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Effect of meteorological variables on the incidence of respiratory tract infections

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Summary
Objective: The possible effect of the various meteorological variables on the incidence of upper and lower respiratory tract infections (RTIs) has intrigued the scientific community for decades.
Methods: We performed a retrospective analysis regarding the association between meteorological variables and clinical data for upper and lower RTIs in the area of Attica, Greece.
Results: There was a statistically significant ($P<0.001$) negative correlation between weekly average temperature with the proportion of weekly house call visits resulting in a diagnosis of upper or lower RTIs 4 days later ($R=-0.56$ and -0.71 for upper and lower RTIs, respectively) as well as 7 days later ($R=-0.57$ and -0.71 for upper and lower RTIs, respectively) and during the same day ($R=-0.55$ and -0.68 for upper and lower RTIs, respectively). In addition, there was a negative correlation between weekly wind chill average (and minimum) temperature as well as a positive correlation of relative humidity with upper and lower RTIs. In contrast, there was no significant correlation between wind speed and upper or lower RTIs.
Conclusions: The findings suggest that house call visits due to upper and lower RTIs increased as the average temperature in the area of Attica decreased.

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Introduction

The possible effect between various meteorological variables on the incidence of upper and lower respiratory tract infections (RTIs) has been a matter of investigation for the scientific community for decades.[1,2] The continuation of scientific interest on the issue is exemplified by recent epidemiological studies that examined the effect of changes of climatic and meteorological variables on an important newly described infection, namely the severe acute syndrome (SARS).[3] Furthermore, there are epidemiological and pathophysiological data supporting an effect of environmental pollution levels in combination with various meteorological factors like temperature, humidity, rainfall, and atmospheric pressure on the upper and lower respiratory system.[4–7] The need for further understanding of the various factors, including meteorological variables, which influence the incidence of RTIs, becomes more evident if someone considers the significant morbidity and mortality of these infections as well as their serious socioeconomic consequences.[8]

The present study focused on the effects of specific meteorological factors, namely average environmental (outdoors) temperature, relative humidity, and wind speed on the incidence of RTIs in the population residing in the region of Attica, Greece.

Methods

Study design

This is a retrospective analysis regarding the association between meteorological variables and clinical data for upper and lower RTIs of patients in the area of metropolitan area of Athens, Attica, Greece.

Meteorological data

We acquired data regarding several meteorological variables that are available for public use from the central weather station situated at the campus of the National Technical University of Athens.[9] This campus is located in the greater area of metropolitan Athens, Attica, Greece and more specifically in the municipality of Zografou (adjacent to the municipality of Athens). From the available information we also computed the wind chill temperature (often mentioned as ''wind chill factor''), an index used to evaluate the apparent temperature felt on exposed skin due to the combination of air temperature and wind speed.[10,11] We used a set of meteorological and clinical data ranging from 01/11/2000 to 18/01/2005 [sample size of 1540 days (220 weeks) based on the intersection of the available sets of meteorological and clinical data].

Clinical data

The clinical data were derived from the archives of SOS doctors, a private organization of doctors providing house call visits to patients in the area of Attica, Greece. The study population was patients who requested medical services from the SOS doctors in the area of Attica, Greece, during the period 01/11/2000–18/01/2005 (although we had available clinical data up for the period 01/11/2000–31/10/2005 there were available meteorological data up to 18/01/2005).[9,12] The study was approved by the Ethics Committee of SOS doctors, Greece. No individual informed consent was obtained from the patients.

Details regarding the availability of physicians and the process of triage of requested medical services and then the visit by a physician at the patient's house have been described in a previous publication.[12] Doctors fill in specially designed forms when completing the evaluation of a patient. Data regarding the chief complaint, history of present illness, past medical, and surgical history, allergies, findings of the physical examination, assessment based on the history and examination, likely diagnosis, and management plan (that may include recommendation for admission to a hospital, laboratory and/or imaging tests, medical and/or surgical treatment, and re-evaluation) are all included in these forms. The diagnosis of upper and lower RTIs was based on clinical findings (history and physical examination).

Design of the analysis

The association between weekly average temperature and the proportion of weekly house call visits (made by SOS doctors) resulting in a diagnosis of upper or lower RTI 4 days later in the area of Attica, Greece was considered as the main analysis during the study design phase. The association between weekly average temperature and the proportion of the same days' weekly house call visits concerning RTIs as well as after a 7-day interval were considered as the secondary analyses. As exploratory analysis we examined the association between weekly average wind chill temperature as well as the weekly minimum temperature, relative humidity, and wind speed with the proportion of weekly house call visits concerning RTIs during the same day as well as 4 and 7 days later. Given that the effect of the wind chill temperature is thought to be absent at temperatures above 20 °C, the sample size was reduced to 150 weeks in an additional subset exploratory analysis.

Statistical testing

We performed statistical tests of correlation between the previously mentioned meteorological variables and the outcomes of interest (upper and lower RTIs) by using Pearson's correlation analysis and obtaining Pearson's correlation coefficient accompanied by the relevant scatter plots. The average weekly values were used. All tests were conducted using SPSS version 13.0 software program (SPSS Inc., Chicago, IL, USA).

Results

In Table 1 we present the results of the statistical analysis. There was a statistically significant negative correlation ($P<0.001$) between weekly average temperature and the proportion of weekly house call visits concerning upper and lower RTIs 4 days later as well as 7 days later and during the same day. Also, there was a statistically significant negative

Table 1 Correlation between various meteorological variables and upper and lower respiratory infections.

Correlation examined	Pearson's *R* bivariate correlation coefficient	*P*-value
Main analysis		
% of house calls for upper RTIs vs. average temperature 4 days earlier	−0.56	<0.001
% of house calls for lower RTIs vs. average temperature 4 days earlier	−0.71	<0.001
Secondary analysis		
% of house calls for upper RTIs vs. average temperature 7 days earlier	−0.57	<0.001
% of house calls for lower RTIs vs. average temperature 7 days earlier	−0.71	<0.001
% of house calls for upper RTIs vs. average temperature on the same day	−0.55	<0.001
% of house calls for lower RTIs vs. average temperature on the same day	−0.68	<0.001
Exploratory analysis		
% of house calls for upper RTIs vs. average wind chill temperature 4 days earlier	−0.39	<0.001
% of house calls for lower RTIs vs. average wind chill temperature 4 days earlier	−0.53	<0.001
% of house calls for upper RTIs vs. minimum temperature 4 days earlier	−0.55	<0.001
% of house calls for lower RTIs vs. minimum temperature 4 days earlier	−0.71	<0.001
% of house calls for upper RTIs vs. relative humidity 4 days earlier	0.39	<0.001
% of house calls for lower RTIs vs. relative humidity 4 days earlier	0.51	<0.001
% of house calls for upper RTIs vs. wind speed 4 days earlier	−0.01	0.91
% of house calls for lower RTIs vs. wind speed 4 days earlier	−0.05	0.46

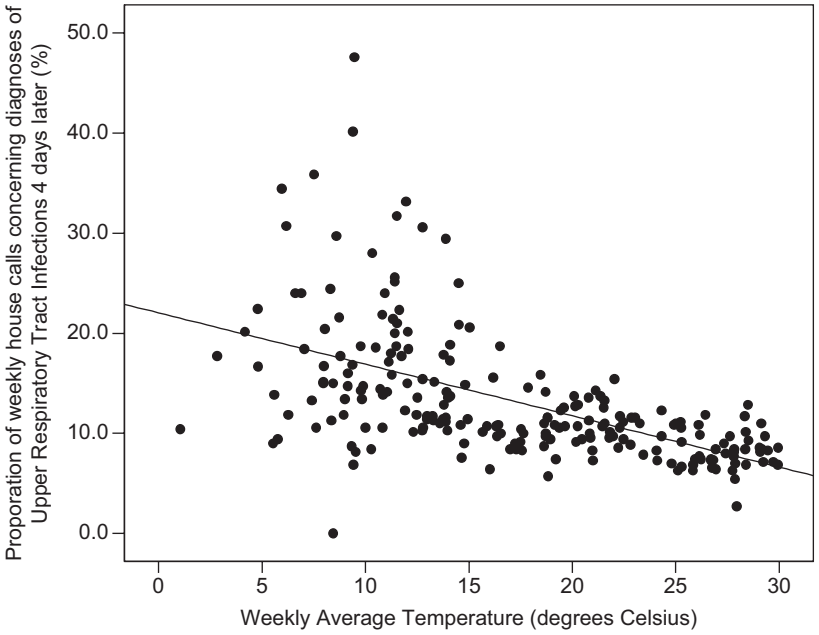

Figure 1 Proportion of weekly house calls for upper respiratory tract infections (*Y*-axis) versus the weekly average temperature in Celsius degrees observed 4 days earlier (*X*-axis).

correlation between weekly wind chill average temperature as well as minimum temperature and the outcomes mentioned above. The negative correlation between wind chill temperature and upper and lower RTIs was also present in the subset exploratory analysis of data regarding the 150 weeks with average temperature $<20\,^{\circ}C$. In addition, there was a positive correlation between relative humidity and the proportion of house call visits concerning upper and lower RTIs. In contrast, there was no significant correlation between wind speed and the examined outcomes.

In Figures 1 and 2 we present data regarding the association between weekly average temperature and the proportion of weekly house call visits resulting in a diagnosis of upper or lower RTI (respectively), 4 days later in the area of Attica, Greece. Both figures graphically depict the association between the examined variables.

Discussion

The main finding of our study is that house call visits due to upper and lower RTIs increased as the average environmental (outdoors) temperature in the area of Attica, Greece decreased. It is interesting that the peak of house call visits

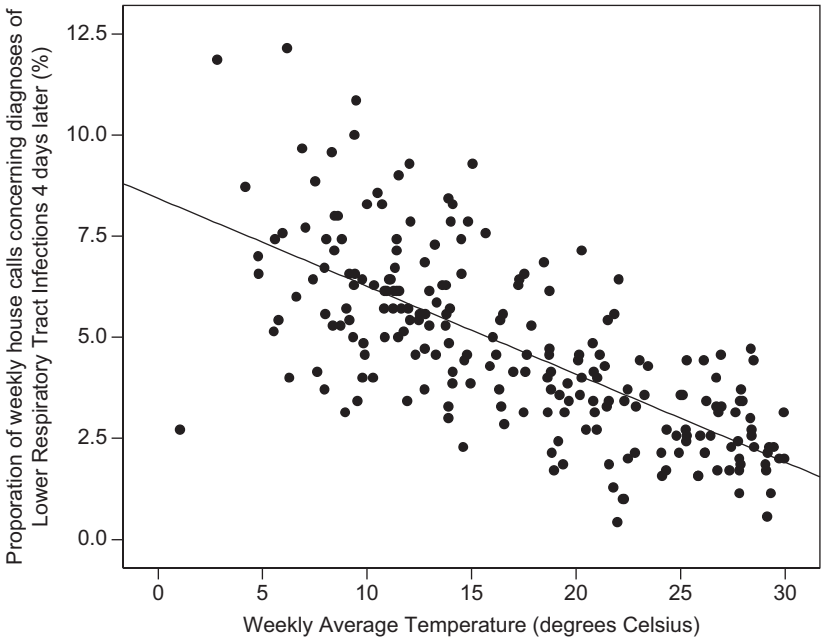

Figure 2 Proportion of weekly house calls for lower respiratory tract infections (*Y*-axis) versus the weekly average temperature in Celsius degrees observed 4 days earlier (*X*-axis).

due to upper and lower RTIs in the studied population was observed when the weekly average temperature reached the one-digit degrees Celsius (Figures 1 and 2).

Our retrospective analysis of meteorological and clinical data from the area of Attica, Greece, offers further support on the association between various meteorological variables and upper and lower RTIs. Although the results of not all previous studies agree, most do support an association between specific meteorological variables and various types of RTIs. Among such associations, these of environmental temperature and influenza and laryngitis/laryngotracheitis have attracted most of the attention of researches and clinicians.[13–17] There has also been a remarkable interest for investigations on the effect of climatic factors on community acquired pneumonia, especially pneumococcal pneumonia, as well as asthmatic bronchitis.[7,18–21] In addition, it is noteworthy that the scientific community has expanded the investigations regarding the meteorological effect on RTIs in animals. In particular, previous studies found a significant association between specific meteorological variables, like rainfall and wind chill temperature, and the occurrence of pneumonia in sheep.[22]

The effect of the exposure to cold on the incidence and severity of RTIs has been reviewed recently.[23] Most of the available evidence from various types of studies does support that exposure to cold is associated with an increased incidence of RTIs, a finding with important public health implications. In addition, the effect of various meteorological variables on other diseases including cardiovascular diseases and respiratory diseases (beyond RTIs) and has been also studied.[24]

The mechanisms by which cold leads to increased incidence of RTIs have not been fully clarified. There is an ongoing controversy among scientists and clinicians regarding the relative contribution of various factors. Among them are the direct effects of cold to viability as well as transmissibility of various types of viruses affecting the respiratory tree, the effects of cold to the function of the respiratory system as well as the immune system leading to susceptibility to infections, and finally the indirect effects of cold to the behavior of people leading to epidemiological changes (such as overcrowding) that permit the transmissibility of RTIs.

Our study has several limitations. First, it is a retrospective analysis, thus it has the problems inherent to this study design. For example, someone may not be sure regarding the accuracy of the diagnosis of an upper or lower RTI in such a study. Such possible inaccuracies in case ascertainment may have influenced the degree of the correlation between the studied meteorological variables and the proportion of house call visits resulting in a diagnosis of upper or lower RTI. Second, it should be mentioned that several factors might have influenced the number of house call visits of SOS doctors during the studied period. For example, house call visits may have been less likely to be done during very cold days for practical reasons related to transportation. For this reason, we elected to study the proportion of house call visits resulting in a diagnosis of upper or lower RTI and not the absolute number of weekly house call visits as the dependent variable (outcome of interest).

Third, the grouping of several types of RTIs into 2 main categories (upper and lower RTIs) may have prevented the identification of stronger or weaker associations between the examined meteorological variables and the various types of RTIs. For this reason we decided, during the design of the analysis phase of the study, to perform analyses of the possible association of the studied meteorological variables with the outcome of interest (proportion of house call visits for upper and lower RTIs) during different times (the day of the measurement of the meteorological variables as well 4 and 7 days later). This was done to take under consideration

the differences in the incubation period of various pathogens leading to RTIs. Finally, the meteorological data we used from the central weather station of the National Technical University of Athens are only indicative of the actual weather conditions in the greater area of Athens during the studied period. However, we believe that any choice of a sole meteorological station would have similar limitations.

In summary, despite the several limitations acknowledged above, we believe that our study adds to the literature useful information regarding the association between various meteorological variables and upper and lower RTIs. The practical implication of the findings of this study is that they may serve, together with results of other relevant studies, as the basis for recommendations for behavioral modifications during cold days that may decrease the effect of the studied meteorological variables on the incidence of RTIs. Such modifiable factors may reduce the serious morbidity and various consequences associated with these infections.

Conflict of interest statement

None to declare.

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