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Changes of meteorological factors and tick-borne encephalitis incidence in the Czech Republic

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Summary

Objectives: The primary objective was to analyze the influence of short-term meteorological changes during the vegetation period on the incidence of tick-borne encephalitis (TBE) in the 1990s, characterized by a dramatic increase in reported TBE cases in the Czech Republic and other European countries. Furthermore, the relationship between TBE incidence and meteorological conditions in the previous winter season was studied.
Material and methods: The TBE incidence data were acquired from the EPIDAT database of the National Institute of Public Health (NIPH). Analyzed were a total of 4637 cases reported in Bohemia (1994-2004). Meteorological data were from the database of the Czech Hydrometeorological Institute in Prague and originated from 22 meteorological stations located in high TBE incidence areas in Bohemia.
Results. A linear relationship was found between TBE incidence and temperature factors in all the years under study. Lagged cross-correlation analysis (with the time lag corresponding to the incubation period from the infected tick bite to the onset of TBE symptoms) revealed a close correlation between TBE incidence and weekly mean air temperature with a lag of 1 to 5 weeks. When considering the previous winter period, the closest relationship was found between TBE incidence and the previous-winter frost index, followed by the minimum air temperature.
Conclusion: A review is presented of the effects of the currently observed climate change on TBE incidence as compared with the data reported in the 1950s. Results of parallel analyses of other factors potentially implicated in higher TBE incidence in the 1990s lead to a critical rejection of the conclusion previously drawn by some authors that the collapse of communism and subsequent dramatic socio-economic changes might have a decisive influence on TBE incidence in Central Europe. The rise in TBE cases reported in West European countries where no such political changes took place confirms the refutation.

Key words: Tick-borne encephalitis – meteorological factors – Czech Republic

Souhrn

Daniel M., Kříž B., Danielová V., Valter J., Beneš Č.: Změny meteorologických faktorů a výskyt klíšťové encefalitidy v České republice

Cíl práce: Hlavním cílem bylo analyzovat vliv krátkodobých změn počasí v průběhu vegetační sezóny na incidenci klíšťové encefalitidy (KE) v období 90. let minulého století, kdy došlo k prudkému vzrůstu případů registrovaných v České republice i v dalších zemích evropského rozšíření této nákazy. Dále byl zkoumán možný vztah výskytu KE k meteorologickým podmínkám předchozí zimy.
Materiál a metodika: Data o incidenci KE byla excerpována z registru EPIDAT (Státní zdravotní ústav, Praha). Celkem bylo analyzováno 4637 případů onemocnění KE registrovaných v Čechách (1994-2004). Meteorologická data byla excerpována z databáze Českého hydrometeorologického ústavu v Praze a zahrnula údaje z 22 meteorologických stanic situovaných v oblastech vysokého výskytu KE v Čechách.
Výsledky: V celém studovaném období byl konstatován pozitivní lineární vztah mezi teplotními činiteli a výskytem KE. Při zjišťování křížové korelace s posunem (s hodnotami časového posunu respektujícími dobu inkubace od napadení pacienta infikovaným klíštětem do objevení prvních příznaků onemocnění) byl nalezen těsný vztah mezi výskytem KE a týdenní průměrnou teplotou vzduchu s časovým posunem 1 – 5 týdnů. Pokud jde o parametry charakterizujícími předchozí zimní období, byl demonstrován nejtěsnější vztah mezi výskytem KE a mrazovým indexem, těsně následovaný hodnotami minimální teploty vzduchu ve sledovaném zimním období.
Závěry: V práci je dále podán přehled výsledků studia vlivu v současnosti pozorovaných změn klimatu na incidenci KE v porovnání s historickými daty publikovanými k tomuto tématu v padesátých letech minulého století. Výsledky paralelně provedených analýz dalších faktorů

možného ovlivnění změn incidence KE registrovaných v 90. letech vedou ke kritickému odmítnutí představ o rozhodujícím vlivu kolapsu komunismu a politických konsekvencích na incidenci KE v prostoru střední Evropy, jak je tradováno některými autory. Porovnání se zeměmi západní části evropského areálu KE, kde došlo rovněž k vzestupu incidence KE, avšak nikoliv k politickým změnám, toto odmítnutí potvrzuje.

Klíčová slova: klíšťová encefalitida – meteorologické faktory – Česká republika.

Introduction

In 1954, the first ever collected findings on TBE by Czech and Slovak authors were published under the guidance of K. Raška [27], within a period of five years from the first isolation of TBE virus in Europe at all (from a patient, and *Ixodes ricinus* ticks collected in the wild in the Czech Republic). At the time of publishing there was lacking data on the spread of this neuroinfection in what now comprises Europe; the monograph was therefore originally entitled 'Czechoslovak Tick-Borne Encephalitis', and only later was the term CETE – Central European Tick-Borne Encephalitis – introduced. The evaluation of five years of comprehensive research was fully representative of the features of this infection, from clinical signs to the phenomenon of natural foci and the dynamic of virus circulation in nature. To date, the work has fully retained its topicality and remains an important source of data for comparison with the current epidemiological situation.

In the early 1990s (specifically starting in 1993) there was a sharp rise in the incidence of human TBE cases. The recorded high values persist to the present day, with certain inter-annual fluctuations. This fact was reported by Danielová and Beneš [13] already in 1997, who were making comparisons with the situation in other European countries affected by TBE spread. In the same year, these authors [14] published a framework analysis of the phenomenon which explored the complex of epidemiological factors associated with TBE and concluding with the influence of climatic changes recorded in the studied period [1]. This conclusion was supported by both results of previous long-term fieldwork monitoring the influence of various microclimates on *I. ricinus* tick development [summarized in 7] and laboratory test monitoring the effects of temperature and relative air humidity on virus replication in ticks [12].

In the Czech Republic, TBE has been subject to mandatory reporting of cases since 1951; since 1971, only laboratory-confirmed cases are registered. The resulting database is supplemented by a variety of anamnestic data and hence enables broad, retrospective analyses for comparison and clarification of newly arising epidemiological situations, particularly over the past two decades. Assessment of this historical data (1971 – 2000) and their relation to climate change was conducted in cooperation with the Czech Hydrometeorological Institute (CHMI) with use of the institute's meteorological database [16]. With the exception of the 1930's (prior to the discovery of the TBE virus) the analysed period of time contains two distinctively warm periods: from 1943 – 1955 and from about 1990 to the present. The temperatures recorded in-between these warm periods make up a series of cold year, excepting certain inter-annual fluctuations. It is certainly no accident that the virus was discovered in Central Europe during the first of these warm periods and that the incidence of human TBE infection culminated in 1953 (see Discussion).

When the cold period began it appeared that the then 'new' infection was in decline and had stopped being an issue. However, even during the cold period there were inter-annual temperature fluctuations which could, to a certain extent, affect TBE incidence (1974 – 79, 1983 – 86). The greatest steep temperature rise has been evident since 1990. The recent warm period is the longest in seventy years and is continuing. It contains all long-term maximum temperature records in terms of years, months and seasons. Nonetheless, even in this overall rising trend there have been individual years with a downturn in temperatures (1996 – 98) which were reflected by a temporary decrease of TBE incidence.

Analysis of registered TBE cases has revealed that the following phenomena have played a part in the overall rise in TBE incidence:

1) An increase in incidence in regions with continuous high TBE occurrence.

2) Reappearance in places where TBE incidence had been mitigated and rather sporadic.

3) TBE occurrence in novel localities, namely

at higher mountain altitudes (above 750 m a.s.l.) which were formerly free of the vector *Ixodes ricinus* and thus also of infections transmitted by it.

4) Changes in seasonal TBE occurrence, namely a shift to earlier spring (March) and later autumn (November).

The latter two points have namely directed our attention towards the correlation of increased TBE incidence with climate changes that have been found since the latter 1980's and most markedly since the beginning of the 9th decade.

A significant finding was that of changes in the 700 m above sea-level [2 and 3] altitude threshold of *I. ricinus* spread, resulting in cases of verifiable TBE infection at an altitude of at least 900 m above sea-level [5] in the Šumava mountains in 1996 and 2001. These findings correlated with those of Swedish authors [22] concerning higher geographic latitude cases in Scandinavia.

Significant results were yielded by research into increased TBE incidence conducted as part of the WHO/EC Climate Change and Adaptation Strategies for Human Health (cCASHh) project in 2000 – 2005. The main theses inspired by the results of this research (analysis of causes, danger areas, exposed population groups, prevention issues, and recommendations for further research) are summarized in the comprehensive final book published at the conclusion of the project [24 and 4]. At that time available information on TBE is presented in a section text [15] intended as a 'background document' for the vector-borne diseases section of the cCASHh project.

The current intensive study of the effects of climate change on human health and associated epidemiological scenarios and preventive options includes close attention to vector-borne diseases, including TBE. Gray et al. [18] recently attempted to summarize relevant work in this field. Some of the associated studies employ short-term time periods and only mean monthly or annual meteorological values, or computer-generated values in lieu of real measured data; the validity of ensuing results is therefore limited, despite sophisticated statistical calculation.

We have made an effort to use the most detailed data available from the NIPH TBE and CHMI meteorological databases and to define the relationship between TBE morbidity and short-term, day-to-day changes of actual meteorological conditions with the help of meteorologists. Likewise, we have paid attention to time-spans that adequately encompassed the periods of major changes in TBE incidence. It is important to bear in mind that the key moment for assessment of climatic influences on TBE incidence is the attachment of an infected *I. ricinus* tick, from which unfold the subsequent stages of the infectious process and clinical course of the disease (see Discussion).

We have also tried to evaluate the extent to which a previous winter season can affect *I. ricinus* activity and associated TBE incidence in the following season. Although both of the above research goals are based on the same data, their analysis and assessment required different approaches which are designated as two stages in the following text.

Material a methods

1. Epidemiological data

Epidemiological data were selected from the database EPIDAT, National Institute of Public Health, Prague (NIPH) in which laboratory-confirmed cases of TBE in the territory of the Czech Republic are recorded by mandate, including anamnestic data on the way of infection. The basic datum for our analysis was the date of initial disease symptoms facilitating, with respect to the incubation period, correlation of the incidence of TBE with meteorological factors at the time of acquiring the infection. (Alimentary infections rather an exceptional in the conditions of the Czech Republic ather an exception [20], have not been included in the series under study.) For the purpose of determining the correlation between meteorological changes and TBE incidence during the vegetative period (research stage 1) data have been used on 4637 cases registered on the territory of Bohemian part of the Czech Republic (1994-2004). To assess the possible influence of the previous winter on TBE incidence in the following season (research stage 2) we used a total of 4196 cases registered in the same area (1995-2004). (Fig. 1.)

2. Meteorological data

Meteorological data at 7, 14, 21 o'clock (1994-2004) were excerpted from the data base of the Czech Hydrometeorological Institute in Prague (CHMI). Data from 22 selected standard meteorological stations complying with the following criteria were taken into the study: a location in an area known for an increased occurrence of TBE at the territory under study; a non-stop observation of all meteorological elements used during the 1994-2005 period. This data represents the Bohemian territory defined approximately by four points with the following geographic coordinates: 49°23' N, 13°18' E (Klatovy); 50°11' N, 15°50' E (Hradec Králové); 50° 38' N, 14° 04' E (Ústí nad Labem); 48° 58' N, 14° 28' E (České Budějovice) with altitude ranging from 158 to 536 m above sea level.

During the first stage of research (vegetation period), the daily and consequently also the weekly values of 9 meteorological parameters (which can be expected to influence the ecosystem in which the TBE virus circulates in nature) were calculated:

Daily mean, maximum and minimum air temperature; daily mean soil temperature at the depth of 5 cm; daily totals of precipitation; daily mean relative air humidity; daily duration of sunshine; daily mean wind speed 2 m above ground; daily value of soil moisture in % of available water capacity (awc) (assessed using a mathematical model from

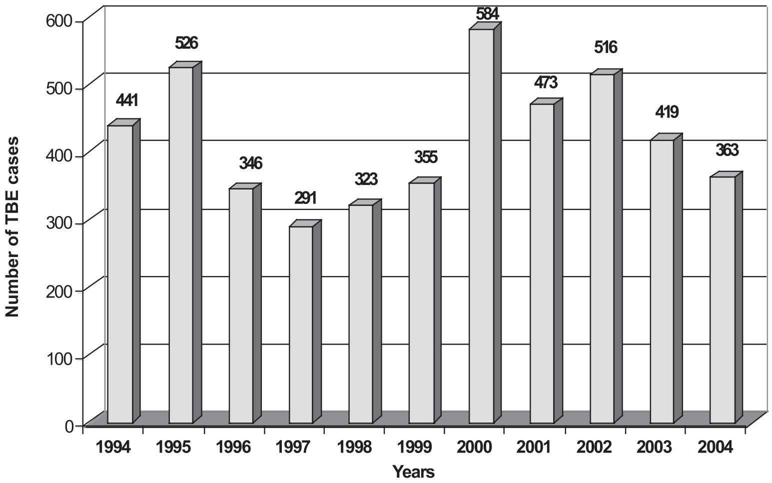

Figure 1. Annual number of tick-borne encephalitis cases in Bohemian region (Czech Republic) in 1994 – 2004. (EPIDAT, NIPH)

precipitation, sunshine, air temperature, relative humidity, wind speed, and atmospheric pressure). Although this item is a characteristic estimated from meteorological elements rather than being a meteorological element itself, we will refer to it as an element hereinafter for ease of reference.

In the second stage of research (winter period) during the preparatory phase, area characteristics (i.e. averages of those 22 stations) of the winter period were calculated for the following items:

- TM_W: mean air temperature
- T_WX: maximum air temperature
- TW_N: minimum air temperature
- TS_W: mean soil temperature in the depth of 5 cm
- TS_WX: maximum soil temperature in the depth of 5 cm
- TS_WN: minimum soil temperature in the depth of 5 cm
- i_THAW: number of thaw days
- iTS: number of days with a below-zero soil temperature in the depth of 5 cm
- iBF: number of days with black frost
- i_FR: number of frost days
- i_ICE: number of ice days
- i_AR: number of Arctic days
- FR_I: frost index
- t_decr: the highest decrease in the air temperature during a 24-hour period (value), the highest decrease in the air temperature during a 24-hour period (date)
- t_incr: the highest increase of the air temperature during a 24-hour period (value), the highest increase of the air temperature during a 24-hour period (date)
- iSn: total number of snowy days
- SM_avg: value of soil humidity at the end of winter (% of available water capacity AWC)

Explanations:

Thaw: sum of days with a mean air temperature 2 m above the ground (TM_W) >0 °C with snow cover (SC>1 cm) or ground surface bare of snow and soil frozen (soil temperature in the depth of 5 cm [TS_5] <0 °C)

Black frost: daily minimum temperature 2 m above the ground (TW_N) <0 °C, ground bare of snow

Frost day: a day with minimum temperature TW_N <0 °C

Ice day: a day with maximum temperature T_WX <0 °C

Arctic day: a day with maximum temperature T_WX –10 °C

Frost index: sum of below-zero values of mean daily air temperatures (TM_W) per winter period taken as a positive number

Humidity of soil: amount of water in the upper 20 cm layer of soil expressed as % of the available water capacity (AWC, difference between the field water capacity and the permanent wilting point of the considered layer of soil)

These area characteristics describe the winter as a whole in terms of winter severity, as used in the following text. It is necessary to emphasize that the data of soil microclimate reflect the insulating role of snow cover.

3. Methods of evaluation

Methods of statistical evaluation of relations between TBE incidence in the role of a dependent variables (predictands) and meteorological elements (including soil humidity) as predictors were analyzed with the aid of the program EXCEL (Microsoft Office) and the statistics package STATISTICA6 including the extension “Non-linear Methods”.

During the 1st stage of research (vegetation period), the following procedures were implemented: Basic statistics (means, extremes, standard deviation, type of probability distribution); simple regression relations between the occurrence of TBE and individual meteorological elements (linear and quadratic regression).The technique of lagged correlations was applied for the testing of the closeness of correlations between TBE incidence and meteorological area values (the weekly values of those variables).

The 2nd stage of research (winter period): As there was a several-month shift of time between the date of acquisition of the predictor and the terms of incidence of the both diseases, the effects of winter factors were studied as a whole, i.e. each factor taken by its total value over the entire winter period. Similarly, the incidences of TBE and LB were taken as total annual incidences in the subsequent year.

Results

1. Correlation between meteorological factor and TBE incidence during vegetation seasons (April – October, 1994-2004)

a) Simple regression relations between the incidence of tick-borne encephalitis and individual meteorological elements

The presumption that the relation between TBE incidence and certain meteorological elements is simply linear (without time lag

Table 1. Cross correlations between weekly TBE incidence in Bohemia, and weekly mean air temperature (Bohemian territorial averages), lag 0 –9 weeks (TD_0 - TD_9). Bold printed: significant value at 1 % level (limits of significance see in Table 1 b). Bold+shadowed: local maximum value).

YEAR	TD_(0)	TD_(1)	TD_(2)	TD_(3)	TD_(4)	TD_(5)	TD_(6)	TD_(7)	TD_(8)	TD_(9)
1994	**0.7018**	**0.7100**	**0.6463**	**0.5496**	**0.5390**	**0.5345**	**0.5362**	**0.4504**	**0.4276**	0.3778
1995	**0.7504**	**0.7310**	**0.5857**	**0.5453**	**0.4872**	0.4115	0.4113	0.3903	0.3432	0.2762
1996	**0.6561**	**0.6722**	**0.6328**	**0.5689**	**0.5712**	**0.5131**	**0.4894**	**0.4855**	0.4212	0.3210
1997	**0.6531**	**0.5960**	**0.4973**	0.4095	0.4293	0.3301	0.2264	0.1506	0.0831	0.0818
1998	**0.5432**	**0.4823**	0.4048	0.4010	**0.4775**	**0.4735**	0.3793	**0.4751**	**0.4548**	0.3439
1999	**0.7343**	**0.7569**	**0.6443**	**0.5527**	**0.4757**	0.4326	0.3468	0.2303	0.1936	0.1960
2000	**0.6361**	**0.6399**	**0.5791**	**0.5233**	**0.4770**	**0.4513**	**0.4631**	**0.4960**	**0.4555**	0.3935
2001	**0.7138**	**0.7067**	**0.6217**	**0.5422**	**0.4603**	**0.4917**	**0.5691**	**0.5976**	**0.5716**	**0.5142**
2002	**0.8612**	**0.8469**	**0.8567**	**0.8049**	**0.7894**	**0.6592**	**0.5896**	**0.4650**	0.3244	0.1817
2003	**0.6450**	**0.6118**	**0.5963**	**0.5960**	**0.4882**	**0.4566**	0.4142	0.3239	0.2560	0.1655
2004	**0.6360**	**0.5869**	**0.4798**	**0.4405**	**0.4292**	0.4189	0.3734	0.2821	0.1904	0.1667
AVG	***0.6846***	***0.6673***	***0.5950***	***0.5394***	***0.5113***	***0.4703***	*0.4363*	*0.3952*	*0.3383*	*0.2744*

Table 1b. Significance limits of correlation coefficient for table 1.

Year	Extent of array	Degree of freedom	p =0.10	p =0.05	p =0.01
1994	36	34	0.2786	0.3292	0.4239
1995	31	29	0.3007	0.3549	0.4554
1996	28	26	0.3171	0.3738	0.4783
1997	27	25	0.3233	0.3809	0.4869
1998	32	30	0.2960	0.3494	0.4487
1999	34	32	0.2869	0.3389	0.4358
2000	35	33	0.2827	0.334	0.4297
2001	34	32	0.2869	0.3389	0.4358
2001	37	35	0.2746	0.3246	0.4182
2002	35	33	0.2827	0.3340	0.4297
2003	36	34	0.2786	0.3292	0.4239

consistent with incubation period), proved successful for temperature elements (mean, maximum, and minimum air temperature and mean soil temperature at a depth of 5 cm) – values of correlation coefficient (r) were significant in all the years investigated. Concerning the elements referring to humidity (precipitation, humidity of air, soil moisture), the closeness of the relations was significant only in some years for humidity of the air (3 times) and for soil moisture (3 times). However, in the whole series of averages, the values of the correlation coefficient (r) were significant for all these elements (negative correlation was identified for soil moisture, while positive correlation was found for precipitation). Wind speed had no confirmed influence on TBE incidence. A review of the detailed results of simple correlations is presented in publication [9].

b) Lagged cross-correlation

This approach can be considered as crucial for the solution of the defined objectives concerning the nature of the relations between TBE incidence and the weather.

The closeness of the relation between the weekly value of TBE incidence and each weekly values of meteorological element depending on the magnitude of the lag (0-9 weeks) has been tested in the sense of comparing TBE incidence with "past" values of a meteorological elements. Tested was the influence of weekly mean ambient air temperatures, weekly duration of sunshine, weekly precipitation totals, weekly mean values of relative ambient air humidity, and mean soil humidity. At each individual lag, besides the value of the correlation coefficient and the coefficient of determination there have also been calculated basic statistical data (dispersion, mean, median, skewness, acuity, standard deviation, parameters of linear regression) characterizing the time series of values of each element.

On the basis of the mean values of correlation coefficients for the years 1994-2004 it is apparent

Table 2. Closeness of association between the annual TBE incidence (for the period from 1st April until 31st October) on the one hand and the 7 best corresponding parameters of winter severity on the other.
TM_W: mean air temperature, TW_N: minimum air temperature, TS_WN: minimum soil temperature in 5 cm depth, i_FR: number of frost days, i_ICE: number of ice days, FR_I: frost index, SM_end: soil humidity at the end of winter (20th March). R annual: values of correlation coefficient related to annual TBE incidence (p [0.1] = 0.669, p [0.05] = 0.755). For definitions of the parameters of winter severity see 'Materials and methods'.

Year	TM_W	TW_N	TS_WN	i_FR	i_ICE	FR_I	SM_end	annual TBE
1994/95	2.1	–13.3	–4.3	72	19	115.5	66.9	526
1995/96	–2.7	–17.2	–5.9	118	68	401.7	77.4	341
1996/97	–0.6	–24.4	–4.8	94	38	320.4	81.7	292
1997/98	1.9	–18.6	–3.7	71	17	134.3	73.9	318
1998/99	–0.1	–14.1	–3.9	93	35	199.8	65.0	348
1999/00	1.0	–16.2	–3.4	84	15	127.5	96.6	564
2000/01	1.4	–12.3	–2.6	70	24	137.4	93.1	464
2001/02	1.2	–18.3	–3.0	73	31	184.3	94.0	510
2002/03	–0.4	–14.3	–5.4	88	43	276.3	68.6	411
2003/04	0.6	–19.5	–2.9	80	23	218.3	53.2	348
R annual	**0.497**	**0.539**	**0.377**	**–0.452**	**–0.436**	**–0.595**	**0.505**	

that highly significant relations exist between TBE incidence and the mean ambient air temperature (Table 1), that being directly proportional. In this element there also exists a connection of the best correlation coefficient values with biologically reasonable lags (of 1 to 5 weeks); the best lag has a zero value.

2. Effects of winter conditions on subsequent TBE incidence (1995–2004)

Meteorological conditions of the preceding winter proved to have a demonstrable relationship with TBE incidence. This applies for the incidence expressed as 'total annual incidence' (number of cases per year).

The following 7 of the 19 climatological parameters of winter severity tested were found most relevant:

- mean air temperature (at 2 m height)
- minimum air temperature (at 2 m height)
- minimum temperature of the soil in 5 cm depth
- number of days with soil temperature ≤ 0 °C
- number of frost and ice days
- frost index
- mean soil humidity (% AWC)

The correlation between these parameters of winter severity and total TBE incidence in the subsequent vegetation period is generally low; in some cases (frost index, minimum winter temperature, average winter temperature) the figures stand only tightly below the level of 90% probability (Table 2). It seems that a colder course of the winter may result in a decrease of TBE incidence in the subsequent seasons. Obviously, the inter-annual fluctuation of overall TBE incidence corresponds with the fluctuation of winter severity. Minimum winter temperature and frost index are important indicators of winter severity and serve as a measure of thermal stress affecting the entire ecosystem. Not much below the mentioned level of significance is the correlation between total TBE incidence and mean soil humidity. This parameter (which is closely related to the parameter "number of days of thaw) most probably influences the population of small mammals, which are hosts of *I. ricinus* immatures during the subsequent spring time.

Discussion

Infection by TBE virus is unequivocally based on attack by an infected tick and the sucking of the host's blood for a certain period of time (with the exception of alimentary infections of humans where the role of the tick is indirect and mediated by a lactating animal host). This route also clearly demonstrates the influence of meteorological factors on TBE incidence. The effects of climate on the existence and developmental dynamics of *I. ricinus* have been demonstrated in the past [7] and during the currently observed climatic changes [6, 23]. Aside from the long-term effects on the whole *I. ricinus* population, a direct connection was uncovered as regards that part of the tick population in the host-seeking phase of its life-cycle [11]. This connection is so stable that it was possible to design software for prognoses of *I.* ricinus host-seeking risk levels using routine meteorological forecasts. This has been available for the past three seasons on the CHMI website [10] for the purposes of prevention of vector-borne disease.

A second basic prerequisite of TBE viral infection is human behaviour which results in their proximity to areas with infected vectors. This factor is also influenced by the weather as we demonstrated in our analysis of TBE incidence in 2006 which has reached peak values during the past two decades [8]. Both of these basic conditions are combined in assessing the effects of meteorological factors on the incidence of TBE.

In the comparison of average values over longer periods of time (e.g. monthly averages) the correlation of TBE incidence and ambient air temperature is evident. A problem arises when we wish to examine such short periods of time that would represent the observed day-to-day changes in meteorological conditions. To that end, from the EPIDAT register of TBE patients data (the calendar day) on the occurrence of the initial symptoms of the disease have been used. However, the actual beginning of the infectious process should be considered the attachment of the sucking infected tick, and therefore, it is necessary to investigate the meteorological situation that prevailed in those days. Thus, there has to be taken into consideration the incubation period of the infection which, of course, varies to a great degree from person to person between 3 to 28 days, mostly in the range of 7 – 14 days [17]. That fact introduces a certain bias into the data series which has to be respected in the assessment of results of correlation tests. In our preliminary study, we worked with a daily values time lag of 0 – 15 days and close relations were found between TBE incidence and daily mean air temperature with time lags of 6 – 14 days and a peak of 9 days [9]. Significant results obtained even at a zero time lag are apparently connected with cases of short incubation and early onset of clinical symptoms. However, it has to be kept in mind that they may be also influenced by uncertainty with the registration of the initial symptoms of infection. Namely in the evaluation of weekly mean values in extreme cases the difference declared in the category "zero lag" can reach up to two weeks from the actual calendar date. The time lag problem caused by the incubation period, in the analyses of longer time units (e.g. months) loses its significance being masked by a robust smoothing out following from the one-month intervals.

In the question of assessing the current influence of meteorological factors on TBE incidence valuable information is contained in a monograph on TBE in Czechoslovakia in the 1950s [27] involving a distinctly warm weather period (albeit of shorter duration) which is comparable to the period of warming which began in the 1990s and is the subject of our evaluation. A passage concerning the exceptionally high incidence of TBE in 1953 associates this warm period with the heightened incidence of *I. ricinus* and the influence of the weather on both quantities (*I. ricinus* counts and TBE incidence) in the second half of the summer is presented in graphic form. The increased migration of people into risk areas during this period for purposes of recreation and gathering woodland fruits is likewise observed, with emphasis on the multi-factor character of the circulation of infection in nature and the influence of meteorological conditions from at least the previous autumn season. The high number of cases registered in the early 1950s, when registration was required on the basis of clinical diagnosis without direct laboratory confirmation, may be due to cases of encephalitis of different aetiology and therefore cannot be explicitly compared to current counts. Nonetheless, the incidence in 1953 was quite exceptional in the context of the day (over 1800 cases) with a decrease totaling 300 cases in 1959 – a level which remained fixed, with certain fluctuations, until the start of the 1990s.

The main aim of the presented research was to study the influence of meteorological factors and climatic changes on the incidence of TBE. In parallel with these studies we also analysed other factors (environmental and socioeconomic) which must be taken into account as an integral part of the ecology and epidemiology of TBE.

Detailed anamnestic data registered in the TBE data base (EPIDAT, NIPH) enabled us to analyze the socio-economic situation of patients diagnosed with TBE. In this respect there has been found no relation to the increased incidence of TBE [21]. Confirmed has been previous experience that TBE in the Czech Republic is a recreation-linked infection that is connected with outdoor activities which in no way are motivated economically.

Human behavior certainly plays an important role in the epidemiological process. Of course, in that sense in the early 1990's there have not occurred any enormous changes. Weekend outing in nature became popular in the 1950's already [27], and over the following decades a considerable part of farmsteads (country homes) have been transformed into private recreation cottages and facilities, so that a considerable part of the urban population had been getting into contact with nature at that time already. The popularity of mushroom picking was closely related to that, becoming a nation-wide sport getting people to localities with great occurrence of *I. ricinus* and the risk of TBE infection during vacations as well as weekend holidays. Of course, even human outdoor activities are influenced by the prevailing weather, as has been demonstrated in the paper by Daniel *et al*. [8].

These results are an important and rigorous basis for a refutal of the absurd assertion published by Randolph and Rogers [26] lacking any concrete data whatsoever with neither knowledge of the true situation nor citation of any Czech information source. The question they had placed themselves, "What caused the widespread increase in TBE cases since 1993?" they answered with a text which has to be called a piece of political propaganda mongering rather than a substantiated hypothesis.

"This was a time of great political change in Eastern Europe. The collapse of communism resulted in de-collectivization of agriculture, with active governmental encouragement of individuals to keep flocks of sheep and goats, often grazed on roadside verges harbouring ticks, and to use their milk products. Clusters of TBE cases have been recorded in the Czech and Slovak Republics within families or villages well known for their cheese making (M. Daniel and M. Labuda, personal communication). At the same time, increased poverty arising from the collapse of centralized welfare has forced many poor people to supplement their diet with fruits gathered from tick-infested forests."

Moreover, that piece of absurdity was presented as a "personal communication" of one of the authors of the present paper, however, without his knowledge or authorization of that text. Neither repeated personal reminding of the erroneous content of that assertion nor our published concrete data have been taken into account and the assertion about the collapse of communism influencing TBE incidence in central Europe is being published over and over again, even being supplemented by reflections of the ideologist of the communist movement Friedrich Engels in the 19th century [25].

Furthermore, that author in support of her conclusions focused her attention at the Baltic countries where in the early 1990's occurred a dramatic increase in TBE incidence which she connects with the end of Soviet rule. We do not intend to dispute that problem in the Baltic region in order to obviate the mistakes which that author has allowed herself to make in the unqualified assessment of the situation in the Czech Republic. Nevertheless, it can be stated that the abrupt increase in TBE incidence in the early 1990's also followed by a sharp decline, cannot be satisfactorily explained by socio-economic factors, rather leading to deliberations on the effect of changes in the organization of the healthcare service and in the registration of TBE cases in the period of historic changes in the Baltic States.

The rise of TBE incidence in the 1990s was manifested in virtually all of Europe, including its western quarter. This is confirmed by data from Germany, Switzerland, Sweden and Norway. In Austria, which has the highest vaccination-rates against TBE and subsequent decrease of the infection in areas of previously commonplace incidence, alimentary infection from goat cheese has been recorded – this from animals grazing in the Alps at 1560 m above sea-level [19], a mountain altitude previously considered risk-free. These states were outside the communist sphere of influence and underwent no political changes in the 1990s. This is another piece of evidence highlighting the unsustainable nature of statements concerning political consequences in the epidemiology of TBE in Central Europe [25].

In the epidemiology of TBE there come into bearing all components determining the existence of natural foci of infections and their changes, including human behavior. All these components are influenced by climatic changes although in different regions with varying intensity.

Conclusions

An analysis targeted at identifying mutual correlation was performed using a cohort of 4673 cases of TBE during the 1994 – 2004 period registered on the territory of Bohemia (the Czech Republic) (EPIDAT, NIPH) and data from 22 meteorological stations representative of the area covered over the corresponding time period (CHMI database). The influence of short-term (day-to-day) weather changes, particularly air temperature on the seasonal curve of TBE incidence was demonstrated for individual years in association with changes in the host-seeking activity of the vector *I. ricinus*. An important role can be ascribed also to the severity of the preceding winter season (mainly frost index). Results are compared with an analysis of the correlation of long-term changes of TBE incidence in the Czech Republic and observed climatic changes since the 1990s. Other factors (environmental and socio-economic) which should be considered integral to TBE epidemiology were concurrently analyzed. This research refutes the statements of some authors concerning the decisive influence of the collapse of communism and associated political consequences on TBE incidence in Central Europe.

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