Original Article

Ambient maximum temperature as a function of Salmonella food poisoning cases in the Republic of Macedonia

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Abstract
Background: Higher temperatures have been associated with higher salmonellosis notifications worldwide. **Aims**: The objective of this paper is to assess the seasonal pattern of Salmonella cases among humans. **Material and Methods:** The relationship between ambient maximum temperature and reports of confirmed cases of Salmonella in the Republic of Macedonia and Skopje during the summer months (i.e. June, July, August and September) beginning in 1998 through 2008 was investigated. The monthly number of reported Salmonella cases and ambient maximum temperatures for Skopje were related to the national number of cases and temperatures recorded during the same timeframe using regression statistical analyses. The Poisson regression model was adapted for the analysis of the data. **Results:** While a decreasing tendency was registered at the national level, the analysis for Skopje showed an increasing tendency for registration of new salmonella cases. Reported incidents of salmonellosis, were positively associated ($P<0.05$) with temperature during the summer months. By increasing of the maximum monthly mean temperature of 1°C in Skopje, the salmonellosis incidence increased by 5.2% per month. **Conclusions:** The incidence of Salmonella cases in the Macedonian population varies seasonally: the highest values of the Seasonal Index for Salmonella cases were registered in the summer months, i.e. June, July, August and September.

Keywords: Salmonellosis, ambient maximum temperature, Seasonal Index, Skopje, Republic of Macedonia.

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Introduction
There are over 2,500 different serotypes of Salmonella, but the two most commonly reported, S. Typhimurium and S. Enteritidis, together account for at least 70% of reported human infections in Europe [1].

Higher ambient temperatures increase replication cycles of foodborne pathogens and prolonged seasons may augment the opportunity for food handling mistakes. In 32% of investigated foodborne outbreaks in Europe, "temperature misuse" is considered a contributing factor [2, 3]. Although seasonal temperature variation is a well-known phenomenon in the epidemiology of enteric infections, simple analytical tools for examination, evaluation, and comparison of seasonal patterns are limited. This obstacle also limits analysis of factors beyond temperature associated with seasonal variations [4, 5].

The objectives of this paper are to outline the notion of seasonality; to define characteristics of seasonality; and, to assess seasonal pattern and the effect of one environmental factor (ambient maximum temperature) on the salmonellosis morbidity. In order to better understand any potential impact of season and warmer temperature in

Table 1 Specific salmonelosis morbidity (per 100,000) by age groups for Skopje and Macedonia during the period 1998-2008

Health Indicators	Total	Age groups								
		0 - 6	7 - 9	10 - 14	15 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 >
Skopje (Salmonella No)	1085	327	88	96	85	131	81	95	85	97
Specific Mb./ 100 000	142.4	646.1	400.9	239.0	198.7	141.8	90.3	117.6	108.0	103.8
Macedonia (Salmonella No.)	3890	1023	334	459	297	416	394	385	272	310
Specific Mb./100 000	190.7	622.1	431.6	307.0	183.2	128.5	131.6	131.3	107.4	97.8

particular on salmonellosis as enteric infections in R. Macedonia, we investigated the relationship between ambient maximum temperature and weekly reports of confirmed cases of Salmonella in Skopje between 1998 and 2008.

Materials and Methods

Data on notified cases of Salmonella infection for the period 1998-2008 were obtained from the National Surveillance Centre, i.e., Institute for Public Health of R. Macedonia for the capital city of Skopje and countrywide. The maximum mean weekly temperatures for the study period were obtained from National Hydro-Meteorological Office. The following age groups were also modelled: young children (0–6 years), children (7–14 years); adults (15–59 years); and the elderly (60+ years).

We investigated the epidemiological characteristics of salmonellosis at the national level and city of Skopje using retrospective research as the primary method of research. We created Seasonal Indices for monthly distribution of reported cases for Skopje and the entire country. As noted above, the analytical approach used an adapted Poisson regression model. This technique allowed us to assess any short-term effects of temperature on disease using Statgraphics Centurion software.

Results

Skopje, the capital, is the most populous Macedonian city. According to an official estimate from 2009, 20.5% of the total population registered in the country (2,052,722) lives in Skopje [6].

During the period 1998-2008, nationally, 3,890 salmonella human cases were registered; 1,951 (50.1%) males and 1,939 (49.9%) females. S. Entiritidis with 90% and S. Typhimurium with 8% are predominant serovars causing human infections in the R. Macedonia. 1,085 salmonella cases were reported in Skopje for the same period with an average of 8.2 patients per month (28% of the total national average; about 29 patients per month). Specific morbidity distribution of salmonellosis (rate per 100,000) in Skopje and countrywide are shown as follows (Figure 1).

While a decreasing tendency was registered at the national level, the analysis for Skopje showed increasing tendency of salmonella incidence. The salmonellosis morbidity rate for Skopje in 1998 was 8.3/100,000; in 2000, the rate was 24.6/100,000 and in 2008 was 41.2/100,000.

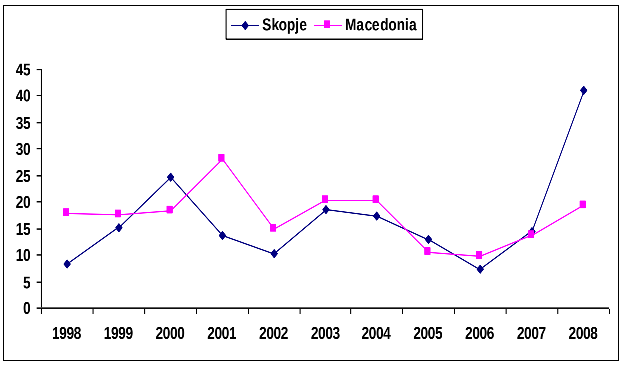

Fig. 1 Reported Salmonella cases in humans in Macedonia and Skopje 1998-2008 (Mb/100.000).

The analysis of specific salmonellosis morbidity by age groups in Skopje showed higher morbidity among 0 to 6 year old children with 646.1/100,000 and lowest among adults from 30 to 39 years old with 90.3/100,000 (Table 1). At the national level, the higher morbidity was registered also among 0 to 6 years old children with 622.1/100,000 but the lowest was recorded among the elderly 60 years and above with 97.8/100,000.

The highest values of the Seasonal Index for Salmonella cases were registered in the summer months, i.e. June with 160.1%, July with 188.6%, August with 171.3% and September with 182.5%. The lowest reported Salmonella cases were registered in February with 20.7% (Figure 2).

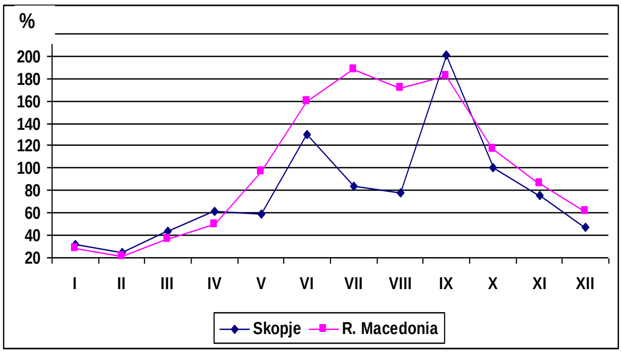

Fig. 2 Seasonal Indexes for reported Salmonella cases in Macedonia and Skopje for the period 1998-2008 -distribution by months

Furthermore, in Skopje, the Seasonal Index for Salmonella cases showed two peaks in the summer months (September with 201.6%, and June with 130.5%). The lowest reported Salmonella cases were registered in February with 24.3%. The largest percentage of outbreaks of salmonellosis in the review period, were registered in the months with the highest seasonal index. A total of 42 outbreaks of salmonellosis or an average of 5 outbreaks per year was registered for the same period with a total 6,015 exposed persons. In these outbreaks, according to data obtained from epidemiological surveys, 1,871 persons (31.1% from total number of exposed) were registered as salmonella cases and 608 patients were hospitalized (32.4% from total registered patients). No deaths were recorded in those outbreaks.

The estimated correlation coefficient (0.54), indicates a moderately strong relationship between the monthly number of reported Salmonella cases for Skopje, and the average monthly maximum temperature at $p<0.05$. The 1 month lag time shows Pearson Correlation coefficient = 0.51 and 2 month lag shows Pearson Correlation coefficient = 0.49. Our investigation indicates that higher and sustained temperatures for longer periods of time are likely to lead to increasing cases of salmonellosis. The 1 month lag time of rising salmonella cases suggests that temperatures might be influential earlier in the production phase. The largest increase of air temperature in the next decades for the Republic of Macedonia is expected in the summer season, associated with a strong decrease in precipitation, due to climate change [7]. It is anticipated that there will be a corresponding rise in the incidence of salmonellosis.

The plot of Poisson distribution with 95% Confidence limits, between the monthly number of reported Salmonella cases for Skopje, and average monthly maximum temperature for the period 1998-2008 has been estimated (Figure 3).

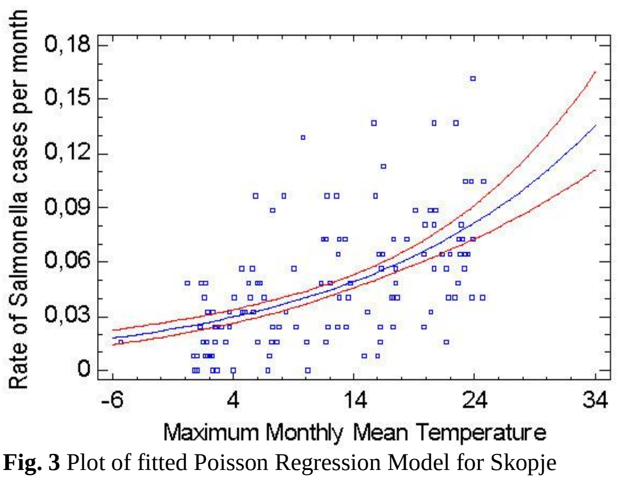

Fig. 3 Plot of fitted Poisson Regression Model for Skopje

The estimated rate ratio for Skopje is 1.052, which means that under conditions of increasing maximum monthly mean temperature of 1°C, salmonellosis incidence will increase 5.2% per month.

Discussion

The Canadian Study showed that, for Alberta, the log relative risk of Salmonella weekly case counts increased by 1.2% for every degree increase in weekly mean temperature [8]. In our Study under conditions of increasing maximum monthly mean temperature for 1°C, the salmonellosis incidence increase for 5.2% per month. Similar higher ambient temperatures have been associated with 5-10% higher salmonellosis notifications for each degree increase in weekly temperature. In other 10 European countries, for ambient temperatures above 5°C, the estimated change in incidence above a common 6°C threshold ranged from 0.3% in Denmark to 12.5% in England and Wales [9].

The strongest effects were found for temperatures 1 week before the onset of illness rather than the longer lag of 1 month found in the Australian study. A significant positive association between mean temperature of the previous month and the number of salmonellosis notifications in the current month, with the estimated increases for a 1°C in temperature ranging from 4% to 10% in five Australian cities were reported [10]. In our Study, food poisoning by salmonellosis, was positively associated with ambient maximum temperature in the previous month, i.e., for each increase in temperature for 1°C resulted in 5.2% increase in salmonellosis notifications in the current month. In the UK, the monthly incidence of food poisoning was most strongly associated with the temperatures occurring in the previous two to five weeks [11]. The time lag of 1 month of rising salmonella cases suggests that temperatures might be influential earlier in the production phase [12].

Roughly one-third of the transmission of salmonellosis (population attributable fraction) in England and Wales, Poland, the Netherlands, the Czech Republic, Switzerland and Spain can be attributed to temperature influences [13]. In our investigation the higher and sustained temperatures for longer periods of time are likely to lead to increasing cases of salmonellosis. Indeed, an analysis of foodborne illnesses from England and Wales showed that the impact of the temperature of the current and preceding week has decreased over the past decades, indicating that the potential risk from elevated temperatures related to climate change can be counteracted through concerted public-health action [14].

Conclusion

The incidence of Salmonella cases in the Macedonian population varies seasonally. During the review period, the highest values of the Seasonal Index for Salmonella cases were registered in the summer months, i.e. June, July, August and September. An understanding of how specific environmental factors influence human disease may improve disease forecasting; enhance the design of integrated warning systems; advance the development of efficient adaptation action plans; and, underline the need for implementing adaptation measures now.

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