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Review Article

Seroprevalence of tick-borne diseases in Europe in occupational settings: A systematic review and metanalysis

Anna Morea [a,*,e], Valentina Schino [a,e], Nicola Bartolomeo [a], Riccardo Ravallese [a], Gabriele Sacino [a], Roberto Ravallese [a], Roberta Iatta [a], Domenico Otranto [b,c], Piero Lovreglio [a,f], Angela Stufano [d,f]

[a] Interdisciplinary Department of Medicine, University of Bari Aldo Moro, Piazza G. Cesare 11, 70124, Bari, Italy
[b] Department of Veterinary Medicine, University of Bari, 70010, Valenzano, Italy
[c] Department of Veterinary Clinical Sciences, City University of Hong Kong, Hong Kong Special Administrative Region of China
[d] Department of Surgical and Medical Science, University of Foggia, 71100, Foggia, Italy

A R T I C L E I N F O

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A B S T R A C T

Objectives: Tick-borne diseases (TBDs) pose a growing occupational risk due to the expanding geographical range of tick species and their associated pathogens. This study aims to assess TBD seroprevalence among different occupational groups in Europe, identifying high-risk professions and guiding targeted prevention efforts.
Study design: A systematic review and meta-analysis were conducted following PRISMA guidelines to evaluate TBD seroprevalence in occupational settings across Europe from January 2013 to June 2024.
Methods: A comprehensive search of PubMed, Web of Science, and Scopus identified 36 relevant studies. Heterogeneity among studies was assessed using Cochran's Q test and the inconsistency index (I^2), with sensitivity and outlier analyses applied to evaluate their impact. Publication bias was examined through funnel plot analysis, Egger's test, and Duval & Tweedie's trim-and-fill method.
Results: Seroprevalence varied significantly across occupations. The highest rates were found for *Coxiella burnetii* among livestock and dairy producers (up to 73.7 % in Italy) and *Borrelia burgdorferi* among forestry workers, particularly in Poland. A meta-analysis of 33 studies revealed seroprevalence rates of 8.2 % in military workers (no publication bias), 26.0 % in forestry workers, 8.0 % in veterinarians, and 18.0 % in farmers, with high overall heterogeneity.
Conclusions: TBD risk is influenced by occupational exposure, environmental factors, and regional differences. Given the substantial variation across worker categories, targeted preventive measures, increased awareness, and enhanced surveillance efforts are necessary to mitigate risks in high-exposure professions.

1. Introduction

The risk of contracting infectious zoonoses in occupational settings has likely been and continues to be largely underestimated.[1] Most etiological agents causing zoonotic diseases could be considered occupational hazards, as they may occur in various work contexts.[2] Tick-borne diseases (TBDs) are recognized as a growing public health problem of medical and veterinary concern in Europe.[3] This is driven by the expansion of the geographical range of certain tick species due to ongoing climate and land-use changes, habitat fragmentation and environmental alterations.[4] The increase in number of identified cases of tick-borne bacterial pathogens can be attributed to advances in diagnostic techniques and increased awareness of infection risks. Additionally, the migration of ticks to broader geographical areas significantly extends the range of vector diseases.[5]

Despite continuous efforts to manage emerging diseases, the growing threat from ticks spreading to new areas, along with the pathogens they transmit, is especially noticeable in Europe. For example, climate change is likely a major factor in the significant rise of TBDs in Europe, leading to an expanded tick distribution in recent years.[6]

* Corresponding author.
E-mail address: anna.morea@uniba.it (A. Morea).
[e] Co-first authors.
[f] Co-senior authorship.

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The circulation of vector-borne diseases (VBDs) requires the presence of an introduced or established vector population, a pathogen, and suitable environmental and climatic conditions for the complete transmission cycle in humans. These conditions impact the survival and abundance of vectors, that of pathogens in host and vector organisms as well as affect vector activity, biting rates, and human exposure to VBDs.[7]

Workers at high risk of contracting TBDs could include those in contact with animals across a range of occupational settings, from veterinary clinics to farms. Moreover, workers performing their duties outdoors may also be at higher risk of being bitten by ticks, even without specific contact with animals.[8] In addition, the rise of antimicrobial resistance in Europe and the inconsistent accuracy of diagnostic testing, further compound the threat posed by TBDs as patients may be left without adequate diagnosis and treatment options. This is especially problematic since many TBDs remain on the margins of clearly defined treatment protocols and surveillance efforts.[9] It results in that epidemiological qualitative and quantitative information for most TBDs is limited, as on their distribution in endemic countries. Reported cases often differ from those actually occurring or diagnosed in most European countries, partly because TBDs frequently go undiagnosed due to their non-specific clinical presentations. The lack of prevalence data makes it impossible to assess the occupational risk of exposure to various tick-borne pathogens (TBPs) in different work activities. This hinders the ability to train workers appropriately and implement specific preventive measures.[10]

While occupational risk related to TBDs is increasingly recognized in Europe, systematic reviews have also highlighted their global burden among specific working populations. Magnavita et al.[11] reported a pooled *Borrelia burgdorferi* seroprevalence of 20.5 % among outdoor workers in regions including North America and Asia, with significantly higher odds in forestry and agriculture. Likewise, Belobo et al.[12] found high global prevalence of *Crimean-Congo Hemorrhagic Fever Virus* (CCHFV), especially among livestock handlers and healthcare workers in Africa, the Middle East, and Central Asia. Ergönül et al.[13] further demonstrated CCHFV risk for healthcare workers across more than 30 countries, highlighting the role of direct contact and the benefits of post-exposure prophylaxis. Together, these findings underline the need for region-specific data and tailored preventive strategies.

However, despite this international evidence, no study has systematically synthesised occupational TBD prevalence across Europe. To address this, we conducted a systematic review and meta-analysis to assess and summarise the available evidence on the seroprevalence of TBD in Europe, focusing on the last decade to capture how these environmental shifts are influencing TBD prevalence among outdoor workers in Europe stratified by occupational group.

2. Methods

2.1. Study design

The current investigation adhered to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses.) guidelines[14] and was registered in the PROSPERO (Prospective Register of Systematic Reviews) database under the ID number CRD42023485675. To initiate the study, research concepts were delineated using the "PICOS" (Patient/Population/Problem; Intervention; Control/Comparator; Outcome; Study Type) strategy.[15] In line with this framework, this review focused on healthy workers in Europe as the target population, particularly those occupationally exposed to tick-borne pathogens. The exposure of interest was defined as the presence of antibodies against tick-borne pathogens (TBDs), while the comparison group consisted of workers without occupational tick exposure or individuals from the general population. The primary outcomes included the prevalence, incidence, and/or seroconversion rates of TBDs among occupationally exposed workers, providing insights into the burden of these infections in professional settings. To achieve these objectives, we included observational study designs, specifically cross-sectional surveys, cohort studies, and case series, conducted between 2013 and 2024. This approach ensures that the evidence synthesis reflects contemporary patterns of occupational exposure, taking into account recent ecological and climatic changes affecting tick distribution across Europe.

2.2. Study eligibility: inclusion and exclusion criteria

A systematic review of electronic databases (PubMed, Web of Science, and Scopus) was conducted for publications from January 2013 to June 2024 using the keywords: ("Tick-borne diseases" OR "Ticks diseases" OR "TBDs") AND ("occupational" OR "workers") AND ("Europe" OR "European"). Searches were adapted to each database, and a "snowball" approach was applied by reviewing references for additional studies. Two reviewers (AM and VS) independently screened and analyzed articles based on PRISMA guidelines and systematic review standards.[16] Extracted data included study settings, sample sizes, demographics, reference populations, and laboratory techniques used for pathogen detection.

2.2.1. Inclusion criteria

Following PRISMA guidelines, studies were included if they examined TBD epidemiology within the WHO European Region (https://www.who.int/countries). Eligible studies focused on the seroprevalence of TBDs in occupationally exposed individuals and included observational research such as cohort studies, case series, case-control studies, and cross-sectional studies. The primary outcome was TBD seroprevalence in the 53 WHO European Region countries. We restricted the inclusion period to studies published from 2013 onwards to ensure that the results reflect current patterns of occupational exposure, accounting for recent climatic, ecological, and land use changes affecting tick distribution in Europe.

2.2.2. Exclusion criteria

Excluded studies were non-human research, editorials, commentaries, expert reports, case reports, or lacked epidemiological observations. Studies were also excluded if they had no full-text access, were not in Italian, English, or French, lacked laboratory technique details, did not specify occupational groups, reported data outside Europe, or involved hospitalized workers with unrelated diseases.

2.3. Definition of outcomes

The main outcome was the detection of an infection or TBD acquired by subjects whose work task was specifically defined. TBDs were considered concerning the list provided by the Centre of Disease and Control.[17] The International Standard of Classification of Occupation (ISCO) of the ILO V.08 was used to classify job titles in four levels of aggregation to provide internationally comparable occupational data.

2.4. Quality assessment-risk of bias

The risk of bias (ROB) assessment ensured transparency in evidence synthesis and was conducted using the National Toxicology Program (NTP) Office of Health Assessment and Translation (OHAT) handbook[18] and its ROB tool.[19] Two reviewers independently assigned ratings, resolving disagreements through consensus or third-party input (GS) if needed.[20]

2.5. Statistical analysis

The meta-analysis included studies meeting key criteria: providing seroprevalence data on TBDs among occupationally exposed individuals in Europe over the past decade, ensuring high methodological quality, and maintaining comparable outcome measures. Only studies with sufficient population and intervention homogeneity were included for meaningful synthesis. The pooled effect size was calculated as a proportion with a 95 % confidence interval (CI) using a random-effects model for heterogeneous studies or a fixed-effects model otherwise.

Heterogeneity was assessed via Cochran's Q test and the inconsistency index (I^2), which remains stable regardless of study count. Outliers were identified if their CI did not overlap with the pooled effect CI, and a sensitivity analysis examined the impact of their exclusion.[21] Funnel plot analysis and Egger's linear regression test evaluated publication bias; if significant, Duval & Tweedie's trim-and-fill method estimated the adjusted effect size.[22] Statistical significance was set at $p < 0.05$. Analyses were performed using MedCalc® version 22.009[23] and R version 4.1.2[24] with the "metafor" package.[25]

3. Results

The literature search results are shown in Fig. 1. 443 entries were identified, with 117 (26.4 %) removed as duplicates. After screening titles and abstracts, 276 (84.7 %) were excluded, leaving 50 full-text articles (11.3 %) for review. An additional 8 studies were identified through a "snowball" approach. Of these, 22 (5.0 %) did not meet inclusion criteria, resulting in 36 studies included in the review. Studies were categorized into six occupational groups following the ISCO classification.[26] Various serological techniques were used, including ELISA, IFA, IIF, CLIA, HA, MA, CFT, WB, and immunoblot. Only seven studies included a control group.[27–33] Geographically, most studies were conducted in Poland (n = 8), followed by Turkey (n = 4), Greece (n = 4),

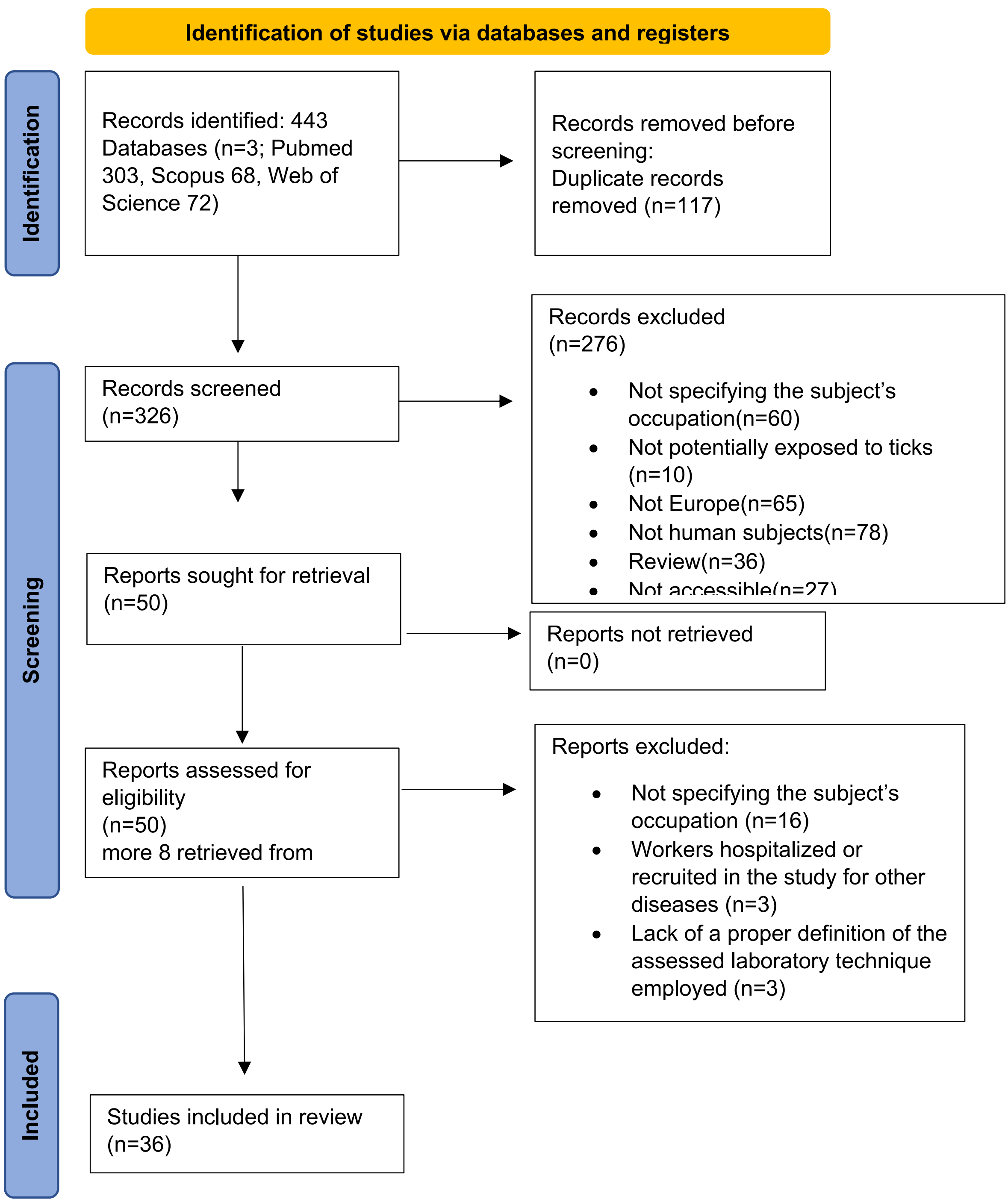

Fig. 1. PRISMA 2020 flow diagram.

and Italy (n = 4). A detailed risk of bias (ROB) assessment is provided in Table S2. All included studies were observational cross-sectional surveys assessing seroprevalence in different occupational groups. The majority of studies used enzyme-linked immunosorbent assay (ELISA) as the primary diagnostic method, often combined with confirmatory tests such as immunofluorescence assays (IFA) or Western Blot to increase diagnostic accuracy.

3.1. Military workers

Four studies (Table S3a) examined military personnel. *Borrelia burgdorferi* seroprevalence ranged from 9.8 % to 17.1 %,[30–34] with the highest rate in Serbia (17.1 %).[30] *Coxiella burnetii* prevalence varied from 0.4 % to 4.8 %,[35,36] while *Francisella tularensis* ranged from 0 % to 6.3 %.[35,36] One study reported Congo-Crimean Hemorrhagic Fever virus (CCHFV) seroprevalence at 0.5 %.[35] Risk factors included tick exposure, high *Ixodes ricinus* larval presence, and rodent activity. In Jovanovic et al. professional tick removal by medical personnel, such as doctors or nurses, was identified as a protective factor against TBP infections, likely because proper removal techniques reduce the risk of incomplete extraction or squeezing of the tick, which can increase pathogen transmission.[35]

3.2. Livestock and dairy producers

Ten studies (Table S3b) focused on livestock handlers and slaughterhouse workers.This occupational category also includes slaughterhouse workers and other personnel involved in handling livestock, carcasses, or animal by-products in processing or factory settings, who may be exposed to ticks through direct contact with infested animals or contaminated work environments. Seven reported CCHFV exposure, with seroprevalence ranging from 0.0 % to 20.0 %.[29,37–42] *C. burnetii* prevalence varied from 6.0 % to 73.7 %,[28,43] with the highest in Italy (73.7 %). One study found no *F. tularensis* cases.[43] Risk factors included exposure to infected animals, contaminated hay, soil, and straw. CCHFV seropositivity was linked to tick bites, rural residence, high altitudes (1152–1985 m a.s.l.), and proximity to rivers.[28,29,43]

3.3. Geologists

One study (Table S3c) assessed *Borrelia* spp., *C. burnetii*, and *Rickettsia conorii* seroprevalence in geologists.[27] *C. burnetii* was most prevalent (26.7 %), with 36.7 % reporting tick bites and 40.0 % finding ticks on clothing during work.[27]

3.4. Forestry workers

Fifteen studies (Table S3d) analyzed forestry workers, with six conducted in Poland.[33,45–49] *B. burgdorferi* was the most studied pathogen (9 studies, 62.5 %),[27,30,31,45,49,50,51,52,53] followed by *Rickettsia* spp. (5 studies, 33.3 %)[27,33,46,50,54,24,30,43,47,51] and *C. burnetii* (4 studies, 26.7 %).[27,31,47,48,24,28,44,45] TBEV was analyzed in 3 studies,[31,53,55,28,50,52] *F. tularensis* in 3,[31,48,53,28,45,50] and *Anaplasma phagocytophilum* and *Babesia microti* in 2.[48,53,45,50] The highest *Rickettsia* spp. seroprevalence was in Poland, reaching 50 %.[45] Risk factors included working in wetlands, mixed forests, and low-light environments. Personal risks included frequent tick bites, lack of protective clothing, and handling rodents or firewood.

3.5. Veterinarians

Seven studies (Table S3e) focused on veterinarians. *C. burnetii* was the most studied pathogen[27,28,43,56,57] followed by *Borrelia* spp.,[27,58] *R. conorii*,[27] and *F. tularensis*.[44] The highest *C. burnetii* seroprevalence (73.7 %) was recorded in Italy.[43] Risk factors included working with ruminants, more than 10 h of animal contact per week, and exposure to raw milk, hay, and parturition products. Needle injuries and cuts increased seropositivity risk.

3.6. Farmers

Thirteen studies (Table S3f) analyzed farmers. The most frequently detected pathogens were CCHFV,[32,37,39,41,42] followed by Borrelia spp.[27,58,59,60] and *C. burnetii*.[27] The highest *C. burnetii* seroprevalence (67.7 %) was found in Italy.[27,59,61,62] Risk factors included frequent tick bites, older age, rural residence, and adobe housing. Occupational risks included working near wetlands, non-irrigated fields, and livestock exposure. Protective factors included medical personnel performing tick removal.[33]

3.7. Risk of bias assessment

The risk of bias assessment indicated that the overall methodological quality of the included studies was moderate. Most studies showed a probably low or definitely low risk of bias in key domains, particularly in outcome and exposure assessment (D3 and D4). However, several studies displayed probable or definite high risk of bias in domains related to selection bias (D1) and control of confounding factors (D2), mainly due to incomplete reporting or lack of adjustment for potential confounders. Reporting bias (D5) and other potential sources of bias (D6) were generally rated as probably low in the majority of studies.

3.8. Meta-analysis results

The meta-analysis included all occupational categories identified in the systematic review, except for geologists (one available study) and livestock/dairy producers due to task diversity. High heterogeneity was observed in all worker categories (Cochran's Q test significance, $I^2 > 75$ %), except for military workers.[63] No significant publication bias was detected (Table 1, Fig. S1).

For military workers, no outliers or publication bias were found, with a TBD seroprevalence of 8.2 % [95 % CI 5.6–11.3]. In forestry workers,

Table 1
Summary of Heterogeneity, Pubblication Bias and pooled effect estimate from random model, by category of workers.

Workers	Number of studies included	Test for heterogeneity (p-value)[a]	I^2 - inconsistency (%) and 95 %CI[b]	Pubblication Bias from Egger's test (p-value)[c]	Pooled effect from random model	
					Sample size	Proportion (%) and 95 %CI
Forestry	15	<0.0001	98.3 [97.9–98.6]	0.5080	7036	26.6 [18.3–35.8]
Military	4	0.020	69.6 [15.5–89.5]	0.6882	1579	8.2 [5.6–11.3]
Veterinars[d]	5	<0.0001	86.2 [69.8–93.7]	0.3628	714	8.6 [3.4–15.8]
Farmers[d]	12	<0.0001	93.7 [90.8–95.7]	0.1113	5050	18.0 [12.4–24.7]

[a] Low P-values indicating presence of heterogeneity
[b] larger values show increasing heterogeneity (Higgins et al., 2003).
[c] low P-values indicating presence of Pubblication Bias
[d] After elimination of studies outliers and/or with publication bias

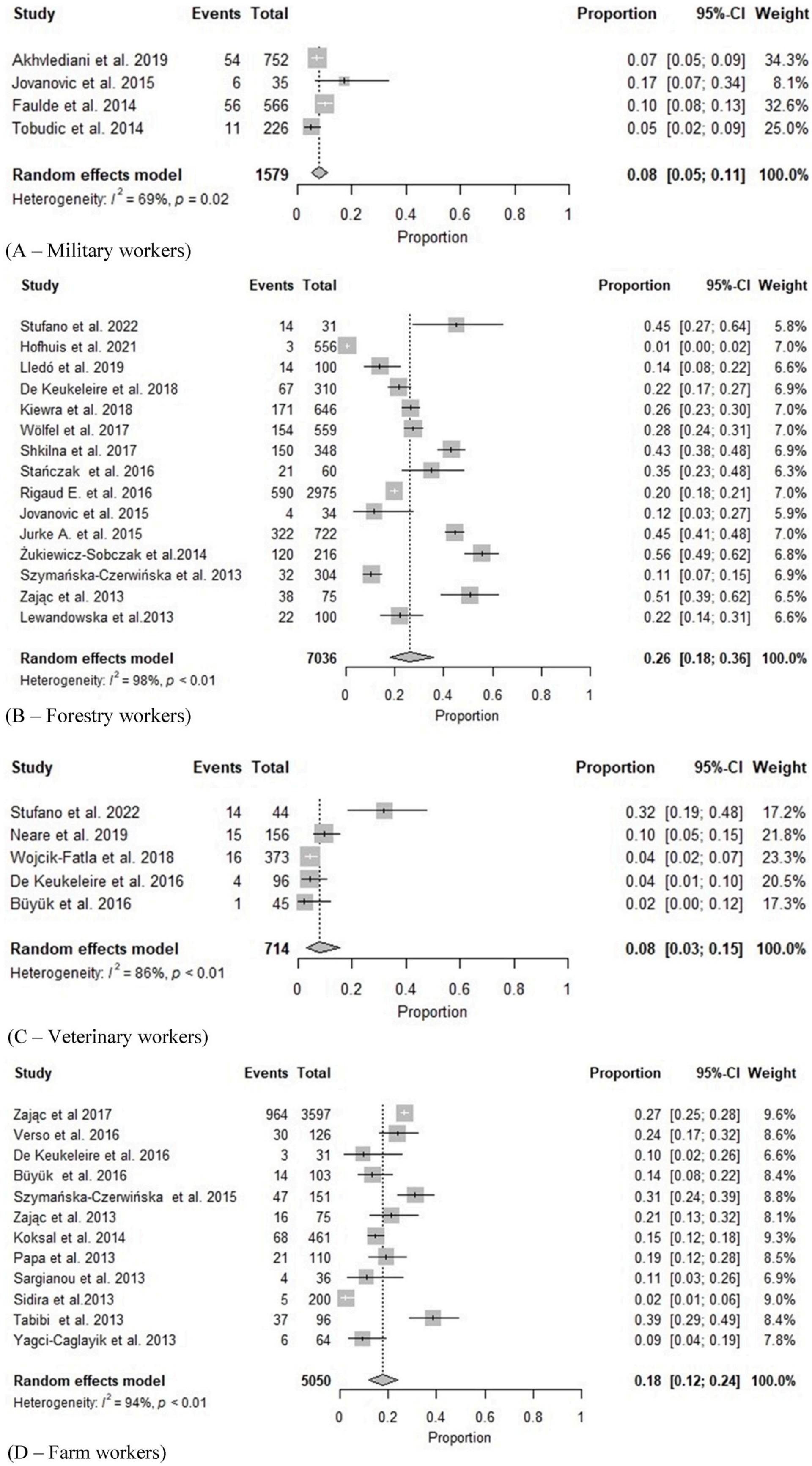

Fig. 2. Pooled effect estimates from random model in (A) Military workers, (B) Forestry workers, (C) Veterinary workers, (D) Farm workers.

nine potential outliers were identified, but their symmetrical distribution made exclusion unnecessary, yielding a seroprevalence of 26.0 %. Among veterinarians, removing two outliers[43,57] reduced seroprevalence from 23.0 % [95 % CI 5–49] to 8.0 % [95 % CI 3–15]. For farmers, excluding an outlier lowered seroprevalence from 21.0 % [95 % CI 15–29] to 18.0 % [95 % CI 12–24]. The pooled effect for all categories was calculated using a random-effects model (Fig. 2A–D).

4. Discussion

This study aimed to assess the seroprevalence of TBDs across various occupational groups in Europe between 2013 and June 2024, through a systematic literature review of 36 studies and a meta-analysis of 33. The findings reveal substantial variations in seroprevalence across different regions and occupations. However, data limitations hinder precise risk assessment and the formulation of targeted public health interventions. The review confirms an overall increase in TBD seroprevalence compared to earlier European studies,[64,65] likely attributable to both biotic and abiotic factors influencing the distribution of TBPs and their vectors. While previously restricted to specific regions, TBDs are now widespread across Europe.[66] Nevertheless, no consistent upward trend in seroprevalence from 2013 to 2024 was observed, possibly due to variability in study recruitment strategies, geographic focus, methodologic quality.

Climate change significantly influences the transmission dynamics of TBDs. A recent study reported an increase in the number of months with optimal conditions for *Ixodes ricinus* nymph feeding between 2013 and 2022 compared to 1951–1960.[67] Climate-related factors such as the greenhouse effect, heatwaves, extreme weather events, altered rainfall patterns, and biodiversity loss are primary drivers of TBD expansion.[65] Rising temperatures enhance tick survival by modifying vegetation, humidity, and drought levels, thereby facilitating TBP transmission.[68,69]

Among the analyzed studies, 33 % included control groups, consistently demonstrating higher seroprevalence among workers than the general population. However, the absence of adequate control groups remains a significant limitation in defining occupational TBD risk. Many studies failed to account for key parameters such as outdoor work duration or non-occupational exposure risks, often due to insufficient data on lifestyle factors.[70] Additionally, the lack of large-scale European population studies complicates direct comparisons between occupationally exposed and non-exposed groups. Nevertheless, available data indicate lower seroprevalence among blood donors and non-exposed individuals. For instance, Coxiella burnetii seroprevalence among workers ranged from 3.2 % to 73.7 %, while European blood donors exhibited rates between 1.4 % and 12.7 %.[71,72,73] Similarly, *Borrelia burgdorferi* seropositivity in workers varied from 4.2 % to 44.0 %, compared to 5.1 %–20.0 % in healthy blood donors.[74,75,76] Elevated seroprevalence was also observed for *Rickettsia* spp. (4.5 %–54.0 %) and *Anaplasma phagocytophilum* (1.7 %–29.6 %) among workers, while blood donor rates were up to 6.0 % and 16.2 %, respectively.[76,77]

Although the included studies span a wide range of European countries and occupational contexts, they were generally consistent in design and reporting, with most using cross-sectional approaches and similar serological methods, mainly ELISA, often confirmed by IFA or Western Blot. However, the risk of bias assessment revealed some variability in the methodological quality of the included studies, which should be considered when interpreting the findings of this review. While most studies demonstrated a probably low risk of bias in outcome and exposure assessment, several presented limitations related to selection processes and the control of potential confounding factors. This is partly due to incomplete reporting or lack of detailed methodological information in some articles. Such heterogeneity in study design and quality may have introduced some degree of uncertainty into the pooled estimates. Therefore, future primary studies should aim for more robust study designs, clearer reporting of sampling strategies, and systematic adjustment for confounders to strengthen the evidence base on occupational exposure to TBDs.

Significant geographic variability in TBD seroprevalence was identified across 15 European countries, underscoring the necessity of region-specific public health strategies. Notably, *B. burgdorferi* seroprevalence was particularly high among Polish forestry workers, whereas *C. burnetii* infection rates were elevated among livestock workers in southern and eastern Europe (e.g., Greece, Italy, Poland). Finally, multiple TBPs infections were more frequently reported in eastern European studies. These regional disparities may be attributed to heightened tick exposure in areas with high tick densities, influenced by environmental and ecological factors such as habitat suitability, climate, wildlife hosts, and human activities, rather than to methodological differences.[78,79,80] Poland and Italy, characterized by extensive forested and agricultural landscapes, provide ideal conditions for tick survival.[4,81,82] Additionally, rodents and ungulates, abundant in both countries, serve as primary tick hosts, sustaining pathogen transmission cycles.[83,84,85] Specifically, rodent species such as *Apodemus flavicollis* and *Myodes glareolus*, prevalent in Polish and Italian woodlands, significantly contribute to the enzootic transmission of TBDs.[79,86] Research indicates a strong correlation between rodent abundance, habitat richness, and human TBD prevalence.[87] Areas with low species diversity, where non-competent tick hosts are scarce, tend to exhibit higher concentrations of TBPs due to an increased reliance on competent reservoirs.[87] Moreover, habitat destruction and fragmentation intensify disease risks by reducing vertebrate diversity, thereby increasing exposure to infected ticks.[87,88] Climate change is also expected to facilitate the northward expansion of tick populations, allowing TBDs to emerge in previously unaffected regions of Poland and Italy.[89]

This review identifies forestry workers, farmers, veterinarians, and livestock handlers as occupational groups at heightened risk of TBDs. For forestry workers, removing outlier studies had minimal impact on seroprevalence rates, reducing them from 26 % to 24 %. This minimal change, coupled with the absence of significant publication bias, confirms that forestry workers face substantial TBD risk due to prolonged outdoor exposure and frequent contact with tick habitats. The most frequently detected pathogens among this group were *Rickettsia* spp. and *B. burgdorferi*, with seroprevalence strongly associated with environmental and personal risk factors such as working in wetlands, frequent tick bites, and inadequate protective measures. However, the presence of potential outliers suggests the need for further research to refine risk assessments.

Veterinary workers exhibited a significant reduction in pooled seroprevalence from 23 % to 8 % following the exclusion of two outlier studies, suggesting that some reports may have overestimated TBD risk. Nonetheless, veterinarians remain vulnerable due to frequent exposure to infected animals and tick-infested environments.

Farmers also demonstrated high seroprevalence, though the removal of one outlier study reduced prevalence from 21 % to 18 %. This indicates that while the risk remains elevated, task-specific exposure and study heterogeneity may influence reported rates.

Occupations involving close contact with animals, such as veterinarians, farmers, and livestock handlers, demonstrated a particularly high seroprevalence of *C. burnetii*, consistent with prior research. Studies suggest that seroprevalence among professionals working with animals or in meat processing can reach 50 %, far exceeding regional non-occupational exposure estimates and national averages.[90] Ecological factors, such as the presence and management of livestock like cattle, can also influence TBP risk through mechanisms that may either increase or reduce human exposure.[91] Reports from the European Food Safety Authority (EFSA) and the European Centre for Disease Prevention and Control (ECDC) recorded C. burnetii seroprevalence rates of 20.9 % in sheep, 17.9 % in goats, and 15.1 % in cattle.[92] Unlike other TBDs, C. burnetii primarily spreads via aerosol transmission, particularly in settings with domestic livestock.[93] Asymptomatic animals shed the bacteria in birth-related tissues, feces, and vaginal mucus, posing a significant risk to workers in direct contact. The pathogen's low infectious dose

(1–10 bacteria) and its ability to persist in the environment for extended periods further facilitate airborne transmission.[94,95] However, the link between animal seroprevalence and human exposure remains unclear, as high worker seroprevalence has been reported even in the absence of seropositive animals.[96] Factors such as prolonged exposure, mechanized milking, and individual susceptibility likely contribute to infection risk.[97,98,99]

Military personnel exhibited significantly lower TBD infection rates (8.2 %) than other occupational groups, with no evidence of publication bias or outliers. This suggests that strict preventive measures effectively mitigate TBD risk among military workers. The implementation of regimented protocols, including protective clothing, insect repellents, and controlled exposure to tick-prone environments, contributes to their lower infection rates compared to high-risk occupations such as farming and forestry.[100,101]

According to the results in military workers studies, the adoption of personal tick prevention measures seems to play a critical role in mitigating tick attachment and disease transmission, yet these practices remain inconsistently applied in the most of the worker categories.[102] Additionally, factors not reported in the present studies, such as pet ownership has been shown to increase the risk of human encounters with ticks in peri-domestic environments, which may contribute to overall exposure risk.[103] Future interventions should address these contextual factors to reduce occupational and peridomestic TBDs risk.

It is also noteworthy that the majority of included studies (35 out of 49) used ELISA as the primary method to determine seroprevalence. While ELISA is widely available, cost-effective, and suitable for large sample sizes, its variable sensitivity and specificity compared to methods like IFA or Western Blot should be considered when interpreting results. The frequent reliance on ELISA highlights the need for confirmatory testing and harmonised diagnostic protocols to improve comparability and accuracy across studies.

4.1. Strengths and limitations

This review highlights several limitations, including the lack of adequate control groups in most of the studies, diagnostic variability in sensitivity and specificity, and the concentration of studies in a limited number of European countries. Also, only a few included studies explicitly reported whether workers were adopting personal tick prevention measures, such as the use of repellents, protective clothing, or regular tick checks. This lack of consistent information limits the ability to fully assess how preventive behaviours may influence seroprevalence rates in different occupational groups.[103] It is worth noting that all the included evidence was based on cross-sectional study designs, which provide valuable prevalence estimates, but limit the ability to infer causality. Despite these constraints, it provides the first comprehensive analysis of TBD seroprevalence across occupational sectors in Europe, revealing significant geographic and occupational disparities. Particularly, a major strength of this review is its broad focus on multiple TBPs, and by synthesizing evidence across sectors such as forestry, agriculture, veterinary work, and the military, this review provides a more comprehensive picture of the current occupational health burden related to TBDs in Europe.

4.2. Conclusions

The elevated seroprevalence among workers underscores the need for targeted public health interventions and standardized risk assessments to identify high-risk populations. The heterogeneity of available data necessitates a systematic, standardized approach to TBD surveillance.

To reduce occupational risk of TBPs, a combination of personal protection (e.g., protective clothing, repellents, tick checks), worker training, site management (vegetation control, buffer zones), and timely medical access is recommended. Integrated measures like these help lower exposure and improve early detection and treatment, ultimately reducing the burden of occupational TBDs. Establishing an active surveillance system for occupational cases across Europe is essential for improving risk assessment and guiding effective prevention strategies, ultimately reducing the public health burden of TBDs. Future research should prioritise harmonised diagnostic approaches, longitudinal studies, and integrated surveillance that combines seroprevalence data with ecological and occupational information, to better inform prevention strategies for both the general population and high-risk worker groups.

Author statements

Ethical approval

Ethical approval was not required for this study, as it is a systematic review and meta-analysis based solely on previously published data and does not involve the collection or analysis of new data from human participants.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

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