

Association Between Diurnal Temperature Range and Respiratory Tract Infections*

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Abstract

Objective This study aimed to assess the association between emergency-room visits for respiratory tract infection (RTI) with diurnal temperature range (DTR), a weather parameter closely associated with urbanization and global climate change.

Methods We conducted a semiparametric time-series analysis to estimate the percentage increase in emergency-room visits for RTI associated with changes in DTR after adjustment for daily weather conditions (temperature and relative humidity) and outdoor air pollution.

Results DTR was significantly associated with daily emergency-room visits for RTI. An increase of 1 °C in the current-day (L0) and in the 2-day moving average (L01) DTR corresponded to a 0.94% [95% confidence interval (CI), 0.34%-1.55%] and 2.08% (95% CI, 1.24%-2.93%) increase in emergency-room visits for RTI, respectively.

Conclusion DTR was associated with increased risk of RTI. More studies are needed to understand the impact of DTR on respiratory health.

Key words: Acute respiratory tract infection; Diurnal temperature range; Time-series

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INTRODUCTION

Respiratory tract infection (RTI) is among the most common acute diseases worldwide, leading to considerable morbidity, complications, and days lost from work and school^[1]. It has long been observed that the incidence of these infections increases in temperate

climates during the colder months of the year^[2]. Although possible explanations for this seasonal variation have been suggested (such as increased crowding of people and other hosts of microorganisms that promote transmission or changes in relative humidity that affect the viability of different microorganisms), the role of meteorological variables in the incidence and

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severity of RTI is not well understood^[3].

Diurnal temperature range (DTR) is a meteorological term defined as the difference between daily maximum and minimum temperature within 1 day and serves as a weather parameter closely associated with urbanization and global climate change^[4]. DTR has been identified as an independent risk factor for coronary heart disease^[5-6], stroke^[7-9], and chronic obstructive pulmonary disease (COPD)^[10]. It is unknown whether within-day variation in temperature (ie, DTR) is a risk factor for RTI independent of the corresponding temperature.

We hypothesized that large diurnal temperature variation is a source of additional environmental stress and, therefore, could be a risk factor for RTI. To test the hypothesis, we gathered data including daily weather and emergency-room visits for RTI from a hospital in Shanghai, China.

MATERIALS AND METHODS

Data

Daily emergency-room visits for RTI between January 1, 2008, and June 30, 2009, were collected from Huashan Hospital, one of the largest medical establishments in Shanghai, China. RTI was described in our analysis as a diagnosis of common cold, pharyngitis, laryngitis, croup, viral otitis, sinusitis, acute bronchitis, viral exacerbations in chronic bronchitis, bronchiolitis, and/or community-acquired pneumonia.

Meteorological data, including daily minimum, maximum, and mean temperature and relative humidity, were obtained from the documentation of the Shanghai Meteorological Bureau. The weather data were measured at a fixed-site station located in Xuhui District of Shanghai. As a possible confounding factor in studying the association between DTR and adverse health outcomes, daily air pollution data (PM₁₀, SO₂, and NO₂) recorded during the research period were collected from the Shanghai Environmental Monitoring Center.

Statistical Analysis

The daily emergency-room visits, weather, and air pollution data are linked by date and can be analyzed with a time-series design^[11]. To overcome the serial correlation of time-series data, we used the semiparametric generalized additive model (GAM). As counts of daily emergency-room visits typically

follow a Poisson distribution, the core analysis was a GAM with log link and Poisson error that accounted for smooth fluctuations in number of daily emergency-room visits.

We first fitted nonparametric smoothing terms for trend on days, temperature level, relative humidity (using the smoothing spline function), dummy variable for day of the week (DOW), and linear terms for air pollutant concentrations. DTR was then introduced into the model. Using residual plots and partial autocorrelation function (PACF) plots, residuals of each model were examined to check whether there were discernible patterns and autocorrelation.

On examination of the lag effects of DTR on RTI, we developed two different lag structures: single-day lag from days 0 to 5 and multi-day average starting from lag 0 (up to 5). For example, lag 01 stands for the 2-day moving average of current and previous day values. Because the assumption of linearity between the log of RTI and DTR may not be justified, we used the smoothing function to graphically analyze their relationship.

All data analyses were calculated using S-PLUS 6.2 software (TIBCO Inc., Seattle, WA) using the convergence criteria recommended by Dominici et al.^[12]. An extended GAM function was used to estimate the exact standard errors of the regression coefficients^[13].

RESULTS

From January 1, 2008, to June 30, 2009, a total of 11 017 emergency-room visits for RTI were recorded in Huashan Hospital. On average, there were approximately 20 visits for RTI per day. During our study period, the average daily mean temperature and DTR were 16.4 °C and 7.1 °C, respectively (Table 1).

Table 2 shows results from the single-day lag (L0-L5) and the cumulative exposure models (L01 and L05) for the percentage increase in emergency-room visits for RTI per 1 °C-increase in DTR. The effects of DTR on RTI are statistically significant for single-day lag (L0 and L1) and multi-day lag (L01 and L05; Table 2). For instance, a DTR increase of 1 °C in the current-day (L0) and in the 2-day moving average (L01) corresponded to a 0.94% [95% confidence interval (CI), 0.34-1.55] and a 2.08% (95% CI, 1.24-2.93) increase in emergency-room visits for RTI, respectively.

Figure 1 presents the exposure-response curve for

Table 1. Summary Statistics for Daily Emergency-room Visits for RTI, Weather Conditions, and Air Pollutant Concentrations in Shanghai, China (January 1, 2008 - June 30, 2009)

	Meant±SD	Min	P (25)	Median	P (75)	Max
Emergency-room visits for RTI (n)	20.1±11.4	1.0	11.0	18.0	27.0	64.0
Temperature (°C)	16.4±9.0	-3.4	8.8	17.0	24.1	33.5
DTR (°C)	7.1±3.5	0.6	4.3	6.5	9.5	17.2
Humidity (%)	69.6±13.3	30.3	62.0	71.3	79.0	95.0
PM ₁₀ (µg/m ³)	84.1±46.1	12.0	49.0	76.0	108.0	355.6
SO ₂ (µg/m ³)	46.9±25.4	10.0	27.0	41.0	62.0	163.0
NO ₂ (µg/m ³)	56.7±21.0	14.4	40.0	54.4	67.2	136.0

Note. SD, standard deviation.

Table 2. Percentage Increase in Emergency-room Visits for RTI per 1 °C Increase in DTR

Lag (L)	Percentage Increase (95% CI)
L0	0.94 (0.34-1.55)*
L1	1.72 (1.00-2.44)*
L2	0.47 (-0.13-1.07)
L3	0.46 (-0.09-1.01)
L4	0.37 (-0.17-0.90)
L5	-0.17 (-0.70-0.36)
L01	2.08 (1.24-2.93)*
L05	1.60 (0.62-2.58)*

Note. *P<0.05.

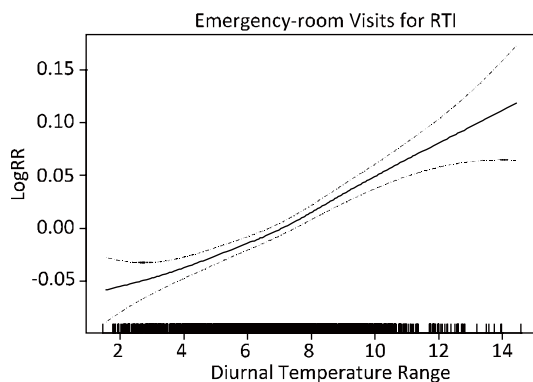


Figure 1. Smoothing Plot of DTR Against Emergency-room Visits for RTI. X-axis is the DTR level (°C, L01). The estimated mean percentage change in RTI is shown by the solid line, and the dotted lines represent twice the point-wise standard error.

the DTR-RTI association (multi-day lag L01). Generally, the DTR levels observed exhibited themselves with linear relationship (chi-square test for linearity, $P>0.05$).

DISCUSSION

Our time-series analysis suggests a significant

association between DTR and emergency-room visits for RTI in Shanghai, China. Previously, the acute effect of environmental factors such as smoking^[14], ambient air pollutants^[15], and temperature^[3,16], on RTI has been documented. Evidence gained in this study shows that temperature variation within 1 day (ie, DTR) is also an important risk factor for RTI. Moreover, the association remained statistically significant after adjustment for temperature level and other covariates, suggesting that DTR is a new risk factor for RTI independent of the corresponding temperature level. To our knowledge, this is the first study to report the relationship between DTR and RTI.

Although the underlying mechanism is still unclear, previous studies have shown that sudden temperature change may increase respiratory workload and induce the onset of a respiratory event^[17]. For RTI, we hypothesized that a wide DTR may be a source of additional environmental stress, and stress on the respiratory system increases during periods of high temperature change. For instance, sudden temperature change of inhaled air has been associated with the release of inflammatory mediators associated with mast cells in a human study^[18]. Also, the decrease in temperature of the respiratory epithelium would result in a decrease in the effectiveness of local respiratory defenses such as mucociliary clearance and leukocyte phagocytosis^[19-20].

There are several limitations in our study. First, we used routinely collected outdoor monitoring data to represent the population exposure to DTR and other weather conditions. Factors such as housing conditions and personal activities may have substantial impact on personal exposure level to weather conditions. Second, our data regarding emergency-room visits came from one hospital only, which may decrease the statistical power to detect the health effect of DTR. Third, we did not include

potential modifiers such as age and sex due to lack of individual-level data for emergency-room visits. Finally, we are not clear about the role of air pollutants in our analysis, as they could be confounders or effect moderators. The interaction between air pollutants and DTR and their influence on health remain unclear.

A noteworthy observation is that DTR is a meteorological indicator associated with global climate change and urbanization^[4]. Data from Shanghai^[5,10,21], Hong Kong^[6], Taiwan^[22], Japan^[8], and Korea^[23] all suggest that DTR contributes to adverse health outcomes. Although the relationship between climate change and DTR varies across the globe, and our findings regarding the association between DTR and RTI may not necessarily apply to other areas of world, our data suggest that even a slight increase in DTR is associated with a substantial increase in RTI. By focusing on potentially preventive factors associated with RTI (eg, DTR), we can more significantly reduce RTI-related health problems.

In summary, we found that DTR may be a new risk factor for RTI. Of course, our findings require replication, especially in areas with different weather patterns and prevalence of air conditioning systems. If our findings are substantiated, public health programs should be implemented to prevent temperature-related health problems, even to the extent of moderating within-day temperature fluctuation.

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