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RESEARCH NOTE

Seasonal changes in climatic parameters and their relationship with the incidence of pneumococcal bacteraemia in Denmark

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ABSTRACT

The seasonal variation in the incidence of invasive pneumococcal disease is well recognized, but little is known about its relationship with actual changes in climatic parameters. In this 8-year longitudinal population-based study in Denmark, a harmonic sinusoidal regression model was used to examine whether preceding changes in climatic parameters corresponded with subsequent variations in the incidence of pneumococcal bacteraemia, independently of seasonal variation. The study shows that changes in temperature can be used to closely predict peaks in the incidence of pneumococcal bacteraemia with a time-lag of 16 days (95% CI 14–18 days), independently of a strong seasonal pattern.

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The seasonal variation in the incidence of invasive pneumococcal disease, with a peak in incidence during the winter months, is well recognized [1–4]. However, few detailed studies of the temporal relationship between actual climatic changes and subsequent pneumococcal disease are available. An 8-year longitudinal population-based ecological study was undertaken in a Danish county to examine whether changes in climatic parameters could be used to predict variations in the incidence of pneumococcal bacteraemia (PB).

Included were cases of PB that occurred from January 1995 through December 2002 in North Jutland County, Denmark, with an average population of 492 845 during the period of study, corresponding to 9% of the total Danish population. Patients with PB were identified in the County Bacteraemia Registry, which comprises blood culture results for the entire county [5]. PB was defined as an episode of clinical disease, with *Streptococcus pneumoniae* detected by blood culture [5].

Meteorological data, i.e. daily summaries from a weather station corresponding to the area under study, were obtained from the Danish Institute of Agricultural Sciences. Daily mean values were calculated for six pre-specified meteorological variables: temperature (minimum, mean and maximum), relative humidity, precipitation and wind velocity. Monthly means and sums of these variables were used in the data analysis.

A harmonic sinusoidal regression model [6] was fitted to estimate the phase difference in months (converted to days by multiplying by 30) between changes in each of the meteorological variables and monthly incidence of PB in North Jutland County:

$$\mathrm{A}\cos(2\pi(\mathrm{t}-\varphi)/365.25)+\mathrm{B}$$

where φ is the phase that indicates the location of the seasonal peak. As the incidences of PB counts were assumed to be Poisson distributed, a square root transformation was used [7]. The differences, in days, between the phase of PB incidence and each of the six meteorological variables were determined in conjunction with a 95% CI. The sign and magnitude of the phase difference indicated the effect of the meteorological variable on the intensity of PB. The model adequacy was evaluated by visual inspection of the residuals.

During the 8 years of surveillance, 63 166 blood cultures were performed and 714 episodes of PB were detected. There were 2329 days during which no episodes of PB were observed, and 493, 82, 15 and 3 days during which one, two, three and four episodes, respectively, were observed. The estimated phase differences between PB incidence and the different meteorological variables are given in Table 1. Statistically significant negative phase differences were found for temperature (minimum, mean and maximum) and relative humidity, indicating that the sinusoidal curves of these variables were located to the left, relative to the PB curve. Thus, these meteorological variables attained their minimum and maximum, respectively, earlier than the time at which PB incidence was at its maximum and minimum, respectively. A close inverse relationship was found between temperature changes and PB incidence, with an observed time-lag of 16 days (95% CI 14–18 days) between temperature peaks and troughs and PB activity. Peaks in relative humidity preceded PB peaks by two months. These relationships were seen independently of a strong seasonal pattern of PB. No relationship was found between PB incidence and precipitation or wind velocity.

Table 1. Phase differences for pneumococcal bacteraemia and the meteorological variables in days

	Phase difference in days (95% CIs in parentheses)
Temperature	−16 (−18 to −14)
Minimum temperature	−13 (−15to −11)
Maximum temperature	−19 (−22 to −17)
Wind velocity	3 (1–5)
Relative humidity	−59 (−65 to −52)
Precipitation	28 (2–55)

Negative values indicate that the meteorological variable is shifted to the left relative to pneumococcal bacteraemia incidence and thus attains its maximum earlier than pneumococcal bacteraemia.

Fig. 1 shows monthly PB incidences together with the monthly mean temperatures during the 8-year study period. Superimposed are the fitted sinusoidal curves showing the lag of approximately 2 weeks between temperature change and PB incidence. Visual inspection of the residuals indicated that observed PB incidences higher than predicted by the model were seen in months with temperatures lower than those of the model.

These analyses confirmed a distinctive seasonal variation in the incidence of PB in Denmark, with summer troughs and winter peaks similar to those reported from various geographical locations, including several states in the USA [1–3] and a temperate region in Australia [4]. These findings are in line with those of Watson *et al.* [4], who examined the relationship between PB and similar specific climatic parameters and found a strong inverse relationship between weekly mean maximum and minimum temperature and PB incidence, whereas other examined climatic parameters were unrelated to PB incidence. As compared with the previous studies, a model-based statistical approach was used in the current study, taking into account the cyclical nature of the quantities, in contrast with calculating the linear Pearson correlation coefficient. This approach made it possible to quantify the phase difference with a corresponding CI, showing that the association between temperature drops and peaks and subsequent PB incidence is independent of seasonal patterns.

The underlying causes of the distinctive seasonal variation in the incidence of PB remain debatable; suggested factors include climatic changes, increased crowding, atmospheric pollutants and exposure to seasonal respiratory viruses [3]. Several studies have noted that patterns of occurrence of PB are similar to patterns of occurrence of respiratory syncytial virus (RSV) and influenza [2–4], suggesting a role of these viruses in the pathogenesis of pneumococcal disease. In Australia, weekly numbers of RSV and PB cases were found to be correlated among children, and the combined RSV and influenza activity was correlated with PB activity in adults [4]. A recent population-based cohort study at an individual

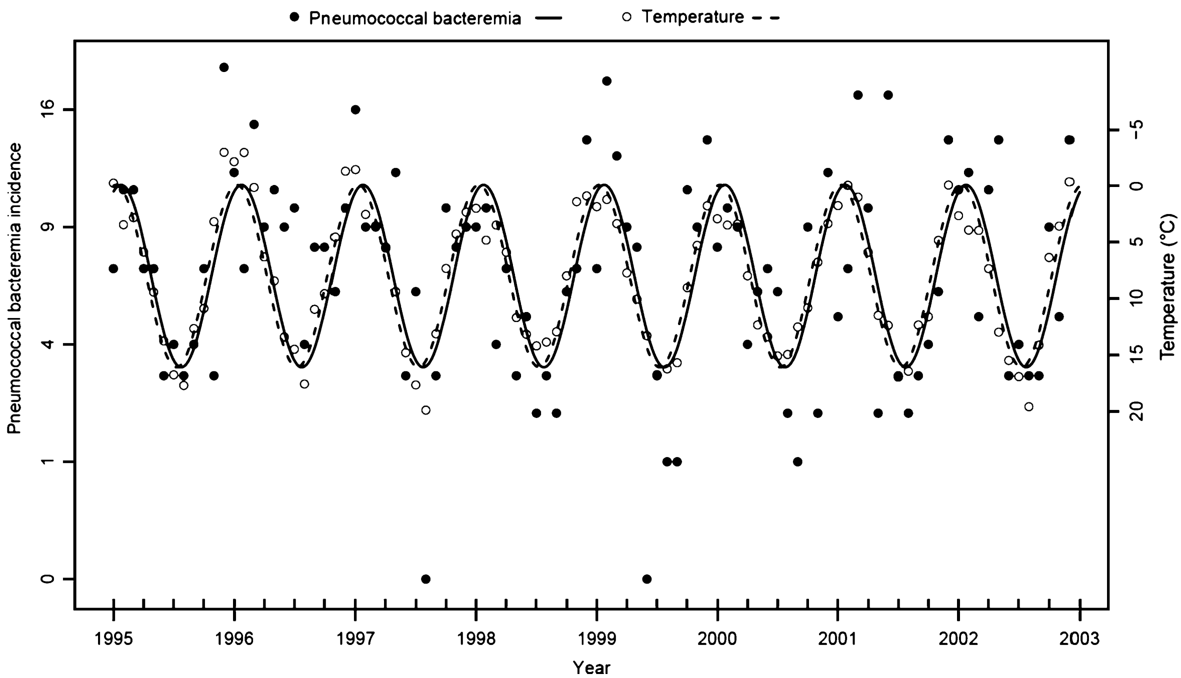

Fig. 1. Monthly incidences of pneumococcal bacteraemia together with monthly mean temperatures in North Jutland County, Denmark, 1995–2003. The panel shows the observed points together with the fitted sinusoids. Black dots and solid line = pneumococcal bacteraemia episodes/month; white dots and dashed line = monthly mean temperatures. Temperature is on a reversed scale.

level in children aged <2 years found that both recent hospitalization for RSV and non-RSV respiratory infection increased the risk of invasive pneumococcal disease [8]. Unfortunately, information on the subjects' age and respiratory viral data were not available from our dataset. Children are the reservoirs for pneumococci in the community [1], and in Denmark's public welfare system, children are usually in day-care centres from the age of 1 year and onwards. The finding of a 2-week lag between temperature drops and peaks of hospitalization with PB is consistent with the hypothesis that increased indoor crowding due to cold weather is followed by increased transmission of respiratory viruses and exchange of new pneumococcal serotypes among children, with subsequent transmission of both to adult contacts, followed by increased occurrence of viral upper respiratory tract infections, pneumococcal pneumonia and, finally, increased occurrence of hospital admissions for PB [1].

In conclusion, this population-based study provides strong evidence that changes in environmental temperature closely predict PB incidence peaks, independently of seasonal patterns.

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TRANSPARENCY DECLARATION

There was no financial support of the study. All authors declare that they have no conflicts of interest.

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