The spatial-temporal association between meteorological factors and bacillary dysentery

Xiangxue Zhang

Beijing Normal University

Li Wang

Henan University

Chengdong Xu (✉ xucd@reis.ac.cn)

Institute of Geographic Sciences and Natural Resources Research Chinese Academy of Sciences

Xinchen Gu

Shihezi University

Yuke Zhou

Institute of Geographic Sciences and Natural Resources Research Chinese Academy of Sciences

Gexin Xiao

China National Center for Food Safety Risk Assessment

Jiajun Qiao

Henan University

Research article

Keywords: GeoDetector, spatial-temporal heterogeneity, meteorological factors, bacillary dysentery, Bayesian spatial-temporal hierarchy model

Posted Date: December 16th, 2019

DOI: <https://doi.org/10.21203/rs.2.18965/v1>

License: This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background

Bacillary dysentery remains a worldwide public health problem, which has been found to have spatial–temporal heterogeneity, however most studies have only focused on the disease from either a time or space perspective, the spatial–temporal association between them has been still unclear.

Method

In this study, the Bayesian space–time hierarchy model was used to identify the spatial-temporal patterns of this disease in Shandong province, China. And then GeoDetector was used to quantify the determinant power of meteorological factors and their interactive effect among different regions in Shandong.

Results

The results indicated that, temporally, the incidence peaked in summer. Geographically, the hot spots were distributed discretely among three regions, among which the effect of meteorological factors on this disease exist significant discrepancy. The most important two dominant factors of eastern coastal region were wind speed and average temperature, with determinant powers of 28% and 25%, respectively. The first two dominant factors of western inland region were average temperature and precipitation, with determinant powers of 47% and 32%, respectively. The first two dominant factors of middle region were average temperature and wind speed, with determinant powers of 66% and 48%, respectively.

Conclusions

These findings suggest that in a hot and humid environment would boost the transmission of bacillary dysentery, which can be served as a suggestion and basis for the surveillance and will be helpful for this disease control and implementing disease-prevention policies.

Background

Bacillary dysentery is an enteric infectious disease caused by different species of *Shigella* (*S. dysenteriae*, *S. flexneri*, *S. boydii*, and *S. sonnei*), a group of Gram-negative, non-spore–forming, and rod-shaped bacteria [1,2]. This disease is mainly transmitted through the fecal–oral route or by contaminated food and water and contact among persons [3,4]. Typically, symptoms include diarrhea, fever, tenesmus, and mucus blood [5].

Up to now, bacillary dysentery has remained a common global public health problem for both developed and developing countries [6,7]. Annually, there are more than 160 million reported cases and 1.1 million deaths worldwide [8]. In China, the disease has caused about 300 deaths annually in the last decades and, in 2015, was perceived as one of the top five infectious diseases [9]. Due to the mechanism of bacillary dysentery is not completely clear, it may cause an epidemic at any time. Therefore, researching

the spatial-temporal heterogeneity of bacillary dysentery incidence and quantify the determinant powers of meteorological factors among different areas would provide suggestions for bacillary dysentery risk control and implementing disease-prevention policies, which were adapted to local conditions.

It is widely accepted in numerous studies that meteorological factors have significant effects on the transmission of bacillary dysentery. For example, in Beijing, the capital of China, the highest incidence occurs from June to September [10]. A study in Jinan, a northern city in China, demonstrates that the risk reaches its peak in the summer and fall seasons [11]. In India, the peak of bacillary dysentery mostly occurs in hot summer [12]. In Dhaka, a city in southern Asia, from September to December, a high incidence occurs [13]. From these numerous previous studies, it can be seen that meteorological factors indeed have an impact on the temporal heterogeneity of bacillary dysentery incidence [14-16].

Meanwhile, the incidence of bacillary dysentery also presents obvious spatially non-homogeneous. Some studies have demonstrated that it is closely related to socioeconomic factors because an overcrowded environment or poor health conditions along with an inadequate infrastructure promote the transmission of bacillary dysentery. For example, Kotloff et al. indicated that the incidence of bacillary dysentery in China was higher than that in many developed countries, such as the United States, England, Australia, and France [17]. Chang et al. denoted that the incidence of this disease in northwest China (including Tibet, Ningxia, and Xinjiang) and northern China (including Beijing and Tianjin) was higher than other regions in China [18]. Similarly, Xu et al. denoted that Beijing and Tianjin, two developed cities, ranked in the top two among China's cities for bacillary dysentery risk [10].

To our knowledge, few studies have concentrated on the heterogeneity of bacillary dysentery from a spatiotemporal perspective and meanwhile, quantified its spatiotemporal heterogeneity, effects of meteorological factors and their interactive effect on this disease among different regions. The aims of this study were to 1) explore the county-level spatiotemporal heterogeneity of bacillary dysentery risk, and 2) quantify the determinant powers of meteorological factors and their interactive impact, and 3) detect the hot, cold spots and its mechanisms.

Methods

Study area

Shandong, a coastal province in eastern China, in which some areas located in the east and north extend into the sea, while the central and western areas are mountainous and hilly, as a part of the North China Plain (Fig. 1). It contains 17 cities with a population of 156,700 km² and a total area of 97.3 million, Jinan serve as the Shandong province's capital and the cultural center. Accordingly, the climate varies greatly across the coast to the inland areas due to the effect of geological environment. The average temperature changes from the coast in the northeast to the southwest, and the coastal cities reach high temperature later than the inland cities in a year. Based on these factors, in this study, Shandong is divided three regions: eastern (Qingdao, Dongying, Yantai, Weifang, Weihai and Rizhao), central (Jinan,

Zibo, Zaozhuang, Jining, Taian, Laiwu, Linyi and Binzhou) and western (Dezhou, Liaocheng and Heze) [19], to detect the spatial-temporal heterogeneity and the determinant powers of meteorological factors, respectively.

Data sources

Weekly data on bacillary dysentery cases were gained from the Chinese Centre for Disease Control and Prevention, which were from September 1, 2012, to August 31, 2013. Weekly meteorological data from the same period, including relative humidity, wind speed, and hours of sunlight, were collected from the China Meteorological Data Sharing Service System (Fig. 2).

The study design based on GeoDetector and Bayesian space–time hierarchy model to quantify the associations between meteorological factors and bacillary dysentery from spatial-temporal perspectives among different regions.

GeoDetector

The GeoDetector q statistics was used to quantify the determinant power of impact factors from spatial-temporal perspectives and the stratified heterogeneity of a responding variable (the temporal and spatial variations of bacillary dysentery risk) [20–22], calculated as:

$$q = 1 - \frac{1}{N\sigma^2} \sum_{h=1}^L N_h \sigma_h^2 \quad (1)$$

where q quantifies the determinant powers of meteorological factors and meanwhile measures the spatiotemporal stratified heterogeneity for the target variable (i.e., bacillary dysentery risk), which value ranges from 0 to 1, denoting the determinant power of a risk factor or a target variable's heterogeneity. The number of counties represented by N , and σ^2 and σ_h^2 are the variance over all the statistical units in the study area and within stratum h ($h = 1, 2, \dots, L$), respectively.

Bayesian space–time hierarchy model

The Bayesian space–time hierarchy model (BSTHM) was contributed to reveal the spatiotemporal patterns of this disease. Exactly, a BSTHM with Poisson distribution was used in modeling the number of cases y_{it} and the risk population n_i as follows:

$$\begin{aligned} y_{it} &\sim \text{Poisson}(n_{it}u_{it}) \\ \log(u_{it}) &= \alpha + s_i + (b_0t^* + v_t) + b_{1i}t^* + \varepsilon_{it} \end{aligned} \quad (2)$$

where u_{it} describes the spatiotemporal risk of bacillary dysentery in county i ($i = 1, \dots, 103$) and week t ($t = 1, \dots, 53$). The term α is the fixed effect. The index s_i indicates the spatial disease risks in county i , affected by some relative stable factors in the study period, such as local geographic environment, economic conditions, and medical resources. The temporal term $b_0t^* + v_t$ expresses the overall time trend with $v_t \sim N$

$(0, \sigma_v^2)$, and t^* represents the time span relative to the midpoint t_{mid} over the study period. And b_{1i} captures the departure extent from b_0 for county i , such as, if $b_{1i} \geq 0$, the local variation intensity is higher than the overall variation trend [23]. The term $\varepsilon_{1i} \sim N(0, \sigma_\varepsilon^2)$ represents the Gaussian noise random variable, according to Gelman [24].

Then, the study area was further classified into hot, cold, and other spots in accordance with the following criteria [25]. A county was defined as a hot spot if the posterior probability $p(\exp(s_i) > 1 \mid \text{data}) \geq 0.975$. Conversely, if that value less than 0.025, the county was defined as a cold spot. The remaining counties were considered as neither hot nor cold spots, in which all processes were implemented in the WinBUGS software [26].

Results

Spatiotemporal Heterogeneity Detection

Between September 1, 2012, and August 31, 2013, a total of 8,014 cases in 53 weeks of bacillary dysentery in 103 counties were reported in Shandong Province. The highest number of cases occurred in summer (June to August), with a monthly incidence of 1.22 per 10,000 people. The lowest number of cases appeared in winter (December to February), with a monthly incidence of 0.35 per 10,000 people.

Geographically, the relative risks (RRs) differed dramatically, with the q statistic value of 0.51, indicating that there exists apparent spatial heterogeneity. Figure 3 presents the spatial RRs of bacillary dysentery by county level from 2012 to 2013. The spatial RRs of counties in eastern and northern Shandong mostly located in coast areas were higher, denoting that these counties have relatively higher bacillary dysentery risk. Conversely, counties in western and southern Shandong mainly belong to inland regions, presented relatively lower disease risk.

Additionally, the overall temporal trend presents an increase (Fig. 4), and meanwhile there remains seasonality, in which the highest disease risk occurred in summer (June to August) and the lowest disease risk occurred in winter (December to February), indicating that the risks of bacillary dysentery have obvious temporal heterogeneity, demonstrated by the q statistic value of 0.51.

Among the 103 counties in Shandong, 13 (12.62%) and 12 (11.65%) counties were perceived as hot and cold spots, respectively. Another 78 (75.73%) counties were considered to be neither hot nor cold spots. Figure 5 presents that hotspot areas were mainly distributed in the eastern and northern coast areas.

Risk Factor Analysis

The bacillary dysentery risk is obviously related to seasonal changes (Fig. 2 and 4), indicating that meteorological factors play a dominant role in the temporal evolution of the disease. In this study, the

GeoDetector model was introduced to quantify individual meteorological factors and their interactive impacts. The result show that, the top factors with the higher determinant power are average temperature, precipitation and wind speed in three different regions.

Specifically, in middle mountainous areas, average temperature presents the most dramatically relationship with bacillary dysentery, with a q value of 0.66, it was the dominant factor explaining the temporal variation of the bacillary dysentery incidence (Table 1).

The other selected potential meteorological risk factors also have a non-negligible impact, such as, wind speed and precipitation had significant association with a higher extent of deviations, with q values of 0.48 and 0.22, respectively (Table 1).

The results of interactive impacts in GeoDetector denote that combined effect between randomly two meteorological factors also play an important role in the transmission of bacillary dysentery. Taking an example, in central regions, the determinant power of average temperature and relative humidity is 0.82, the determinant power of average temperature and sun hour is 0.82, and the determinant power of average temperature and precipitation is 0.81 (Table 1). Among these meteorological factors, comparing with their independent influence, all shows “bivariate enhance” effect.

Meanwhile, in western hilly areas, there also was a strong relationship between bacillary dysentery and average temperature, with the value of q being 0.47 (Table 2). Precipitation and wind speed have a similar determinant power with a higher extent of deviations, and q values were 0.32 and 0.32, respectively (Table 2).

The results of interaction in GeoDetector indicate that interactive impact between randomly two meteorological factors also play an important role in the transmission of bacillary dysentery. For example, in western regions, the determinant power of average temperature and wind speed is 0.64, the determinant power of wind speed and sun hour is 0.62, and the determinant power of sun hour and precipitation is 0.58 (Table 2). Comparing with their independent influence among these meteorological factors, all shows “bivariate enhance” effect.

Additionally, in eastern coastal areas, wind speed presents the most significant impact on the bacillary dysentery, with the value of q was 0.28. And then average temperature and sun hour also show obvious association with bacillary dysentery, with the q value was 0.25 and 0.22, respectively (Table 3).

And the results of interaction in GeoDetector present that interactive effect between randomly two meteorological factors play an important role in the transmission of bacillary dysentery. For example, in eastern regions, the determinant power of sun hour and wind speed is 0.71, the determinant power of wind speed and precipitation is 0.69, and the determinant power of sun hour and average temperature is 0.59 (Table 3). Comparing with their independent influence among these meteorological factors, also shows “bivariate enhance” effect. These results indicated that a hot and moist environment is more likely to promote the transmission of bacillary dysentery.

Discussion

Bacillary dysentery has remained a worldwide public health threat in recent years [6,7]. In this study, the spatiotemporal heterogeneity of the disease risk was examined by BSTHM, and the effects of meteorological factors on bacillary dysentery were measured by GeoDetector. Results indicated that the risk of bacillary dysentery was relatively higher in eastern and northern Shandong and meteorological factors, especially temperature, have the most significant effect on disease risk among different regions.

The spatial distribution of bacillary dysentery risk was non-homogeneous in Shandong. Counties with the highest risk (hot spots) of this disease were discretely distributed in the eastern, north central coastal areas and southwestern, where the economic level has significant difference, such as, higher in eastern or lower in western areas, which were consent to previous studies [10,18]. Although the exact mechanism cannot be explained completely, several reasons include but are not limited to the followings. On the one hand, in these regions, a moist environment would promote the virus to breed and spread. On the other hand, economies in these areas are almost higher than other parts of Shandong, contributing to a high population density and attracting a large migrant population from other counties; while, economies in western areas are almost lower than other parts of Shandong, poor medical conditions, imperfect public facilities and lack of personal hygiene awareness, which explain the high risk of bacillary dysentery in these areas.

Meanwhile, the risk of bacillary dysentery presents obvious seasonality. Meteorological factors are perceived as crucial environmental factors, which are widely accepted, influencing the breeding and spreading of viruses that cause this disease [14, 27-29]. This study found that average temperature takes on the strongest positive association with bacillary dysentery risk among different areas, especially to the central regions, the value of q was 0.66, which was coincide with the findings of other studies. For example, Gao et al. demonstrated that, in Changsha, the incidence of bacillary dysentery would rise by 14.8% as 1°C increase in average temperature [30]. A study, conducted in Jinan, also found that, as each 1°C increase in average temperature, the incidence of bacillary dysentery is responded to increase by 11% [15]. The conduction is similar to that in Peru, where it was found that bacillary dysentery risk increased by 8% with a rise of 1°C in temperature [31]. In the United Kingdom, a rise in average temperature was associated with a 5% increase in the bacillary dysentery risk [32]. The potential mechanism may be that higher temperatures enhance exposure to pathogens, promote the breeding of the bacteria, and prolong the survival of bacteria in the moderate environment and contaminated food or water [31]. Another mechanism could be that moderate and warm temperatures in the environment may promote specific behavioral patterns in the population, such as more outdoor activities, which can increase contact among people, thereby facilitating the spread of bacillary dysentery infection.

Precipitation was also found to have strong association with bacillary dysentery, especially in western areas with the q value was 0.32. This result was consistent with some of previous studies, such as, Ma et al. denoted that there was a strong correlation between the incidence of bacillary dysentery and precipitation [33], whereas Li et al. indicated that precipitation have a significant impact on the incidence

of bacillary dysentery [34]. The potential impact mechanism may be that precipitation affects water and food, which affects the growth and reproduction of bacteria, and therefore has a certain role in promoting the transmission of this disease.

Furthermore, in this study, wind speed also was found to have significant association with bacillary dysentery, especially to eastern regions. Notably, the effect of wind speed on bacillary dysentery in past research was not always consistent. A previous study conducted by Li et al. denoted that wind speed does not affect the incidence of bacillary dysentery [34], while Liu et al. demonstrated that, in low wind speed conditions, the number of bacillary dysentery incidences would increase [15]. Reasons for these phenomena could be that regional characteristics in different study areas may have different climate conditions, thus affecting the epidemiology of bacillary dysentery.

Additionally, the interactive effect of these meteorological factors was non-negligible among three regions. Taking some examples, in central regions, the determinant power of average temperature combined with relative humidity was 0.82; in eastern regions, the determinant power of wind speed integrated with sun hour was 0.71; in western regions, the determinant power of average temperature and wind speed was 0.64. A potential explanation was that a hot and moist environment would enhance the breeding of bacteria, furthermore promote the transmission of this disease. And strong wind would also play an important role in the spread of this disease by facilitating the transmission of bacterial.

This study has some limitations that should be mentioned. Firstly, spatial data at the county level was used, introducing an inevitably ecological fallacy [35]. Second, other risk factors for bacillary dysentery that were not included in the model may have introduced some uncertainties.

Conclusions

This study presents the detailed spatiotemporal heterogeneity of bacillary dysentery and quantifies the determinant powers of meteorological factors on this disease from 2012 to 2013 in Shandong Province, China. Specifically, the hot spots (high-risk areas) were distributed in the eastern and northern coastal counties, western inland areas. Meanwhile, there had an apparent seasonality, and high risk mostly occurred in hot and moist environments. Therefore, these findings show that public health preparations should be enhanced to prevent and control a potential increased risk of bacillary dysentery under this weather condition, meanwhile considering the difference among different areas.

Abbreviations

HFMD: Hand, foot and mouth disease; BSTHM: Bayesian Space-Time Hierarchy Model; RR: Relative risk

Declarations

Ethical approval and consent to participate

Not applicable.

Consent for publication

N/A

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to policy of Chinese Disease Control and Prevention.

Competing interests

The all authors declare that they have no competing interests.

Funding

The study was supported by the following grants: National Natural Science Foundation of China (41601419); Innovation Project of LREIS (O88RA205YA). And the funders played no role in this study.

Authors' contributions

ZXX and XCD conceived and designed the experiments; ZXX, GXC and WL performed the experiments; ZXX and XGX analyzed the data; ZXX, ZYK and QJJ contributed reagents, materials, analysis tools; ZXX and XCD wrote the paper. And all authors have read and approved the manuscript.

Acknowledgements

The authors wish to thank the National Natural Science Foundation of China (41601419); Innovation Project of LREIS (O88RA205YA).

References

1. Kotloff KL, Riddle MS, PlattsMills JA, et al. Shigellosis. Lancet. 2018; 391(10122) : 801-12.
2. Livio S, Strockbine NA, Panchalingam S, et al. Shigella isolates from the global enteric multicenter study inform vaccine development. Clinical Infectious Diseases. 2014; 59(7): 933-41.
3. Mather AE, Baker KS, McGregor H, et al. Bacillary dysentery from world war 1 and NCTC1, the first bacterial isolate in the national collection. Lancet. 2014; 384(9955): 1720.
4. Lee LA, Ostroff SM, McGee HB, et al. An outbreak of shigellosis at an outdoor music festival. American Journal of Epidemiology. 1991; 133(6): 608-15.
5. Simini B. Shigellosis strikes Italian cruise ship passengers. Lancet. 1996; 348(9029): 742.
6. Vincent JL, Marshall JC, NamendysSilva SA, et al. Assessment of the worldwide burden of critical illness: the Intensive Care Over Nations (ICON) audit. Lancet Respiratory Medicine. 2014; 2(5): 380-6.

7. Ombelet S, Ronat JB, Walsh T, et al. Clinical bacteriology in low-resource settings: today's solutions. *Lancet Infectious Diseases*. 2018; 18(8): E248-58.
8. Kotloff KL, Winickoff JP, Ivanoff B, et al. Global burden of Shigella infections: implications for vaccine development and implementation of control strategies. *Bulletin of the World Health Organization*. 1999, 77(8): 651-66.
9. National Health and Family Planning Commission of the PRC. 2015, Available online:<http://www.nhfpc.gov.cn/jkj/s3578/201602/b9217ba14e17452aad9e45a5bcce6b65.shtml> (accessed on 18 February 2016).
10. Xu CD, Lihaode Y, Wang JF, et al. Spatial-temporal detection of risk factors for bacillary dysentery in Beijing, Tianjin and Hebei, China. *BMC Public Health*. 2017; 17: 743.
11. Zhang Y, Bi P, Hiller JE. Weather and the transmission of bacillary dysentery in Jinan, northern China: A time-series analysis. *Public Health Reports*. 2008; 123(1): 61-6.
12. Moors E, Singh T, Siderius C, et al. Climate change and waterborne diarrhoea in northern India: Impacts and adaptation strategies. *Science of the Total Environment*. 2013; 468: S139-51.
13. Albert MJ, Faruque ASG, Faruque SM, et al. Case-control study of enteropathogens associated with childhood diarrhea in Dhaka, Bangladesh. *Journal of Clinical Microbiology*. 1999; 37(11): 3458-64.
14. Liu J, Wu X, Li C, et al. Identification of weather variables sensitive to dysentery in disease-affected county of China. *Science of the Total Environment*. 2017; 575: 956-62.
15. Liu Z, Liu Y, Zhang Y, et al. Effect of ambient temperature and its effect modifiers on bacillary dysentery in Jinan, China. *Science of the Total Environment*. 2019; 650: 2980-6.
16. Li ZJ, Zhang XJ, Hou XX, et al. Nonlinear and threshold of the association between meteorological factors and bacillary dysentery in Beijing, China. *Epidemiology and Infection*. 2015; 143: 3510-9.
17. Yan L, Wang H, Zhang X, et al. Impact of meteorological factors on the incidence of bacillary dysentery in Beijing, China: A time series analysis (1970-2012). *Plos One*. 2017; 12: e0182937.
18. Chang Z, Zhang J, Ran L, et al. The changing epidemiology of bacillary dysentery and characteristics of antimicrobial resistance of Shigella isolated in China from 2004-2014. *BMC Infectious Diseases*. 2016; 16: 685.
19. Zhu L, Wang XJ, Guo YM, et al. Assessment of temperature effect on childhood hand, foot and mouth disease incidence (0-5years) and associated effect modifiers: A 17 cities study in Shandong Province, China, 2007-2012[J]. *Science of The Total Environment*. 2016; 551: 452-9.
20. Wang JF, Li XH, Christakos G, et al. Geographical Detectors-based health risk assessment and its application in the neural tube defects study of the Heshun region, China. *International Journal of Geographical Information Science*. 2010; 24(1): 107-27.
21. Wang JF, Zhang TL, Fu BJ. A measure of spatial stratified heterogeneity. *Ecological Indicators*. 2016; 67: 250-6.
22. Wang JF, Xu CD. Geodetector: Principle and prospective. *Acta Geographica Sinica*. 2017; 72(1): 116-34.

23. Li G, Haining R, Richardson S, et al. Space-time variability in burglary risk: A Bayesian spatio-temporal modelling approach. *Spatial Statistics*. 2014; 9: 180-91.
24. Gelman A. Prior distributions for variance parameters in hierarchical models. *Bayesian Analysis*. 2006; 1(3): 515-33.
25. Richardson S, Thomson A, Best N, et al. Interpreting posterior relative risk estimates in disease-mapping studies. *Environmental Health Perspectives*. 2004; 112(9): 1016-25.
26. Lunn DJ, Thomas A, Best N, et al. WinBUGS - A Bayesian modelling framework: Concepts, structure, and extensibility. *Statistics and Computing*. 2000; 10(4): 325-37.
27. Cheng J, Xie MY, Zhao KF, et al. Impacts of ambient temperature on the burden of bacillary dysentery in urban and rural Hefei, China. *Epidemiology and Infection*. 2017; 145(8): 1567-76.
28. Guan P, Huang D, Guo J, et al. Bacillary dysentery and meteorological factors in Northeastern China: A historical review based on classification and regression trees. *Japanese Journal of Infectious Diseases*. 2008; 61(5): 356-60.
29. Lee CCD, Tang JH, Hwang JS, et al. Effect of meteorological and geographical factors on the epidemics of hand, foot, and mouth disease in island-type Territory, East Asia. *BioMed research international*. 2015; 2015: 805039.
30. Gao L, Zhang Y, Ding G, et al. Meteorological variables and bacillary dysentery cases in Changsha City, China. *American Journal of Tropical Medicine and Hygiene*. 2014; 90(4): 697-704.
31. Checkley W, Epstein LD, Gilman RH, et al. Effects of El Nino and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. *Lancet*. 2000; 355(9202): 442-50.
32. Tam CC, Rodrigues LC, O'Brien SJ, et al. Temperature dependence of reported campylobacter infection in England, 1989-1999. *Epidemiology and Infection*. 2006; 134(1): 119-25.
33. Ma S, Tang Q, Liu H, et al. Correlation analysis for the attack of bacillary dysentery and meteorological factors based on the Chinese medicine theory of Yunqi and the medical-meteorological forecast model. *Chinese Journal of Integrative Medicine*. 2013; 19(3): 182-6.
34. Li Z, Wang L, Sun W, et al. Identifying high-risk areas of bacillary dysentery and associated meteorological factors in Wuhan, China. *Scientific Reports*. 2013; 3: 3239.
35. Jelinski DE, Wu JG. The modifiable areal unit problem and implications for landscape ecology. *Landscape Ecology*. 1996; 11(3): 129-40.

Tables

Table 1. The q statistic values of all meteorological factors in central regions.

Meteorological factors	Mean temperature	Relative humidity	Precipitation	Wind speed	Sun hours
Mean temperature (°C)	0.66				
Relative humidity (%)	0.82	0.12			
Precipitation (mm)	0.81	0.62	0.22		
Wind speed (m/s)	0.78	0.67	0.61	0.48	
Sun hours (h)	0.82	0.34	0.61	0.64	0.17

Table 2. The q statistic values of all meteorological factors in western regions.

Meteorological factors	Average temperature	Relative humidity	Precipitation	Wind speed	Sun hours
Average temperature (°C)	0.47				
Relative humidity (%)	0.53	0.30			
Precipitation (mm)	0.51	0.40	0.32		
Wind speed (m/s)	0.64	0.55	0.43	0.32	
Sun hours (h)	0.50	0.56	0.58	0.62	0.29

Table 3. The q statistic values of all meteorological factors in eastern regions.

Meteorological factors	Average temperature	Relative humidity	Precipitation	Wind speed	Sun hours
Average temperature (°C)	0.25				
Relative humidity (%)	0.40	0.14			
Precipitation (mm)	0.40	0.36	0.20		
Wind speed (m/s)	0.59	0.48	0.69	0.28	
Sun hours (h)	0.61	0.34	0.40	0.71	0.22

Figures

Figure 1

Geographic location of the Shandong Province in China and its monthly incidence of bacillary dysentery from 2012 to 2013. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

Heatmap of cases and meteorological factors in prefectural-level cities from September, 2012 to August, 2013.

Figure 3

Spatial relative risks of bacillary dysentery in each county of Shandong Province. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 4

Temporal relative risks of weekly bacillary dysentery from September 1, 2012, to August 31, 2013.

Figure 5

Distribution of the hot and cold spots of bacillary dysentery in Shandong Province. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.