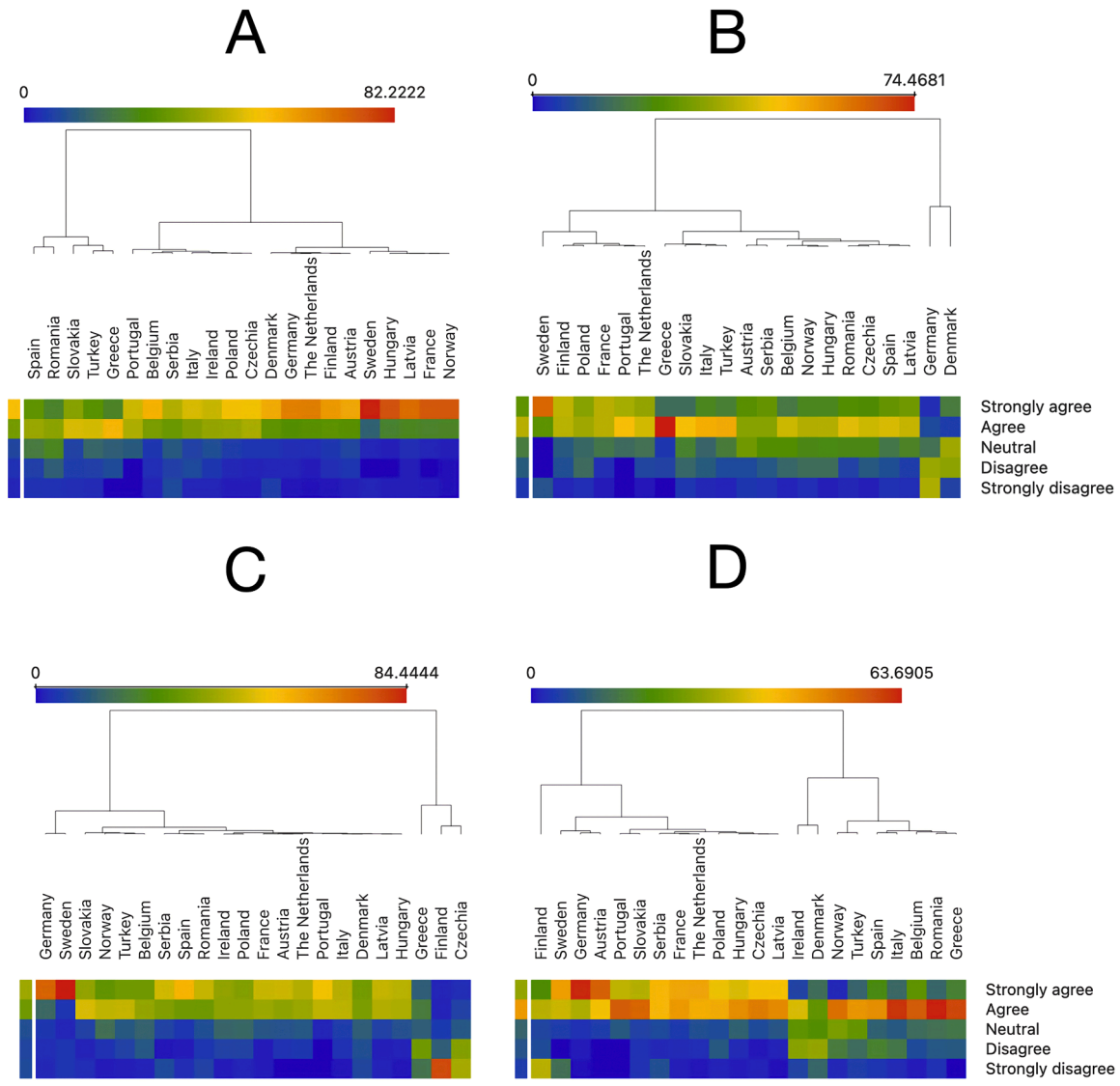

Fig. 8. Likert scale responses to known or perceived tick questing habitats including (A) Deciduous forests, (B) Coniferous forests, (C) Open pastures, (D) Private or public gardens. Countries are clustered using a k-means algorithm based on the percentage distribution of responses (shown at the top of the charts).

at the beginning and end of the year. The decline in reported tick activity during the winter was most evident in responses from northern and central European countries (although not from Germany and Austria).

3.4. Awareness of TBPs and past infections

Ninety-eight percent of respondents correctly indicated that ticks can transmit pathogens to both animals and humans (Fig. 10A) and the majority of participants from central and northern countries (including Sweden, Austria, Germany, Finland, Norway, Poland, Czechia, Denmark, Latvia, and Hungary) were confident that they could list the TBPs that occur in their country (Fig. 10B). In contrast >30 % of respondents from Serbia, Belgium, Portugal, Turkey, Slovakia, Greece, Ireland, and Spain reported not knowing which pathogens were transmitted by ticks (Fig. 10C). Most of those who indicated that they did know, correctly identified the prevailing agents in their country (Fig. 10D) with respondents from northern and central Europe selecting mostly TBEV and *Borrelia* spp. Participants from Greece, Sweden, Ireland, Romania and Hungary (and to a lesser extent Portugal, Italy, Czechia, Austria and Germany) also highlighted *Babesia* spp. *Rickettsia* spp. were most commonly chosen by respondents from Portugal, Italy, Spain and France and CCHFV only by participants from Turkey and Spain. *Anaplasma* spp. was not considered important by respondents from any country.

The reported occurrence of past infections with TBPs averaged 12 % but varied strongly among countries, with participants from two Mediterranean countries stating 'no infections' (Greece and Turkey), while respondents from Czechia reported up to 30 % and those from Sweden around 20 % (Fig. 11A). The predominant diagnosis was borreliosis in all countries except for Spain and Portugal where the most prominent reported diagnosis was rickettsiosis (Fig. 11B). Tick-borne encephalitis was selected by a small number of respondents from eastern European countries and babesiosis by participants from Portugal and Ireland. Anaplasmosis was rarely, and CCHF was never reported (Greece and Turkey were excluded from this analysis due to the lack of reported infections).

In most countries the diagnosis of infection by TBP was made by a general practitioner (Fig. 12A and B). In contrast, over three quarters of respondents from Austria, Finland, Hungary, Ireland and Serbia reported having to attend a consultant or several consultants before receiving the diagnosis (again, Greece, Turkey and in this instance also Spain were excluded from the analysis).

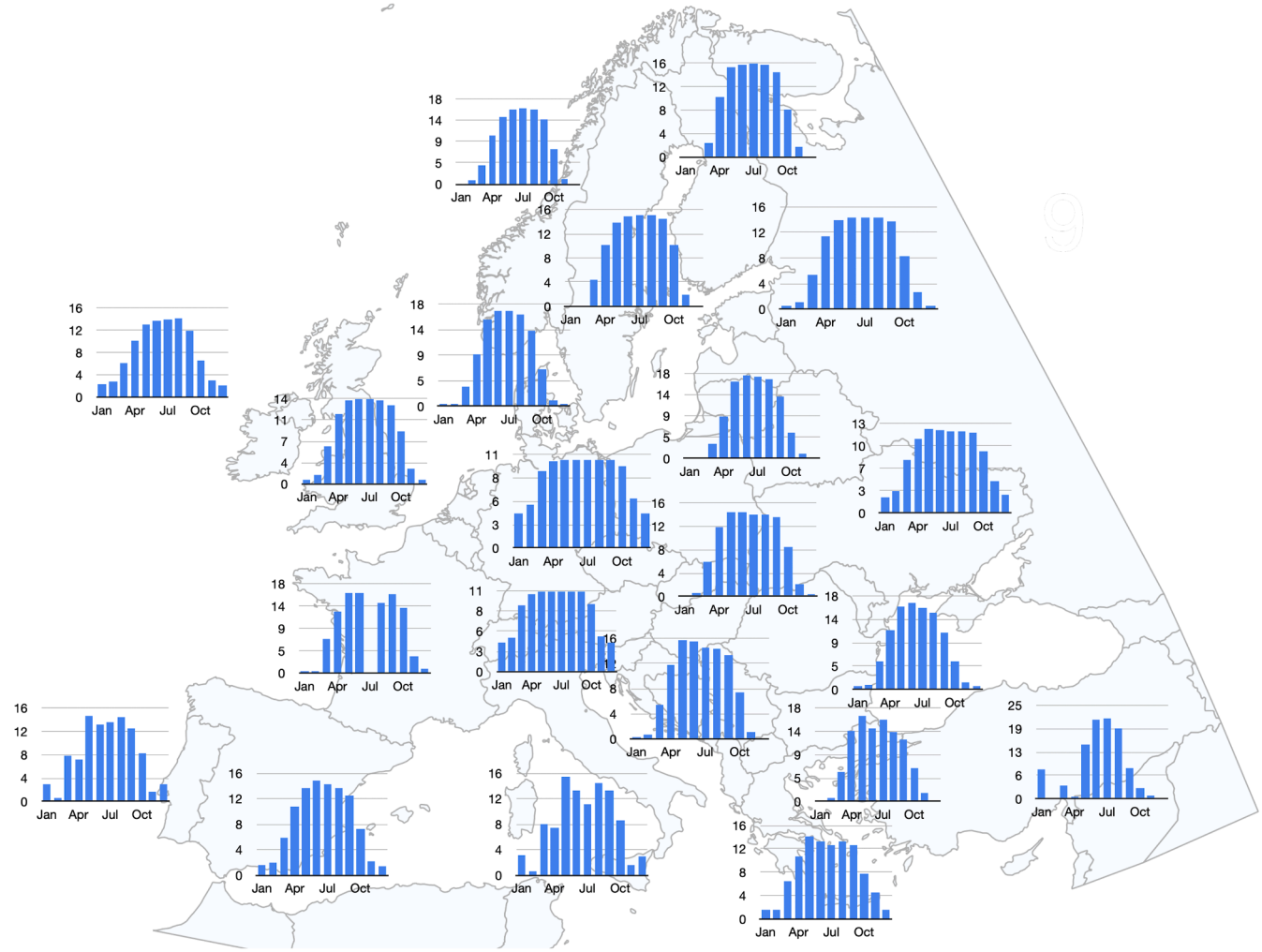

Fig. 9. Known or perceived patterns of seasonal tick activity, charted across Europe. Each chart is placed close to the country of reference. The Y-axis represents the percentage of responses for each month.

3.4. *Effective tick protection and removal methods*

Regarding measures that can be taken to reduce the risk of tick bites, most respondents selected the options 'wearing closed shoes, long sleeves, and long socks' and 'staying on paths and avoiding walking through tall grasses and shrubs.' Notable exceptions were respondents from Belgium and Greece for the former option, and respondents from Sweden for the latter (Fig. 13A and B). There was no strong consensus amongst respondents regarding regular applications of natural or synthetic repellents (Fig. 13C and D) and only a small proportion selected the use of 'anti-tick bracelets' or 'ultrasound devices' (Fig. 13E and F). Interestingly, the last four questions (the use of natural or synthetic repellents, anti-tick bracelets and ultrasound devices) received a high proportion of 'neutral' responses, suggesting a level of uncertainty regarding their usefulness.

When considering respondents' attitudes on personal protective measures together with their reported frequency of tick bite (Fig. 14) we found that about 50 % of respondents who selected 'staying on paths and avoid walking through tall grasses and shrubs', also reported a tick frequency of 'no bites' or 'can't remember'. In contrast, the use of ultrasound devices, natural repellents, or synthetic repellents was associated with higher rates of tick bites. However, these relationships were not statistically significant (chi-square = 20.39, DF = 20, $p = 0.189$).

Regarding tick removal methods many respondents from eastern and Mediterranean countries preferred to consult a physician while others opted to remove ticks themselves (Fig. 15) with 'pulling out the tick with forceps' given as the most frequent response (>81 %). However, other methods such as 'squeezing the tick out, using your fingers' were also selected in several central and northern European countries (18 % on average for Austria, Czechia, Finland, Germany, Hungary, Slovakia and Sweden).

3.5. *Health education campaigns and national reporting systems*

The final questions in the survey focused on public health campaigns and national or regional reporting systems for ticks and TBPs. Respondents from Austria, Czechia, Denmark, Germany, Latvia, The Netherlands, Poland and Sweden stated that there were information campaigns but said that they were primarily promoted during the high-risk season and should be rolled out beyond that period (Fig. 16A). In contrast, many participants from Mediterranean countries indicated that there were no public health campaigns focused on ticks in their countries or that they did not know.

Many respondents were also unaware of any reporting systems for ticks or TBPs (Fig. 16B). Participants from just about one third of the countries said there were official reporting systems, while respondents from The Netherlands, Norway, and Latvia, and to a lesser extent from Sweden, France, and Finland, believed that 'groups of citizens or patient associations' were responsible for recording these figures. Notably, respondents from The Netherlands, Norway, and Latvia thought that

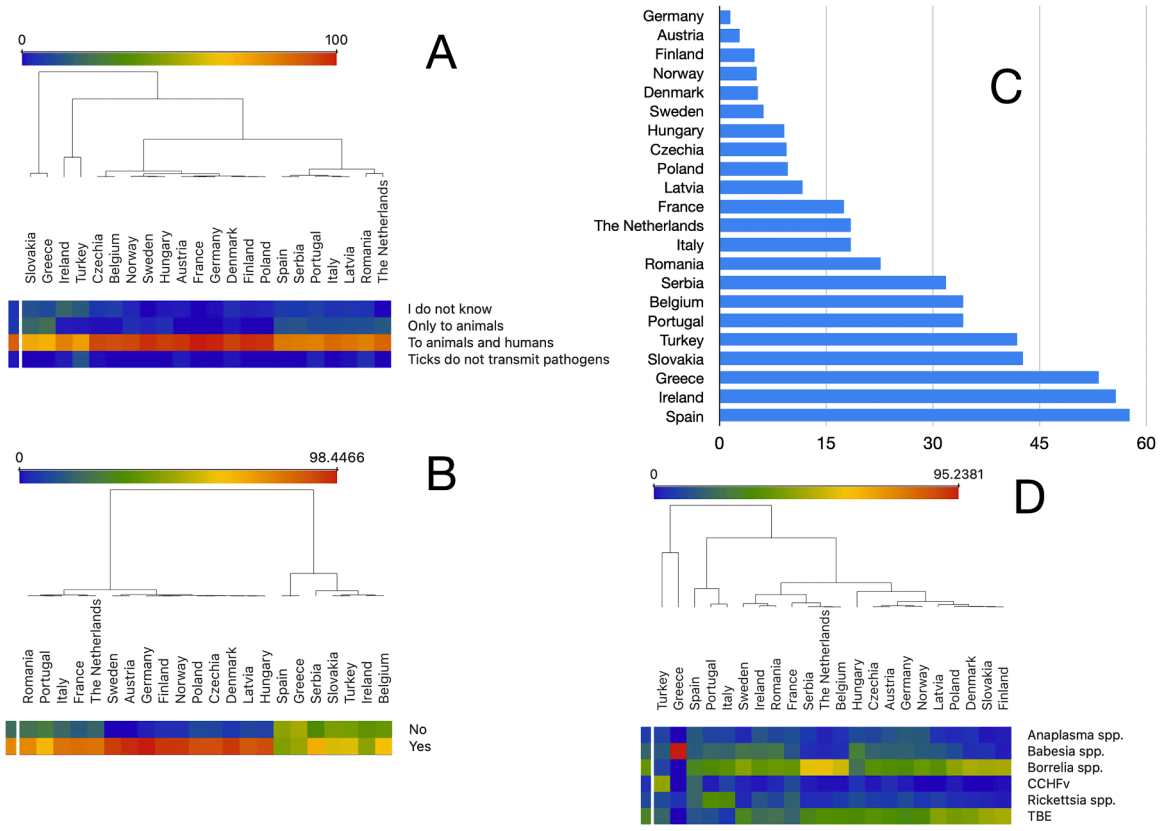

Fig. 10. Respondents' knowledge and perceptions of the importance of ticks as vectors of pathogens. (A) shows Likert scale responses to the question 'Do ticks transmit pathogens?' and (B) to the question 'Do you know which pathogen(s) are transmitted by ticks?'. (C) provides a breakdown of respondents who did not know which pathogens are transmitted by ticks by country; (D) shows Likert scale of responses regarding of the pathogens that are known to be transmitted by ticks in the respective country, according to survey participants. Countries are clustered using a k-means algorithm based on the percentage distribution of responses (shown at the top of the charts).

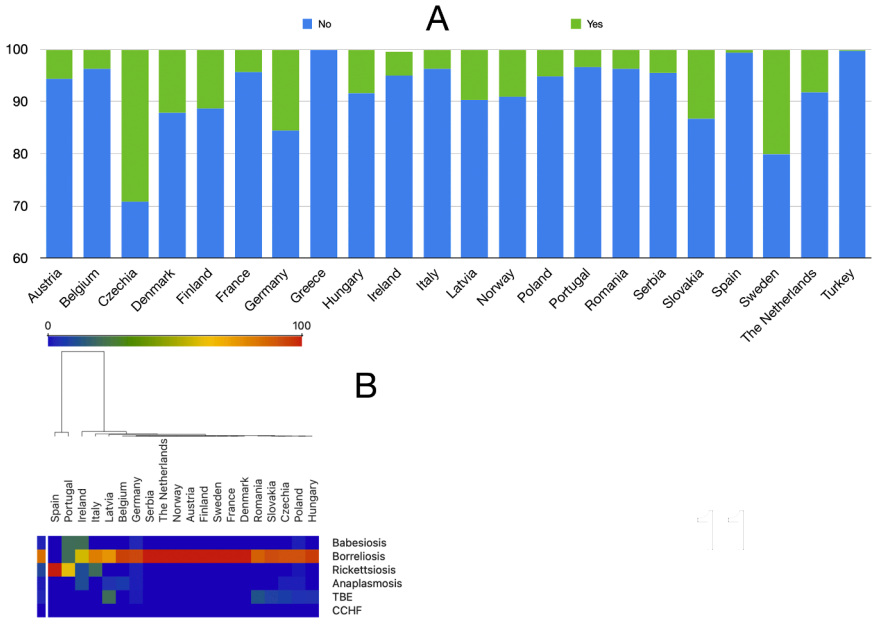

Fig. 11. (A) Percentage of respondents reporting a diagnosis of one or more tick-borne diseases by country and (B) Likert scale responses regarding the identified disease/pathogen. Countries are clustered using a k-means algorithm based on the percentage distribution of responses (shown at the top of the chart).

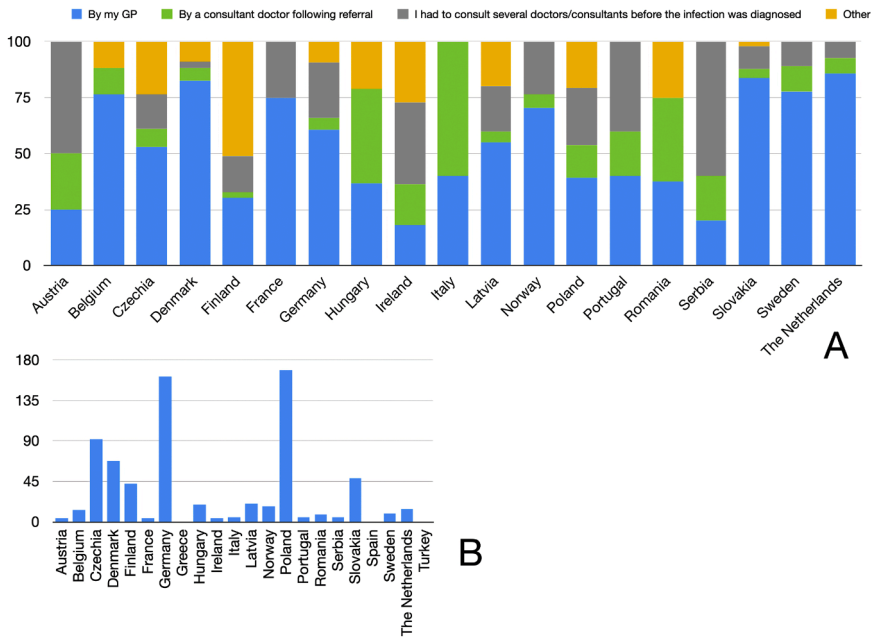

Fig. 12. (A) Percentage responses by country to the question 'How was your diagnosis of a tick-transmitted pathogen carried out?' (B) Number of self-reported cases of tick-transmitted pathogens by country.

reporting of ticks and TBPs was entirely dependent on citizen groups.

3.6. *The knowledge, attitudes and practices index*

The 'KAP index' (range 0–100), which summarizes the responses to 4 key questions in each country, namely (i) the ability to recognize ticks, (ii) the perception of the importance of ticks and TBPs, and the ability to identify effective methods for (iii) tick avoidance and (iv) tick removal, indicates a considerable range in public awareness across Europe with residents from northern, central and eastern Europe generally more concerned about ticks and TBPs than residents from Mediterranean countries (Fig. 17). However, several countries bucked this trend with comparatively lower values calculated for Slovakia, Belgium, and Ireland, and a higher index calculated for Italy (compared to other Mediterranean countries).

4. Discussion

While questionnaire-based studies regarding ticks and tick-borne diseases been carried out in several countries across Europe (e.g. Aenishaenslin et al., 2014; Zoldi et al., 2017; Slunge and Boman, 2018; Jepsen et al., 2019; Vasić et al., 2022), this study represents the largest initiative of this kind in terms of the number of participating European countries and respondents, with 9401 completed questionnaires collected from 22 countries. The results reveal a high level of knowledge in general, with widespread awareness that ticks can serve as vectors of pathogens and that they can represent a serious health risk for humans and animals. There was also good knowledge of the habitats that are most likely to be tick-infested in the various regions of Europe and the time of year when they are active. Moreover, most respondents correctly identified well-established self-protection measures such as wearing closed shoes, long-sleeves and socks pulled over trousers, and avoiding walking through tall grasses and shrubs, all of which have been shown to be effective in preventing tick-borne disease (Beaujean et al., 2013; Eisen and Dolan, 2016). Regarding tick repellents (either natural or synthetic) there was a greater level of uncertainty. A survey carried out in The Netherlands on awareness to Lyme borreliosis recorded similar results with the percentage of respondents taking preventive measures against ticks ranging from 37 % (wearing protective clothing) to 6 % (repellent skin products). As a matter of fact, research into the efficacy of natural repellents is ongoing (e.g. Staub et al., 2002; Carroll et al., 2010) and there are no synthetic repellents that have been developed specifically to protect humans against ticks in Europe. Instead, compounds used against mosquitoes have been adopted for use against ticks, reportedly with reduced efficacy (Bissinger and Roe, 2010; Benelli and Pavela, 2018). This survey question also included 'anti-tick bracelets' and 'ultrasound devices' as possible protective measures representing popular local customs and/or gadgets promoted by social media. There were generally few respondents who agreed with their use but quite a number were unsure as to their efficacy.

In line with many published guidelines our results indicated that protective behaviours such as 'staying on paths and avoid walking through tall grasses and shrubs' reduced the frequency of tick bites. Simple, but highly effective measures such as these should be highlighted in future information campaigns, especially in countries where our survey indicated somewhat lower levels of awareness.

The ability to correctly identify the tick image was generally high among the respondents, except for 10 to 15 % of respondents from Ireland, Portugal, Spain, Greece and Turkey who misidentified the image. Interestingly the same countries were amongst the cohort of respondents that reported either no tick bites or tick bites being extremely rare contrasting with other European countries, where around 75 % of all respondents reported being bitten by ticks at least once or twice a year (the comparable figure from a Scandinavian survey was 68 %; Jepsen et al., 2019). It is impossible to determine whether there is a genuine lower risk of tick bite in some countries (either due to the specific habitats that are infested or the tick species that predominate, or both) or whether the reported lower tick bite frequency is due to an inability to correctly identify ticks by respondents in these countries. Another possible explanation is that respondents from some countries were somewhat less likely to recognize ticks because they encounter them less often. It also needs to be born in mind that it is possibly more difficult to recognize an unfed magnified tick photographed against a white background than a tick that is attached to the body and engorging.

As already mentioned, a large proportion of respondents reported having been bitten by ticks in the past, however, <10 % of respondents from most countries reported ever having been diagnosed with a TBP. The exceptions were Czechia (29 %), Sweden (20 %), Germany (15 %),

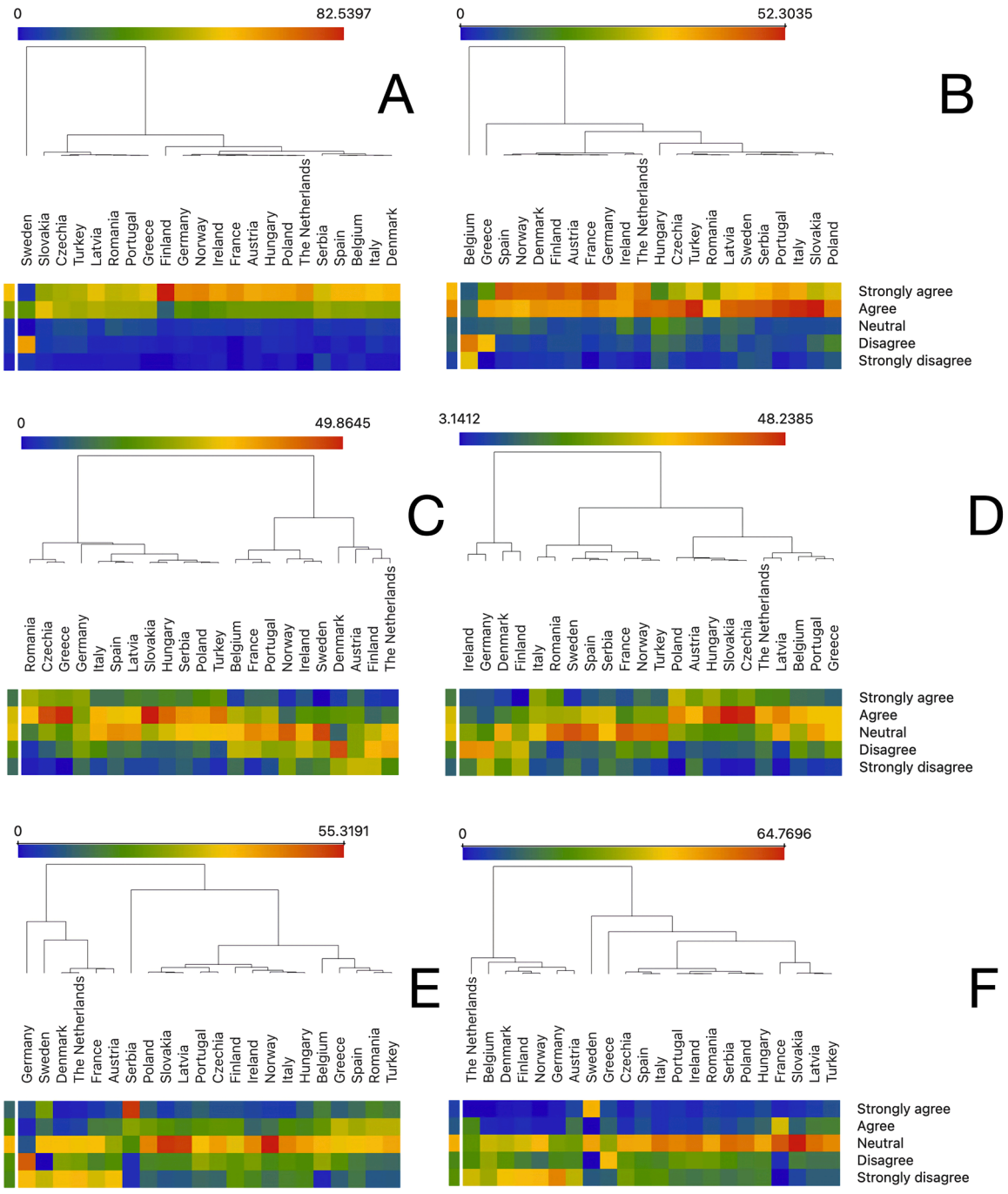

Fig. 13. Likert scale responses to the known/ perceived effectiveness of tick protection measures including (A) 'Wearing closed shoes, long sleeves, and socks over trousers'; (B) 'Staying on pathways and avoiding walking through tall grasses and shrubs'; (C) 'Applying natural tick repellents'; (D) 'Applying synthetic tick repellents'; (E) 'Wearing an anti-tick bracelet' and (F) 'Using an ultrasound device'. Countries are clustered using a k-means algorithm based on the percentage distribution of responses (shown at the top of the charts).

Slovakia (13 %), Denmark and Finland (both 12 %) with borreliosis being by far the most common diagnosis. Again, to what extent these differences are a genuine reflection of exposure to TBPs or due to awareness among clinicians in the various countries is difficult to say. Health professionals may also apply different standards to confirm infections by TBPs, which could lead to over- or underreporting, respectively.

It is well established that removing feeding ticks promptly and correctly is critical for reducing the risk of tick-borne diseases and scientific studies and health guidelines agree on the best practices for tick removal, namely grasping the tick as close to the skin as possible with pointed forceps, and pulling the tick upward while applying steady, even force without twisting. Improper removal techniques, on the other hand, such as squeezing the tick's body or using substances such as petroleum jelly or nail polish to smother or suffocate the tick, can increase the likelihood of disease transmission by causing the tick to regurgitate infectious material into the wound (Needham, 1985; Spieksma and Jouda, 1998; Pitches, 2006; Taylor et al., 2019). Most survey respondents answered the tick removal question correctly, however, a significant cohort said they would consult a physician to have ticks removed. Considering that this could lead to unnecessary delays, increasing the chance of pathogen transmission, this is an issue that should be

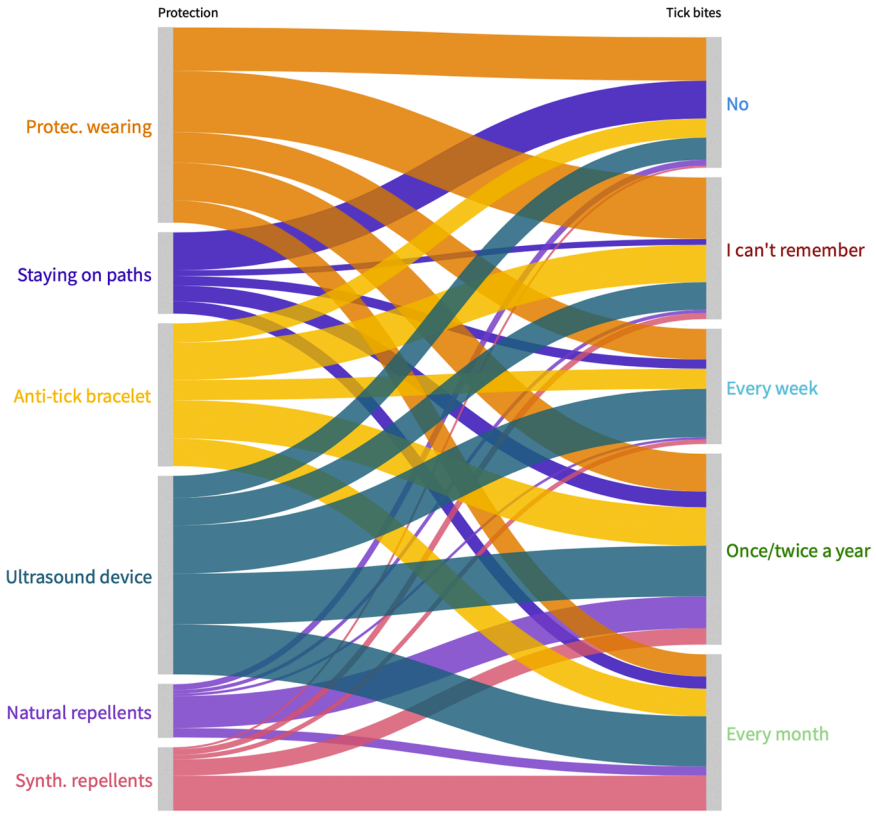

Fig. 14. Association of reported self-protection methods against ticks (left) with the reported frequency of tick bites (right). The width of the bands connecting responses on the left to those on the right is proportional to the percentage of responses.

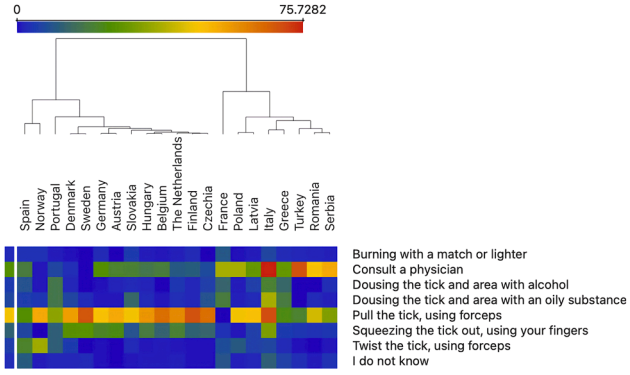

Fig. 15. Selection of tick removal methods by country. Countries are clustered using a k-means algorithm based on the percentage distribution of responses (shown at the top of the chart).

addressed by future health campaigns.

Up to 98 % of all respondents were aware that ticks can act as vectors. Yet over 30 % of respondents from Serbia, Belgium, Portugal, Turkey, Slovakia, Greece, Ireland, and Spain reported not knowing which pathogens were transmitted by ticks in their countries. Respondents who said they did know, highlighted *Borrelia* spp. and, to a lesser extent, TBEV and *Babesia* spp. This was particularly the case for respondents from central and northern Europe. *Rickettsia* spp. were only included by respondents from Mediterranean countries and CCHFV only by participants from Turkey and Spain. Aigai virus, formerly known as CCHFV genotype IV (Papa et al., 2022) was not referred to by any respondent, presumably due to its relatively recent discovery and/or low pathogenicity. It is likely that the high awareness of CCHFV in Turkey is due to prolonged campaigns by the Turkish health authorities

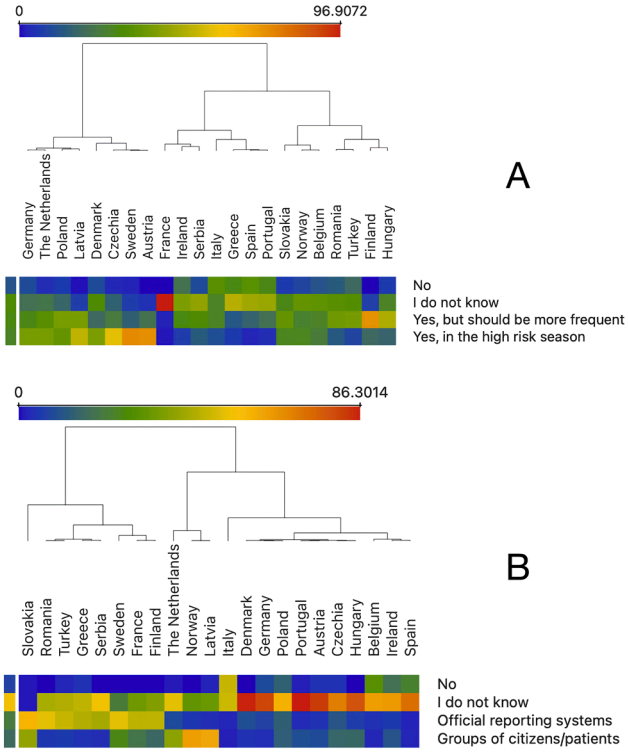

Fig. 16. Known or perceived (A) frequency of information campaigns on ticks and TBPs and (B) national organisations that focus on the prevention of tick-borne diseases. Countries are clustered using a k-means algorithm based on the percentage distribution of responses (shown at the top of the chart).

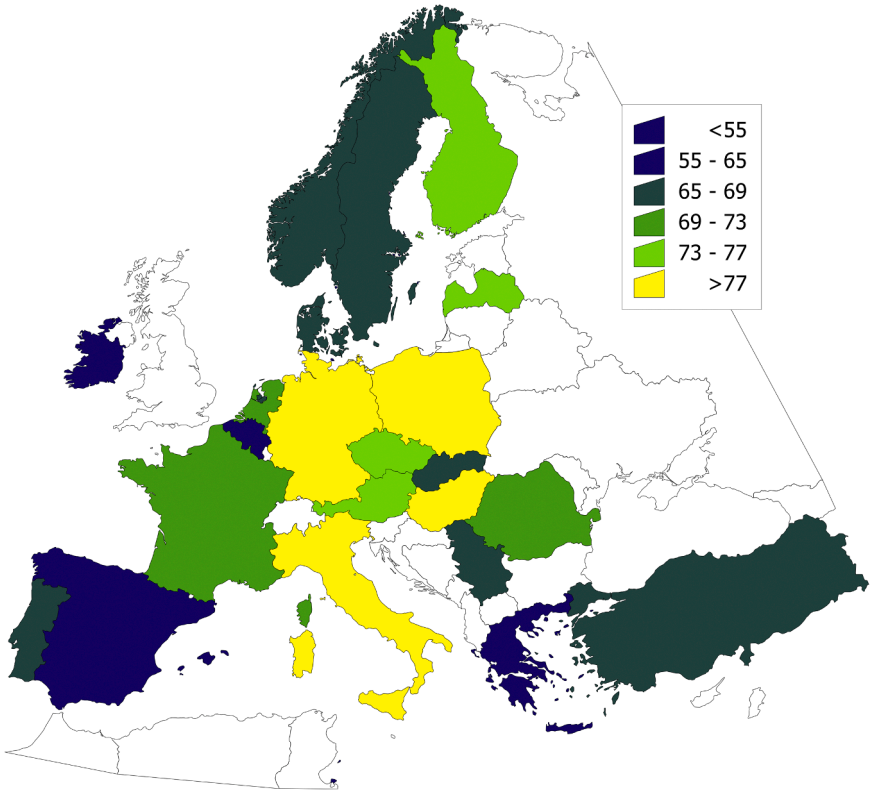

Fig. 17. 'KAP index' (0–100) summarising (i) the ability to recognize ticks, (ii) the perception of the importance of ticks and TBPs, and the ability to identify effective methods for (iii) tick avoidance and (iv) tick removal in participating countries.

on the risks of infection with CCHFV (Leblebicioglu et al., 2016). Moreover, CCHFV has acquired considerable notoriety in the Spanish media since its emergence in Spain in 2013, and the subsequent increase in cases (Estrada-Peña et al., 2012; Juanes et al., 2023; Negredo et al., 2019; Sánchez-Seco et al., 2022). Therefore, differences in reported TBPs in each country largely reflect the geographical distributions of the tick species that occur there and the TBPs they carry. Similarly, the habitats that were highlighted by respondents as to where ticks would be expected to quest, more than likely reflected the typical habitats occupied by the prevalent species. This indicates a considerable level of local knowledge, and it should be taken into account when preparing information campaigns focused on potential incursions of new, exotic tick species or TBPs.

A considerable proportion of participants reported that there were no public health campaigns focused on ticks in their countries or that they did not know of any and many were not aware of any national organisations (private or public) that gathered and/or disseminated information regarding ticks and TBPs. This is clearly another area where public education could be improved. However, overall, the KAP index indicated a high level of awareness although there was some heterogeneity among responses, with participants from Poland, Italy, Hungary, and Germany scoring highest and participants from Greece, Spain, Belgium, and Ireland lowest. It is possible that this discrepancy was at least partially due to the cohort that took the survey in the participating countries.

One of the limitations of this study was that, due to data protection concerns, it was not possible to collect demographic information on the survey participants. Parameters such as age, gender and socioeconomic background are reported to have a strong impact on risk perception and protective behaviour. For example, younger people tend to have a decreased risk perception from older people (Aenishhaenslin et al., 2014; Shadick et al., 1997) and men generally express less concern for risk than women (Gustafson 1998). Moreover, immigrant populations in LB endemic areas in the USA were reported to be less likely to take precautions against becoming infected than the local population, even though they are more likely to be employed as outdoor workers (Heller et al., 2010). Another limitation of our study was the sampling strategy which precluded weighting the number of received responses against the overall number of invitees. Two countries with very high KAP indices (Poland and Germany) were also the ones that provided the highest number of responses (nearly 50 % of the total) again giving rise to a potential bias. However, preliminary analyses indicated that a balanced number of responses was obtained. Importantly, our study revealed regional differences in perceptions and behaviors, highlighting the need for targeted educational programmes to improve preventive measures and public health outcomes.

4. Conclusion

The relationship between knowledge and awareness of ticks and TBPs on the one hand and concern and use of protective measures on the other is complex. While it has been shown that a higher level of risk perception of TBPs is often associated with increased adoption of preventative behaviours, there can also be a tendency to overestimate the risk associated with ticks. On the other hand, it has been reported that greater familiarity with ticks can also lead to a reduction in protective behaviour, an effect that has been coined 'learning to live with ticks'. Our survey indicated a high level of awareness about ticks and TBPs in Europe in general but suggested that information gaps exist in some regions; addressing these gaps would ensure that robust personal protective methods are employed where needed. Good evidence and reliable information on the effectiveness of such methods will help citizens across Europe make rational choices and develop realistic attitudes towards the risks associated with ticks and TBPs.

4.1. Permission and declarations

Although this study does not legally qualify as research involving human subjects and relies solely on the collection of anonymous data, national ethics committees still required approval. Therefore, we sought a general ethical clearance from the University of Zaragoza (Spain), the study's sponsor. The final questionnaire received approval from the University's Ethical Commission under protocol number RAT 2022–192. The ethics committees of the other participating institutions reviewed the questionnaire and the original ethical clearance, and issued additional ethical approvals for their respective institutions, if necessary, in accordance with the regulations of each country.

CRediT authorship contribution statement

Agustín Estrada-Peña: Writing – original draft, Formal analysis, Conceptualization, Methodology, Visualization, Data curation. **Sandra Antunes:** Conceptualization, Writing – review & editing. **Ana Domingos:** Conceptualization, Writing – review & editing. **Helen Esser:** Conceptualization, Writing – review & editing. **Gábor Földvári:** Conceptualization, Writing – review & editing. **Hans-Peter Fuehrer:** Conceptualization, Writing – review & editing. **Aysen Gargili:** Conceptualization, Writing – review & editing. **Mats Van Gestel:** Writing – review & editing, Conceptualization. **Giulio Grandi:** Writing – review & editing, Conceptualization. **Maria Kazimirova:** Writing – review & editing, Conceptualization. **Dorota Kiewra:** Conceptualization, Writing – review & editing. **Tero Klemola:** Conceptualization, Writing – review & editing. **Lene Jung Kjær:** Writing – review & editing, Conceptualization. **Vivian Kjelland:** Conceptualization, Writing – review & editing. **Katarzyna Kubiak:** Writing – review & editing, Conceptualization. **Daniele de Meneghi:** Writing – review & editing, Conceptualization. **Andrei Daniel Mihalca:** Conceptualization, Writing – review & editing. **Sarah Moutailler:** Conceptualization, Writing – review & editing. **Aleksandar Potkonjak:** Conceptualization, Writing – review & editing. **Pavel Prokop:** Writing – review & editing, Conceptualization. **Käthe Robert:** Writing – review & editing, Conceptualization. **Renate Ranka:** Conceptualization, Writing – review & editing. **Angel Sainz:** Writing – review & editing, Conceptualization. **Jani Sormunen:** Conceptualization, Writing – review & editing. **Smaragda Sotiraki:** Conceptualization, Writing – review & editing. **Christina Strube:** Conceptualization, Writing – review & editing. **Snorre Stuen:** Conceptualization, Writing – review & editing. **Pavel Široký:** Conceptualization, Writing – review & editing. **Laura Tomassone:** Writing – review & editing, Conceptualization. **Annetta Zintl:** Writing – original draft, Writing – review & editing, Conceptualization, Formal analysis.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Data availability

The authors do not have permission to share the raw data.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ttbdis.2025.102515.

Data availability

Data will be made available on request.

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