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Epidemiologic features of shigellosis and associated climatic factors in Taiwan

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Abstract
The consistent, sporadic transmission of shigellosis in Taiwan necessitates an exploration of risk factors for the occurrence of shigellosis. The purpose of this study was to study the epidemiologic characteristics and the relationship between climatic factors and the incidence of shigellosis in Taiwan. We collected data from cases of shigellosis reported to the Taiwan Centers for Disease Control (Taiwan CDC) from 2001 to 2016. Climatic data were obtained from the Taiwan Central Weather Bureau. The relationships between weather variability and the incidence of shigellosis in Taiwan were determined via Poisson regression analyses. During the 16-year study period, a total of 4171 clinical cases of shigellosis were reported to the Taiwan CDC. Among them, 1926 (46.2%) were classified as confirmed cases. The incidence of shigellosis showed significant seasonality, with the majority of cases occurring in summertime (for oscillation, $P < .001$). The number of shigellosis cases started to increase when temperatures reached 21°C ($r^2 = 0.88$, $P < .001$). Similarly, the number of shigellosis cases began to increase at a relative humidity of 70–74% ($r^2 = 0.75$, $P < .005$). The number of shigellosis cases was positively associated with the mean temperature and relative humidity in the period preceding the infection. In conclusion, the occurrence of shigellosis is significantly associated with increasing temperature and relative humidity in Taiwan. Therefore, these factors could be regarded as warning signals indicating the need to implement preventive measures.

Abbreviations: AIC = Akaike's information criterion (AIC), CIs = confidence intervals, ORs = odds ratios, Taiwan CDC = Taiwan Centers for Disease Control.

Keywords: climate, climatic factors, modeling, shigellosis

1. Introduction

Shigellosis is caused by *Shigella bacillus*, a facultatively anaerobic, nonmotile gram-negative rod belonging to the *Enterobacteriaceae* family.[1] The *Shigella* species are antigenically diverse pathogens that comprise four species or serogroups: Group A, *Shigella dysenteriae*; Group B, *Shigella flexneri*; Group C, *Shigella boydii*; and Group D, *Shigella sonnei*. Each species is subdivided into serotypes and subtypes, distinguished by components of the lipopolysaccharide O antigen repeats.[1]

Shigellosis is spread from person to person via the fecal-oral route or through food or drinking water. Epidemics are frequent in overcrowded populations with poor sanitation.[1,2] Community outbreaks have been frequently associated with daycare centers and school attendees.[3] In Taiwan, there was a huge outbreak of shigellosis affecting more than 40% (n=730) of students due to school underground well water to be contamination by sewage from a toilet in 1993.[4] Epidemiological investigation revealed that the more a student used the school water, the higher risk of infected shigellosis.[4]*Shigella* is the leading cause of diarrheal death after rotavirus. Annually, there are 165 million reported or confirmed cases of shigellosis globally and approximately 1 million deaths worldwide.[5,6] On a global scale, developing countries have a reportedly greater risk than developed counties.[7]

The effects of climatic factors on infectious diseases in the context of climate change have attracted global attention in recent years. It is widely believed that climate has an important impact on the sustainability and spread of many infectious diseases.[8,9] Climate change refers to changes in weather variables such as temperature, precipitation, wind speed, humidity, and others.[10] Climate change affects infectious diseases by impacting three epidemiological aspects: the pathogens themselves, their hosts/vectors, and transmission.[11,12] It has been predicted that there will be unprecedented global climate change that will lead to increases in waterborne and foodborne infectious diseases.[8–13] The risk of shigellosis shows spatial heterogeneity, and the incidence rates of shigellosis vary considerably worldwide. Previous studies have shown a positive association between temperature and the incidence of shigellosis.[13–15] Rainfall, relative humidity, air pressure and maximum wind speed also affect the reproduction of pathogens and the contamination of drinking water, which may increase the incidence of shigellosis.[16,17] However, few studies have investigated the effects of meteorological factors on the occurrence of shigellosis in Taiwan. A further understanding of the relationships between climatic factors and the occurrence

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of shigellosis could help improve both disease forecasting and preventive efforts. The purpose of this study was to study the epidemiologic characteristics and the relationships between weather-related factors and the number of shigellosis cases in Taiwan.

2. Methods

2.1. Study area

Taiwan comprises a total land area of 35,980 km^2 and approximately 23 million people for an average population density of 635 individuals per km^2. Taiwan is in East Asia and is located between 21°45′N and 25°56′N. The northern part of Taiwan belongs to the subtropical climate zone, whereas the southern part belongs to the tropical climate zone. Consequently, the weather in Taiwan is relatively warm, and high humidity occurs throughout the year.[18]

This study was approved by the Institutional Review Board of the Show Chwan Memorial Hospital, Changhua, Taiwan (IRB No. 1060601).

2.2. Surveillance for shigellosis

Shigellosis is a national, notifiable infectious disease in Taiwan. Physicians are required to report all cases that meet the clinical case definition of shigellosis and collect samples, which are sent to the Centers for Disease Control of Taiwan (Taiwan CDC) for examination within one week of the case report.[19]

We collected data from all shigellosis-confirmed cases reported to the Taiwan CDC from January 2001 to December 2016. The reported information included patient age, sex, area of residence, geographic location of exposure, travel history, vaccination status, and date of shigellosis onset.

2.3. Case definitions

A clinical case was defined as a patient with one or more loose, bloody stools.[17,19] A confirmed case was defined as a clinical case with a positive laboratory test or that met the clinical case definition and was epidemiologically linked to a confirmed case.[19,20] The differentiation of *Shigella* and enteroinvasive *E Coli* (EIEC) was performed by Taiwan CDC laboratory using a PCR method targeting the *ipa*H-gene.[19,20]

2.4. Meteorological data

Complete climatic data from January 2001 to December 2016, including the maximum and minimum daily mean temperatures, relative humidity, vapor pressure, precipitation, and sunshine rates, were obtained from the Taiwan Central Weather Bureau (http://www.cwb.gov.tw). Because Taiwan is a relatively small island, we used the mean climatic data value for each calendar week obtained from all 17 weather stations across the island, excluding stations in isolated islands and areas in the mountains.

2.5. Statistical analysis

We calculated the annual incidence of shigellosis by dividing the number of reported shigellosis cases by the mid-year population, as reported in the Taiwan census data between 2001 and 2016. This was expressed as the number of shigellosis cases per 1,000,000 individuals. Seasonal trends in the occurrence of shigellosis were assessed using Poisson regression models that incorporated sine and cosine oscillators with yearly terms:[18,21]

$$E[Y_i(t)] = \exp\left\{ \begin{array}{l} \alpha + \beta_1 \times \text{year}_i(t) + \beta_2[\sin(2\pi \times (t)/12)] + \beta_3[\cos(2\pi \times (t)/12)] + \beta_4[\text{temperature}_i(t)] \\ +\beta_5[\text{vapor pressure}_i(t)] + \beta_6[\text{humidity}(t)] + \beta_7[\text{precipitation}(t)] + \beta_8[\text{sunshine hours}(t)] \end{array} \right\}$$

$$Y_i(t) = \begin{cases} = 1 \text{ if year} = i \\ = 0 \text{ otherwise} \end{cases}$$

$$\text{Month}(t) = 1\text{if}t = 1, \text{so month}(t) = t$$

where $E[Y_i(t)]$ denotes the expected case counts at month t in year I, α is a constant value, each β term denotes a regression coefficient for a year or month, t indicates the months between January 2001 and December 2016, and i indicates each year during the years 2001 and 2016. The function year$_i$ (t) denotes whether it is year i (1=yes, 0=no), and the function month (t) indicates a month number (i.e., 1 to 12 for January to December). We constructed univariable and multivariable Poisson regression models to evaluate the correlation between the monthly number of shigellosis cases and weather exposure. We also used oscillatory seasonal adjustments to account for annual variations during the 16-year study period. We used Akaike's information criterion (AIC) to optimize the knots within the spline model to avoid the pitfalls associated with both overfitting and underfitting.[22] A backwards-elimination algorithm was applied to the multivariable models, with covariates retained for $P \leq .2$.

To investigate the relationship between shigellosis and various temperatures and relative humidity levels, we estimated the incidence of shigellosis at various temperatures and relative humidity levels. According to previous studies,[13–17] we assumed that the survival and transmission of *Shigella* would change as the temperature and relative humidity changed, and this might therefore affect the infectivity of the *Shigella* organism in a defined population. The average incidence of shigellosis (N_T) in various temperature domains (T to $T+\Delta T$) was estimated using the following formula:[18,21]

$$N_T = \frac{\sum_i^n C_i f(t_i)}{\sum_i^n f(t_i)}$$

where i denotes an index from 0 to n, t_i is the average temperature for the ith 7-day period, C_i is the total number of cases of shigellosis for the i + 2nd 7-day period, and $f(t_i)$ is a function of the following equation:

$$f(t_i)\begin{cases} = 1 \text{ when } T < t_i \leq T + \Delta T \\ = 0 \text{ otherwise} \end{cases}$$

Similarly, the average incidence of shigellosis (N_h) in various relative humidity domains (H to $H+\Delta H$) was assessed using the following formula:

$$N_H = \frac{\sum_i^n C_i f(h_i)}{\sum_i^n f(h_i)}$$

The application of standard methods for stratified data was used to analyze the data. A conditional logistic regression analysis was performed to determine exposure odds ratios (ORs) as estimates of incidence rate ratios and 95% confidence intervals (CIs) associated with meteorological variables.[21–23] We used

Table 1

Demographic characteristics of patients with shigellosis in Taiwan, 2001–2016.

Variables	Case number	Percent	Annual incidence rate per 1,000,000
Total	1926		8.5
Gender			
Male	923	47.9	8.0
Female	1003	52.1	9.0
Age groups (years)			
≤ 9	735	38.2	26.2
10–19	239	12.4	7.2
20–29	338	17.5	9.0
30–39	174	9.0	4.7
40–49	113	5.9	3.1
50–59	111	5.8	4.4
≥ 60	216	11.2	7.4
Region of residence			
Northern	844	43.8	8.5
Central	512	26.6	9.0
Southern	166	8.6	2.6
Eastern	404	21.0	68.3
Seasons			
Spring	305	15.8	1.3
Summer	708	36.8	3.1
Autumn	613	31.8	2.7
Winter	300	15.6	1.3

SAS software Version 9.2 (SAS Institute Inc., Cary, NC, USA) to perform all statistical analyses. A *P*-value of <.05 was considered statistically significant.

3. Results

3.1. Epidemiological characteristics of patients with shigellosis

Table 1 shows the number and annual incidence rate of shigellosis cases by gender, age, region, and season. Between January 2001 and December 2016, a total of 4171 cases that met clinical definitions were reported to the Taiwan CDC. Among them, 1926 (46.2%) patients with shigellosis were classified as confirmed shigellosis cases. The incidence rate (cases per 1,000,000 individuals per year) of shigellosis was 8.5 (range: 1.7–17.5). Shigellosis predominantly affected females more so than males (9.0 vs 8.0). The highest incidence of shigellosis was among children aged ≤ 9 years old, followed by the age groups 20–29 years old (9.0/1,000,000), older than or equal to 60 years old (7.4/1,000,000), and 10–19 years old (7.2/1,000,000). The highest and lowest incidences of shigellosis were 68.3/1,000,000 and 2.6/1,000,000 in the eastern and southern regions of Taiwan, respectively. Compared to the eastern region, the northern, central, and southern regions had significantly lower incidence of shigellosis ($P<.001$ in each). The highest incidence of shigellosis was 3.1/1,000,000 in the summer (June to August), followed by 2.7/1,000,000 in the autumn and 1.3/1,000,000 in the spring and winter.

3.2. Seasonality and effects of weather factors

We developed a Poisson regression model that incorporated terms for the calendar year as well as sine and cosine functions to assess time trends and the seasonality of shigellosis using the monthly aggregate case number as the response variable. In addition to the time trends and seasonality, we added the mean temperature, mean relative humidity, vapor pressure, precipitation, and sunshine rate into the model using a backward-elimination algorithm. After oscillatory seasonal adjustments were incorporated into the model, mean temperature and mean relative humidity were the only factors found to be independently associated with shigellosis infection.

The association between climatic factors and the incidence of shigellosis is presented in Table 2. Univariate analysis using Poisson regression models showed several meteorological factors associated with the incidence of shigellosis; however, in multivariate analysis, after annual trends and oscillatory seasonal adjustments were incorporated into the models, only the mean temperature and relative humidity were independently associated with the incidence of shigellosis (Table 2). Age and sex did not modify the effects of temperature or relative humidity.

3.3. Temperature, relative humidity, and the occurrence of shigellosis

The relationship between the occurrence (case count) of shigellosis and temperature is shown in Fig. 1. The occurrence of shigellosis changed with different temperatures. The number of shigellosis cases began to rise when temperatures reached 21°C ($r^2=0.88$, $P<.001$). The average case count (N_T) increased by 8% (95% CI: 3–13%) for each 1°C increase in temperature (Table 2).

Fig. 2 presents the association between the variation in the number of shigellosis cases and the various relative humidity domains (N_h). The number of shigellosis cases began to increase at a relative humidity of 70–74% ($r^2=0.75$, $P<.05$). A 5% increase in relative humidity was correlated with a 6% increase in shigellosis cases (95% CI: 2–11%) (Table 2).

Table 2

Weekly weather patterns 8–14 days prior to symptom onset and the incidence of shigellosis infection in Taiwan, 2001–2016.

	Univariable models			Multivariable model including oscillatory seasonal adjustments and annual trends		
Meteorological element	IRR	95% CI	*P* value	IRR	95% CI	*P*-value
Mean temperature, °C	1.07	1.06, 1.09	<.001	1.08	1.03, 1.13	<.001
Mean relative humidity, %	1.07	1.05, 1.08	<.001	1.06	1.02, 1.11	.007
Mean vapor pressure, hPa	1.30	1.26, 1.34	<.001			
Mean cumulative precipitation, mm	1.07	1.06, 1.08	<.001			
Mean sunshine rate, %	1.02	1.01, 1.02	<.001			

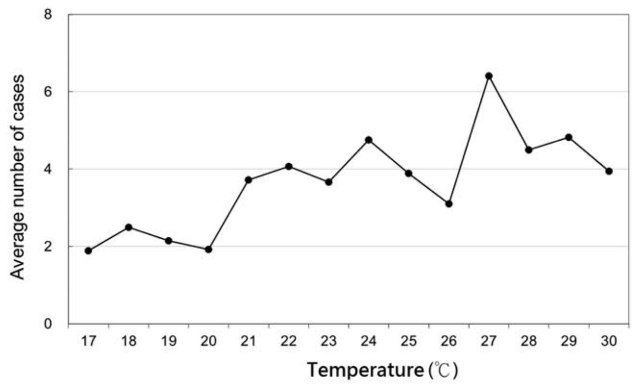

Figure 1. The average number of shigellosis infections in various temperature domains.

4. Discussion

Epidemiological evidence has demonstrated that shigellosis remains an important public health problem in Taiwan. We analyzed shigellosis data reported to the Taiwan CDC from 2001 to 2016 using Poisson regression analyses. We found that the incidence of shigellosis was highest during the summer months, and the incidence was positively correlated with increased mean temperature and mean relative humidity in the long-term analysis. In this study, we also identified the importance of meteorological exposure in determining the incidence and seasonality of shigellosis in Taiwan.

Shigellosis is transmitted through the fecal-oral route, by flies, and through contaminated drinking water or food.[1] The emergence of shigellosis is driven by environmental factors such as climate.[1,2,5,6] Various patterns of seasonality in the occurrence of shigellosis have been reported in various countries.[24–28] Previous research has demonstrated apparent seasonal variations in China, with shigellosis infections apparently peaking in the summer and fall seasons.[24,29,30] In Vietnam, the highest incidence of shigellosis was reported in May to October (wet season).[31,32] In Dhaka City in Bangladesh, the highest risk period was from September to December.[33] In Nepal, the seasonal tendency of shigellosis was the summer-monsoon season.[28] Similar to previous studies, our results showed a seasonal pattern of shigellosis infection, with a peak occurrence in the summer (June to August) months.

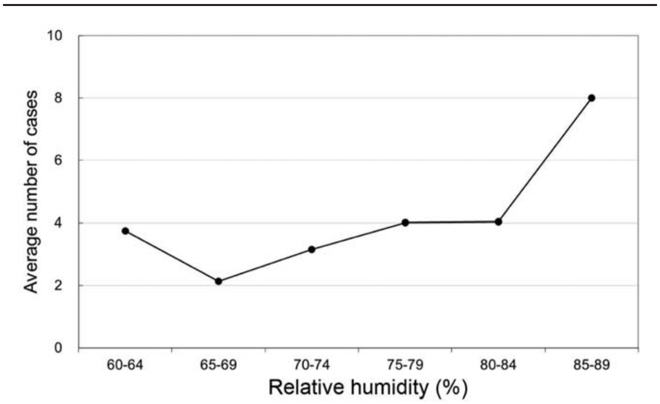

Figure 2. The average number of shigellosis cases in various relative humidity domains.

Long-term stable factors in the local ecological environment, in addition to social-economic status, infrastructure, and sanitation conditions, are the main drivers of spatial patterns of disease risk. The local and global risk of bacillary dysentery shows seasonality. Seasonality in the heterogeneous risk of shigellosis indicates that climatic factors, such as air temperature, precipitation, relative humidity, wind speed, and sunshine hours, may play an important role in the varying temporal incidence of this disease.[34–36]

Shigellosis can be affected by changes in the ambient environment. It has been reported that the activity of shigellosis is affected by temperature, relative humidity, and precipitation.[15,35,36] Higher temperatures in summer may increase the reproduction of bacteria along the food supply chain and water supply.[2,15] Several theories have been postulated. First, increasing temperatures can increase the survival and replication of pathogens in the environment.[25] Second, ambient temperature can increase the chance of contamination of food sources through behavior changes during hot temperatures, such as the elevated consumption of raw foods in the summer.[15,34–36] Third, higher temperatures may increase the chance of person-to-person contact, resulting in more people exposed to *Shigella* pathogens.[15,32,34–36] Elevated temperatures may lead to increased exposure to pathogens, promote the growth of bacteria, and prolong the survival of bacteria in the environment and in contaminated food.[2] In addition, high temperatures may be associated with specific behavioral patterns in the population, such as increased demands for water, which could accelerate the transmission of shigellosis. According to one study, a rise of 1°C in air temperature led to a nearly 11% to 16% increase in the risk of disease in China.[29] In Peru, each 1°C rises in air temperature was associated with an 8% increase in shigellosis risk.[25] In Korea, the incidence of shigellosis increased by 13.6% with a temperature increase of 1°C.[37] Similar to previous studies,[25,29,37] the present study found that temperature was positively associated with the risk of shigellosis, with a rise of 1°C in air temperature corresponding to an 8% increase in the risk of disease.

A previous study in Taiwan indicated that daily precipitation levels were significantly correlated with the incidence of shigellosis,[14] but other studies have not found any specific population disproportionately at risk for shigellosis.[38] A study in northern China observed that shigellosis was positively associated with relative humidity and precipitation.[26,30,36] Similar findings were reported in studies conducted in the Pacific Islands[16] and the USA.[38] Conversely, a study conducted in Wuhan indicated that precipitation had a negative effect on the occurrence of shigellosis.[35] We found that the number of shigellosis cases increased with increasing relative humidity, and the increase started at a relative humidity of 70% to 74%. Increased contact rates with contaminated droplets on days with high relative humidity may be a potential mechanism underlying the association of humidity and precipitation with shigellosis.[32]

Our study could not detect an association between the incidence of shigellosis and other climate variables, including rainfall and mean pressure, in multiple analyses. This finding is similar to the findings in the USA, Denmark, Australia, China, and Bangladesh, which all found that rainfall did not directly affect shigellosis.[8,37–39] However, some studies from the Pacific Islands reported a dose-response relationship between rainfall and the incidence of shigellosis,[16] suggesting that extremely high and low values of rainfall may lead to an increase in the number of cases.

In the present study, an increase in the number of hours of sunshine had a positive relationship with shigellosis in the univariate analysis but not in the multivariate analysis. The potential mechanism may be that sunshine is associated with a prolonged rise in temperature, thus promoting the spread of shigellosis. However, another study conducted in China pointed to an inverse association between hours of sunshine and shigellosis.[26] Differences among the studies might be due to the use of diverse observation scales or regional characteristics, as different study areas may have different climatic conditions that influence the epidemiology of shigellosis.

In our study, female patients had a higher annual incidence rate of shigellosis than male patients (9.0 vs 8.0 per 1,000,000). We are unable to definitively explain this epidemiological finding in Taiwan, but we postulate that contributing factors may include different behavioral patterns or different reporting patterns. In Nepal, males had a higher prevalence of shigellosis than females.[28] This might be because males leave the house much more frequently than females to eat food in restaurants and from street vendors. Therefore, males in Nepal had a greater chance of exposure to sources of *shigella*.[28]

Previous studies showed that young children were considered a high-risk group for shigellosis because of poor personal hygiene, the absence of past exposures, and close contact among children who attended child-care facilities or schools.[2,40,41] In contrast, there was a higher incidence rate of shigellosis in elderly individuals than in young children in Korea.[37] The reason might be that the elderly population was not included as a priority target for the national sanitation control program. Consequently, the high incidence rate of shigellosis among elderly individuals in Korea has been reported. However, our study found that the highest incidence rate of shigellosis occurred in the age range <9 years old.

In our study, the highest incidence of shigellosis occurred in the eastern region of Taiwan. A previous study showed that the disparity in incidence was associated with urbanization and economic status.[8] Compared to the western region of Taiwan, the eastern region is a more underprivileged region. Public health infrastructure, sanitation, and water supply in this region is poorer than in the western region of Taiwan.

This study had several limitations. First, the public health surveillance data may be incomplete. It is believed that many notifiable infectious diseases (e.g., shigellosis) are underreported.[18,21] A reporting bias may occur anywhere in the reporting chain. However, this bias would occur only if weather effects were somehow correlated with the likelihood of disease reporting. Second, the burden of shigellosis as defined by laboratory-confirmed diagnosis probably represents an underestimation.[5,6]

5. Conclusions

In summary, our findings demonstrate the importance of climatic factors in determining shigellosis case occurrence and can help explain the notable seasonal pattern of shigellosis. Public health authorities should consider the results of the threshold estimation as a warning signal, and by applying these results with a prediction model for long-term trends, they can develop and deploy public health interventions before early summer to reduce the risk of infection and spread of the shigellosis pathogen.

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Author contributions

Chian-Ching Chen contributed to the study design, data collection, data analysis, and drafting; Chuan-Yao Lin contributed to the study design and data collection; Kow-Tong Chen served as the principal investigator of this study and contributed to the conception, study design, drafting, and revision; all authors read and approved the final version of the manuscript.
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References

[1] Yang F, Yang J, Zhang X, et al. Genomic dynamics and diversity of *Shigella* species, the etiologic agents of bacillary dysentery. Nucleic Acids Res 2005;33:6445–58.

[2] 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 Infect Dis 2016;16:685.

[3] Ko CF, Lin NT, Chiou CS, et al. Infrequent cross-transmission of Shigella flexneri 2a strains among villages of a mountainous township in Taiwan with endemic shigellosis. BMC Infect Dis 2013;13:354.

[4] Chen KT, Chen CJ, Chiu JP. A school waterborne outbreak involving both Shigella sonnei and Entamoeba histolytica. J Environ Health 2001;64:9–13.

[5] Kotloff KL, Riddle M, Platts-Mills S, et al. Shigellosis. Lancet 2018;391:801–12.

[6] Kotloff KL, Nataro JP, Blackwelder WC, et al. Burden and aetiology of diarrhoeal disease in infants and young children in developing countries (the Global Enteric Multicenter Study, GEMS): a prospective, case-control study. Lancet 2013;382:209–22.

[7] GBD Diarrhoeal Diseases CollaboratorsEstimates of global, regional, and national morbidity, mortality, and aetiologies of diarrhoeal diseases: a systematic analysis for the Global Burden of Disease Study 2015. Lancet Infect Dis 2017;17:909–48.

[8] Zhang H, Si Y, Wang X, et al. Patterns of bacillary dysentery in China, 2005–2010. Int J Environ Res Public Health 2016;13:164.

[9] Valcour JE, Charron DF, Berke O, et al. A descriptive analysis of the spatio-temporal distribution of enteric diseases in New Brunswick, Canada. BMC Public Health 2016;16:204.

[10] Wu X, Lu Y, Zhou S, et al. Impact of climate change on human infectious diseases: empirical evidence and human adaptation. Environ Int 2016;86:14–23.

[11] Liu J, Wu X, Li C, et al. Identification of weather variables sensitive to dysentery in disease-affected county of China. Sci Total Environ 2017;575:956–62.

[12] Walker JT. The influence of climate change on waterborne disease and Legionella: a review. Perspect Public Health 2018;138:282–6.

[13] Hashizume M, Armstrong B, Hajat S, et al. Association between climate variability and hospital visits for non-cholera diarrhoea in Bangladesh: effects and vulnerable groups. Int J Epidemiol 2007;36:1030–7.

[14] Chen MJ, Lin CY, Wu YT, et al. Effects of extreme precipitation to the distribution of infectious diseases in Taiwan, 1994–2008. PLoS One 2012;7:e34651.

[15] Xu C, Xiao G, Wang J, et al. Spatiotemporal risk of bacillary dysentery and sensitivity to meteorological factors in Hunan Province, China. Int J Environ Res Public Health 2017;15:

[16] Singh RB, Hales S, de Wet N, et al. The influence of climate variation and change on diarrheal disease in the Pacific Islands. Environ Health Perspect 2001;109:155–9.

[17] Wang XY, Du L, Von Seidlein L, et al. Occurrence of shigellosis in the young and elderly in rural China: results of a 12-month population-based surveillance study. Am J Trop Med Hyg 2005;73:416–22.

[18] Ho YC, Su BH, Su HJ, et al. The association between the incidence of mumps and meteorological parameters in Taiwan. Hum Vaccin Immunother 2015;11:1406–12.

[19] Centers for Disease Control, Taiwan. Notifiable Infectious Disease Statistical System. 2018. Available at http://nidss.cdc.gov.tw. Accessed February 15, 2018.

[20] van den Beld MJ, Reubsaet FA. Differentiation between *Shigella*, enteroinvasive *Escherichia coli* (EIEC) and noninvasive *Escherichia coli*. Eur J Clin Microbiol Infect Dis 2012;31:899–904.

[21] Chang HL, Chio CP, Su HJ, et al. The association between enterovirus 71 infections and meteorological parameters in Taiwan. PLoS One 2012;7: e46845.

[22] Woodward M. Epidemiology: study design and data analysis. 2nd ed. Boca Raton, FL: Chapman & Hall/CRC; 2005. p.515-600.

[23] Cameron AC, Trivedi PK. Regression analysis of count data. 1st ed. Cambridge, UK: Cambridge University Press; 1998.

[24] 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. Jpn J Infect Dis 2008;61:356–60.

[25] Checkley W, Epstein LD, Gilman RH, et al. Effects of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. Lancet 2000;355:442–50.

[26] Zhao Y, Zhu Y, Zhu Z, et al. Association between meteorological factors and bacillary dysentery incidence in Chaoyang city, China: an ecological study. BMJ Open 2016;6:e013376.

[27] Curriero FC, Patz JA, Rose JB, et al. The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948–1994. Am J Public Health 2001;91:1194–9.

[28] Shakya G, Acharya J, Adhikari S, et al. Shigellosis in Nepal: 13 years review of nationwide surveillance. J Health Popul Nutr 2016;35:36.

[29] Zhang Y, Bi P, Hiller JE. Weather and the transmission of bacillary dysentery in Jinan, northern China: a time-series analysis. Public Health Rep 2008;123:61–6.

[30] Li ZJ, Zhang XJ, Hou XX, et al. Nonlinear and threshold of the association between meteorological factors and bacillary dysentery in Beijing, China. Epidemiol Infect 2015;143:3510–9.

[31] Kelly-Hope LA, Alonso WJ, Thiem VD, et al. Temporal trends and climatic factors associated with bacterial enteric diseases in Vietnam, 1991–2001. Environ Health Perspect 2008;116:7–12.

[32] Lee HS, Ha-Hoang TT, Pham-Duc P, et al. Seasonal and geographical distribution of bacillary dysentery (shigellosis) and associated climate risk factors in Kon Tam Province in Vietnam from 1999 to 2013. Infect Dis Poverty 2017;6:113.

[33] Albert MJ, Faruque ASG, Faruque SM, et al. Case-control study of enteropathogens associated with childhood diarrhea in Dhaka, Bangladesh. J Clin Microbiol 1999;37:3458–64.

[34] Gao L, Zhang Y, Ding G, et al. Meteorological variables and bacillary dysentery cases in Changsha City, China. Am J Trop Med Hyg 2014;90:697–704.

[35] Li Z, Wang L, Sun W, et al. Identifying high-risk areas of bacillary dysentery and associated meteorological factors in Wuhan, China. Sci Rep 2013;3.

[36] Zhang Y, Bi P, Hiller JE, et al. Climate variations and bacillary dysentery in northern and southern cities of China. J Infect 2007;55:194–200.

[37] Song YJ, Cheong HK, Ki M, et al. The epidemiological influence of climatic factors on Shigellosis incidence rates in Korea. Int J Environ Res Public Health 2018;15:

[38] Hines JZ, Jagger MA, Jeanne TL, et al. Heavy precipitation as a risk factor for shigellosis among homeless persons during an outbreak—Oregon, 2015–2016. J Infect 2018;76:280–5.

[39] Lewis HC, Ethelberg S, Olsen KE, et al. Outbreaks of *Shigella sonnei* infections in Denmark and Australia linked to consumption of imported raw baby corn. Epidemiol Infect 2009;137:326–34.

[40] Mohle-Boetani JC, Stapleton M, Finger R, et al. Communitywide shigellosis: control of an outbreak and risk factors in child day-care centers. Am J Public Health 1995;85:812–6.

[41] Taneja N, Mewara A. Shigellosis: epidemiology in India. Indian J Med Res 2016;143:565–76.