

Effect of meteorological variables on the incidence of lower urinary tract infections

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The influence of environmental factors on human health has long been an intriguing issue. In fact, scientific data support the notion that certain diseases are related to environmental conditions. A seasonal variation has been observed for diverse clinical entities such as myocardial infarction and cervical cancer, and particularly so for several infectious diseases, typically for those with a respiratory mode of transmission [1]. The seasonal variation in the incidence of infectious diseases could generally be attributed to factors like the epidemiology of the culprit pathogens, changes in environmental and meteorological parameters, alterations in human behavior, and even seasonal changes in host physiology.

Urinary tract infections represent a major category of community-acquired infections. Most aspects of the epidemiology of these infections have been clarified, including the

fact that they are encountered more frequently in women, due to anatomical reasons, and adolescents, due to the increased sexual activity in this age group [2]. Still, whether environmental parameters are associated with the occurrence of these infections has not been adequately studied.

In this context, we aimed to assess the effect of meteorological variables, such as environmental temperature and relative humidity, on the incidence of lower urinary tract infections. Specifically, we performed a retrospective study that analyzes the association between meteorological variables and the relative frequency of lower urinary tract infections in a primary care setting. Both meteorological and clinical data were recorded in a systematic prospective manner.

The analyzed meteorological data consisted of average weekly temperature (measured in degrees Celsius) and average weekly humidity (expressed as a percentage), regarding the metropolitan area of Athens, Attica, Greece, in the time period between 1st November 2000 to 18th January 2005 (a total of 1,540 days or 220 weeks). These data were recorded at the meteorological station of the National Technical University of Athens, which is in the municipality of Zografos. The university grants public access to these data (<http://www.meteo.ntua.gr/e/histdata/>).

The analyzed clinical data referred to the types of diagnoses recorded by specialized physicians after house call visits. Patients' demographic characteristics, such as age and sex, were also assessed. The study population included all patients examined after house calls in the region of Attica, Greece, during the time period between 1st November 2000 and 18th January 2005. All of the above-mentioned clinical data were provided by SOS Doctors, which is a private health-care organization that offers urgent medical services. The study was approved by the Ethics Committee of SOS Doctors, Greece.

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The detailed process from the triage of house calls to the subsequent physician's visit at the patient's residence, for the provision of medical services, has been previously reported [3]. Findings regarding the clinical evaluation of the patients were systematically and immediately recorded by the physicians performing the house call visits on a specially designed case report form. Variables included in these forms referred to the presenting symptoms, past and preset medical history, primary clinical findings, most probable diagnosis selected among specific coded diagnostic categories, and suggested treatment. Diagnoses were reached on the basis of clinical criteria, with the additional use of simple bedside tests, at the physician's discretion. Lower urinary tract infections were primarily diagnosed on the basis of characteristic clinical manifestations. A urine dipstick test was used at the physician's discretion. Pyelonephritis, prostatitis, or epididymitis were recorded as separate diagnostic categories.

The primary focus of this study was the temporal association between average weekly temperature as well as average weekly humidity with the weekly percentage of house call visits resulting in a diagnosis of lower urinary tract infection, relative to all house call visits with the exclusion of those performed for respiratory tract infections. Weekly values were elected over daily values to adjust for high frequency variability in the measured variables. A time lag of 3 days between meteorological measurements and the house call visits was arbitrarily elected to adjust for the estimated time interval between the occurrence of a facilitating event and the subsequent development of clinical symptoms/signs of a lower urinary tract infection to the degree that an urgent house call visit by a physician would be performed. The percentage of house call visits for lower urinary tract infections, rather than the absolute number of these infections, was included in the analysis to adjust for the temporal variation in the

number of house calls for SOS Doctors, potentially attributed to factors such as vacation periods, environmental conditions facilitating or precluding the use of other types of primary care services, or the availability of other primary care services. House call visits for upper and lower respiratory tract infections were not taken into account for the calculation of the percentage of house call visits performed for urinary tract infections, so as to correct for the recognized association between the occurrence of the former type of infections and meteorological parameters. In secondary analyses, we evaluated the same above associations without excluding house call visits for respiratory tract infections from the calculation of the percentage of house call visits performed for urinary tract infections, as well as with the use of a 2-day instead of a 3-day time lag between meteorological and clinical measurements.

Variables included in the analysis were examined for normality of data with the one-sample Kolmogorov-Smirnov test. Bivariate correlations between meteorological variables and the percentage of house call visits for urinary tract infections were obtained using Spearman's rho, in the case of variables without a normal distribution, or using Pearson's correlation coefficient, in the case of variables with a normal distribution.

In the time period of the study, 3,221 house call visits of SOS Doctors performed for lower urinary tract infections were recorded. The mean age ($\pm$ standard deviation) of affected patients was 62.9 ($\pm$ 21.0) years. Female patients constituted the majority (53.77%). The outcomes of the analyses are reported in Table 1. In the primary analysis, the weekly percentage of house call visits performed for lower urinary tract infections, relative to all house call visits excluding those performed for respiratory tract infections, recorded 3 days after meteorological measurements, was found to have a significant positive correlation with the average weekly temperature (Spearman's $\rho=+0.468$,

Table 1 Correlation between the weekly percentage of house call visits for urinary tract infections and average weekly meteorological variables

Correlation examined	Spearman's rho	P-value
Main analysis		
% of house calls for urinary tract infections excluding visits for respiratory tract infections vs. temperature 3 days earlier	0.468	<0.001
% of house calls for urinary tract infections excluding visits for respiratory tract infections vs. average relative humidity 3 days earlier	-0.394	<0.001
Secondary analysis		
% of house calls for urinary tract infections including visits for respiratory tract infections vs. average temperature 3 days earlier	0.491	<0.001
% of house calls for urinary tract infections including visits for respiratory tract infections vs. average relative humidity 3 days earlier	-0.406	<0.001
% of house calls for urinary tract infections excluding visits for respiratory tract infections vs. temperature 2 days earlier	0.468	<0.001
% of house calls for urinary tract infections excluding visits for respiratory tract infections vs. average relative humidity 2 days earlier	-0.386	<0.001

$P<0.001$) and a significant negative correlation with the average weekly humidity (Spearman's $\rho=-0.394$, $P<0.001$) (Fig. 1).

In the secondary analysis of the correlation of the weekly percentage of house call visits performed for lower urinary tract infections, relative to all house call visits including those performed for respiratory tract infections, recorded 3 days after meteorological measurements, and the meteorological variables of the average weekly temperature and the average weekly humidity, similar significant associations (Spearman's ρ for temperature=0.491, Spearman's ρ for humidity=-0.406, P -values<0.001) were found as in the primary analysis (Table 1).

In the secondary analysis of the correlation between the weekly percentage of house calls performed for lower

urinary tract infections, relative to all house call visits excluding those performed for respiratory tract infections, recorded 2 days after meteorological measurements, and the meteorological variables of the average weekly temperature and the average weekly humidity, similar significant associations (Spearman's ρ for temperature=0.468, Spearman's ρ for humidity=-0.386, P -values<0.001) were found as in the above analyses (Table 1).

The findings of our study suggest that, in a wide metropolitan area with a temperate climate, higher environmental temperature and decreased humidity are associated with an increase in house call visits for lower urinary tract infections. Due to the large number of observations included in the analysis, statistical correlations are of high significance. It should be mentioned, however, that the strengths of the observed associations are not of a great degree. Nonetheless, strong correlations between the examined parameters would be rather unexpected, considering the multifactorial nature of the pathogenesis of lower urinary tract infections.

The association of temperature and humidity with the development of urinary tract infections could be explained considering that these meteorological parameters affect mood in humans [4] and, therefore, they may affect social behavior, including sexual activity, which is a factor strongly linked to the development of lower urinary tract infections, particularly in women. It should be mentioned, though, that the great majority of patients included in our analysis belonged to less sexually active age groups, so the above presumptive associations could only partly account for the findings of our study. This consideration may explain why women only marginally outweighed men in our study population, whereas in a younger age group, it would be expected that considerably more lower urinary tract infections would be observed in female patients.

Another potential relation between increased environmental temperature and the development of lower urinary tract infections could be attributed to the fact that higher temperature may relate to decreased diuresis, which, in turn, is one of the principal factors associated with the development of urinary tract infections. In detail, increased temperature enhances perspiration and, consequently, the total body water loss [5]. Furthermore, peripheral vasodilation and the pooling of blood in the skin that ensue upon exposure to heat can cause a decrease in effective blood volume. All of these factors may lead, especially in individuals with compromised physiologic responses, to diminished urine output [5]. On the other hand, the physiologic thermoregulatory response to cold includes adrenergic stimulation, which induces peripheral vasoconstriction, along with a rise in cardiac output and blood pressure. These factors in concert with a rise in the concentration of atrial natriuretic peptide may account for

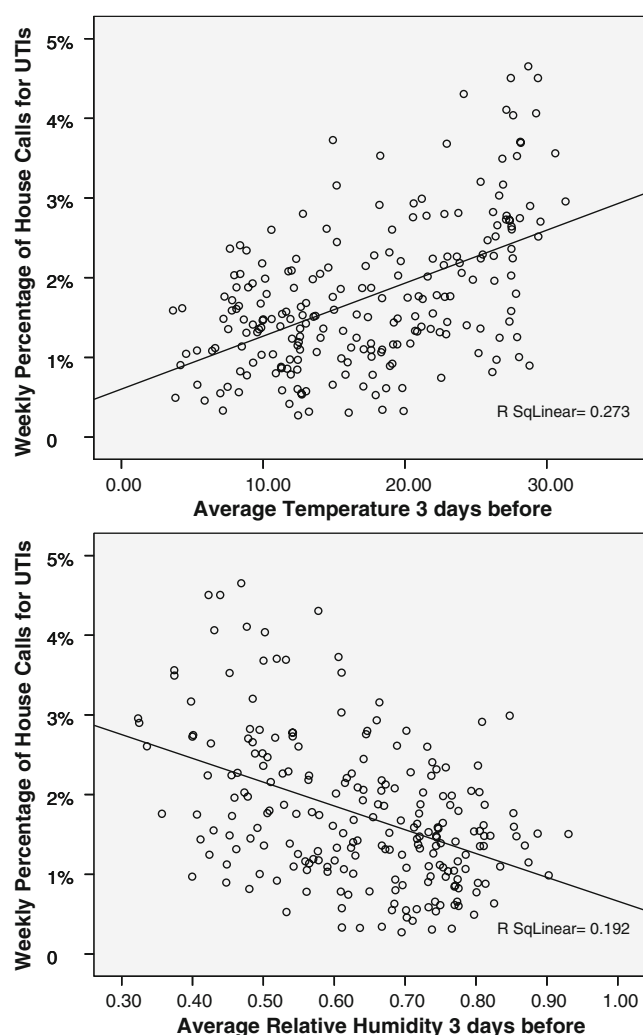


Fig. 1 Scatter plots depicting the correlation of the weekly percentage of house call visits (after the exclusion of respiratory tract infections) for urinary tract infections (UTIs) (Y-axis of the figures) versus the average weekly temperature (degrees Celsius) observed 3 days earlier (X-axis; upper panel) and the average weekly relative humidity observed 3 days earlier (X-axis; lower panel)

the increased diuresis that is frequently observed upon cold exposure. Thus, exposure to cold may facilitate the clearance of potential bacterial contaminants of the urinary tract.

Data in the literature regarding the subject of this study are not conclusive. Specifically, a study performed in Canada has shown a seasonal variation in hospital admissions due to urinary tract infections, although the specific characteristics of the seasonal pattern of these infections were not reported [6]. Another study in South Korea has shown that acute pyelonephritis occurs more commonly during the summer season [7]. To the contrary, there are some reports in children that indicate a temporal association between urinary tract infections and those of the respiratory tract [8, 9]. Whether this association can be translated into a seasonal variation in the incidence of urinary tract infections in children, considering that respiratory tract infections are known to occur more frequently in the winter, is controversial [10].

A number of potential limitations should be taken into account in the interpretation of the findings of our study. First, the diagnosis of lower urinary tract infections was not relied in strict diagnostic criteria, such as urine culture, and, therefore, some cases may have been misclassified. Yet, in routine clinical practice, obtaining urine culture for the diagnosis of acute uncomplicated cystitis is not deemed necessary. The inherent limitations regarding the methodological aspects of retrospective studies should also be considered. Nevertheless, the data included in the analyses of our study were recorded in a prospective manner and should be regarded as of high quality.

Although no selection criterion was applied, the majority of the population included in our study consisted of patients belonging in advanced age groups. This may be attributed to the fact that younger individuals may be more likely to seek primary medical care in other types of services than house call visits. Accordingly, the findings of our study may not be representative of the whole population in the community and, therefore, should be extrapolated with caution in younger age groups. In the same manner, it may not be appropriate to extrapolate the findings of our study in populations residing in areas with substantially diverse climates.

Another shortcoming of our study may be that data regarding the meteorological variables were retrieved from a single meteorological station. It is expected that slight differences in meteorological variables should have existed in other locations within the study area. However, these differences could not have appreciably influenced the findings of the analysis, since variations in the meteorological parameters in different locations of relatively close proximity are expected to be highly correlated.

Despite the aforementioned limitations, the findings of our study may aid in the design and institution of specific

public health preventive measures, such as measures to draw public attention on the need to consume more fluids and to avoid exposure to heat during days of warm and dry weather. This may be particularly important for elderly patients, such as the population of our study, who often have underlying diseases, and, thus, a concomitant infection could cause clinical decompensation.

In conclusion, our study indicates that the occurrence of lower urinary tract infections in the community may be partly associated with meteorological parameters, such as temperature and humidity. Irrespective of the potential interpretation regarding the underlying factors that are responsible for this association, the findings of our study clearly imply that elderly individuals, who constituted the majority of the included patients, may run an increased risk, albeit not of a high degree, for lower urinary tract infections at times of higher environmental temperature or lower humidity. From a public health standpoint, the awareness of this association may facilitate potential preventive strategies.

Conflict of interest None.

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