

# Examining geographical disparities in the incubation period of the COVID-19 infected cases in Shenzhen and Hefei, China

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## Research Article

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# Abstract

**Aim** Current studies on the COVID-19 depicted a general incubation period distribution and did not examine whether the incubation period distribution varies across patients living in different geographical locations with varying environmental attributes. Profiling the incubation distributions geographically help to determine the appropriate quarantine duration for different regions.

**Subject and Methods** This retrospective study mainly used publicly-accessible clinical report data for patients (n=543) confirmed as infected in Shenzhen and Hefei, China. Based on 217 patients on whom the incubation period could be identified by the epidemiological survey. Statistical and econometric methods were used to investigate how the incubation distributions varied between infected cases reported in Shenzhen and Hefei.

**Results** The median of incubation periods of the COVID-19 for all 217 infected patients was 8 days (95% CI 7 to 9), while median values were 9 days in Shenzhen and 4 days in Hefei. The incubation period probably has an inverse U-shaped association with the meteorological temperature. The warmer condition in the winter of Shenzhen, average environmental temperature between 10°C to 15°C, may decrease viral virulence and result in more extended incubation periods.

**Conclusion** Case studies of the COVID-19 outbreak in Shenzhen and Hefei indicated that the incubation period of COVID-19 had exhibited evident geographical disparities, although the pathological causality between meteorological conditions and incubation period deserves further investigation.

## 1 Introduction

The outbreak of the 2019 novel corona virus (COVID–19) has rapidly spread across China and then to several other countries/regions in the month since it emerged in Wuhan in December 2019. Although the vast majority of the infected cases were reported in China, the sudden public health crisis caused by this novel respiratory virus poses a serious and imminent threat to the global community (Wang *et al.*, 2020). According to the World Health Organization, this virus primarily spreads by respiratory droplets, saliva and nasal discharge. After being infected, the mild symptoms include a runny nose, sore throat, cough, and fever, which in severe cases can lead to pneumonia or dyspnea (WHO, 2020).

Compared to the clinical symptoms, which gradually are well established, debates on the incubation period are more diversified. The incubation period refers to the time gap between infection and the onset of clinical symptoms. As a key epidemiological parameter, the incubation period has been extensively investigated by clinical studies on COVID–19 (Li *et al.*, 2020; Backer *et al.*, 2020; Guan *et al.*, 2020; Yang *et al.*, 2020; Xu *et al.*, 2020; Lai *et al.*, 2020). These studies, however, all depicted a general incubation period distribution based on the available cases and did not examine whether the incubation period distribution varies across cases living in different geographical locations with varying environmental attributes. A few studies have confirmed the effects of air conditions on the viability of SARS virus (Tan *et al.*, 2005; Lin *et al.*, 2006; Casanova *et al.*, 2011). For instance, Chan *et al.* (2011) described the prevalence of the SARS

coronavirus in the spring in subtropical Asia areas with an average temperature of 22–25°C and a relative humidity of 40–50%. Based on the strong similarity between the SARS virus and COVID–19 (Zhu *et al.*, 2020), it is reasonable to hypothesize that there are geographical effects of meteorological conditions on COVID–19 and further examine whether infected persons in different places experience varying incubation periods.

Hence, the research question in this study is how geographical factors affect the incubation period of COVID–19 and whether that period varies by location. Incorporating geographical variance into an analysis of the incubation period could refine the appropriate duration of quarantine in different locations and determine how many days should be included in the analysis of contacts made by infected cases.

## 2 Data And Methods

### 2.1 Data source and research area

This retrospective study mainly used publicly accessible data. As one measure to address COVID–19, local health authorities in China have been required to release information on the infection situation online every day since the middle of January. Most city/county authorities provide the day-to-day aggregated numbers of infected cases. However, some cities release brief clinical reports (including travel routes and clinical features) for each confirmed infected case. Among them, two cities, Shenzhen in the subtropical zone and Hefei in the temperate zone were selected (Table 1).

Shenzhen, adjacent to Hong Kong, is in the southern part of Guangdong Province in China, with a straight-line distance of 875 km to Wuhan. The latitude of this subtropical city is 22°32' N. The average maximum and minimum temperatures in January are 20°C and 13°C, respectively. The weather in January is commonly cloudy and calm. Another city, Hefei, the capital of Anhui Province, is in the middle of China. The distance from Hefei to Wuhan is 300 km. The latitude of Hefei is 31°86' N, and the average maximum and minimum temperatures in January are 8°C and 0°C, respectively. The weather in January is commonly rainy and snowy, with higher relative humidity (Figure 1).

### 2.2 Data processing and methods

This analysis was based on clinical reports of confirmed patients in Shenzhen and Hefei. Basic demographic variables, travel history, date and place of symptom onset, admission date and confirmed infection date were first collected for each patient. Then, all cases were grouped into three types according to residence, namely, local residents, Hubei residents, and other residents. Second, according to the retrospective travel history, all cases were divided into three groups, namely, traveled to Hubei, traveled to other places, and did not travel. According to this grouping, it was possible to compute the number of imported cases and cases of local community transmission in each city (Figure 2).

According to travel history and residence, we attempt to identify the incubation period for some cases. The cases who were Hubei residents were first excluded because the clinical reports generally did not

have clear dates of contact with transmission sources. We mainly looked at two groups. The first group included local residents who had clear contact records with infected persons in local communities. The second group included non-Hubei residents who had clear travel histories to Hubei or other places and became infected. For the individuals who visited and stayed in Hubei or other places for more than one day, it is challenging to define the exact date on which direct contact was made with an infected source. After careful consideration, we eventually selected the arrival date as the initial date of infection, considering the highly contagious nature of this disease (Chan *et al.*, 2020) and lack of prevention measures taken by these individuals.

After obtaining the incubation period for each patient, statistical methods including descriptive analysis, variance analysis (ANOVA) and regression were used to look at how the incubation distribution varied between Shenzhen and Hefei.

## 3 Empirical Results

### 3.1 Demographic characteristics of infected cases

By 12 February 2020, 386 and 157 cases were reported in Shenzhen and Hefei, respectively (Table 2). Considering the permanent populations in Shenzhen and Hefei, the incidence rates were 0.035‰ and 0.020‰, respectively. The number of infected cases varied slightly by sex. Shenzhen had slightly more female patients, while the number of male patients in Hefei was higher than that of female patients.

In contrast to the slight variation by sex, the number of patients clearly varies with age (Figure 2). In general, an inverse U-shaped relationship possibly exists between age and the number of infected cases reported in Shenzhen and Hefei. Namely, compared to children and the elderly population, more infected cases are adults between the ages of 30 and 50 years. This feature is evident in Hefei, where the largest proportion of cases is in the age interval from 41 to 50 years. In Shenzhen, there were two peaks in the age distribution. The first is the age group from 31 to 40 years, and the second is the age group from 61 to 70 years (Figure 3).

This difference was probably caused by demographic features between these two cities. As the largest immigrant city in China, a large proportion of young residents (approximately 30 years) in Shenzhen traveled to their hometown in Hubei Province for family reunions during the Spring Festival holiday and were finally reported as infected when they came back Shenzhen. At the same time, a large number of potentially infected elderly patients living in Hubei Province came to Shenzhen to celebrate the Spring Festival holiday with their children. According to the data, 43.8% of all 137 infected cases who resided in Hubei and traveled to Shenzhen were over the age of 60 years. Hence, the percentage of infected patients who live in Hubei Province but were reported as infected in the city of Shenzhen is high. In contrast, the largest number of infected cases in Hefei were local residents who did not have travel histories. This indicates that most cases were likely to be infected by human-to-human transmission within local communities in Hefei.

### 3.2 Symptom onset location

Eighty percent of patients confirmed in Shenzhen or Hefei first exhibited symptoms in Shenzhen and Hefei. However, some patients were reported to have initial symptoms in Hubei and other places. Forty-eight patients reported in Shenzhen, and 14 patients in Hefei had relevant symptoms first in Hubei (Table 3). Among them, 37 patients lived in Hubei, 31 patients finally travelled to Shenzhen, and 6 patients travelled to Hefei. On the other hand, 43 patients exhibited related symptoms in other places (beyond Shenzhen, Hefei and cities in Hubei Province). These places even include some cities outside China, i.e., Phuket Island in Thailand, Yangon in Myanmar, London and Rome (Figure 5). These infected cases have become traveling transmission sources, substantially enlarging the infected areas worldwide.

### 3.3 Variance analysis of the incubation period

Although all patient cases had detailed records of the symptom onset date and location, the initial infection date could be identified for only 176 cases reported in Shenzhen and 41 cases in Hefei (Table 4). A total of 64.7% of the 217 cases were local residents in Shenzhen and Hefei who traveled to Hubei. Among all patients, the average incubation period was 8.58 days, and the median value was 8 days.

It is notable that the incubation period varied between Shenzhen and Hefei. Specifically, the median was 9 days for cases reported in Shenzhen and 4 days in Hefei. The interquartile range was from 5 days and 13 days in Shenzhen and from 3 days to 8 days in Hefei. After normal testing, a one-way analysis of variance (ANOVA) indicated that differences in the incubation periods across two cities are statistically significant at the 99% level (Figure 6). This suggests geographical disparities in the incubation period.

### 3.4 Regression on the incubation period

Since the variable of incubation period basically fits the normal distribution (Table 4), this variable was directly used as the dependent variable in the following models (Table 5). Model 1 aimed to examine the effects of demographic variables on the incubation period. Due to data availability, only age and sex could be examined in Model 1. Considering the possible curvilinear relationship between age and incubation period, the quadratic term for age (age-squared) was incorporated as one explanatory variable as well. On the basis of Model 1, a 0–1 dummy variable, city, referring to the location where the patient was reported as infected, was used as a proxy variable in Model 2 to geographically test variance in the incubation period between Shenzhen and Hefei. To clarify geographical disparity effects, referring to Tan et al. (2005), the variable temperature (average maximum environmental temperature in the place where the patient case first developed related symptoms) and its quadratic item were incorporated in Model 3.

All three models were estimated by the ordinary least square (OLS) method, with significant F-statistics at the 99% level. The R-squared value of model 1 was as low as 0.075, indicating that the power of the demographic variables for explaining the variance in the incubation period is not adequate. However, the R-squared value increased steadily after incorporating geographical factors in Model 2 and Model 3. For

limited pathogenesis-related variables, the R-squared values for both models, to some extent, were acceptable.

First, the factor of sex does not have a statistically significant linkage with the variance in incubation period in any models. This outcome is line with the finding that no evident differences exist based on sex with regard to the number of infected cases.

Second, the coefficient for the effect of age and its quadratic term (age-squared) on the incubation period are  $-0.258$  and  $0.003$ , respectively. Both estimations were statistically significant at the level of 99%. Although the positive elasticity in the quadratic term of age is very small, it, together with the negative elasticity in age, statistically confirms that a U-shaped relationship exists between age and incubation period (Haans, *et al.*, 2016). This suggests that adults are probably more vulnerable to this coronavirus virus after infection, resulting in a shorter incubation period in adults. Considering that the largest proportion of infected cases are adults from 30 years to 50 years, persons in this age interval should be more cautious about the risk of being infected.

Third, the increasing R-squared values from Model 1 to Model 3 support the hypotheses regarding the geographical disparities in the incubation period. The incubation period distributions are not the same in different locations. The shorter incubation period in patient cases in Hefei was statistically verified. The underlying reason could partly be attributed to temperature. According to the results of Model 3, the coefficient for the variable of temperature is positive ( $0.717$ ), while the coefficient for the quadratic term (temp-squared) is negative ( $-0.030$ ). Both elasticities are statistically significant at the level of 99%. These outcomes statistically demonstrate the possible inverse U-shaped relationship between the environmental temperature of the symptom onset location and the incubation period in this study. Estimating the inflexion of this inverse U-shaped curve, we further infer that the incubation period of COVID-19 virus is longest in this study when the outdoor environment temperature is approximately  $10\sim 15^{\circ}\text{C}$ .

## 4 Discussion

As one of the critical parameters for understanding the COVID-19 epidemic, incubation periods are being continually updated as an increasing number of clinical case records have been obtained. As shown in Figure 7, the outcome varies across the cases used in each study. Li *et al.* (2020) first declared that the mean incubation period was 5.2 days among the 425 infected patients identified early in the epidemic, and the value at the 95th percentile of the distribution was 12.5 days. Using the 88 early cases with travel histories to Wuhan, Backer *et al.* (2020) found that the mean incubation period was 6.4 days, ranging from 2.1 (2.5th percentile) to 11.1 days (97.5th percentile). Nevertheless, the findings obtained from some large-size case studies were slightly conservative in that the incubation period had a lower median and broader range. For instance, based on 1,099 patient cases, Guan *et al.* (2020) concluded that the incubation period ranged from 0 to 24 days, and the median was 3 days. In this study, the median (8 days) for 176 valid patient cases was larger than in other studies. Only for the 41 cases reported in the

city of Hefei, the median value was 4 days, less than the incubation periods reported in other studies (Figure 7). Hence, the variance probably did not result from the number of cases in each study. The problem partly lies in the feature of patient cases. The early patient cases, resided in Wuhan which were mainly studied by current studies, probably were infected with the early-generations virus that has more substantial virulence. Along with human-to-human transmissions to local communities in Shenzhen, the virulence of the virus on the third-or-fourth generations of cases may decrease and lead to a shorter incubation period.

In addition, the methods of identifying the incubation period also lead to some basis. According to Backer *et al.* (2020), the incubation period was determined as the duration from the date when the case left Wuhan to the date of illness onset. As the authors admitted, this determination may be slightly conservative. In contrast, the incubation period in this study is determined from the date the patient arrived in Hubei to the illness onset day. It is slightly overestimated, which would inevitably result in some basis. The reason why we insisted on adopting this definition is that the travels on the part of patients who had been to Hubei in this study generally occurred after January 10, 2020, unlike the cases in Backer *et al.*, who traveled from Wuhan during in the initial stage of this epidemic. In light of the extremely rapid transmission of this virus along with the pre-Spring Festival travel rush and the fact that the infected patients did not usually take any preventive measures before January 22, 2020, the risk of being infected after arriving at Hubei was high. Therefore, we defined the incubation period as described above in this study, given that there are not any more commonly accepted methods. With more updated data, the following research could just investigate the incubation period for cases who have clear epidemical contact date no matter the cases were imported ones or were infected by transmission within local communities.

Compared to calculating the specific values of the incubation period, the focus of this research was to look at the geographical disparities in the incubation period distribution. After employing several statistical methods, this study sufficiently demonstrated that the incubation periods of COVID-19 vary across the patients reported in two cities, Hefei and Shenzhen, China. The infected cases in Shenzhen averagely had more extended incubation periods. From the perspective of medical geography, we attempt to attribute this geographical variability to the variances in the average outdoor daytime maximum temperature prior to the date of illness onset, the explanatory power of which reached 15% in this study. We further infer that under the warmer condition in the winter of Shenzhen, the multiplication and transfer of this novel coronavirus within the human body may decrease. The decrease of viral virulence probably decelerates the process of cell lesions and immune injury, and then postpones the incubation duration from being infected to the clinical symptom onset. On the contrary, a cold environment in Hefei, could result in physiological responses and weaken the function of human immune system (Inoue *et al.*, 1995; Shephard *et al.*, 1998), which in turn may raise the risk of being infected and leads to a short incubation period.

The association between viral virulence and environmental temperature for COVID-19 probably is line with Chan *et al.* (2020) and Casanova *et al.* (2020), which revealed the stability of the SARS virus at

different temperatures and relative humidity by laboratory experiments. To further verifying this process, subsequent studies or experiments could consider incorporating more environmental indicators, i.e., relative humidity and ultraviolet intensity, subject to data availability.

## 5 Conclusion

Understanding the incubation period of COVID-19 is crucially important in the face of the ongoing epidemic (The Lancet, 2020). Based on the clinical reports of infected cases in Shenzhen and Hefei, this contradistinctive study determined the incubation period for each patient and disclosed the geographical disparities in incubation period distribution of this novel coronavirus. In particular, the median incubation period for infected cases in Shenzhen was 9 days, with an interquartile range from 5 to 13; while in Hefei the median incubation period was 4 days, with an interquartile range from 3 to 8. The incubation period has an inverse U-shaped numeric relationship with the maximum temperature of the outdoor environment. In this study, when the meteorological temperature was maintained at approximately 10~15°C, the incubation period became the longest. The reason probably lies in the hypothesis that the viral virulence may reduce when the temperature increases, which deserve further investigation.

Profiling the incubation distribution geographically benefits policy-makers determining the appropriate quarantine duration for different regions and evaluating how many days should be included in the tracing of contacts for both infected cases and suspected cases (Xu *et al.*, 2020, Wang and Zhang, 2020). Acknowledging the association between environmental temperature and the incubation period facilitates the forecasting of the transmission and evolution cycle.

## Declarations

Conflict of Interest

*The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.*

Data availability: All the data used for this research is from the website of local public health authorities, which can be found here: <http://wjw.hefei.gov.cn/ztzl/xxgzbdg>

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## Tables

**Table 1.** Basic information on Shenzhen and Hefei

City	Shenzhen	Hefei
Permanent population	10.77	7.96
Geographical zone	subtropical	temperate
Latitude	22°32' N	31°86' N
Average temperature	Min 20°C	8°C
in January	Max 13°C	0°C

**Table 2.** Demographic information on infected cases by February 12, 2020

Variable	Shenzhen		Hefei		Variable	Shenzhen		Hefei	
	<i>N</i>	%	<i>N</i>	%		<i>N</i>	%	<i>N</i>	%
No. of cases*	386	100	157	100	<i>Sex</i>				
<i>Incidence ratio</i>	0.035‰		0.020‰		Male	184	47.67	84	53.50
<i>Age</i>					Female	202	52.33	73	46.50
≤10	24	6.22	2	1.27	<i>Residence</i>				
11~20	16	4.15	4	2.55	Local	234	60.62	116	73.89
21~30	33	8.55	29	18.47	Hubei	136	35.23	28	17.83
31~40	87	22.54	30	19.11	Other places	15	3.89	11	7.01
41~50	61	15.80	41	26.11	<i>Travel history</i>				
51~60	71	18.39	29	18.47	Hubei	287	74.35	42	26.75
61~70	80	20.73	12	7.64	Other places	30	7.77	16	10.19
≥71	16	4.15	10	6.37	No travel history	68	17.62	97	61.78

**Table 3.** Distribution of symptom onset locations

Symptom onset location	Shenzhen		Hefei		Total	
	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%
Local city	305	79.01	132	84.07	437	80.62
Hubei	48	12.44	14	8.92	62	11.44
# Hubei resident	31		6		37	
Other places	33	8.55	11	7.00	43	7.93

**Table 4.** ANOVA on the incubation period between infected cases in Shenzhen and Hefei

Variable		Shenzhen	Hefei	Total
No. of infected cases with clear incubation period	No. of infected cases	176	41	217
	Proportion of all infected cases	45.59%	26.11%	39.96%
	# Traveled Hubei	139	12	141
	# Traveled to other places	12	4	16
	# No travel history	25	25	50
Normal testing	Median	9	4	8
	Mean	9.27	5.61	8.58
	Std. Dev.	4.59	3.62	4.65
	95% <i>Conf. Interval</i>	[8, 10]	[4, 6]	[7, 9]
	Skewness	0.32	0.90	0.42
	Kurtosis	2.43	2.99	2.45
F testing	F	22.67		
	Prob > F	0.000		

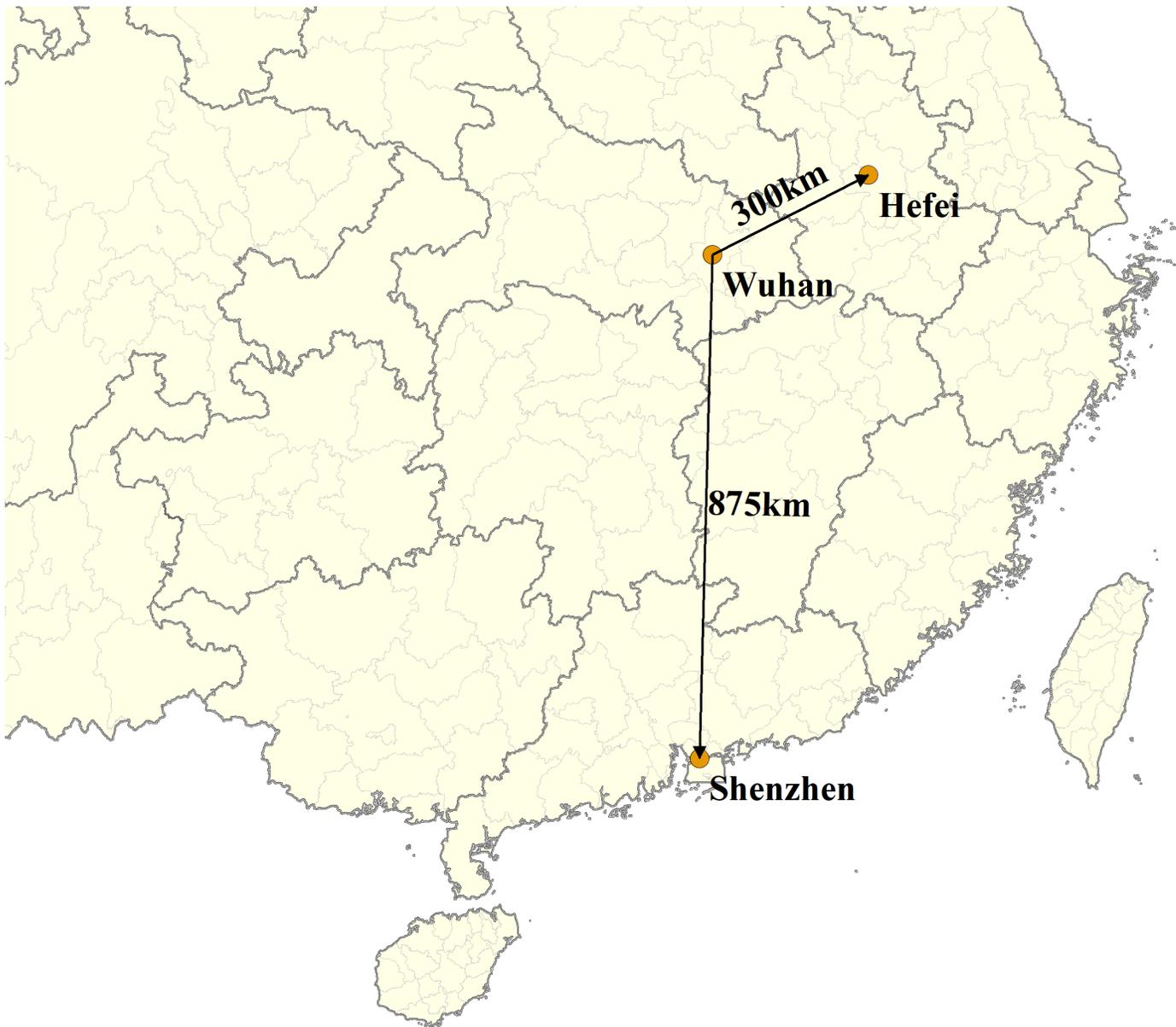
**Table 5.** Regression results for the geographical disparities in incubation period

Variable	Model 1		Model 2		Model 3	
	<i>Coef.</i>	<i>p</i>	<i>Coef.</i>	<i>p</i>	<i>Coef.</i>	<i>p</i>
constant	13.331	0.000	13.325	0.000	9.662	0.000
sex	0.191	0.755	-0.032	0.957	-0.047	0.933
age	-.297	0.000	-0.258	0.000	-0.250	0.000
age-squared	0.003	0.000	0.003	0.000	0.003	0.000
city <sup>#</sup>			-3.313	0.000		
temp <sup>##</sup>					0.717	0.001
temp-squared <sup>##</sup>					-0.030	0.000
No. of obs.	217		217		217	
Prob > F	0.000		0.000		0.000	
R-squared	0.075		0.151		0.226	
Adj. R-squared	0.062		0.135		0.208	

Note: #. The baseline is Shenzhen; this variable was deleted from Model 3 because of collinearity.

##. Average maximum temperature in the place where the patient first developed related symptoms.

## Figures



**Figure 1**

The Locations of Shenzhen and Hefei in China. 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.

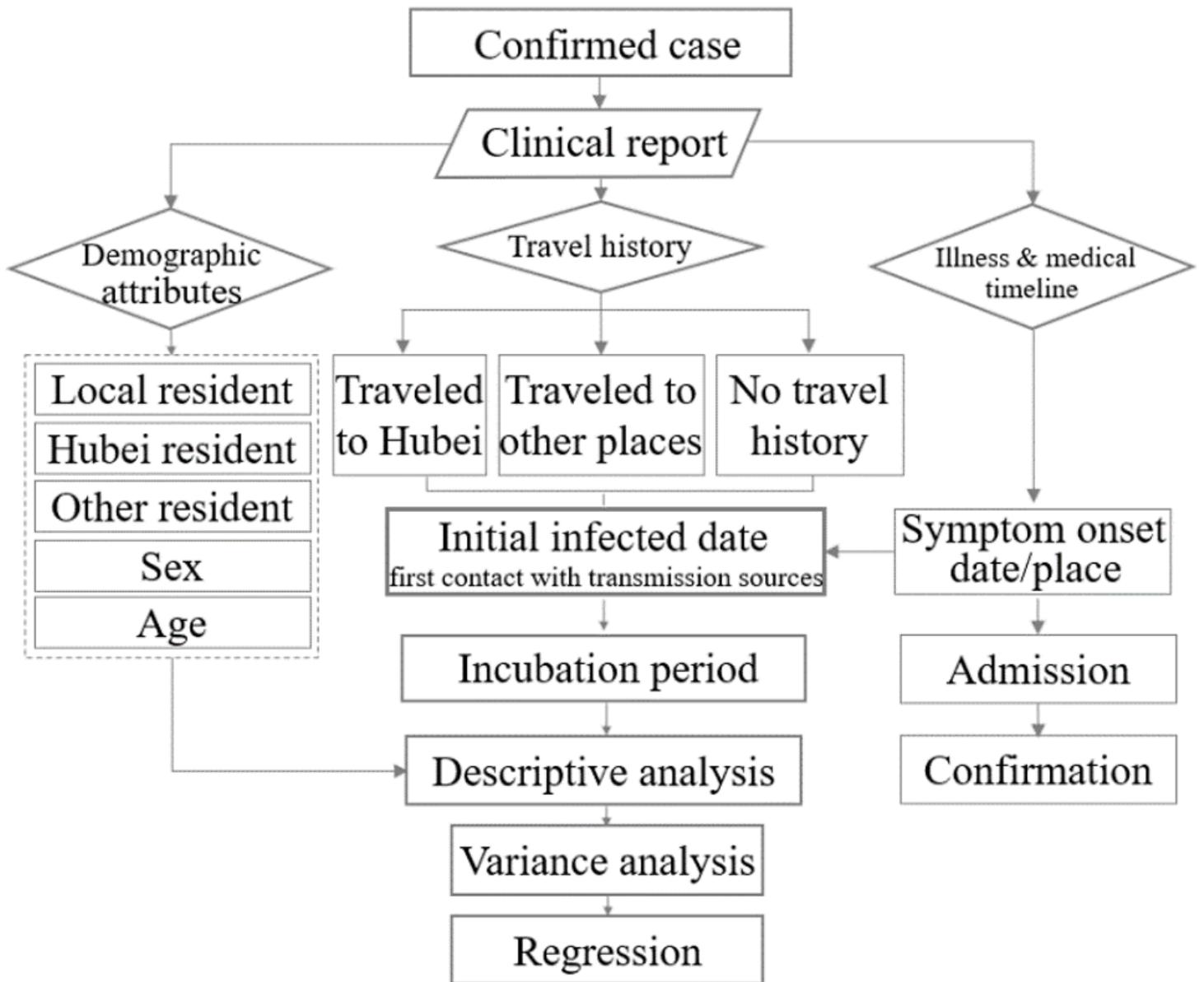


Figure 2

Flow chart

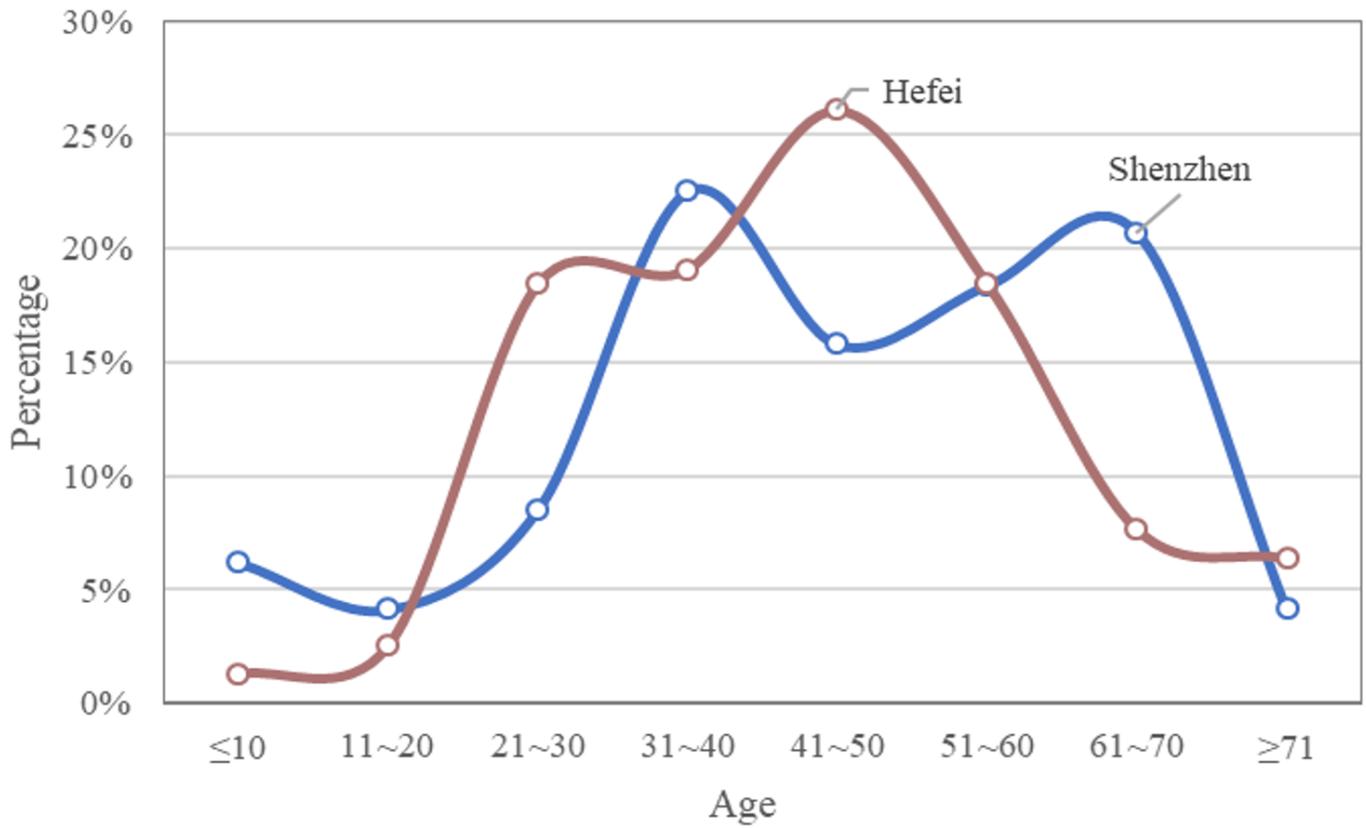


Figure 3

Association between age and the number of infected cases

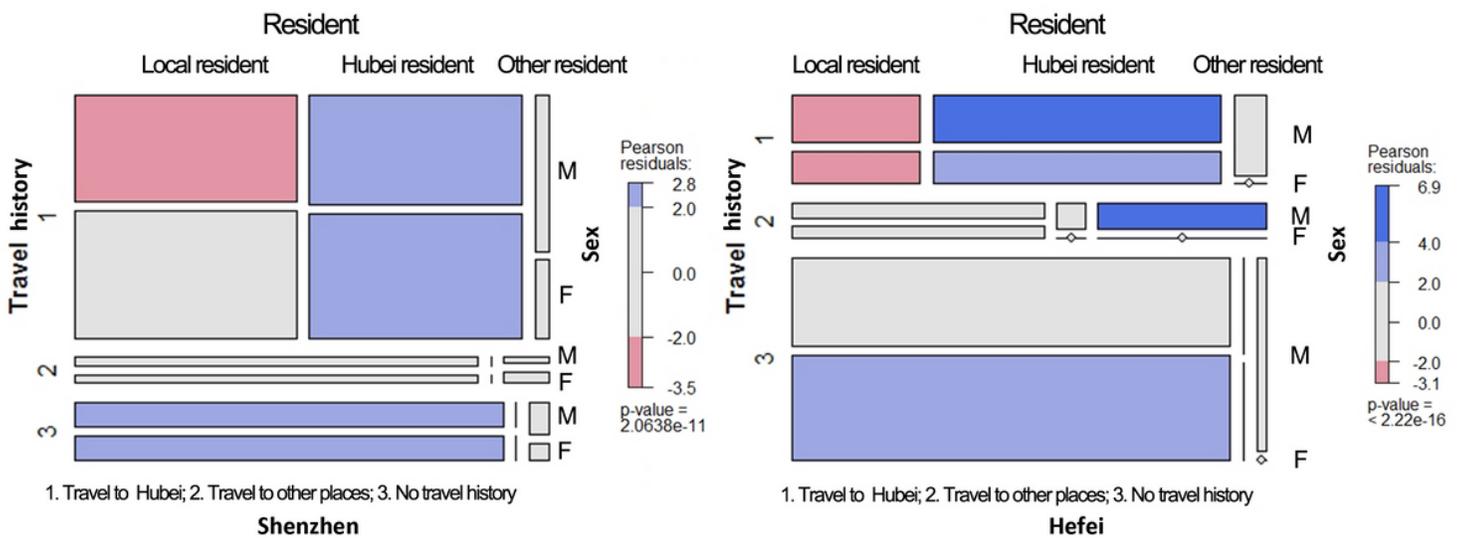


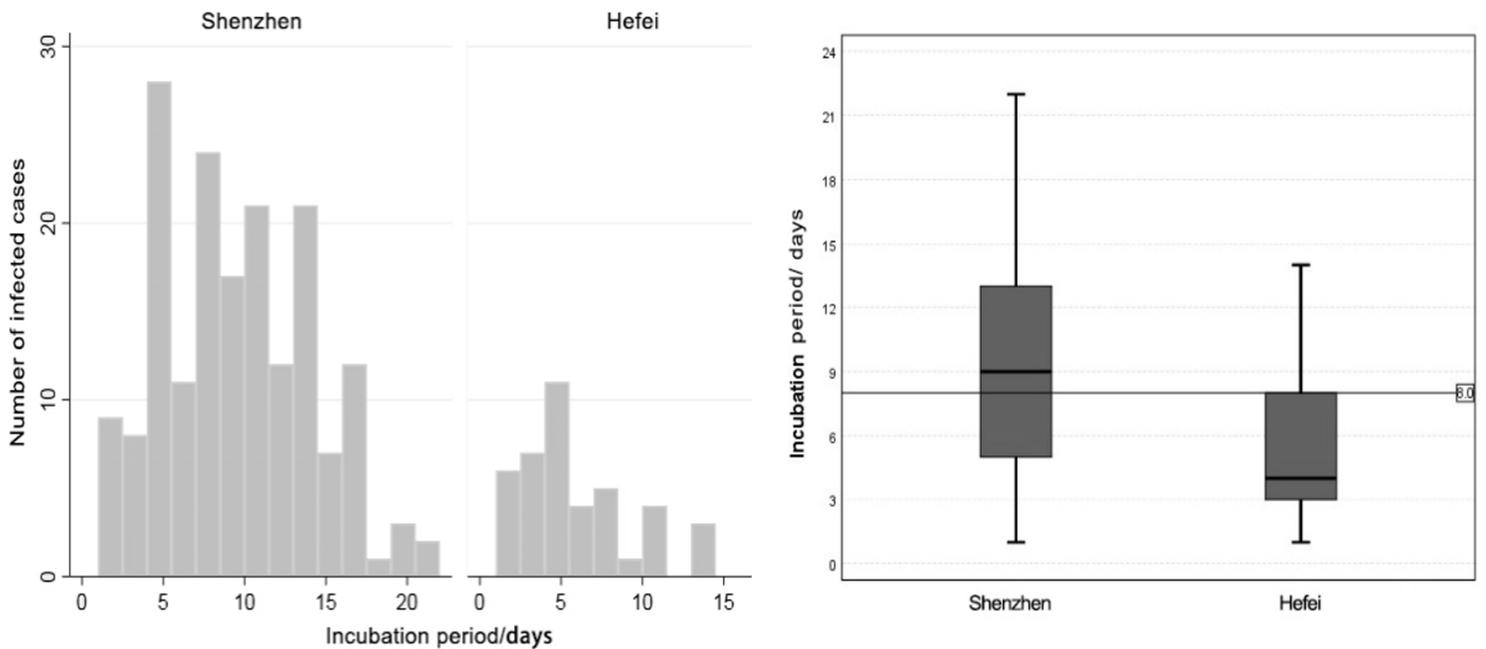
Figure 4

Demographic structure of infected cases in Shenzhen and Hefei



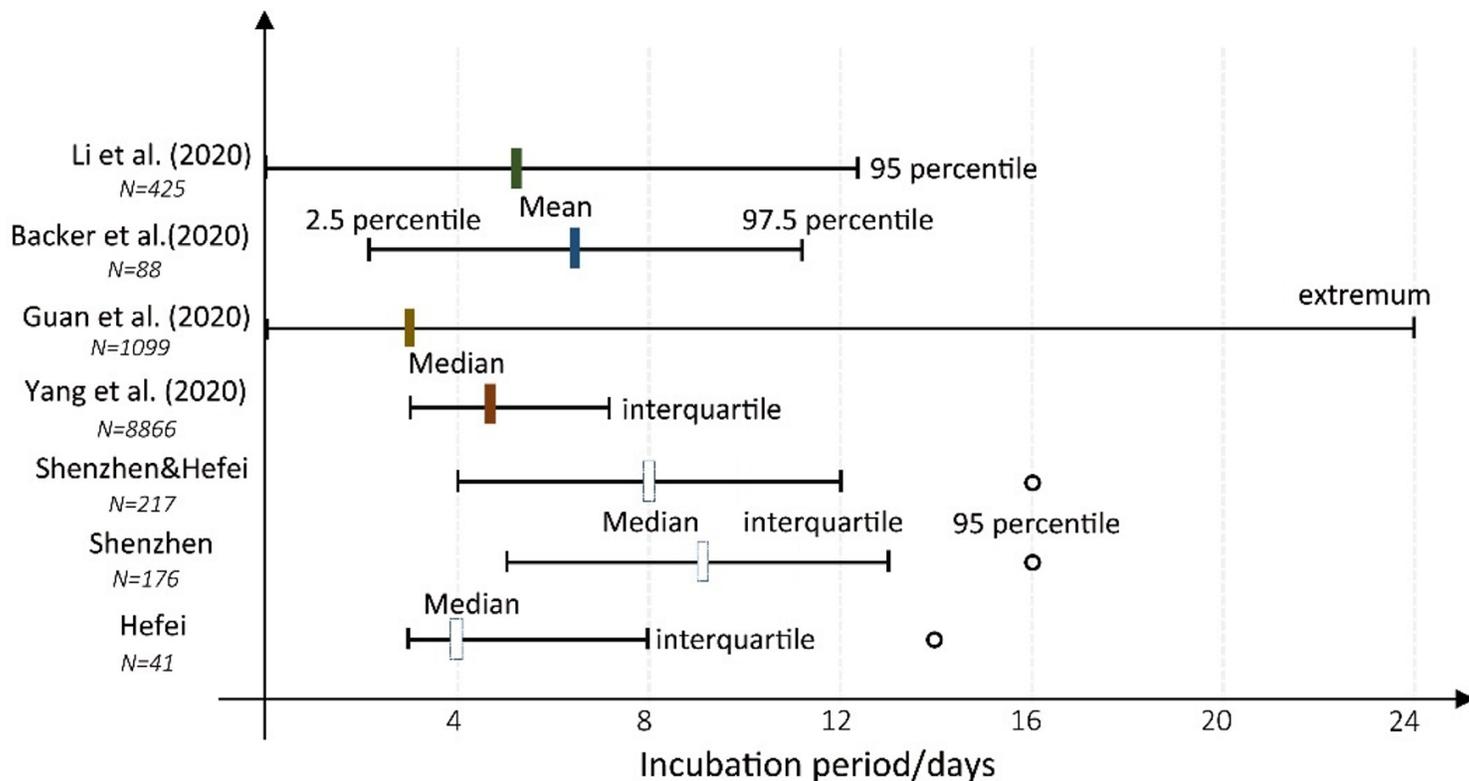
**Figure 5**

Geographic distribution of symptom onset locations. 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 6**

Incubation period distributions for infected cases reported in Hefei and Shenzhen



**Figure 7**

Incubation periods of COVID-19 from different studies

## Supplementary Files

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