A climatologic investigation of the SARS-CoV outbreak in Beijing, China

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The first cases of severe acute respiratory syndrome (SARS) were identified in November 2002, in Guangdong Province, China. The epidemic spread rapidly within China and internationally, with 8454 recorded infections and 792 deaths by June 15, 2003. Temperature, relative humidity, and wind velocity were the three key meteorological determinants affecting the transmission of SARS. The peak spread of SARS occurred at a mean temperature of 16.9°C (95% CI, 10.7°C to 23.1°C), with a mean relative humidity of 52.2% (95% CI, 33.0% to 71.4%) and wind speed of 2.8 ms^{-1} (95% CI, 2.0 to 3.6 ms^{-1}). In northern China, these conditions are most likely to occur in the spring and suggest that SARS has a seasonal nature akin to viruses such as influenza and the common cold. A regression equation ($Y = 218.692 - 0.698X_t - 2.043X_h + 2.282X_w$) was derived to represent the optimal climatic conditions for the 2003 SARS epidemic. Further investigations in other regions are necessary to verify these results. (Am J Infect Control 2006;34:234-6.)

By June 15, 2003, severe acute respiratory syndrome (SARS) had infected 8454 people and caused 792 deaths in Asia, Europe, and North America.[1-5] Transmission of the SARS coronavirus from animals to humans in southern China was suspected as the source of the disease,[6] and China was the worst affected country, with 5327 clinically diagnosed cases and 343 deaths (http://www.who.int). The epidemic pattern of transmission was complicated by variable persistence of the disease in different age groups, and was facilitated by air travel.[7]

METHODS

Data sources

Information on clinically diagnosed cases, suspected cases, and SARS-caused deaths was abstracted from the daily reports of the China Center for Disease Control, Beijing. At the same time, data on temperature, barometric pressure, relative humidity, wind speed, cloudiness, and precipitation were obtained from the National Meteorological Center Climate Database (http://cdc.cma.gov.cn/).

After a review of both information sets, Beijing was selected as the study site because of the high quality of the data collected. Beijing also was the first city in China to officially recognize the epidemic and begin surveillance, with 2522 SARS cases resulting in 87 deaths recorded between April 3 and June 11, 2003.

Beijing is located in the northwestern part of the North China Plain (39°6′N and 116°6′E), and has a continental climate with four distinct seasons. Spring extends from early March until May, with a mean temperature of 5.8°C to 19.9°C (42.4°F to 67.8°F) and mean rainfall of 8.3 to 34.2 mm (0.33 to 1.35 in).

Statistical analysis

An investigation was conducted into the association between the spread of SARS and 8 climatologic parameters: (1) mean temperature, (2) maximum temperature, (3) minimum temperature, (4) mean barometric pressure, (5) relative humidity, (6) mean wind velocity, (7) mean cloudiness, (8) mean precipitation.

The correlation between the daily numbers of SARS cases and each individual meteorological factor was calculated, with the influence of each factor investigated for up to 20 days before and on the date of clinical diagnosis. This 20-day time period covered the reported mean disease incubation period of 6.4 days, the mean time of 3 to 5 days from the onset of clinical symptoms of SARS to hospital admission, and delays in clinical diagnosis once hospitalized.[7]

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The data were further investigated to determine the effect of prolonged weather conditions over 2- to 5-day periods in the 20 days before clinical diagnosis. Parameters producing significant correlations ($P < .05$) were then used in multiple stepwise linear regression modeling to identify the meteorological factors most strongly correlated with the spread of SARS.

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots + b_mX_m$$

in which Y is the estimated number of SARS cases and X_m is the m^{th} meteorological factor on the selected day or selected period before clinical diagnosis. All analyses were performed using SPSS (version 11.0, SPSS Inc, Chicago, IL).

RESULTS

Significant positive associations ($P < .05$) were obtained for the number of SARS cases in Beijing and wind velocity ($r^2 = 0.617$), barometric pressure ($r^2 = 0.210$), and temperature range ($r^2 = 0.337$). By comparison, relative humidity ($r^2 = -0.784$), temperature ($r^2 = -0.718$), cloudiness ($r^2 = -0.569$), and precipitation ($r^2 = -0.379$) showed negative associations. The peak spread of SARS occurred at a mean temperature of 16.9°C (95% CI, 10.7°C to 23.1°C), with a mean relative humidity of 52.2% (95% CI, 33.0% to 71.4%) and wind speed of 2.8 ms^{-1} (95% CI, 2.0 to 3.6 ms^{-1}). These weather conditions indicate that in northern China the SARS epidemic was most likely to occur in the spring.

To determine the optimal climatic conditions for the 2003 SARS epidemic in Beijing, a regression equation was derived using the most strongly correlated factors:

$$Y = 218.692 - 0.698X_t - 2.043X_h + 2.282X_w$$

in which Y is the estimated number of SARS cases, and X_t, X_h, and X_w are the mean temperature, humidity, and wind velocity, respectively, on the selected day or a selected period during the SARS epidemic. The regression model was tested against rigorous case report data from the Beijing epidemic and found to fit well with the reported daily number of new SARS cases ($r^2 = 0.847$, mean = 58.5, SD = 40.4; Table 1). The strongest associations were identified for the mean temperature and humidity recorded 13 to 17 days before the confirmation of SARS, and the mean wind speed 9 to 13 days before a clinical diagnosis of the disease.

Table 1. Statistical test of the constant and independents in the regression equation
$Y = 218.692 - 0.698X_t - 2.043X_h + 2.282X_w$

Variable	Coefficient of regression (b)	SE	Standardized coefficient (b′)	*t* value	*P* value
Constant	218.69	8.68		5.51	<.001
Temperature (X_t)	−2.04	0.38	−0.45	−5.38	<.001
Humidity (X_h)	−0.70	0.09	−0.50	−7.63	<.001
Wind velocity (X_w)	2.28	0.84	0.21	2.63	<.05

DISCUSSION

It is not possible to predict whether SARS epidemics will reoccur. In addition to the three key elements of the initial epidemic, ie, the causative agent (SARS-associated coronavirus [SARS-CoV]), incubation period (5 to 7 days), and transmission route (from environmental sources, and by direct contact, infected droplets, and aerosolization),[8] the possible role of permissive environmental factors needs to be addressed.

The present study has identified specific climatic conditions that could serve as predictors of a peak of SARS onset. Intuitively, these climatic variables may represent a straightforward outcome of the biological interactions between SARS-CoV and humans, ie, representing the optimal temperature, humidity, and wind velocity for the survival and transmission of the SARS virus. Conversely, weather conditions that seemed to preclude or minimize infection included low humidity, high barometric pressure, and wide daily temperature fluctuations.

Clearly, the Beijing SARS epidemic was too complex to facilitate its explanation solely in terms of a set of climatic variables. Additional factors that merit consideration include the interaction of biological components (the physical characteristics of the virus itself, the infectious dose or viral load received by an individual, the mode of transmission, and differential genetic predispositions of the human hosts), environmental factors (climate, hygiene, density of housing occupation), and public interventions (personal protection, mandatory home quarantine, limitations on public meetings, the isolation of high-risk residents, and rural isolation camps). It also is accepted that external weather conditions may have had a minimal impact in temperature-controlled environments, such as hospitals and airplanes, although how they might have affected the presentation of the disease on exiting these environments is uncertain.

The Beijing data suggest that SARS is likely to behave in a seasonal manner, initially appearing between late autumn and early spring. To predict the course of the disease, it is important that our understanding of associations between environmental factors and climatic determinants in the spread of SARS are improved. With the various public health measures now in place to prevent further outbreaks, this may be difficult. However, in the event that subsequent outbreaks occur, additional analysis of the underlying climatic conditions is needed to verify the seasonal nature of the disease.

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