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Spatial transmission of COVID-19 via public and private transportation in China

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Wuhan, the capital city of Hubei province with a population of more than 11 million people, is the largest city and the most important traffic hub in Central China. Since December 2019, the outbreak of coronavirus disease 2019 (COVID-19) hit the Wuhan city [1]. The time of the outbreak coincided with the Chinese Spring Festival, when the largest annual population movement began. Before the lockdown on January 23rd, an estimated 5 million residents left Wuhan [2]. The infected people in incubation period had brought the virus to other cities and person-to-person transmission of the new coronavirus caused the spread of infections across the country.

Up until February 9th, there have been 330 cities in addition to Wuhan with reported confirmed COVID-19 cases in mainland China (figure A). In the study of Zhao et al., they found significant association between travel by train and spread of COVID-19 infections, but not for travelling by car and flight [3]. In order to evaluate the role of public transportation in the spatial transmission of COVID-19, we searched daily flights, buses, and trains from Wuhan to these cities in January (https://www.ctrip.com). The figure shows destinations and frequencies of these flights (B), buses (C) and trains (D) from Wuhan. We also obtained straight line distances between Wuhan and these cities (https://map.baidu.com) and excluded those ≥1500 km to avoid outlier effects. The daily number and the cumulative number of COVID-19 cases in each city were obtained from the official website (http://health.people.com.cn/GB/26466/431463/431576/index.html) with real-time updates at 12:00 pm on each day since January 24th. All the data were logarithmically transformed and the Pearson´s correlation analysis was used to examine correlations of daily frequencies of each transportation methods and the distance between Wuhan and other cities, with the daily

number and the cumulative number of COVID-19 cases.

We found a significant and positive association between the frequency of flights, trains, and buses from Wuhan and the daily as well as the cumulative numbers of COVID-19 cases in other cities with progressively increased correlations for trains and buses (all *P* values < 0.001) (figures E, F). The distance between Wuhan and other cities was inversely associated with the numbers of COVID-19 cases in that city (all *P* values < 0.001), and the correlation became increasingly stronger and went stable after February 1st. The mean incubation period was estimated to be 5.2 days [1], therefore real associations appeared after most infected cases out from Wuhan presented typical symptoms and were diagnosed [4].

Our findings indicated that imported cases via public transportation played an important role in the spread of COVID-19. The connectivity and distance between the epicenter and the destination are important determinants of transmission risks. Strong preventive measures should be taken in cities with shorter distances and more frequent public transportation connectivity with epicenter in order to contain the COVID-19 epidemic.

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Availability of data and materials

All data and materials used in this work were publicly available.

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Disclaimer

The funder of the study had no role in study design, data collection, data interpretation, or writing of the report. Drs R. Zheng, Y. Xu, Y. Bi, W. Wang, and G. Ning had full access to all the data in the study. The corresponding authors had final responsibility for the decision to submit for publication.

Author`s contributors

Drs R. Zheng, Y. Xu, Y. Bi, W. Wang and G. Ning designed the study. Dr. R. Zheng independently collected and analyzed the data. Drs Y. Xu, Y. Bi contributed to the interpretation of the data. Drs R. Zheng, Y. Xu, and Y. Bi drafted the manuscript. Drs W. Wang and G. Ning revised it critically for important intellectual content. All authors agreed to be accountable for all aspects of the work and approved the final version of the paper.

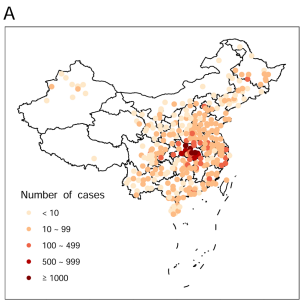
Declaration of competing interest

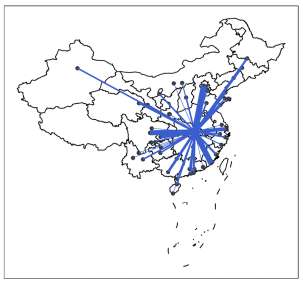
We declare that we have no conflicts of interest.

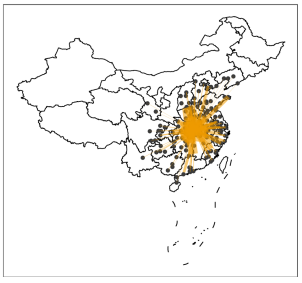
Figure legend

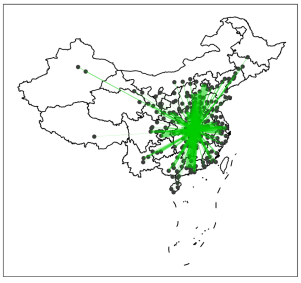
Figure. The destinations and frequencies of different public transportation methods from Wuhan and the associations of transportation and distance with the epidemic of COVID-19 in mainland China.

Panel A shows distributions of COVID-19 cases within mainland China. Darker dots indicate larger numbers of COVID-19 cases. Up until February 9th, 118 cities have reported 1-9 cases; 174 cities have reported 10-99 cases; 28 cities have reported 100-499 cases; 5 cities have reported 500-999 cases; and 6 cities have reported ≥1000 cases. Panel B shows flight destinations and frequencies from Wuhan. Panel C shows bus destinations and frequencies from Wuhan. Panel D shows train destinations and frequencies from Wuhan. Higher weights of lines indicate higher frequencies. Panel E shows the correlation coefficients of daily frequencies of each transportation methods from Wuhan and the distance between Wuhan and other cities, with the daily number of COVID-19 cases. Panel F shows the correlation coefficients of daily frequencies of each transportation methods from Wuhan and the distance between Wuhan and other cities, with the cumulative number of COVID-19 cases. (A high resolution version of the image is available: https://data.mendeley.com/datasets/cgckdx7ykj/draft?a=10faa741-a27b-49e3-a576-22ebbf313c81)









E

Flight	Bus	Train	Distance	
0.392	0.432	0.359	-0.346	Jan. 24
0.239	0.568	0.537	-0.496	Jan. 25
0.321	0.566	0.551	-0.495	Jan. 26
0.239	0.646	0.542	-0.566	Jan. 27
0.179	0.653	0.533	-0.588	Jan. 28
0.246	0.655	0.601	-0.613	Jan. 29
0.229	0.650	0.596	-0.609	Jan. 30
0.254	0.684	0.602	-0.597	Jan. 31
0.221	0.670	0.613	-0.622	Feb. 1
0.239	0.661	0.602	-0.611	Feb. 2
0.222	0.675	0.601	-0.618	Feb. 3
0.240	0.662	0.604	-0.614	Feb. 4
0.208	0.647	0.573	-0.581	Feb. 5
0.208	0.656	0.592	-0.586	Feb. 6
0.186	0.669	0.583	-0.605	Feb. 7
0.187	0.637	0.577	-0.583	Feb. 8
0.184	0.643	0.529	-0.588	Feb. 9

F

Flight	Bus	Train	Distance	
0.436	0.456	0.456	-0.252	Jan. 24
0.376	0.564	0.559	-0.413	Jan. 25
0.379	0.615	0.622	-0.482	Jan. 26
0.348	0.636	0.627	-0.521	Jan. 27
0.319	0.651	0.641	-0.538	Jan. 28
0.314	0.658	0.648	-0.559	Jan. 29
0.305	0.659	0.649	-0.569	Jan. 30
0.312	0.676	0.657	-0.586	Jan. 31
0.309	0.684	0.668	-0.599	Feb. 1
0.307	0.687	0.674	-0.612	Feb. 2
0.302	0.693	0.673	-0.621	Feb. 3
0.302	0.691	0.674	-0.624	Feb. 4
0.299	0.689	0.673	-0.626	Feb. 5
0.298	0.691	0.674	-0.632	Feb. 6
0.295	0.693	0.675	-0.634	Feb. 7
0.293	0.693	0.678	-0.634	Feb. 8
0.293	0.695	0.677	-0.634	Feb. 9