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Time series analysis of correlativity between pulmonary tuberculosis and seasonal meteorological factors based on theory of Human-Environmental Inter Relation

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—Environmental Inter Relation;
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Abstract *Objective:* This paper aims to study the correlativity between the number of pulmonary tuberculosis (PTB) cases and seasonal meteorological factors in Beijing.
Methods: Based on theory of Human—Environmental Inter Relation in *Huangdi's Internal Classics*, we adopted monthly cases of PTB in Beijing from 2004 to 2011, and established a Seasonal Autoregressive Integrated Moving Average (SARIMA) model. Using the cross-correlation function (CCF), we then analyzed the correlation between meteorological factors and number of infected patients. The related meteorological factors were subsequently integrated, to establish a Seasonal Autoregressive Integrated Moving Average with explanatory variables (SARIMAX) model, which was used to estimate and verify the number of PTB cases in 2012.
Results: In this study, a SARIMA(0,1,1) $(0,1,1)_{12}$ model was established; CCF analysis was used to reveal the correlativity between PTB and precipitation with 1 lag, relative humidity with 1 lag. Then, integrated with relative humidity with 1 lag ($\beta = 2.405$, 95% confidence interval: 0.433—4.377), the SARIMAX prediction model was proved to be an accurate approach for predicting local situations of PTB occurrence.
Conclusions: The occurrence of PTB is correlated with seasonal meteorological factors. Combining these factors, an exact prediction model can be established, to estimate of the number of PTB infected patients.

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Introduction

The "Human—Environmental Inter Relation" is one of the important basic theories of traditional Chinese medicine. This theory believes that both human life activities and diseases are closely related to natural environment and weather. "Feilao" (known as pulmonary obstruction) belongs to the "cough" symptom in *Huangdi's Inernal Classics*, and the symptoms, including cough, deformity, body heat, weak pulse, and described in the *Lingshu Yuban*, are similar to modern pulmonary tuberculosis. Tuberculosis (TB) is an infectious disease caused by *Mycobacterium tuberculosis* infection, and pulmonary tuberculosis (PTB) is the result of this infection affecting the lungs. TB also causes secondary infections when other body parts are infected, such as the neck lymph nodes, meninges, peritoneum, intestines, skin, and bone. The basic transmission route is respiration or contact with respiratory droplets of people with PTB.[1] Common symptom of active PTB is cough, which is sometimes accompanied by expectoration, hemoptysis, thoracalgia, physical fatigue, weight loss, fever, and night sweats.

TB ranks fourth among all causes of death worldwide, and about one-third of the global population has latent TB. Although much progress has been achieved in TB control, the disease remains a global public health problem. According to the World Health Organization Global Tuberculosis Report 2016, about 10.4 million people were infected with TB and 1.8 million people died of the disease in 2015 (http://www.who.int/tb/en/). China is one of 30 countries with the heaviest TB burden and has the second largest population with TB in the world. By 2015, there were about 0.55 billion people infected with TB, with an incidence rate of 98/100,000, which is much higher than the global average rate.[2] TB epidemics and pathogenesis mean that the harm caused by this disease will continue long into the future. TB causes intense patient suffering and a heavy financial burden to families and society, resulting in concomitant social instability. Therefore, TB represents one of the most severe public health hazards in China.

In recent years, many studies have reported that seasonal changes have a certain degree of impact on TB infections. In countries such as Cameroon, India, Kuwait, Spain, the United States, Japan, and South Africa, the incidence of TB has presented a trend of high paroxysm rate in certain seasons.[3—9] The occurrence of TB in China is also evidently periodic and seasonal, occurring most often in the spring, which suggests that the disease may be related to meteorological factors.[10] Wang et al expatiated the correlation between dust storm events and PTB in Minqin, Gansu Province, in northwestern China.[11] Rao et al used spatial clustering panel analysis to obtain the correlation between local incidence of PTB and meteorological factors in Qinghai Province, China.[12] However, no correlation has been reported between the number of PTB cases and meteorological factors in Beijing. Although in Chinese ancient medical books there are a lot of related descriptions of the disease, but there was no record of the correlation between the occurrence of the disease and the four seasons.

Therefore, this study used time series analysis to explore this correlativity between the number of PTB cases and seasonal meteorological factors in Beijing based on the theory of "Human-Environmental Inter Relation" in *Huangdi's Internal Classics*, in order to predict the occurrence of PTB and prevent and treat PTB more effectively with both traditional Chinese medicine theory and modern techniques.

Materials and methods

Characteristics and meteorological features of Beijing

Beijing (39.9°N, 116.3°E), the capital of China, is located on the northern part of the North China Plain. Beijing comprises an area of approximately 16,410 km^2. The climate in Beijing is a warm, temperate, semi-humid and semi-arid monsoon climate, with four distinct seasons: spring is mostly arid; summer is torrid and rainy; autumn is cool and fresh; winter is frigid and dry. Beijing's population rose from 14,930,000 to 20,690,000 during 2004—2012 (http://data.stats.gov.cn/).

Data sources

From January 2004 to December 2012, the number of PTB cases in Beijing was 74,017. These figures were obtained from the National Scientific Data Sharing Platform for Population and Health (http://www.ncmi.cn). Diagnosed cases of PTB were based on the criteria of National Health and Family Planning Commission (formerly the Ministry of Health of China). According to the Law of the People's Republic of China on Prevention and Treatment of Infectious Diseases, PTB is a Class-B infectious disease. The disease surveillance data used in this study were obtained from statutory reports of infectious diseases in Beijing.

We collected data of five basic meteorological factors, from 1 January 2004 to 31 December 2012: average daily temperature (°C), daily average wind speed (m/s), daily precipitation (mm), daily average relative humidity (% RH), and daily average water vapor pressure (hPa). The statistics of these factors were provided by the Beijing Meteorological Bureau. For convenience, daily values were converted into monthly values.

Statistical techniques

The time series analysis Autoregressive Integrated Moving Average (ARIMA) model was first introduced by Box and Jenkins in 1976, and includes an autoregressive (AR) model and moving average (MA) model. Because the ARIMA model can fulfill the duties of practical function and accurate prediction, it has been widely used in the research and prediction of epidemic trends of infectious disease in recent years.[13—15]

When seasonality is integrated into time series analysis, the ARIMA model can be extended to a multiplicative seasonal autoregression integrated moving average model, SARIMA (p, d, q) (P, D, Q)s.[16—21] The SARIMA (p, d, q) (P, D, Q)s model has six parameters: autoregressive parameters

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