Identifying Flood-Related Infectious Diseases in Anhui Province, China: A Spatial and Temporal Analysis

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Abstract. The aim of this study was to explore infectious diseases related to the 2007 Huai River flood in Anhui Province, China. The study was based on the notified incidences of infectious diseases between June 29 and July 25 from 2004 to 2011. Daily incidences of notified diseases in 2007 were compared with the corresponding daily incidences during the same period in the other years (from 2004 to 2011, except 2007) by Poisson regression analysis. Spatial autocorrelation analysis was used to test the distribution pattern of the diseases. Spatial regression models were then performed to examine the association between the incidence of each disease and flood, considering lag effects and other confounders. After controlling the other meteorological and socioeconomic factors, malaria (odds ratio [OR] = 3.67, 95% confidence interval [CI] = 1.77–7.61), diarrhea (OR = 2.16, 95% CI = 1.24–3.78), and hepatitis A virus (HAV) infection (OR = 6.11, 95% CI = 1.04–35.84) were significantly related to the 2007 Huai River flood both from the spatial and temporal analyses. Special attention should be given to develop public health preparation and interventions with a focus on malaria, diarrhea, and HAV infection, in the study region.

INTRODUCTION

Over the last decade, flooding has been the most common natural disaster globally,¹ which has been responsible for almost half of all victims of natural disasters with economic losses of nearly US\$185 billion (EM-DAT, 2011, www.emdat.be).² China is one of the most flood-prone countries in the world. Large population, complicated topography and climate conditions, and rapid urbanization promote a high risk of exposure to flood.

From June 29 to July 25 in 2007, Huai River basin experienced heavy rainfall, which resulted in long-term severe flood.³ The flood event examined in this study was the worst flood event of Anhui Province in last 50 years, leading to a total cost of US\$1.9 billion.⁴ There were more than 7,000 displaced persons with a total affected population of approximately 15 million.⁵

The floods had serious implications on public health through contamination of drinking water and accumulation of waste. Active proliferation of pathogen and disease vectors around stagnant waters can be induced by flood events.^{6,7} In addition, flood events often cause population displacement.⁸ Insufficient public health condition, overcrowding, and intimate contact among refugees may lead to outbreaks of infectious diseases.^{9,10} Floods may particularly assist the transmission of the following infectious diseases, including waterborne diseases, vector-borne diseases, and rodent-borne diseases.¹¹

Although, some literatures have analyzed the relationship between flood event and a specific infectious disease in China, no previous studies have systematically detected sensitive diseases from arrange of infectious diseases with different pathways of transmission. Our study aimed to examine the impact

of flood events to detect sensitive infectious diseases in Huai River basin. Results will be helpful to explore flood-related sensitive infectious diseases so as to assist in developing policies to prevent and reduce the risk of infectious diseases associated with floods.

MATERIALS AND METHODS

Study area and floods. Anhui Province is located between longitude 114°54' and 119°37'E and latitude 29°41' and 34°38'N. The total population of Anhui Province is approximately 61.2 million, of which the proportion of rural population is 61.30%.¹² Huai River flows through the north part of Anhui Province, forming the Huai River basin. Many branches of Huai River cross north Anhui Province, leading the adjacent regions (including seven cities Fuyang, Bozhou, Huaibei, Suzhou, Luan, Huainan, and Bengbu, which can be further divided into 29 counties), the worst affected area in the 2007 Huai River basin flood event. Our study area covers all these 29 counties (Figure 1C). The study area locates in a subhumid warm temperate continental monsoon climate zone, with a rainy weather in summer seasons. During the flood period, the average temperature was 27°C. Figure 2 showed meteorological conditions in the study area from 2004 to 2011. The daily accumulated rainfall peaked during the flood period in 2007, with the highest value of 5,500 mm. The average precipitation of Huai River basin was 370 mm during this period, which equaled to two to three times of precipitation during the same period of previous years. Other meteorological variables in flood period were similar with the corresponding periods in other years.^{5,13}

Data collection. On the basis of the transmission mechanism of infectious diseases and findings from previous research, floods mainly affect vector-borne,^{14,15} waterborne,¹⁴ and rodent-borne diseases.¹⁶ This study examined these three types of infectious diseases regarding their relationship to the flood event, including malaria,^{17–19} dengue, diarrhea,²⁰

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FIGURE 1. (A) China and the location of Anhui Province, (B) meteorological stations in Anhui Province, and (C) Huai River basin.

bacillary dysentery,²¹ hepatitis A virus (HAV) infection, hepatitis E virus (HEV) infection, typhoid and paratyphoid,²² schistosomiasis, cholera, leptospirosis,^{23–25} Japanese encephalitis,²⁶ pestis, and hemorrhagic fever with renal syndrome (HFRS).¹⁹ According to the law of the People's Republic of China on Prevention and Treatment of Infectious Diseases (2013 Amendment),²⁷ diarrhea is infectious diarrhea other than cholera, dysentery, typhoid, and paratyphoid.²⁷ Disease surveillance data on these selected diseases and the annual population from 2004 to 2011 were obtained from the National Notifiable Disease Surveillance System (NDSS). All infectious disease cases were diagnosed by National Notifiable Disease diagnostic criteria reported in the law of the People's Republic of China on the Prevention and Treatment of Infectious Diseases. In China, statutory notifiable infectious diseases were divided into three categories: A, B, and C. The statutory notifiable category A infectious disease should be reported within 2 hours, while statutory notifiable category B and C infectious disease should be reported within 24 hours.²⁸ In our study, both clinical and laboratory cases were included. The laboratory-confirmed frequency of each disease has been included in Table 1.

Daily meteorological data from 2004 to 2011 were collected from the China Meteorological Data Sharing Service System.¹³ The flood event were defined by Yearbook of Meteorological Disasters in China and Bulletin of Flood and Drought Disaster in China 2007.^{4,5} All the 17 stations in the whole Anhui Province were used to record the climatic data. If there was a meteorological station in the city, the meteorological data from this station were used in the study for this city. If no meteorological station was in the city, we chose the meteorological data reported by the nearest station for this city (Figure 1B). The meteorological data retrieved from each meteorological station represented the condition of all the counties in this city.

The meteorological variables were selected based on findings from literature review and biological possibility. The proliferation of parasites, such as flies and mosquitoes, and pathogens would boost during hot and humid days.^{29–31} There were some evidence of the effect of rainfall on infectious diseases, while the association between infectious diseases and rainfall is far complex than that with temperature.³² Rainfall may also affect the frequency and level of contamination of drinking water.³² The results of some studies also indicated that air pressure may affect the transmission of waterborne diseases.³³ Remarkable increase was observed in risks of vector-borne diseases associated with increased sunshine hours in previous studies.³⁴ All the meteorological factors that have a potential biological impact on the diseases were initially included in the spatial regression model. Therefore, the accumulated rainfall data from June 29 to July 25 in 2007 for each county were included only in the spatial regression models as control factors. The mean measurements from June 29 to July 25 in 2007 of the following variables were also included in the multivariate spatial regression models as control factors, including daily mean temperature (MeanT), daily maximum temperature (MaxT), relative humidity (RH), mean air pressure (MeanP), mean speed of wind (MeanSW), daily maximum speed of wind (Max SW), and daily sunshine hours (SH).

To control the potential confounding caused by socioeconomic status and health-care conditions in different cities, Gross Domestic Product/person (GDP/person), health facilities/100,000 persons, and health faculties/100,000 persons of each county were also included in the spatial regression analysis as control factors. These data were collected from Statistical Yearbook of Anhui Province 2007.¹²

Temporal analysis. In temporal analysis, the study area included all 29 counties in Huai River basin (Figure 1C). June 29 to July 25 in 2007 was chosen to be the exposed period. To alleviate the seasonal variation and secular trend

FIGURE 2. Daily meteorological conditions in Huai River basin, 2004–2011.

TABLE 1

Incidence rates and number of cases during flood period in 2007 in flood-affected areas with lag effects

Diseases	Proportion of laboratory-confirmed cases	Number of cases	Incidence (1/100,000)
Malaria	0.67	5,904	17.867
Diarrhea	0.08	2,681	8.113
Bacillary dysentery	0.15	1,148	3.474
Japanese encephalitis	0.48	111	0.336
HAV infection	0.51	104	0.315
HEV infection	0.83	55	0.166
Typhoid and paratyphoid	0.40	16	0.048
HFRS	0.25	4	0.012
Leptospirosis	0	0	0.000
Schistosomiasis	0	0	0.000
Pestis	0	0	0.000
Cholera	0	0	0.000
Dengue	0	0	0.000

HAV = hepatitis A virus; HEV = hepatitis E virus; HFRS = hemorrhagic fever with renal syndrome.

of diseases, the same periods from 2004 to 2006 and 2008 to 2011 were defined as the control period, which were all in summers but not affected by floods. Lag effects were detected by using daily odds ratios (ORs) of the flood event for each disease. We compared daily incidences between exposed periods and control periods (from June 29 to July 25, 2004 to 2011 except 2007). The lag value with the maximum significant OR for each disease was selected for inclusion in subsequent temporal and spatial analysis. Considering the results from previous studies and biological plausibility of infectious diseases, up to 30-day lagged effects were examined in our study.^{14,21}

We defined flood event as a binary independent variable. The exposed period coded to 1 and the control period coded to 0. We used daily accumulated incidence for each disease of all 29 counties in Huai River basin as a dependent variable. The lag effect adjusted incidence during June 29 and July 25 from 2004 to 2011 was included in the Poisson regression model. We assumed that the socioeconomic conditions, environment, human immunity, and other control programs in the study areas were same during these years. The Poisson regression analysis was performed to examine the association between flood event and each disease. All the temporal analysis was performed in SAS 9.1.3 (SAS Institute Inc., Cary, NC).

Spatial analysis. In recent years, spatial analysis had been widely implemented to describe the geographic distribution of diseases and to identify the factors associated with changing incidences.^{35–38} It could adjust the mutual effect among the spatial neighbors, which may be ignored by traditional regression analysis.³⁹ In this study, spatial autocorrelation and regression analysis were attached to detect disease aggregation and association between diseases and flood event, respectively. Lagged effect was controlled in spatial analyzes. In the spatial analysis, the study area included all 79 counties in whole Anhui Province (Figure 1B). The sample size was sufficient to perform the spatial analysis to detect any patterns in the spatial distribution.^{37,40} We defined flood event as a binary variable. All the counties were defined into two categories based on the Huai River basin flood event: flood-affected counties (Figure 1B without color), coded to 1 and non-affected areas (Figure 1B in colors), coded to 0. This binary variable was regarded as flood event factor. All the independent and dependent variables were included in county level.

For each of the 79 counties in Anhui Province, daily incidence for each disease from June 29 to July 25 in 2007 with

lag phase was accumulated. Accumulated incidences, binary flood event variable, and meteorological and socioeconomic variables were included in a shapefile map of Anhui Province according to the county ID by ArcGIS software version 10.0 (ESRI Inc., Redlands, CA). County-level polygon map of Anhui Province was gained from Geographic Sciences and Natural Resources Research Data Center.

Spatial autocorrelation analysis. Global spatial autocorrelation analysis was performed by Open GeoDa 1.2.0 (Luc Anselin, Phoenix, AZ). Global Moran's *I* statistic was used to measure the correlation among neighboring observations, to detect whether the diseases were randomly distributed in the whole Anhui Province.^{36,41} Queen criterion was attached to create the contiguity spatial weight file from the polygon shapefile constructed by ArcGIS software version 10.0 (ESRI Inc.). The null hypothesis assumed that the disease distributed randomly in Anhui Province.³⁹ The range of Moran's *I* is from -1 to 1. There is a higher regional aggregation of incidence between counties, if the absolute value of Moran's *I* is more close to 1, otherwise, there is a lower correlation, which indicates the incidence may distribute randomly.³⁹ $P < 0.05$ indicates the disease had a character of regional aggregating.⁴² Some factors may result in the regional aggregation. Therefore, spatial autocorrelation is the prerequisite of spatial regression analysis.³⁹

Spatial regression analysis. The exploration of the relationship between disease spatial distribution and flood event was adjusted by other meteorological variables and socioeconomic factors from a geographical aspect. Traditional regression models assume that the observation are mutually independent, which is not valid due to the spatial structure. Spatial regression models do not make such an assumption. Random effects were included to explain the potential impact caused by the spatial correlation. Randomly distributed diseases tested by a spatial autocorrelation analysis were not included in the regression models. The spatial regression model is expressed as follows:

$$\text{Logit}(\pi_i) = \alpha + \sum_k \beta_k X_k + u_i + e_i$$

where u_i is spatial unstructured effect, which represents spatial heterogeneity, and e_i is spatial structured effect, which reflects spatial dependence, for example, spatial autocorrelation.³⁹

With Open GeoDa 1.2.0, the distributions of incidences in whole Anhui Province were obtained. For the incidences of diseases that were not normally distributed, incidences were log transformed. Each incidence then was included for the spatial regression modeling as a dependent variable based on the significant result from the spatial autocorrelation analysis (for those spatial autocorrelated diseases). Flood was input to the models as an explanatory variable. Control variables, including all the other meteorological variables (MeanT, MaxT, RH, RF, MeanP, MeanSW, Max SW, and SH) and socioeconomic and health-care conditions variables (GDP/person, health facilities/100,000 person, and health faculties/100,000 person of each county) were input into the model as well. Diseases, which reached a significance level of 0.05 or less in the global autocorrelation analysis, were selected for inclusion in multiple spatial regression models.⁴³

Three regression models, including classic ordinary least squares (OLS) regression model, spatial lag model (SLM), and spatial error model (SEM) were used in our analysis.

TABLE 2

The lag days and maximum relative risks based on incidence comparison between exposed period and control periods

Diseases	Lag (days)	OR	95% CI
Malaria	27	4.62	(2.83, 6.41)
Diarrhea	11	1.70	(1.29, 2.10)
Bacillary dysentery	11	1.64	(1.12, 2.16)
Japanese encephalitis	11	4.50	(1.40, 7.60)
HAV infection	15	3.75	(1.78, 5.72)
HEV infection	18	4.50	(1.86, 7.14)
Typhoid and paratyphoid	9	6.00	(3.54, 8.46)

CI = confidence interval; HAV = hepatitis A virus; HEV = hepatitis E virus; OR = odds ratio.

The OLS models were first performed on each disease separately to fit the data, and spatial dependence test was then conducted to compare these three kinds of models. If test shows no significant dependence, the OLS model was adopted, otherwise, *P* values of SLM and SEM were used to decide which model was appropriate for spatial regression.⁴⁴

Ethical review. Disease surveillance data used in this study were obtained from the NDSS with an ethical approval by the Chinese Center for Disease Control and Prevention. This study was fully reviewed and approved by the human research ethical committee of Shandong University.

RESULTS

Descriptive analysis. During the flood event in 2007, the most commonly notified diseases were malaria (incidence rate = 17.867/100,000), diarrhea (incidence rate = 8.113/100,000), and bacillary dysentery (incidence rate = 3.474/100,000). Incidences of HAV infection, HFRS, Japanese encephalitis, typhoid and paratyphoid, and HEV infection were less than 1/100,000. No cases of leptospirosis, schistosomiasis, pestis, cholera, and dengue were notified in the study areas over the study period (Table 1). Given a very low number of notified cases may cover the real association, HFRS was excluded with only four cases occurred.

Lagged effects. Detected lagged effects with the maximum significant OR of the seven diseases notified in the study region are presented in Table 2. The lag days with maximum significant OR for typhoid and paratyphoid (OR = 6.00, 95% confidence interval [CI] = 3.54–8.46), bacillary dysentery (OR = 1.64, 95% CI = 1.12–2.16), Japanese encephalitis (OR = 4.50, 95% CI = 1.40–7.60), diarrhea (OR = 1.70, 95% CI = 1.29–2.10), HAV infection (OR = 3.75, 95% CI = 1.78–5.72), HEV infection (OR = 4.50, 95% CI = 1.86–7.14), and malaria (OR = 4.62, 95% CI = 2.83–6.41) were varying from 9 to 27 days.

Temporal analysis. The results of Poisson regression analysis were shown in Table 3. It suggested that, compared with con-

TABLE 3

Poisson regression analysis between flood and diseases

Diseases	OR	95% CI of OR	P value
Malaria	3.44	(3.28, 3.62)	< 0.05
Diarrhea	1.10	(1.05, 1.15)	< 0.05
Bacillary dysentery	1.04	(0.97, 1.12)	> 0.05
Japanese encephalitis	0.58	(0.47, 0.71)	< 0.05
HAV infection	1.40	(1.11, 1.77)	< 0.05
HEV infection	0.94	(0.67, 1.31)	> 0.05
Typhoid and paratyphoid	0.40	(0.14, 1.14)	> 0.05

CI = confidence interval; HAV = hepatitis A virus; HEV = hepatitis E virus; OR = odds ratio.

TABLE 4

Global spatial autocorrelation analysis

Disease	Moran's <i>I</i>	<i>P</i> value
Bacillary dysentery	0.336	0.001
Diarrhea	0.311	0.001
Japanese encephalitis	0.154	0.017
HAV infection	0.341	0.001
HEV infection	0.278	0.001
Malaria	0.475	0.001
Typhoid and paratyphoid	0.165	0.020

HAV = hepatitis A virus; HEV = hepatitis E virus.

trol periods, the ORs of malaria (OR = 3.44, 95% CI = 3.28–3.62), diarrhea (OR = 1.10, 95% CI = 1.05–1.15), HAV infection (OR = 1.40, 95% CI = 1.11–1.77), and Japanese encephalitis (OR = 0.58, 95% CI = 0.47–0.71) were significant. Bacillary dysentery (OR = 1.04, 95% CI = 0.97–1.12), typhoid and paratyphoid (OR = 0.40, 95% CI = 0.14–1.14), and HEV infection (OR = 0.94, 95% CI = 0.67–1.31) were not significantly associated with flood event.

Spatial autocorrelation analysis. The global spatial autocorrelation analysis for each disease showed that bacillary dysentery (Moran's *I* = 0.336, *P* = 0.001), diarrhea (Moran's *I* = 0.311, *P* = 0.001), Japanese encephalitis (Moran's *I* = 0.154, *P* = 0.017), HAV infection (Moran's *I* = 0.341, *P* = 0.001), HEV infection (Moran's *I* = 0.278, *P* = 0.001), malaria (Moran's *I* = 0.475, *P* = 0.001), and typhoid and paratyphoid (Moran's *I* = 0.165, *P* = 0.020) were all spatially autocorrelated in the study region (Table 4).

Spatial regression analysis. As shown in Table 5, malaria and bacillary dysentery were included in the SLM, typhoid and paratyphoid was analyzed by SEM. Classic OLS

TABLE 5

Spatial regression model selection

Diseases	Model type	Function	Value	<i>P</i> value
Malaria	SLM	LM	44.231	0
		Robust LM	20.840	0
	SEM	LM	25.919	0
HAV infection OLS	SLM	LM	2.527	0.112
		Robust LM	3.394	0.065
	SEM	LM	0.069	0.793
		Robust LM	3.434	0.064
Bacillary dysentery	SLM	LM	0.109	0.741
		Robust LM	4.663	0.031
	SEM	LM	3.122	0.077
		Robust LM	2.337	0.126
HEV infection OLS	SLM	LM	0.796	0.372
		Robust LM	0.663	0.415
	SEM	LM	1.728	0.189
		Robust LM	0.196	0.658
Diarrhea OLS	SLM	LM	1.261	0.261
		Robust LM	0.198	0.657
	SEM	LM	0.285	0.593
		Robust LM	0.371	0.542
Japanese encephalitis OLS	SLM	LM	0.459	0.498
		Robust LM	0.034	0.855
	SEM	LM	2.178	0.140
		Robust LM	0.397	0.529
Typhoid and paratyphoid	SLM	LM	2.541	0.111
		Robust LM	3.798	0.051
	SEM	LM	1.196	0.274
		Robust LM	4.751	0.029

HAV = hepatitis A virus; HEV = hepatitis E virus; LM = Lagrange multiplier; OLS = classic ordinary least squares regression model; SEM = spatial error regression model; SLM = spatial lag regression model.

TABLE 6
Parameters estimated by spatial regression analysis

Spatial regression analysis diseases	OR	Standard error	P value	95% CI of OR	R ²
Malaria	3.67	0.372	0.000	(1.77, 7.61)	0.786
HAV infection	6.11	0.902	0.048	(1.04, 35.84)	0.286
Bacillary dysentery	2.46	0.276	0.001	(1.43, 4.23)	0.518
Japanese encephalitis	0.7	0.349	0.316	(0.35, 1.39)	0.262
Diarrhea	2.16	0.285	0.008	(1.24, 3.78)	0.248
Typhoid and paratyphoid	0.66	0.369	0.264	(0.32, 1.36)	0.182
HEV infection	1.24	0.375	0.569	(0.59, 2.59)	0.200

CI = confidence interval; HAV = hepatitis A virus; HEV = hepatitis E virus; OR = odds ratio.

regression model was applied to HAV infection, HEV infection, diarrhea, and Japanese encephalitis.

Table 6 shows the ORs derived from the spatial regression models. Compared with the non-flood-affected areas, malaria (OR = 3.67, 95% CI = 1.77–7.61), HAV infection (OR = 6.11, 95% CI = 1.04–35.84), bacillary dysentery (OR = 2.46, 95% CI = 1.43–4.23), and diarrhea (OR = 2.16, 95% CI = 1.24–3.78) were significantly increased in Huai River basin in 2007. Japanese encephalitis (OR = 0.70, 95% CI = 0.35–1.39), typhoid and paratyphoid (OR = 0.66, 95% CI = 0.32–1.36), and HEV infection (OR = 1.24, 95% CI = 0.59–2.59) were not significantly impacted by flood. The *R* squares, which represent the goodness of fit for models in Table 6, indicated the proportion of disease variation that could be explained by all the variables in the model.

DISCUSSION

Our study has identified flood-related infectious diseases in Anhui Province, using both spatial and temporal analyses. Flood events may induce differential health impacts among different demographic groups. Therefore, our study has raised valuable epidemiology information for flood-related infectious disease control in a flood-prone area, Huai River basin. Results indicate that the increased incidences of malaria, diarrhea, and HAV infection are associated with the flood event in Huai River basin.

It is well known that risk of malaria outbreaks increases in the wake of flood events. The results from both the temporal analysis and the spatial analysis show that malaria is sensitive to flood. The changed living condition, environmental ecosystem, and human behaviors during flood events may increase the incidence of vector-borne infectious diseases.^{8,17,18,23} Natural systems and environmental health are damaged during the flood.⁴⁵ In that mosquitoes and pathogens are sensitive to external moisture levels and temperature. Expanded waterlog, stagnant water, and high temperature can conduce to proliferation of pathogens, mosquitoes, and other arthropods.⁴⁶ Large rainfall also impacts the breeding of mosquitoes. Heavy rainfall may increase larval habitat and vector population size by creating new habitat. Epic rainfall events can synchronize vector host seeking and virus transmission. Humid environment has been found to be one of the most critical determinants in vector-borne diseases.²³ Our study shows that even after controlling these factors, flood has independent impacts on malaria.

The results suggest that flood may increase the incidence of waterborne diseases including diarrhea and HAV infection. There is some evidence that the increment in waterborne

disease incidences during flood may be due partly to direct exposure to floodwater.^{23,46,47} During the flood, people living in flood-hit houses are at the risk of waterborne diseases.^{46,48} Flood event may lead to the transmission of waterborne diseases, by affecting pathogens, contaminating the drinking water⁴⁷ and then influence the incidences of diarrhea and HAV infection.³⁰ Flood may cause disruption of water purification and sewage disposal systems, rupture of underground pipelines and storage tanks, and overflowing of toxic waste sites. These events can result in increased exposure to contaminated waste, food and more pathogens.⁴⁹ The damp and hot living condition in disaster areas may assist the growth and reproductive of pathogenic bacteria of gastrointestinal disease.⁵⁰ Meanwhile, in the humid and heat environment, pathogenic factors are easily formed in the human body. The combination of terrible meteorological condition, flood contaminated water and food, substantial refugees and emergency workers displacement following spoiled houses, and lower degree of health care facilitate the transmission of communicable diseases in the Huai River basin.^{8,23,32,51} The result from spatial analysis indicated that compared with the non-affected areas, the increment of bacillary dysentery in Huai River basin was statistically significant. Temporal analysis showed that the OR of bacillary dysentery was also larger than one, although it was not statistically significant. The temporal results indicated that there was an increment of bacillary dysentery incidence during flood period while the increment was not significant compared with the control periods. Both analyses suggested that bacillary dysentery could be sensitive to flood events. In terms of typhoid and paratyphoid, there were only 19 cases observed during the flood event in Huai River basin. The ORs from both temporal and spatial were all less than one and not statistically significant. The results indicated that typhoid and paratyphoid might not be associated with flood event. In addition, a very low number of notified cases may cover the real associations. There was a low basic incidence of typhoid and paratyphoid in Huai River basin. During June 29 and July 25, from 2004 to 2006 and 2008 to 2011, the average number of cases of typhoid and paratyphoid was 17. This may not be sufficient to detect any significant trend over the period.

No significant associations have been detected between rodent-borne diseases and flood.

The results of the current work provide useful framework to identify infectious diseases related to flood events. Understanding the associations between diseases and flood events would be beneficial to examine population vulnerability to flood events. The capacity of people to have a better resilience to the event in specific region is also essential. More locally driven actions can be effectively taken to deal with the disease epidemic, once the flood-related diseases could be identified. In addition, with limited health resources, our quantified results of the association between diseases and flood events could help to control the flood-related diseases in public health preparation. It can assist local government to intensify their surveillance of sensitive diseases to achieve better resilience. The design of early warning system should take the lag effects of flood for different diseases into consideration. The combination of temporal and spatial analysis could provide more robust results. The Poisson regression analysis compares disease incidences in different years in the same region, which has overcome any secular trend and

seasonal variation. Spatial analysis could adjust the mutual effects among counties, which completes and confirms the results from the temporal analysis. Factors that vary over different cities in Anhui Province, such as daily meteorological data and health facilities, have been controlled as potential confounders.

Local demand-driven governmental responses had been taken to deal with the flood events. For example, affected population were transferred and relocated to safe areas as quickly as possible.⁵² Finance support from the government, donation from home, and abroad and rescue workers were all allocated to the flood-affected area as emergency. Buildings, transportations, medical, and educational facility reconstruction were all incorporated in post flood actions.⁵² However, the governmental actions were not very effective to protect people from impacts of flood events.⁵³ A lot of defects still exist in flood disaster emergency management.⁵⁴ First, the measures mentioned were not specifically for the response to floods but rather general preparation for all natural disasters. No flood alerts system linked to special disease surveillance data were developed. Evidence shows that in regions where flood events are common, early warning systems to prevent and control potential disease outbreaks may contribute to a more rapid return to baseline levels of incidence after flood.⁵⁵ Second, health emergency management related to flood disaster lacks suitable indicators and evaluation.⁵⁴ Extreme precipitation during flood events that overwhelm sewer systems and treatment plant can induce untreated water to be released directly into receiving waters. Therefore, monitoring environmental sanitation (particularly disinfection and water potability) and providing continuity of medical and social care by training health professionals should be integrated into flood-related action plans.⁴⁹ Third, a very low proportion of population in the flood-affected area would know appropriate actions to respond to flood, for example, self-rescue behaviors and disease prevention measures during flood events, even though Huai River basin was prone to flood events. The propagations of post flood health prevention knowledge, including increased public awareness of environmental hygiene, safe and clean food, should be carried out by mass media and health-care institutions.⁵⁶ In addition, clearly describing flood impact on health and identifying flood-related diseases are necessary for developing strategies to respond to future flood event and to reduce associated health burden.

Results indicate that more work need to be done to reduce the risk of infectious diseases related to flood events. Our study on the association between flood events and diseases is useful for developing models to predict future health impacts from floods, which could be useful to prevent and reduce disease outbreaks. With the advanced notice of potential risk of flood event to related diseases, those in charge of water quality can take proactive actions to reduce disease risks.⁵⁷

Limitations of our study should be acknowledged. First, under-report is an issue in any communicable disease surveillance systems in China and other countries as well.^{58–60} Because of the underreporting, there might be some underestimations in our results regarding the impact of flood events on diseases. However, the underreporting rate was assumed stable over the study period, and the impact on our analysis would be minimal. Second, we just selected 1 year flood exposure. To obtain a more general result, more flood events in the Huai River basin and other areas should be further evaluated

in the future to have a better understanding of the health impact of flood events.

CONCLUSION

The study shows that malaria, diarrhea, and HAV infection are sensitive to flood in the study region. Given the increasing frequency of flood events and the considerable health burden caused by infectious diseases, prevention of these flood-associated infectious diseases is paramount.

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