Journal of Virus Eradication 7 (2021) 100040

Contents lists available at ScienceDirect

Journal of Virus Eradication

journal homepage: www.sciencedirect.com/journal/journal-of-virus-eradication

Prevention and control measures significantly curbed the SARS-CoV-2 and influenza epidemics in China

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A R T I C L E I N F O

Keywords:
SARS-CoV-2
COVID-19
Influenza
Prevention
Control measures
China

A B S T R A C T

At the end of 2019, an outbreak of pneumonia took place caused by a new coronavirus (SARS-CoV-2 virus), named coronavirus disease 2019 (COVID-19). A series of strict prevention and control measures were then implemented to reduce the spread of the epidemic. Influenza, another respiratory tract virus, may also respond to these measures. To assess the impact of these measures, we used the total number of passengers movement in mainland China from 2018 to 2020 and daily number of railway passenger flow during the 2020 Spring Festival travel rush to reflect the population movement and to analyze newly and cumulatively confirmed COVID-19 and influenza cases. We found that implementing the series of measures against COVID-19 mitigated both COVID-19 and influenza epidemics in China. Prevention and control measures for COVID-19 might be used to control respiratory tract infections to reduce the national health economic burden caused by these pathogens.

Introduction

At the end of December 2019, an outbreak of pneumonia caused by an unknown pathogen occurred in Wuhan, China,[1] which was later identified as a novel coronavirus (2019-nCoV) on January 7, 2020, and is now named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) by the Coronaviridae Study Group of the International Committee on Taxonomy of Viruses,[2] and its clinical disease is referred to as coronavirus disease 2019 (COVID-19).[3] In order to control the rapid spread of COVID-19, Wuhan was locked down on January 23, 2020, and China raised the national public health response to the first state of emergency – the first of four levels of severity in the Chinese emergency system, defined as an extremely serious incident.[4] A series of prevention and control measures were implemented to curb the spread of the epidemic. The main measures of the first-level response are described on the Table S1. Among them, strictly limiting population movement is a key measure to mitigate viral spread, particularly as the epidemic took place at the time of the peak period of the Spring Festival travel rush.

Similar to SARS-CoV-2, the influenza virus is also a respiratory infectious disease, which causes an estimated 3–5 million cases of severe respiratory infection-related illness and 0.29–0.65 million deaths worldwide annually.[5,6] The influenza virus mutates easily, is highly contagious, and can cause seasonal epidemic every year, mostly in winter and spring.[7] The influenza prevalent season in China is at the end and beginning of each year.

This study mainly analyzes the influence of national first-level prevention and control measures on the epidemic of COVID-19 and influenza, and aims to provide some insights into curbing COVID-19,

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https://doi.org/10.1016/j.jve.2021.100040
Received 1 September 2020; Received in revised form 30 April 2021; Accepted 4 May 2021
Available online 8 May 2021

influenza and other respiratory infectious diseases.

Methods

Ethics

This study was approved by the Ethics Committee of Peking University People's Hospital.

Collection of population flow data

To assess the first-level response for the prevention and control measures of the epidemic, we used the total number of passengers movement in mainland China from 2018 to 2020 and the daily number of railway passenger (DNRP) flows in 2020 during the Spring Festival travel rush to reflect the population movement. The total number of passengers traveling by railway, highway, waterway and civil aviation during the Spring Festival in 2018–2020 and the daily number of passengers traveling by railway during the 2020 Spring Festival were obtained from the website of the Ministry of Transport of China.[8]

Surveillance of COVID - 19 data in China Hubei province excluded

To prevent and control the COVID-19 epidemic in China, except the National Health Commission (NHC) organized and updated the national diagnosis and treatment plan for COVID-19 in a timely manner. New and cumulative cases of COVID-19 in China, except for Hubei province, were obtained from the NHC website.[9]

COVID-19 cases were diagnosed by following at least one of the criteria: 1. SARS-CoV-2 nucleic acid detected by real-time fluorescence quantitative reverse transcription-polymerase chain reaction (RT-PCR). 2. Detection of highly homologous gene sequences to SARS-CoV-2 in serum. 3. Detection of specific IgM and IgG antibodies against SARS-CoV-2 in serum. Absence of specific SARS-CoV-2 IgG response to a positive ≥4 times increase in titer in the recovery period as compared to the acute disease period.[10]

Surveillance of influenza data

The NHC is responsible for the influenza epidemic monitoring throughout the country, which uses nationwide Notifiable Infectious Diseases Reporting Information System (NIDRIS).[11] There are 554 national sentinel hospitals for the influenza surveillance network laboratories. Surveillance subjects had influenza-like illness (ILI) associated with fever (body temperature≥38 °C), and accompanied by cough or pharyngeal pain. All national sentinel hospitals for influenza case monitoring and influenza surveillance network laboratories conducted surveillance of ILI throughout the year. In terms of ILI reporting, the national influenza surveillance sentinel hospitals and influenza surveillance network laboratories report their surveillance data to the Chinese National Influenza Center (CNIC) before midnight each Monday. The ILI and influenza positive rates from October 2017 to February 2020 which were used in the present study, were obtained from the weekly report of the CNIC.[12]

Statistical analysis

All statistical tests were performed using the SPSS version 19.0. Categorical data were expressed as numbers (percentages), and the chi-square test was used to compare differences between groups. Continuous data were expressed as the mean ± standard deviation ($\bar{x}\pm$ s), and the *t*-test or Mann-Whitney *U* test was used for inter-group comparisons. Statistical significance was set at $P < 0{\cdot}05$. The trends of population flow, COVID-19, and influenza epidemics were plotted using GraphPad Prism.

Results

Population flow significantly dropped since launching the first-level response for COVID-19

The Spring Festival travel rush period is a national transportation peak organized by the Ministry of Transport and the Civil Aviation Administration. The Spring Festival, lasts 40 days, from the 15th of the 12th lunar month to the 25th of the first lunar month of the following year. The festival occurred from January 10 to February 18, in 2020 (January 25 is the date of the Spring Festival), from January 21 to March 1 in 2019, and from February 1 to March 12 in 2018. In general, the Spring Festival travel rush period refers to intercity transportation in mainland China, including national railways, highways, waterways and civil aviation, and among them, national railways and highways are the main transportation routes. We employed the DNRP flow in mainland China to reflect the population movement and the speed and effectiveness of the first-level response to the epidemic.

During the Spring Festival travel rush period in 2020, a total 1.48 billion passengers had moved by railways, highways, waterways and civil aviation, which was a decrease of 50.5% and 50.3% compared to the same period in 2019 and 2018, respectively (Table 1). Among them, 210 million passengers moved by railway in 2020, which was a decrease 48.4% and 45.0% as compared to the same period in 2019 and 2018, respectively.

On January 10, 2020, the DNRP flow in China had reached more than 10 million people, at a maximum level from 10.49 to 12.44 million. According to previous data, railway passenger flow showed a rapid downward trend two days before the New Year from 2018 to 2020 (Fig. 1). On January 23, 2020, the DNRP flow was 9.85 million, higher than that of the same period in 2019 (6.0%) and 2018 (11.5%). On the same day, Wuhan was locked down and the government launched a first-level response for COVID-19. Therefore, on January 24 (the first day of lockdown), the flow dropped to 5.15 million, which was lower than at the same period in 2019 (6.0%) and 2018 (2.8%), and to 2.47 million on January 25, which was lower than the same period in 2019 (41.5%) and 2018 (36.6%). Furthermore, the daily railway flow dropped rapidly to 0.83 million on February 13, 2020.

Based on data from 2018 to 2019 after the Spring Festival the DNRP flow quickly recovered to a high level. In 2020, the daily flow in the first, second and third weeks after the Spring Festival were only at 26.6%, 13.0% and 8.7% of the same period in 2019, and 28.3%, 13.3% and 10.0% of the same period in 2018.

The COVID-19 epidemic dramatically mitigated after launching the first-level response

After the first-level response prevention and control measures were launched, the newly confirmed cases of COVID-19 still showed an upward trend in other provinces and cities in China, except in Hubei

Table 1
Passenger numbers moving by railway, highway, waterway and civil aviation during the Spring Festival travel rush period in 2018, 2019 and 2020.

Passenger number	2020	2019	2018	Comparison (2020 VS. 2019)	Comparison (2020 VS. 2018)
Railway (Million)	210	407	382	48.4%	45.0%
Highway (Million)	1210	2460	2480	50.8%	51.2%
Waterway (Million)	16.89	40.77	43.22	58.6%	60.9%
Civil aviation (Million)	38.39	72.88	65.41	47.3%	41.3%
Total (Million)	1475	2981	2971	50.5%	50.3%

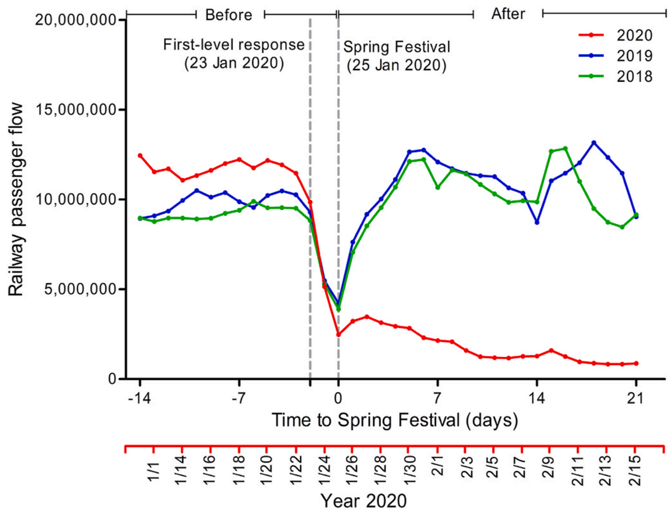

Fig. 1. Trends of railway passenger flow in the Spring Festival travel rush period during 2018, 2019 and 2020.

province, and peaked on February 3 (Fig. 2). This temporary rise may be related to COVID-19 patients who traveled from Wuhan to other provinces and cities. Therefore, the outbreak continued to spread geographically, with a mounting number of cases and deaths. After February 3, the number of newly confirmed cases in other provinces in China, except for Hubei province, began to decrease. By February 21, the number of newly confirmed cases was less than 50 per day.

Shortened 2019–2020 influenza season in China

According to the influenza data of influenza released by the CNIC, the 2019–2020 influenza season lasted from the 46th week of 2019 to the 9th week of 2020, with a peak in the first week of 2020. The 2018–2019 influenza season stretched from the 48th week of 2018 to the 30th week of 2019, with a peak in the third week of 2019. The 2017–2018 influenza season lasted from the 45th week of 2017 to the 14th week of 2019, with a peak in the 4th week of 2018. The duration of the 2019–2020 influenza season lasted only 15 weeks, which was significantly shorter than that of 2017–2018 (21 weeks) and 2018–2019 (34 weeks) (Fig. 3). In the 2019–2020 influenza season, the ILI incidence decreased by 59.2% and 64.0% as compared to 2018–2019 and 2017–2018, respectively, and the influenza by a 82.8% and 78.1% as compared to 2018–2019 and 2017–2018, respectively.

One week before the first-level response on January 23, 2020

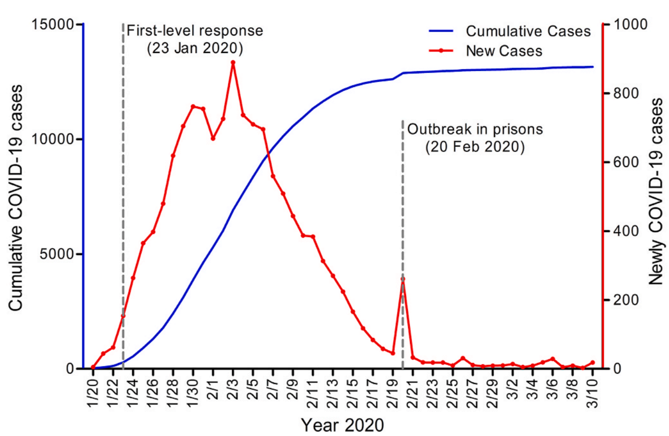

Fig. 2. Numbers of new and cumulative COVID-19 cases tended to ease after February 3, 2020. There was a small outbreak in the prisons of China's Shandong and Zhejiang Provinces on February 20, 2020.

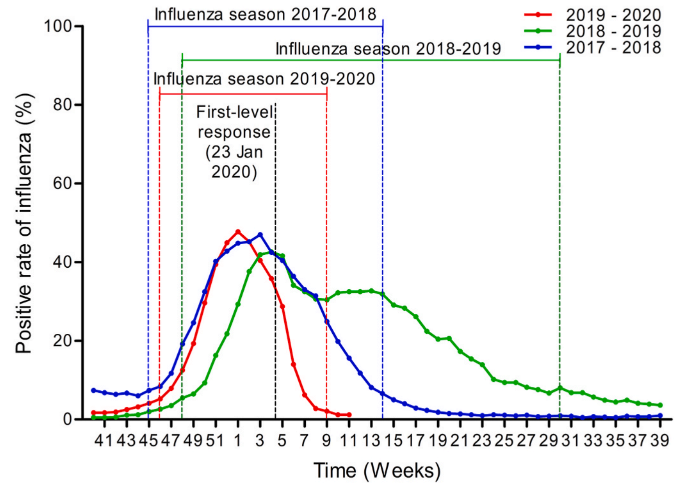

Fig. 3. Influenza data observed using weekly data from the first week in October to the last week in September of the subsequent year. The trends of influenza epidemic were very different in the past three years. The space between the two dashed lines of the same color represents the influenza season; red, green, and blue colors represent the influenza season of 2019–2020, 2018–2019, and 2017–2018, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

(January 13rd to 19th), the positive rate of influenza was 40.4%. The positive rate of influenza on January 20th to 26th decreased to 35.8%, and the following week (January 27th to February 2nd) decreased to 28.7%. By February 24th to March 1st, the positive rate had decreased rapidly to 2.1%.

In 2019–2020, the time from the peak of the influenza positive rate to the Chinese first-level public health emergency response was 4 weeks. Accordingly, "the boundary point" was defined as 4 weeks added to the time when the influenza positive rate peaked in 2018–2019 and 2017–2018, which was the 8th week in 2018–2019 and the 7th week in 2017–2018, respectively. After "the boundary point", the ILI incidence in 2019–2020 decreased rapidly to 23.3% in 2018–2019 and 55.7% in 2017–2018. The number of influenza patients in 2019–2020 dropped by 11.0% and 31.6%, compared to 2018–2019 and 2017–2018, respectively. Influenza-A incidence decreased by 13.1% and 26.9% compared to 2018–2019 and 2017–2018, respectively, whereas influenza B cases decreased by 9.2% and 40.5%, respectively (Fig. 4 and Table 2).

Containment of COVID-19 and influenza epidemic after initiation of first-level response, and population movement decrease

On January 23, 2020, the Chinese government issued a travel ban policy to lock down Wuhan and launched a first-level response to COVID-19. The DNRP flow dropped rapidly, to 0.83 million on February 13, which was equivalent to only 30.2%, 13.6% and 9.5% of the flow during the first, second and third weeks after the 2019 Spring Festival, respectively. With DNRP flow dropping throughout China, the newly confirmed COVID-19 cases in the country, except for Hubei province, showed a rapid decline after achieving the maximum number of cases (890 cases per day) on February 3. The number of newly confirmed cases has been less than 50 cases per day since February 21. Meanwhile, the prevalence of influenza has also shown a significant decline, with the positive rate dropping from 47.7% to 2.1% during the period from January 1 to March 1, 2020 (Fig. 5).

Discussion

SARS-CoV-2 and COVID-19 were first detected in Wuhan, Hubei province, China, and then quickly spread across the country. The first-

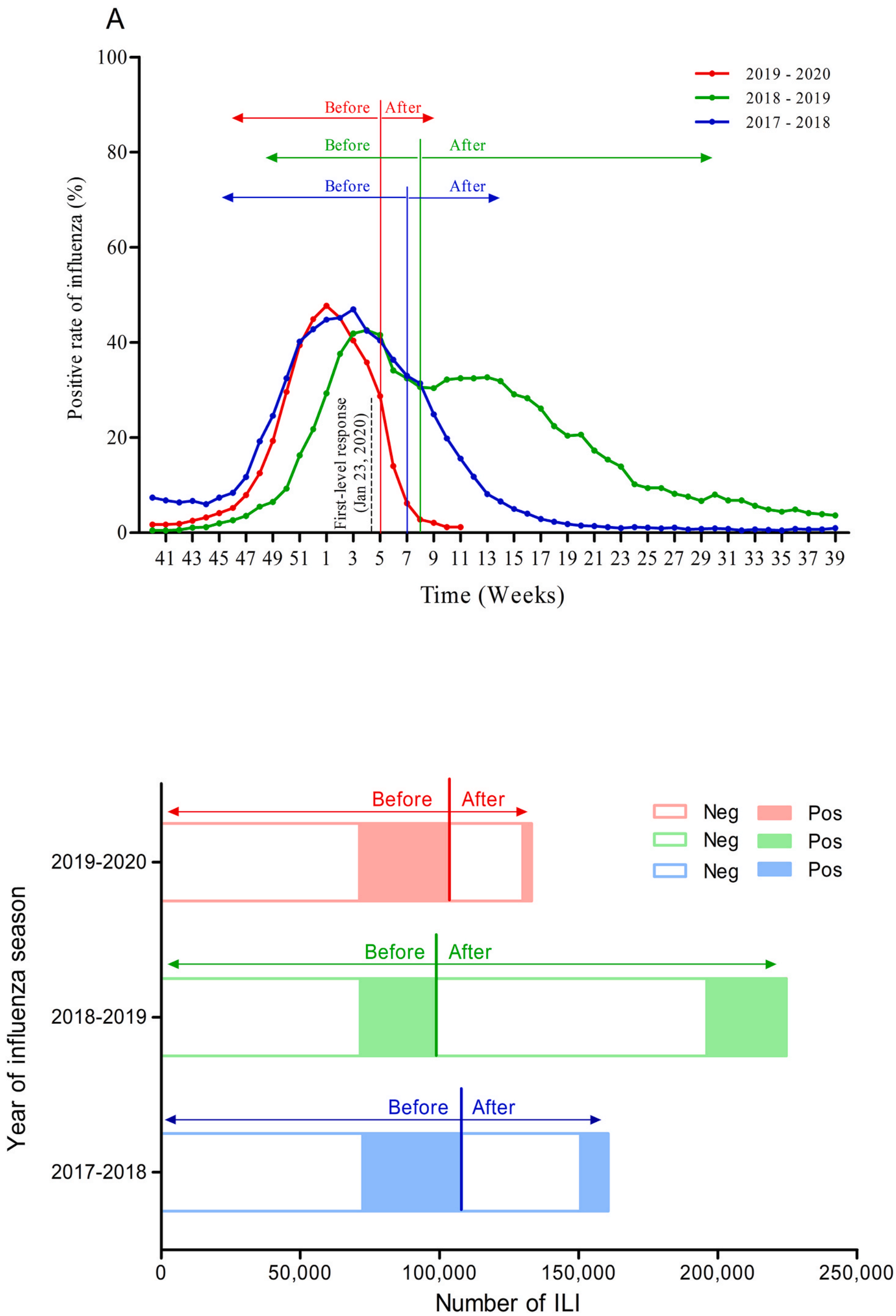

Fig. 4. Influenza epidemic trends over the past three years. The time (weeks) from the peak of the influenza positive rate to the first-level response in 2019–2020 was calculated. The same number of weeks was added to the time when the influenza positive rate peaked in 2018–2019 and 2017–2018, the boundary point corresponding to the first-level response time in 2018–2019 and 2017–2018 was calculated. (A) Weekly positive rates of influenza in the past three years, before and after the boundary point. The red, green, and blue vertical lines represent the boundary point of 2019–2020, 2018–2019, and 2017–2018, respectively. (B) The incidence of influenza-like illness (ILI) and positive influenza patients in the past three years, before and after the boundary point. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

level response was launched to control the spread of COVID-19. This coincided with the Spring Festival travel rush in 2020. According to Chinese tradition, people return to their hometown to celebrate the coming of the New Year. Large-population long distance mobility greatly enhances rapid virus transmission. In this study, we have particularly focused on the measure-restriction of population flow, and analyzed its relationship with the COVID-19 and the influenza epidemic.

The DNRP flow is used to reflect the population flow and indirectly evaluates the speed and effectiveness of the first-level response to the epidemic. The first-level response period coincided with the Spring Festival travel rush in 2020, with a total of 1.48 billion passengers moving by railways, highways, waterways and civil aviation, this was a 50.5% and 50.3% decrease compared to the same period in 2019 and 2018, respectively. From January 23, 2020 the DNRP flow also decreased compared with the same period in 2019 and 2018. This suggested that the first-level response had been effectively implemented and population movement was reduced. Chinazzi et al. have reported that Wuhan city closure and restrictions on international population movement had an impact on the spread of COVID-19 between China and other countries.[13] Indeed, a series of prevention and control measures, such as controlling domestic population flow, has significantly inhibited the prevalence of COVID-19 in mainland China, together with Wuhan closure and decrease international population travel. In our study, after the first-level response starting point (January 23, 2020), new COVID-19 cases in China showed a slow rise, and the actual cumulative number of COVID -19 cases (excluding Wuhan) after January 23 was smaller than the epidemic curve in Wuhan without closure, as predicted by Chinazzi et al., and the difference gradually increased with time.[13] Based on the

Table 2
Comparison of the rate of influenza after the implementation of the first level responses with the same period in 2019 and 2018.

		Monitoring, No.		Positive, No		Influenza- A, No.		Influenza-B, No.	
2019–2020	Before	103677	(28.3%)[a]	32407	(9.7%)[a]	23771	(34.4%)[a]	8636	(7.4%)[a]
	After	29351		3157		1763		1394	
	Sum	133028		35564		25534		10030	
2018–2019	Before	98434	(121.7%)[a]	26929	(106.4%)[a]	26609	(83.0%)[a]	320	(50.6%)[a]
	After	126199		28644		13459		15185	
	Sum	224633		55573		40068		15505	
2017–2018	Before	107968	(48.8%)[a]	35570	(28.1%)[a]	16884	(57.6%)[a]	18686	(38.8%)[a]
	After	52696		9997		6553		3444	
	Sum	160664		45567		23437		22130	

Note: In 2019–2020, the time from the peak of the influenza rate to the Chinese first-level public health emergency response was 4 weeks. Accordingly, "the boundary point" was defined as 4 weeks added to the time when the influenza peaked in 2018–2019 and 2017–2018. The incidence of ILI and positive influenza patients in the past three years, before and after the boundary point are described in Table 2.

[a] The percentages in brackets represent the ratio of the number after the boundary point to before the boundary point.

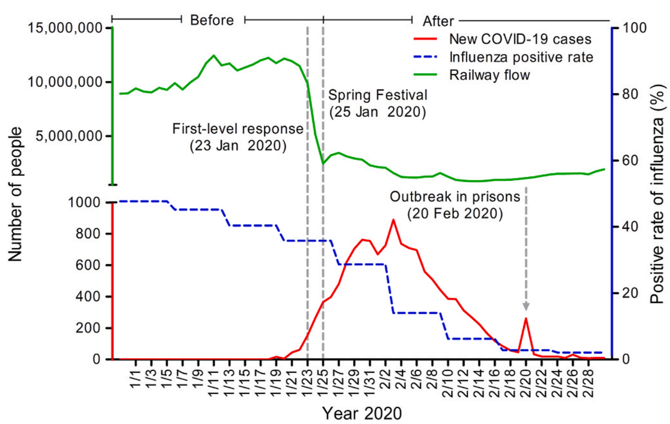

Fig. 5. The effect of first-level response on the trends of railway passenger flow, SARS-CoV-2 and and influenza epidemics. Influenza data were derived from the weekly data reported by the Chinese National Influenza Center. In order to facilitate the observation of the daily dynamics of the epidemic prevention and control measures on population mobility and epidemic development, the daily positive rate of influenza was calculated by using weekly data published by the influenza surveillance laboratory network in mainland China.

modeling and analysis of 15 top research institutions across the world, the Wuhan travel ban, as the largest isolation event in human history, combined with the first-level prevention and control measures, had reduced the number of Chinese patients with COVID-19 by more than 700,000 according to the report by Tian et al.[14] Another study also has also shown that these measures may have been conducive to controlling the epidemic.[15] At present, most governments around the world have adopted different degrees of lockdown against COVID-19,[16] and these are considered to be effective in reducing the number of people infected by SARS-CoV-2.[17]

Data released by CNIC in mainland China showed that the influenza positive rate dropped during the week before and after the first-level response, and the 2020 influenza season was shortened. Although after reaching a peak in 2020, there has been a downward trend in China, the influenza epidemic trends in the United States, France and Italy were similar to previous years (Fig. S1). China's first-level response strongly was associated with a curbing of the prevalence of COVID-19 within two months. This suggests that the shortened influenza season in China may be attributed to the first-level response.

It is estimated that influenza causes 3–5 million cases of severe respiratory infection-related illnesses and 0.29–0.65 million deaths worldwide annually (Table S2). Overall, the seasonal mortality in the in the elderly population with influenza in China and some countries is about 38.5–53.7/100,000 persons.[18,19] The annual health economic burden associated with influenza is substantial.[19–21] The direct medical outpatient cost for influenza is 156–595 renminbi (RMB)/person, and the indirect cost 198–366 RMB/person. The economic burden of in-patient cases was approximately 10 times that of outpatient ones in China.[22] The estimated worldwide losses in 2015 were approximately US $500 billion per year, and the economic losses caused by influenza vary (0.3–1.6%) due to differences in national economic conditions, accounting for approximately 0.6% of global income.[19,20] Therefore, first-level responses not only prevent the spread of influenza, but also reduce its health economic burden, which occurs regularly every year.

First-level responses can effectively control population flow and slow down the spread of COVID-19 and influenza. However, there were several limitations to this study. The first-level response also included other measures, such as wearing face masks, washing hands and other good respiratory hygiene habits, as well as contact tracing and isolation.[23] Hand hygiene is recommended in most national pandemic plans and has been proven to prevent many infectious diseases.[24] Recently, Nancy et al. indicated that surgical face masks could prevent the transmission of COVID-19 and influenza virus from symptomatic individuals.[25] According to Chu et al. Masks and goggles are the best personal protective measures in the public and healthcare environment.[26] The impact of these measures on the spread of COVID-19 and influenza were not assessed in this study.

In summary, our results suggest that the first-level response had an impact on both the COVID-19 and influenza epidemics. Our study further implies that China's approach to their COVID-19 control policy would not only reduce the health and economic burden caused by COVID-19, but also by other respiratory infectious diseases such as influenza.

Author contributions

Hong-Song Chen, Hui-Ying Rao and Feng-Min Lu designed the study; Xiang-Sha Kong, Feng Liu, Rui-Feng Yang, Dong-Bo Chen, and Xiao-Xiao Wang collected the data; Xiang-Sha Kong and Feng Liu interpreted the data; Hai-Bo Wang and Xiang-Sha Kong conducted the statistical analysis; Xiang-Sha Kong and Feng Liu wrote the manuscript; Hong-Song Chen, Hui-Ying Rao and Feng-Min Lu revised the manuscript.

Funding

This work was supported by the Special Research Fund of Peking University for Prevention and Control of COVID-19 [PKU2020PKYZX001].

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jve.2021.100040.

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