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LYME BORRELIOSIS IN SOUTH-EASTERN POLAND: RELATIONSHIPS WITH ENVIRONMENTAL FACTORS AND MEDICAL ATTENTION STANDARDS

Katarzyna Bartosik[1], Patrycja Lachowska-Kotowska[2], Jolanta Szymańska[3], Artur Pabis[1], Alicja Buczek[1]

[1]Chair and Department of Biology and Parasitology, Medical University of Lublin, Lublin, Poland
[2]Department of Internal Medicine, Medical University of Lublin, Lublin, Poland
[3]Chair and Department of Paedodontics, Medical University of Lublin, Lublin, Poland

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Abstract: Yhe aim of the study was the investigation of the dynamics of LB prevalence in central Europe over a 12-year period and estimation of its dependence on the environmental factors and on the level of medical services. Epidemiological studies of LB were conducted in the years 1996–2007 in 9 regions of the Świętokrzyskie province in south-eastern Poland (Central Europe). On the basis of patient registry, the incidence, prevalence in various months of the year, the mean number of cases in various seasons and the seasonality factors (SF) of LB were calculated. Between 2000–2007, an increased borreliosis incidence was observed in the study area. During the entire study period, the highest incidence (25.93 and 30.66) was observed in the regions with the highest density of *Ixodes ricinus* ticks – vectors of *Borrelia burgdorferi* spirochetes, and where the inhabitants are offered the best available LB diagnosis and treatment due to a sufficient number of doctors (r = 0.74) and all medical personnel (doctors, nurses and diagnosticians) (r = 0.89). The highest LB incidence was present in the summer and autumn seasons (SF = 113.25 and 155.18%) in the areas with the highest density of nymphs and adult *I. ricinus* ticks (≥19/1 h of sampling). Improved standards of public medical care as well as environmental monitoring of tick threat may contribute to a decrease in prevalence of LB and to its better detection.

Address for correspondence: Katarzyna Bartosik, Chair and Department of Biology and Parasitology, Medical University of Lublin, Radziwiłłowska 11, 20-080 Lublin, Poland.
E-mail: katarzyna.bartosik@umlub.pl

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INTRODUCTION

Lyme borreliosis (LB) is a widely distributed zoonosis which poses a great challenge for the medical services. The highest prevalence is reported from the USA [13] and from nearly all European countries [56]. Spirochetes from the *Borrelia burgdorferi* sensu lato (B.b.) complex, within which 11 genospecies have been discovered so far in various species of the world, are the etiological factor of LB. *Borrelia burgdorferi* sensu stricto, *Borrelia garinii* and *Borrelia afzelii* [29, 58, 59] are the human-pathogenic species in Europe, while in North America – *B. burgdorferi* sensu stricto [12, 33, 36]. Ticks from the genus *Ixodes* are the LB vectors: in Europe – mainly *I. ricinus* [26], in America – *Ixodes scapularis* and *Ixodes pacificus* [10], whereas in Asia – *Ixodes persulcatus* [9, 19, 40]; they infect humans and other hosts while feeding.

Long-term persistence and circulation of B.b. in nature is possible due to the environmental co-existence of ticks and their mammalian, avian or reptilian hosts, which simultaneously are competent reservoirs for spirochetes [39, 42, 50, 54].

The aim of the study is to investigate the dynamics of LB prevalence in central Europe over a 12-year period, and to estimate its dependence on the environmental factors and on the level of medical services.

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MATERIALS AND METHODS

Epidemiological studies of Lyme borreliosis. The study was conducted between 1996–2007 in 9 Regional Sanitary-Epidemiological Stations (RSES) in the Świętokrzyskie province of south-eastern Poland. The data concerning borreliosis cases were obtained from the patient registry. On this basis we calculated: the incidence proportion, i.e. the number of disease cases per 100 thousand inhabitants of the regions supervised by the particular stations and in the entire Świętokrzyskie province, borreliosis prevalence in various months of the year, the mean number of cases in various seasons and the seasonality factors (SF), which express the percentage differences between prevalence in successive months in relation to the prevalence in the study area.

Medical care in the Świętokrzyskie province. The availability of borreliosis diagnosis and treatment in various regions of the province and throughout the area was estimated on the basis of the number of medical care institutions (hospitals, outpatient clinics or village health centres and diagnostic laboratories), the total number of doctors and the number of doctors of various specializations dealing with the treatment of borreliosis (internists, neurologists, cardiologists, GPs and family doctors, dermatologists, epidemiologists), and the total number of medical personnel (doctors, nurses and laboratory diagnosticians) per 10 thousand inhabitants. The data were provided by the Regional Statistics Office in Kielce.

Estimation of Lyme borreliosis prevalence risk. The threat of tick attacks and the risk of infection with *Borrelia burgdorferi* spirochetes were estimated on the basis of occurrence and density of *I. ricinus* in 21 localities in the regions supervised by the Regional Sanitary-Epidemiological Stations. Ticks were sampled with the flagging method, which involves sweeping the vegetation with a 100 × 70 cm white cloth, during the *I. ricinus* spring activity in this area, i.e. from April to the beginning of July 1999 and 2000. In order to compare tick density in various habitats, sampling was performed for 1 hour each time at the same time of the day (between 16:00–18:00) and the temperature in the tick habitats measured with the accuracy of 1ºC. The specimens were placed in test-tubes containing 70% ethyl alcohol and examined in laboratory conditions in order to determine the species and developmental stage. Furthermore, in order to predict tick prevalence in various regions of the Świętokrzyskie province, we used the information provided by the Regional Directorate of State Forests in Radom for comparison of the forested areas and the vegetation type in 6 forest inspectorates associated with the study RSESs.

Statistical analysis. The results were elaborated using the STATISTICA statistical package for Windows. All correlation analyses were performed by calculation of Spearman's correlation coefficients. Probability at $p \leq 0.05$ was regarded as significant and as highly significant at $p \leq 0.01$.

RESULTS

In 1996–1999, the borreliosis incidence proportion in various regions of the Świętokrzyskie province was low. Between 2000–2007, increased borreliosis incidence was observed in almost the entire study area. In that period, the incidence ranged from 0–30.66, depending on the region. The highest mean incidence in the whole study period was reported from the RSES Końskie and Skarżysko-Kamienna: 10.729 and 8.383, respectively, while it was slightly lower in the area of the RSES in Kielce, Busko and Starachowice (Tab. 1). A great number of cases were registered in the areas with the biggest number of general practitioners and specialists (from 21.81–29.03 GPs and specialists per 10 thousand inhabitants) and all medical staff (from 77.91–81.85 nurses and diagnosticians per 10 thousand inhabitants) (Tab. 1, 2).

The lowest incidence in the particular years (Tab. 1) and the lowest mean incidence throughout the study period were noted in the area of the RSES in Jędrzejów (1.22) and Ostrowiec Świętokrzyski (3.71), which are characterised with the lowest numbers of general practitioners and

Table 1. Lyme borreliosis incidence in particular RSES in Świętokrzyskie province in 1996–2007.

RSES[a]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Mean[b]
Busko	2.11	2.12	2.13	1.42	9.99	4.44	8.89	7.76	12.37	13.05	18.37	9.25	7.66
Jędrzejów	0	0	0	1.21	0	0	0	2.21	1.11	4.49	5.58	0	1.22
Kielce	7.12	3.27	3.26	1.78	11.26	8.85	7.13	8.59	10.07	8.84	10.08	10.84	7.59
Końskie	2.21	0	3.34	0	0	7.97	7.97	5.58	23.54	30.66	22.49	24.99	10.73
Opatów	2.89	2.9	1.46	1.47	1.48	0	3.38	1.72	0	6.98	15.82	10.61	4.06
Ostrowiec	0	0	1.75	6.11	1.75	2.46	2.46	2.55	0.85	5.98	16.30	4.32	3.71
Skarżysko	0	0	3.39	0	7.73	11.87	14.30	9.90	7.46	25.93	4.97	15.05	8.38
Starachowice	0	0	2.7	3.65	1.81	11.15	1.01	11.45	7.33	14.69	10.56	9.54	6.16
Włoszczowa	1.8	1.79	3.63	0	1.81	16.63	6.23	2.09	4.20	0	8.46	21.22	5.65

[a] – Regional Sanitary-Epidemiological Station; [b] – Mean incidence in the whole study period reported from particular RSES.

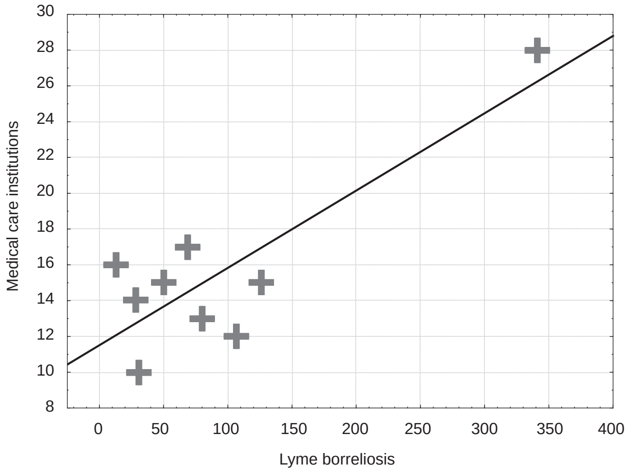

Figure 1. Correlation between the number of all medical staff and registered Lyme borreliosis cases in 9 RSES studied, confirmed by Spearman's correlation coefficients (r = 0.8667, p < 0.01).

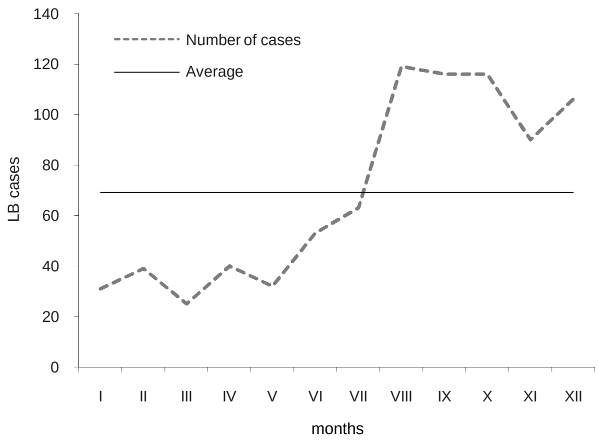

Figure 2. Number of LB cases noted in particular months in Świętokrzyskie region in 1996–2007.

specialist (14.42 and 17.11 per 10 thousand inhabitants, respectively) and other medical staff (43.63 and 67.79 per 10 thousand inhabitants, respectively) employed. Strong correlations between the number of all medical staff and the registered borreliosis cases were confirmed by Spearman's correlation coefficients (r = 0.8667, p < 0.01) (Fig. 1). However, no correlation (r = 0.2008) was observed between the number of health care institutions and the number of diagnosed borreliosis cases.

As shown in the study, borreliosis prevalence was markedly lower than the mean in spring (SF = 46.75%), slightly higher in summer (SF = 113.25%), considerably higher in autumn (SF = 155.18%) and slightly lower in winter months (SF = 84.82). In all the study years, the prevalence rates increased in the summer and autumn seasons (Fig. 2, 3). The data obtained indicate a tendency towards increased prevalence of borreliosis during the last 12 years (Tab. 1, Fig. 3).

696 *I. ricinus* specimens (189 adults and 245 nymphs and 262 larvae) were collected in the 21 localities. The field study indicated the presence of *I. ricinus* ticks in the whole province with different density in the particular regions. The biggest numbers of ticks were sampled in the areas where borreliosis cases were more frequently registered (Tab. 1, 3). Statistical analysis did not confirm a correlation between the mean number of the ticks collected

Table 2. Number of doctors and health care institutions (per 10,000 residents) in the area under surveillance of Regional Sanitary-Epidemiological Stations in Świętokrzyskie province.

RSES[a]	Physicianss	Internal medicine physicians	Infectious disease physicians	Neurologists	Cardiologists	GPs doctors[b]	Family doctors	Dermatologist	Epidemiologists	Nurses	Diagnosticians	Outpatients clinics and hospitals
RSES Kielce	16.8	1.63	x	1.19	0.25	0.77	0.41	0.05	0.05	56.1	0.1	28
RSES Busko	40.6	6.9	0.05	0.36	0.26	2.6	1.6	0.54	0.13	71.3	0.13	15
RSES Końskie	16.2	3.76	0.57	x	0.11	0.23	0.46	0.48	x	56	0.1	12
RSES Jędrzejów	11.6	2.38	x	x	x	x	x	0.22	0.22	29.1	0.11	16
RSES Opatów	19.3	1.35	x	0.34	x	0.85	0.85	x	0.34	29.9	0.34	14
RSES Ostrowiec Świetokrzyski	10.5	4.69	x	0.74	0.25	0.41	x	0.52	x	50.6	0.08	15
RSES Skażysko-Kamienna	20.9	4.05	0.48	1.19	0.36	1.19	0.48	0.38	x	52.7	0.12	13
RSES Starachowice	17.8	2.74	0.30	0.61	0.10	0.71	1.42	0.21	0.10	50.6	0.3	17
RSES Włoszczowa	16.2	3.74	x	0.42	x	0.63	0.42	0.21	0.42	50.9	x	10
Świętokrzyskie province	17.6	3.2	0.20	0.7	0.3	0.23	0.27	0.38	0.7	51.6	x	x

[a] – Regional Sanitary-Epidemiological Station; [b] – general practitioners; x – no data; shadowed – the highest mean borreliosis incidence.

Table 3. Characteristic of six forest inspectorates studied.

Forest Inspectorates	Forest area (ha)	Structure of tree cover (%)	RSES[a]	Location	Number of ticks collected[b] T/F/M/N/L	Temperature (ºC)	Mean tick density[c]
Busko	10,858	pine (79.4) oak (7.3) birch (4.5) alder (3.8) fir (2) hornbeam (0.7) poplar (0.5) and others	Busko	Raków Chmiel	4/0/0/4/0 4/3/1/0/0	23 20	4
Jędrzejów	14,598	pine (67.8) oak (10.7) alder (6.6) birch (5.2) beech (2.6) fir (2.1) larch (1.1) spruce (0.9) and others	Jędrzejów	Kniecpol	1/1/0/0/0 3/2/0/1/0	12 20	2
Kielce	16,212	pine (73.4) fir (14.4) oak (3.8) beech (3.4) birch (2.6) alder (1.5) spruce (0.3) hornbeam (0.3) and others	Kielce	Chęciny Dąbrowa Jaworznia Kaniów Kielce Folwark Karczówka Kielce Słowik Kielce Telegraf Morawica Niwka	44/0/9/35/0 27/3/5/16/3 59/5/5/27/22 31/1/1/5/24 29/1/3/24/1 38/2/2/4/30 24/1/1/20/2 5/3/1/1/0 22/1/0/15/6 15/0/1/12/2	21 19 18 23 11 15 12 27 18 24	29,4
			Włoszczowa	Brzozowa	8/2/2/4/0	18	8
Ostrowiec Świętokrzyski	17,266	pine (87.1) oak (7.4) birch (2.2) larch (0.8) alder (0.8) poplar (0.5) and others	Opatów	Święty Krzyż Widełki	2/0/1/1/0 18/4/6/8/0	27 22	10
			Ostrowiec Świętokrzyski	Bodzedzyn	9/1/0/8/0	23	9
			Starachowice	Starachowice	46/13/15/18/0 74/40/20/14/0	21 14	39
Barycz	12,689		Końskie	Stęporków	38/9/8/6/15	24	38
Skarżysko	14,673	pine (58) fir (28.4) birch (3.5) spruce (2.8) oak (2.4) beech (1,6) alder (1.6) larch (0.9) and others	Skarżysko Kamienna	Kleszczów Górki	43/4/6/11/22 52/2/4/11/35	28 17	42

[a] – Regional Sanitary-Epidemiological Station; [b] – Number of tick stages found during single collection in particular location; [c] – Average number of ticks collected with one flag during 1 h of collection; T – total; F – females; M – males; N – nymphs; L – larvae.

and borreliosis incidence in a particular area ($r=-0.1441$, $p>0.05$).

The ticks were collected in mixed forests with thick understory and with a predominance of pines and deciduous trees such as oaks, beeches, birches, black alders, alders and hornbeams. The highest *I. ricinus* density (42, 39, and 38 specimens/1 h of sampling) was observed in large woodland areas (Tab. 3).

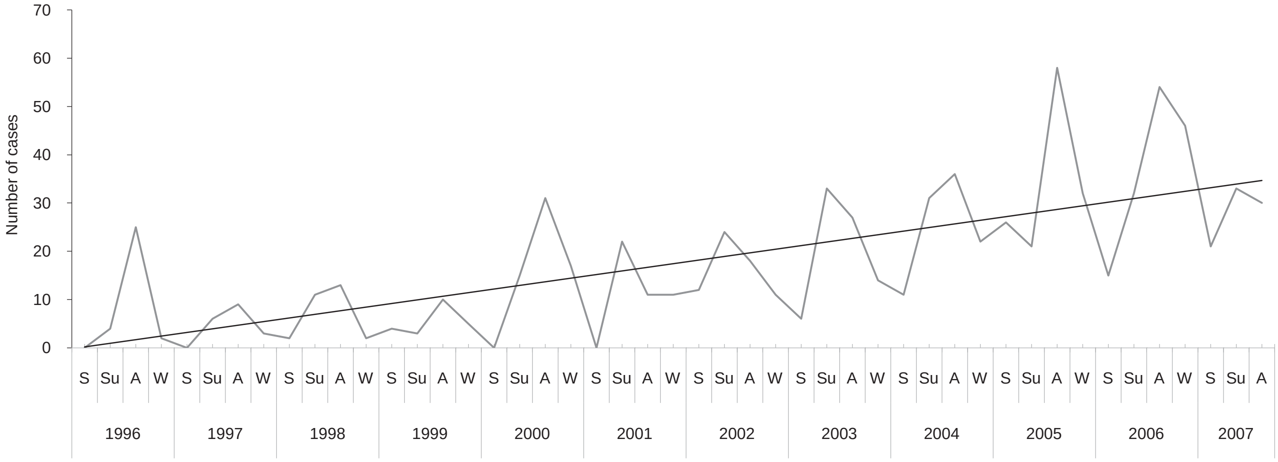

Figure 3. Trends of LB incidence in time, in Świętokrzyskie province in 1996–2007. S – spring; Su – summer; A – Autumn; W – winter.

DISCUSSION

The present study confirmed borreliosis prevalence in the whole Świętokrzyskie province; its frequency, however, varied between the different regions and the different study years. An increased risk of borreliosis was observed in areas where favourable habitats ensured a high density of these arthropods. Also, the types of biotopes present in the study area provided suitable conditions for small and medium mammals. They are both the hosts for young stages of ticks and spirochete reservoirs [37]; therefore, they participate in the horizontal transmission of *B. burgdorferi* among the larval and nymphal *I. ricinus*. Also, big mammals occur in the Świętokrzyskie province, e.g. the roe deer (*Capreolus capreolus* L.), which are the main hosts for adult *I. ricinus* in Europe which contribute to the higher density of tick population [27] and persistence of the pathogenes in the environment. Therefore, the biotype may serve as an indicator of the risk of infection with a particular pathogen. This is corroborated by the study carried out by Daniel *et al.* and Hubalek *et al.* [16, 28], who claim that deciduous and mixed forests with a structure similar to that observed in our study area pose the highest risk of infection with the *B. burgdorferi* spirochete and with the tick-borne encephalitis viruses.

In Poland, the percentage of *I. ricinus* ticks infected with *B. burgdorferi* spirochetes ranges from 0–58.3% in individual localities [15, 53, 55]. In Slovakia, from 8–22.5% of ticks are infected [32], in the Czech Republic from 12.6–20.0%, and in some localities the percentage is as high as 35.0% [28]. The percentage in Germany ranges from 13.9 –29.8% [46], in Spain it is 9.3% [2], in Norway 16% [30] and in Switzerland it is in the range of 5–47.5% [11]. The United States report 18% of spirochete-infected ticks [35], while Canada – 12.9% [39]. Such a high level of infection is reflected in the results of serological assays in humans, especially in forestry workers who are exposed to these arthropods. In Poland prevalence of anti-*B. burgdorferi* antibodies detected in foresters' blood serum sometimes reaches several dozen percent, e.g. it amounts to 43.2% in the south-east [60], in the east it is 60–70% [23], in the west – 66.7% [20], and in the south-eastern part of the country – 34.8% [8]. In other European countries, the prevalence of anti-*B. burgdorferi* antibodies in the sera of foresters and other workers exposed to tick bites is varied and reaches, e.g. 23.9% in Germany [49], 23.8% in Slovenia [51], 12.8% in Slovakia [4] and 7.5% in Italy [52].

The risk of contracting LB increases as the exposure to tick attacks is prolonged. Buczek *et al.* [8] reported a distinct increase in the level of anti-*B. burgdorferi* antibodies in long-tenure forestry workers in south-eastern Poland. The highest percentage of positive results in both classes of IgM (17.4%) and IgG (34.8%) antibodies was observed in the group of over 50-year-olds, whereas it was the lowest in the under 30-year-old age group (13.0% IgM and 14.1% IgG). The levels of positive results in anti-*B. burgdorferi* antibodies are lower in the total population. In Poland, depending on the region and place of living, they vary from 6.0% in urban dwellers to 33.0% in rural inhabitants of the endemic area for borreliosis in the eastern part of the country [14]. In an endemic focus of north-eastern Poland, LB seropositive results were found in as many as 49.7% of inhabitants [44]. Anti-*B. burgdorferi* antibodies were detected in 13.5% of the inhabitants of Sweden [21], in 1.4% in the USA [24], and in as many as 34.3% of the inhabitants of LB foci in Ukraine [5].

The increased borreliosis prevalence is a consequence of the global climate changes which contribute to prolonged activity of *I. ricinus* ticks [17, 34, 57] and to an increase in the population density [6, 34, 48]. In our study, we observed almost year-round activity of ticks in the Upper Silesian Industrial Region, an area with considerable heat emission into the atmosphere (unpubl. data). The phenology of *I. ricinus* is also affected by the long-term saturation deficit. Tick density [25, 31, 38] and *B. burgdorferi* prevalence in ticks [11, 38] declined in localities at higher altitudes above sea level. For instance, in the Swiss Alps the prevalence of nymphal tick infection varied from 20–46% at different altitudes a.s.l. [11].

The increased threat of tick attacks and the high tick-borne disease prevalence rate in the Świętokrzyskie province is related, on the one hand, to changes in the life style adopted by some groups of citizens after the system reforms (e.g., increased interest in recreation); on the other hand, this may be connected with the general deterioration of living standards and a high unemployment rate in the region [7], which forces the inhabitants to find sources of income in forest work due to lack of alternative earning possibilities.

Borreliosis has a seasonal character. Increased prevalence in autumn follows the periods of the highest tick activity in Świętokrzyskie province. Seasonality of prevalence of tick borne diseases has also been noted in other countries [22, 43].

As suggested in our study, more available diagnosis and treatment provided by more numerous medical staff in the particular regions increase the chance of recognition of borreliosis. The borreliosis diagnosis is confirmed by the occurrence of erythema migrans or at least one of the late symptoms and by detection of anti-*Borrelia burgdorferi* antibodies in serological tests [47].

Due to the diverse borreliosis course, recognition of the initial phase poses great difficulties [1]. However, according to our previous study [3], knowledge about tick threat and prophylaxis of tick-borne diseases is still insufficient in Poland and in other parts of the world [45].

Due to prophylaxis, monitoring of the threat and use of various laboratory methods, the number of borreliosis diagnoses in the USA increased in 1992, compared to previous years. In the same period in UK, the number of borreliosis diagnoses was several times lower than in the USA; later, borreliosis notification became obligatory and information about the risk of spirochete infection and the course of the disease was propagated [41].

The increased LB incidence in south-eastern Poland (Tab. 1) corresponds with the general tendency towards an increased number of registered cases of this disease in other parts of Poland and in central Europe, especially in Germany, Austria, Slovenia and Sweden [18].

Abundant occurrence of tick populations and the increase in infections caused by pathogens which they transfer necessitates multidirectional activity for the improvement of medical services, promotion of prophylaxis methods and continuous environmental monitoring.

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