REVIEW ARTICLE

Annals of Agricultural and Environmental Medicine
www.aaem.pl

Impact of tick-borne pathogens on the health risk of soldiers

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A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article

Borecka A, Szczypek M, Pabin A, Kowalczuk K, Maculewicz E. Impact of tick-borne pathogens on the health risk of soldiers. Ann Agric Environ Med. doi: 10.26444/aaem/159702

Abstract

Introduction. Vector diseases are common in Europe, including Poland. Every year, 77,000 Europeans are infected with transmissive diseases as a result of contact with infected vectors. In Poland, ticks are vectors of great epidemiological importance. The most important etiological factors causing disease in humans and transmitted by ticks include bacteria of the genus Borrelia and the species Francisella tularensis, Anaplasma phagophytophilum and Coxiella burnetii; as well as tick-borne encephalitis viruses. The level of the number of diagnosed cases of vector diseases in humans is influenced by environmental conditions, the most important of which is the COVID-19 pandemic that has been spreading for two years.
Objective. The aim of the review was to assess knowledge about tick-borne diseases in humans, as well as etiological factors, epidemiology of these diseases in Poland and other European countries. Infection with pathogens can occur both during recreation in nature and during work related to a profession. Professional groups include those particularly exposed to contact with vectors and pathogens – foresters, farmers and soldiers.
Review methods. A comprehensive assessment was conducted of extant publications.
Brief description of the state of knowledge. The results of the literature research revealed that in recent years an increase in the number of people suffering from tick-borne diseases has been recorded, possibly influenced by the changing climate. The vector diseases of the greatest importance for the inhabitants of Poland include Lyme disease and tick-borne encephalitis.
Summary. Soldiers, as a professional group who perform their duties in an environment where there is a high risk of exposure to infected ticks, are particularly at risk of acquiring transmission of vector diseases.

Key words
Lyme disease, soldiers, Ixodes ricinus, Dermacentor reticulatus, TBE

INTRODUCTION AND OBJECTIVE

Vector Borne Diseases (VBD) are diseases of bacterial, viral and parasitic aetiology. Vectors of greatest epidemiological importance include: ticks, mosquitoes, flies, bed bugs, fleas, midges and lice [1]. The process of transmission of pathogens by vectors and the size of their populations, and thus the increase in vector-borne diseases, are influenced by climate change and extreme weather events such as floods and storms [2]. Intensive agriculture and industry, overgrazing of livestock, drainage/desiccation of wetlands and deforestation lead to transformation of the landscape. Changes in vegetation cover and water management can affect local rainfall and temperature conditions, resulting in changes to the ecosystem. They also affect plant and animal populations, and consequently the distribution of vectors and vector-borne diseases [3]. According to Müller et al. [4], an indirect effect of climate change may also be a prolonged period of transmission of pathogens by vectors.

Some human activities can also directly affect pathogen transmission at the local level. The intensity of contacts between pathogens, vectors and humans depends on human use of the environment. The density of population in certain areas and lifestyle can strongly influence this [5].

The major vector-borne diseases together account for around 17% of the estimated global burden of communicable diseases and claim more than 700,000 lives every year [6].

The epidemiological dynamics of vector-borne diseases are influenced by complex interactions between vectors, pathogens and hosts, as well as by climate change [7]. According to epidemiological reports of the National Institute of Public Health (Narodowy Instytut Zdrowia Publicznego – PZH), the most frequent vector-borne diseases in Poland are borreliosis and tick-borne encephalitis.

Tick-borne diseases are a constant threat, especially in forest, scrub and meadow environments. People who are professionally connected with places of this nature, such as foresters, farmers and soldiers, are at an increased risk of acquiring tick-borne diseases. In 2019, 2,065 cases of occupational diseases were found in Poland, among which the most commonly recorded diseases were infectious or parasitic diseases or their consequences – 700 cases, i.e. 33.9% of occupational diseases. Lyme disease predominated with 628 cases, accounting for 89.7% of this group [8].

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Received: 15.07.2022; accepted: 23.01.2023; first published: 09.02.2023

OBJECTIVE

The aim of this review is to present the current state of knowledge on tick-borne diseases in humans, with particular emphasis on the group o professional soldiers. Vector diseases are rarely mentioned in the context of this professional group, and especially in the course of ongoing armed conflicts, in which soldiers are an important element in ensuring national and global security. Tick-borne diseases negatively affect the health condition of people, making it difficult for them to perform their professional duties. The review describes the etiological factors influencing the risk of tick-borne diseases and their epidemiology in Poland and other European countries, and presents the most important data determining the incidence of vector diseases among soldiers.

STATE OF KNOWLEDGE

Adaptation of ticks to a parasitic lifestyle. Under natural conditions, the infection of ticks with pathogenic microorganisms can occur during feeding on the host, as well as through transovarian, transstadial and transspermal transmission [9, 10]. Ticks thus pass on many microorganisms to the next generation. These phenomena create opportunities for germs to circulate from one tick generation to the next, without contact with their hosts. An important property of ticks as vectors of pathogenic microorganisms is their adaptation to host changes during the life cycle. Evidence for this includes the different expression of the relevant gene sets that occurs when the tick is stimulated to feed under laboratory conditions [11].

Due to the ability of each stage of the tick to adapt to a new host, these arachnids can be and sometimes are (vectors) conditioning the continuity of microbial circulation in wildlife populations, and between wild animals and humans who would not normally come into direct contact with these wild animals.

Tick species occurring in Poland. There are about 860 species of ticks worldwide, grouped into four families. Nineteen species of *Ixodida* are recorded as permanent elements of the Polish fauna, moreover, 11 other species of ticks have been found to enter Poland naturally or artificially [12]. The most important in human medicine are the castor bean tick (*Ixodes ricinus*) and the meadow tick (*Dermacentor reticulatus*).

The specific microclimatic conditions of the habitat influence the choice of living space by ticks. Consequently, for many tick species, their presence within the range is restricted to numerous 'islands' and 'islets'. An example is the dispersal of castor bean ticks, which are usually not evenly distributed within a habitat, and their numbers can vary even at intervals of a few metres – the so-called 'patchwork distribution' [12]. Hundreds of locations of the castor bean tick have been recorded in Poland, with its choosing habitats with high relative humidity (about 80–100%), mainly in deciduous and mixed forests or bushy thickets [13].

As far as the meadow tick is concerned, the opinion about its area of occurrence has changed over the years. Formerly, its locations were thought to be in north-eastern, eastern and western Poland. However, research by Mierzejewska et al. [14] indicate the occurrence of two distinct populations of this tick species – western and eastern, separated by the valley of the river Vistula.

In Poland, *D. reticulatus* is found in forested or overgrown river valleys, along streams and drainage channels, in swamps of mixed forests, in mid-forest clearings and meadows, and in areas of clearings and bushy pastures [15].

Vector-borne diseases in Europe. The geographical distribution of vector-borne diseases is closely linked to the distribution and expansion of the vectors that spread them. In Europe, tick-borne zoonoses are now of the highest importance and their incidence has increased over the last decade. According to Norwegian researchers, the emergence of tick-borne diseases in the north of Norway is related to the occurrence of a single vector species (tick) for many pathogens and the variability of hosts and their characteristic pathogens [16].

Regulating the density of ticks in the environment is a difficult task but which can be achieved by controlling populations of invasive species, pests and game, as their high density favours the development of tick populations and the spread of tick-borne diseases [17]. Cultural traditions (such as hunting and berry picking) and the increasing popularity of outdoor leisure activities in Europe, has led to increased human contact with ticks, thereby increasing the likelihood of contracting pathogens transmitted by these vectors [18].

Vector-borne diseases in Europe are predominantly viral (tick-borne encephalitis) and bacterial (Lyme disease, tularemia, anaplasmosis, Q fever). Cases of tick-borne encephalitis (TBE) have been reported throughout Central and Eastern Europe and Scandinavia. At the beginning of the 21st century, within just a few years, there was an increase in the incidence of TBE, not only in most Central European countries, but also in European areas previously considered free of the disease, such as Norway. In Latvia, Finland, Russia and the Czech Republic, a very high incidence was reported, while in Austria there was a significant decrease after a vaccination programme [19].

Another common vector-borne disease in Europe is Lyme disease, which occurs with similar prevalence in its different regions, except for the coldest areas in the north and the hottest areas in the south [20].

Cook and Puri [21], using two mathematical models that exploited the correlation between data on incidence, infection rate and total human *Borrelia* infection rate derived from serology results, determined the number of Lyme disease cases for each country. Thus, for Germany, France and the UK, the number of cases of Lyme disease in 2018 was set at 471,000/year, 434,000/year and 132,000/year, respectively. Estimates for the whole world for 2018 are: incidence 12.3 million/year; prevalence 62.1 million; and total infection burden 262.0 million. However, there are differences in the prevalence of Lyme disease and clinical presentations in different European countries, which may partly be due to the heterogeneous distribution of *Borrelia burgdorferi* s.l. genogroups in Europe, influenced by different climatic conditions [22].

Another tick-borne disease, tularemia, is caused by the gram-negative bacterium *Francisella tularensis*, which is one of the most virulent micro-organisms known today. The life cycle of this pathogen takes place in terrestrial or aquatic environments. In the terrestrial life cycle, lagomorphs, rodents and ticks are the main sources of human infection, and the incidence of tularemia is associated with changes in rodent dynamics and the expansion zone of ticks [23]. In 2019, 21 European Union countries reported 1,463 cases of tularemia. The EU/EEA notification rate in that year was 0.3 cases per 100,000 population. The ratio of men to women was 1.5:1. As in previous years, the proportion of submissions among males was higher in all age groups, with the exception of the 0–4 age group. Notification rates increased with age and peaked at 45–64 years [24].

Anaplasmosis caused by *Anaplasma phagophytophilum* is also widespread on the European continent [25]. The bacterium *A. phagophytophilum* is the causative agent of tick fever, equine, canine and human granulocytic anaplasmosis. A common route of transmission of this bacterium is by tick bite, with the castor bean tick *(Ixodes ricinus*) being the cause in Europe. Despite the widespread occurrence in ticks and in a variety of wild and domestic animal species, data have been published to date demonstrating the low number of clinical cases of human granulocytic anaplasmosis (HGA), compared with the worldwide situation [26]. It is not known whether this reflects the epidemiological dynamics of human infection in Europe, or whether the disease is understated or underreported.

Epidemiological studies in Europe suggest an increased risk of occupational infection for forest workers, hunters, veterinarians and farmers with a history of tick bites and living in endemic areas. Although the overall genetic diversity of *A. phagocytophilum* in Europe is greater compared to the USA, the strains responsible for human infections are related on both continents. However, the study of genetic variability and the assessment of variation in pathogenicity and infectivity between strains of different hosts have not yet been sufficiently investigated. Most European cases of HGA are presented as mild infections [27].

Another tick-borne disease that occurs in Europe is Q-fever, a bacterial disease caused by *Coxiella burnetii* bacteria. This bacterium is relatively rarely detected in ticks, with additional diagnostic difficulties posed by *Coxiella-like* endosymbionts (CLE), which are difficult to differentiate from *C. burnetii*, calling into question the importance of ticks in the epidemiology of Q fever [28]. Körner et al. [29] conducted a meta-analysis of the results presented in 72 scientific articles reporting on the presence of *C. burnetti* in 25 tick species collected from 23 European countries. Overall, the presence of genetic material of these bacteria was confirmed in 4.8% of the ticks tested.

Tick-borne diseases in Poland. The result of humans being bitten by an infected vector is usually the development of a tick-borne disease**.** The most dangerous tick-borne diseases in Poland include borreliosis (Lyme disease) and tick-borne encephalitis (TBE), while anaplasmosis, bartonellosis, tularemia and babesiosis are less important due to the low number of diagnosed human cases.

Data published by the NIZP-PZH for the period 2015–2019 show that there was an increasing trend in the number of diagnosed cases of Lyme disease in particular (Tab. 1).

The epidemiological data from 2020–2021 are significantly different from those of earlier years, likely influenced by the COVID-19 pandemic. For example, according to Australian researchers, the COVID-19 pandemic had a differential effect on the number of vector-borne disease diagnoses; firstly, as a result of the restriction of aeroplane flights, the number of imported cases of these diseases was reduced; on the other hand, the importation of foreign vector species decreased [30]. Other researchers are now highlighting another problem associated with the COVID-19 pandemic, i.e. the overburdening of the health care system in many countries, which may also have a direct impact on the diagnosis of vector-borne diseases and the underestimation of the number of newly emerging cases of vector-borne diseases [31].

In addition to the issues mentioned above, the impact of climate change on the biology of vectors, and thus on their activity in transmitting pathogens dangerous to humans, should also be taken into account.

According to the final report drawn up from the research carried out as part of the National Health Programme 2016–2020, it appears that the 5% decrease in the number of cases of Lyme disease in Poland in 2018 was due to fewer cases in the central and northern provincial belt of Poland, influenced by the very hot and dry months. Multivariate analysis showed a decrease in the number of cases in months with a low maximum temperature [32].

Climate change alters the areas and timing of viral vectors of human infections, e.g. those causing tick-borne encephalitis. Warm winters cause constant tick activity and thus the possibility of infecting people with the TBE virus throughout the year. The researchers compiling the aforementioned report noted a slight trend towards an increase in the overall number of cases of TBE in Poland between 2009–2018, compared to 1999–2008. Both temperature and the sum of precipitation have been found to influence tick activity and thus the incidence of tick-borne encephalitis, but this relationship is not straightforward and requires further multivariate analyses [32].

Level of infestation of ticks with particular pathogen species in Europe, including Poland. For many years, ticks have been tested for pathogens dangerous to human health and life in Poland. These include bacteria of the genera *Borrelia*, *Anaplasma*, *Francisella,* viruses that cause tick-borne encephalitis and protozoa of the genus *Babesia*.

Table 1. Incidence of Lyme disease, TBE and tularemia in Poland from 1 January 2015–31 December 2021

Disease	Number of cases of tick-borne diseases						
	2015	2016	2017	2018	2019	2020	2021
	No. of cases	No. of cases	No. of cases	No. of cases	No. of cases	No. of cases	No. of cases
borreliosis	13,625	21,220	21,528	20,139	20,614 (309 neuroborreliosis)	12,524 (104 neuroborreliosis)	12, 427 (203 neuroborreliosis)
TBE	149	284	279	197	265	158	212
tularemia	9	17	1	16	21	3	43

Source: Data from the Department of Epidemiology of Infectious Diseases and Surveillance of the National Institute of Public Health and the Department for Prevention and Control of Infections and Infectious Diseases in Humans of the Central Statistical Office. Table compiled from data on website: http://wwwold.pzh.gov.pl/oldpage/epimeld/index_p.html

According to scientists, there are at least eight species of *Borrelia*, namely *Borrelia burgdorferi* (s.s.), *B. garinii*, *B. afzelii*, *B. spielmanii* and *B. bavariensis*, *B. lusitaniae* and *B. valaisiana* which may be pathogenic to humans, but each of these species is associated with different clinical signs.

In Europe, as in Poland, the prevalence of *Borrelia* among ticks removed from humans ranges from a few to about 30% [33, 34]. Studies on castor bean ticks collected in the areas of Warsaw and in the area of Białowieża in north-eastern Poland, revealed the presence of six bacterial species occurring in both types of areas, with different frequency of occurrence, i.e. dominance of *B. afzelii* (69.3%) in urban areas and of *B. garinii* (48.1%) in natural areas [35]. The presence of *B. burgorferi* sensu lato was confirmed in 4.4%, 11.5–39,5% and 15% of *I. ricinus* from north-western, south-western and southern Poland [36, 37, 38].

Other authors have also found other pathogens in the tested ticks – *B. lusitaniae* and *B. valaisiana*. For example, Bertolotti et. al. [39] found *B. lusitaniae* in 82% of 1,203 *Ixodes ricinus* tested ticks collected in Tuscany, central Italy. *B. valaisiana* was recorded, respectively, in 1.8%, 6.9% and 7% of *I. ricinus* ticks caught in Spain, Estonia and Finland [40, 41, 42].

The level of *Anaplasma phagocytophilum* infestation in Poland is generally low. Recent studies have shown the presence of this bacterium in 0.54% of *Ixodes ricinus* ticks in northern Poland, 1.01% in the north-western area and 4.5% in the south-western region [43, 44, 45].

A pathogen found in ticks also relatively rarely is *Francisella tularensis*, the bacterium that causes tularemia. Research by Bielawska-Drózd et al. [46] showed the presence of this pathogen among 0.49% of those caught in north-western Poland.

Research in Poland has also focused on determining the level of tick-borne encephalitis virus infection. Studies carried out by two research teams led by Beata Biernat [47, 48] demonstrated the presence of these viruses in 0.96% of castor bean ticks caught in north-western Polan, and in an average of 1.12% of meadow ticks from north-eastern and eastern areas of the country.

The last of the mentioned vector-borne diseases, babesiosis, is only occasionally reported in humans in Europe. To date, 60 cases, mainly caused by *Babesia divergens* infection, have been confirmed in several European countries, including France, the United Kingdom, Austria, Czech Republic, Finland, Germany, Italy, Portugal, Switzerland and Poland [49].

The four-year research conducted by Pawelczyk et al. [50] involving the examination of common and meadow ticks removed from humans, showed the presence of protozoa of the genus *Babesia* in 1.3% of the castor bean ticks examined.

Soldiers as a risk group for acquiring vector-borne diseases. The testing of vectors operating in an area where soldiers are stationed for the presence of pathogens dangerous to humans is used in many armies. Over the past decade or so, entomological research conducted in the army has produced entomological and epidemiological models of human risk of contracting dangerous diseases [51, 52]. The need for such research has already been demonstrated by the historic research work carried out by Walton et al. [53], which showed the presence of *Ehrlichia* spp. among 2–15% of ticks removed fromAmerican soldiers during training exercises in the USA and *B. burgdorferi* in 11–21% of the same ticks. Among 6071 specimens of *Ixodes ricinus* ticks collected from Swiss soldiers on exercise in five regions of Switzerland, 26.54% contained *B. burgdorferi,* and in Finland, IgM class antibodies to *B. burgdorferi* were diagnosed in 11.9% of Finnish soldiers during summer exercises [54].

Data published by the US Army indicates the high incidence of vector-borne diseases among soldiers and the need to prevent them, which is considered 'essential to maintaining combat readiness and strength' [55]. A study conducted between 2004 and 2013 by Hurt and Dorsey [56] among active duty soldiers stationed at West Point in the USA found a Lyme disease incidence rate of 155 cases per 100,000 persons/year. And the results of a 2016–2018 study by Schubert and Melanson [57] on *Borrelia* infection of military service personnel and their family members also from the West Point area showed 63 cases of Lyme disease among military personnel for a total of 21,595 infections/year. And 81 cases of infection were found in their family members for a total of 13,931 infections/year.

According to Vondra's calculations [55], 86 out of 137 cases of vector-borne diseases among active duty soldiers in 2017 were Lyme disease cases. According to the Centers for Disease Control, an increase in the number of cases has been documented in recent decades, and representatives of the Institute summed it up as follows: 'This trend is expected to continue for the foreseeable future' [55].

Data on the incidence of various diseases, including tick-borne diseases, among Polish soldiers are not available. Korzeniewski [58] described the reason for this. In his opinion, immunization, anti-malarial chemoprophylaxis, sanitary training and other undertakings are carried out in the closed circuit of the military health service for the duration of operations abroad, while military personnel residing in Poland use primary health care services, usually in a civilian environment.

CONCLUSIONS

To develop an effective vector control strategy, it is necessary to know the entomological situation in the given areas used by the military. Additionally, the development of effective research programmes into the vectors themselves and the diseases they transmit will benefit both the military and local communities.

Vector-borne diseases affect the deterioration of soldiers' health, so determining the level of risk of acquiring vector-borne diseases in specific areas where soldiers serve in peacetime, and during armed conflict can affect the maintenance of their good health and thus full operational capability.

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