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RESEARCH ARTICLE

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Effects of the enhanced public health intervention during the COVID-19 epidemic on respiratory and gastrointestinal infectious diseases in China

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Abstract

The public health interventions to mitigate coronavirus disease 2019 (COVID-19) could also potentially reduce the global activity of influenza. However, this strategy's impact on other common infectious diseases is unknown. We collected data of 10 respiratory infectious (RI) diseases, influenza-like illnesses (ILIs), and seven gastrointestinal infectious (GI) diseases during 2015–2020 in China and applied two proportional tests to check the differences in the yearly incidence and mortality, and case-fatality rates (CFRs) over the years 2015–2020. The results showed that the overall RI activity decreased by 7.47%, from 181.64 in 2015–2019 to 168.08 per 100 000 in 2020 ($p < 0.001$); however, the incidence of influenza was seen to have a 16.08% escalation ($p < 0.001$). In contrast, the average weekly ILI percentage and positive influenza virus rate decreased by 6.25% and 61.94%, respectively, in 2020 compared to the previous 5 years (all $p < 0.001$). The overall incidence of GI decreased by 45.28%, from 253.73 in 2015–2019 to 138.84 in 2020 per 100 000 ($p < 0.001$), and with the greatest decline seen in hand, foot, and mouth disease (HFMD) (64.66%; $p < 0.001$). The mortality and CFRs from RI increased by 128.49% and 146.95%, respectively, in 2020, compared to 2015–2019 ($p < 0.001$). However, the mortality rates and CFRs of seven GI decreased by 70.56% and 46.12%, respectively ($p < 0.001$). In conclusion, China's COVID-19 elimination/containment strategy is very effective in reducing the incidence rates of RI and GI, and ILI activity, as well as the mortality and CFRs of GI diseases.

Lan Wang, Xiangyu Guo, and Na Zhao contributed equally to this study.Shelan Liu, Ta-Chien, Hui Jiang and Wangli Xu are co-corresponding authors.

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KEYWORDS
case fatality rates, COVID-19, gastrointestinal diseases, influenza-like illnesses, mortality, respiratory diseases

1 | INTRODUCTION

On March 11, 2020, the World Health Organization announced that coronavirus disease 2019 (COVID-19) qualified as a pandemic.[1,2] Currently, the world is still in the middle to the high of this COVID-19 pandemic.[3] In the absence of effective pharmaceutical interventions against the SARS-CoV-2 in the early stages, most countries used non-pharmaceutical interventions (NPIs) to prevent the spread of COVID-19, including suppression/mitigation strategies.[4–6] China, especially, used an elimination/containment strategy, successfully controlling its initial COVID-19 epidemic by March 2020.[7] These NPIs and human behavioral changes used to mitigate COVID-19 could also have acted in decreasing the circulation of other respiratory diseases, such as the activity of influenza in the USA, New Zealand, and Japan.[4,8–13] However, the impact of NPIs on other common infectious diseases in China is not clear.[9,11] Here, by comparing the incidence, mortality, and case-fatality rates (CFRs) of respiratory and gastrointestinal infectious diseases (RI and GI diseases, respectively) in 2020 with those recorded for the previous 5 years in China, this study aimed to assess the efficacy of enhanced NPIs public health intervention during the COVID-19 epidemic on RI and GI diseases in China. This large sample size study provides the scientific evidence to guide control strategies for RI and GI diseases in China in the future.

2 | MATERIALS AND METHODS

2.1 | Data source and data collection

To date, a total of 40 notifiable infectious diseases are monitored by the internet-based China Information System for Disease Control and Prevention.[14] These diseases are divided into three categories—classes A (2 diseases), B (27 diseases), and C (11 diseases)—all of which must be reported within a specified timeframe, in 2 , 24 , and 24 h, respectively.[14] In this study, we collected 10 RI diseases, namely COVID-19, diphtheria, influenza, measles, scarlet fever, rubella, pertussis, meningitis, mumps, and TB (Tubercle Bacillus); seven GI diseases, namely HFMD (hand-foot-and-mouth disease), dysentery, cholera, typhoid, hepatitis E, hepatitis A, and infectious diarrhea other than cholera, dysentery, typhoid and paratyphoid (hereinafter referred to as other infectious diarrheal diseases).

Annual and monthly numbers of cases and deaths, the incidence and mortality data of 10 RI and seven GI diseases recorded from January 2015 to December 2020 were extracted from the National Health Statistical Yearbooks published by the National Health Commission of China. Population data are from the National Bureau of Statistics of the People's Republic of China and are updated at the end of every year.

Influenza-like illness (ILI) and virological testing results of respiratory specimens across the 31 provinces of mainland China were downloaded from the Chinese National Influenza Center's surveillance website from 2015 to 2020, by week.

2.2 | Case definition

The criteria for confirmed, diagnosed, suspected cases of the 10 RI and 7 GI were defined according to the national diagnosis and treatment issued by the National Health Commission of the People's Republic of China. Noticeably, the diagnosis standard of confirmed influenza cases was changed since 2019, which influenza antigen rapid test is now included in the diagnosis guidelines of influenza-confirmed cases according to the national diagnostic and treatment protocol for seasonal influenza (2019 edition). Confirmed influenza case is defined as clinical symptoms consistent with acute influenza (fever, cough, coryza, difficulty breathing) or with a history of contact with a confirmed or suspected case and a laboratory test positive for influenza virus; influenza antigen rapid test, PCR, viral isolation or a fourfold or greater increase in serum antibodies specific for this virus isolated in paired sera.

According to the national influenza surveillance guideline, ILI was defined as any individual who had a body temperature of ≥38.0°C and either a cough or sore throat. The weekly influenza-positive rate was calculated as the number of influenza-positive samples divided by the total respiratory samples tested in any 1-week period.[4]

2.3 | Emergency response stage and routine response stage

We investigated 10 RI, ILI, and 7 infections based on key dates for NPIs in China, which we substratified into two timeframes, emergency response stage (January 1 to April 30 of 2020, strict and combined NPIs were performed in China) and the routine response stage (May 1 to December 31 of 2020), to assess the epidemiological features of the diseases, compared to the same period of 2015–2019.

2.4 | Data analysis and statistical analyses

We defined incidence (per 100 000) as the number of annual incident cases divided by the population size; overall mortality (per 100 000) as the number of deaths per year divided by the total population size; and CFRs (per 1000) as the number of annual deaths divided by the number of annual incident cases.[14] Descriptive statistics were conducted using R software (R is a programming language and free software environment for statistical computing and graphics. It is designed by Ross Ihaka and Robert Gentleman, supported by the R Core Team and the R Foundation for Statistical Computing). Two proportional tests, two-ratio *Z* tests, and a Mann–Whitney test were applied to test the differences of NPIs' effectiveness (corresponding incidence or mortality rates or CFRs) between 2020 and the previous 5 years, between the state of emergency and nonemergency period. We also used R ggplot2 package to make the plot figures.

3 | RESULTS

3.1 | Overall trend of RI incidence

Between 2015 and 2020, a total of 14 878 299 cases of the 10 RI diseases investigated were reported in China. The overall RI disease activity decreased by 7.47%, from 181.64 per 100 000 in 2015–2019 to 168.08 per 100 000 in 2020 ($p < 0.001$; Figure 1A and Table S1). However, the overall incidence of the 10 RI in 2020 was seen to have a 37% rise, compared to the lowest annual incidence in 2015 ($p < 0.001$; Figure 1B; Table S2).

A dramatic decrease in activity was seen in seven of the RI diseases in 2020 (all $p < 0.001$, Table S1). By contrast, an increase was seen in influenza, with a 16.08% escalation in influenza ($p < 0.001$; Figure 1C, Table S1). The yearly incidence of influenza in 2020 increased by 502%, compared to the lowest incidence in 2015 ($p < 0.001$; Figure 1D; Table S2). Differently, the incidence of TB and mumps decreased significantly in 2020 compared to the previous 5 years and the lowest level in 2019 and 2016. respectively ($p < 0.001$; Figure 1E–H; Tables S1 and S2).

Exploring this in greater detail, it became evident that the activities of the nonvaccine preventable and nonviral RI decreased to a much greater extent than the vaccine-preventable and viral RI (all $p < 0.001$; Table S3).

3.2 | Overall trend of ILI activity

The average weekly ILI percentage and average weekly positive influenza virus rate in all China decreased by 6.25% and 61.94% during 2020, compared to 2015–2019. respectively (all $p < 0.001$; Figure 2A–D; Table S4). The same results were seen in the south of China and north of China (Table S4). The ILI percentage in 2020 did not change when compared to the lowest level of activity in 2015 ($p > 0.05$, Figure 2B). However, the influenza-positive rate decreased significantly compared to the lowest rate in 2018 ($p < 0.001$, Figure 2D).

3.3 | Overall trend of GI incidence

Between 2015 and 2020, a total of 19 442 945 cases of the seven GI diseases investigated were reported in China. The overall incidence of the seven GI diseases decreased significantly by 45.28%, from 253.73 per 100 000 in 2015–2019 to 138.84 per 100 000 in 2020 ($p < 0.001$; Figure 3A; Table S1). Similarly, the overall incidence of the seven GI in 2020 decreased by 40%, compared to the lowest annual incidence in 2015 ($p < 0.001$, Figure 3B; Table S5).

The incidence of all GI diseases was found to have significantly decreased, with the greatest decline seen in HFMD (64.66%; $p < 0.001$; Figure 3C; Table S1). The yearly incidence of HFMD in 2020 has a decline of 60%, compared to the lowest incidence in 2019 ($p < 0.001$; Figure 3D; Table S5).

The incidence of other diarrhea in 2020 decreased by 10.45% than the previous 5 years while increased by 10% compared to the lowest incidence in 2015 ($p < 0.001$; Figure 3E,F; Tables S1 and S5). The incidence of dysentery decreased significantly in 2020 compared to the previous 5 years and the lowest level in 2019 ($p < 0.001$; Figure 3G,H; Tables S1 and S5).

The incidence of each vaccine-preventable and viral GI disease in 2020 decreased by 63.87%, compared to the previous 5 years ($p < 0.001$, Table S3).

3.4 | Overall trend of RI mortality and CFRs

The overall mortality of RI increased by 128.49% (from 0.15829 to 0.36168 per 100 000) in 2020, compared to the previous 5 years ($p < 0.001$; Table 1). The yearly mortality rates in 10 respiratory infectious diseases in 2020 increased by 177.31% compared to the lowest mortality rates in 2015 (see Table S6).

There were a total of 5051 deaths caused by RI in 2020, of which COVID-19 accounted for 66.20% (3344/5051), see Table S7. The CFRs from the 10 RI diseases increased by 146.95% (from 0.8714 to 2.1518 per 1000) in 2020, compared to the previous five years ($p < 0.001$; Table S7). The CFR of influenza in 2020 has an 8.5% escalation compared to the previous years ($p < 0.001$), see Figure 4 and Table S7.

3.5 | Overall trend of GI mortality and CFRs

The mortality rates of the seven GI diseases decreased by 70.56% (from 0.01094 to 0.00322 per 100 000) in 2020 compared to the previous 5 years ($p < 0.001$) (Table 1). The overall mortality of the seven GI in 2020 increased by 11.50%, compared to the lowest annual mortality in 2017 ($p = 0.28$), see Table S8.

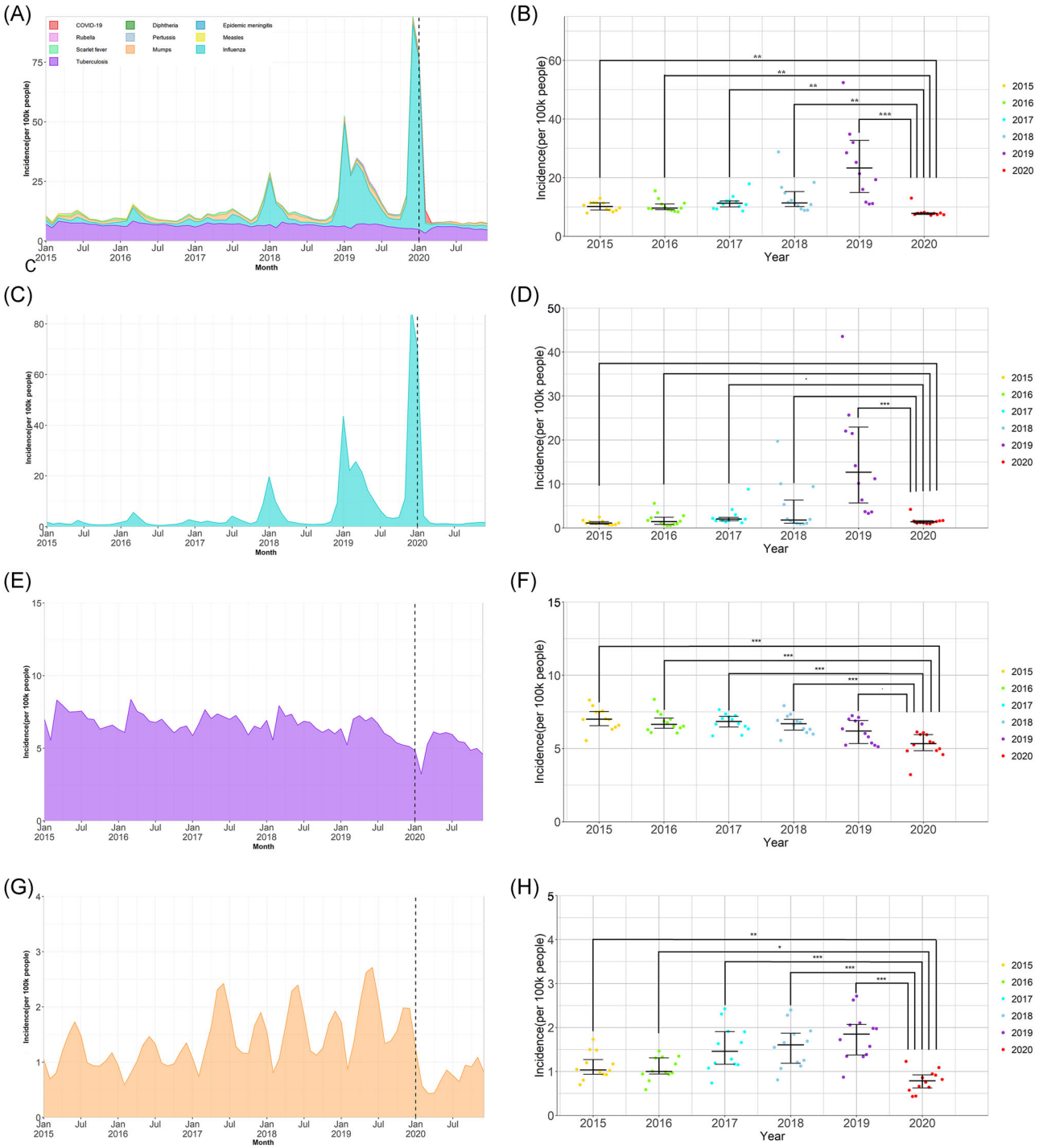

FIGURE 1 Monthly incidence rates and trends of 10 respiratory infectious diseases in 2020 (during the COVID-19 pandemic) compared with the five preceding years (2015–2019) in China. (A) Monthly incidence of overall RI; (B) the monthly incidence of overall RI in 2020 was compared to distributions in 2015–2019; (C) monthly incidence of influenza; (D) the monthly incidence of influenza in 2020 was compared to distributions in 2015–2019; (E) monthly incidence of TB (tuberculosis). (F) The monthly incidence of TB in 2020 was compared to distributions in 2015–2019. (G) Monthly incidence of mumps. (H) The monthly incidence of mumps in 2020 was compared to distributions in 2015–2019. (B), (D), (F), (H) are generated by using a Mann–Whitney test (***$p < 0.001$; **$0.001 < p < 0.01$; *$0.01 < p < 0.05$; no * $p < 0.1$); black lines indicate P25, P50, and P75, respectively, from the upper and lower quartiles; the dots indicate the monthly incidence in different years

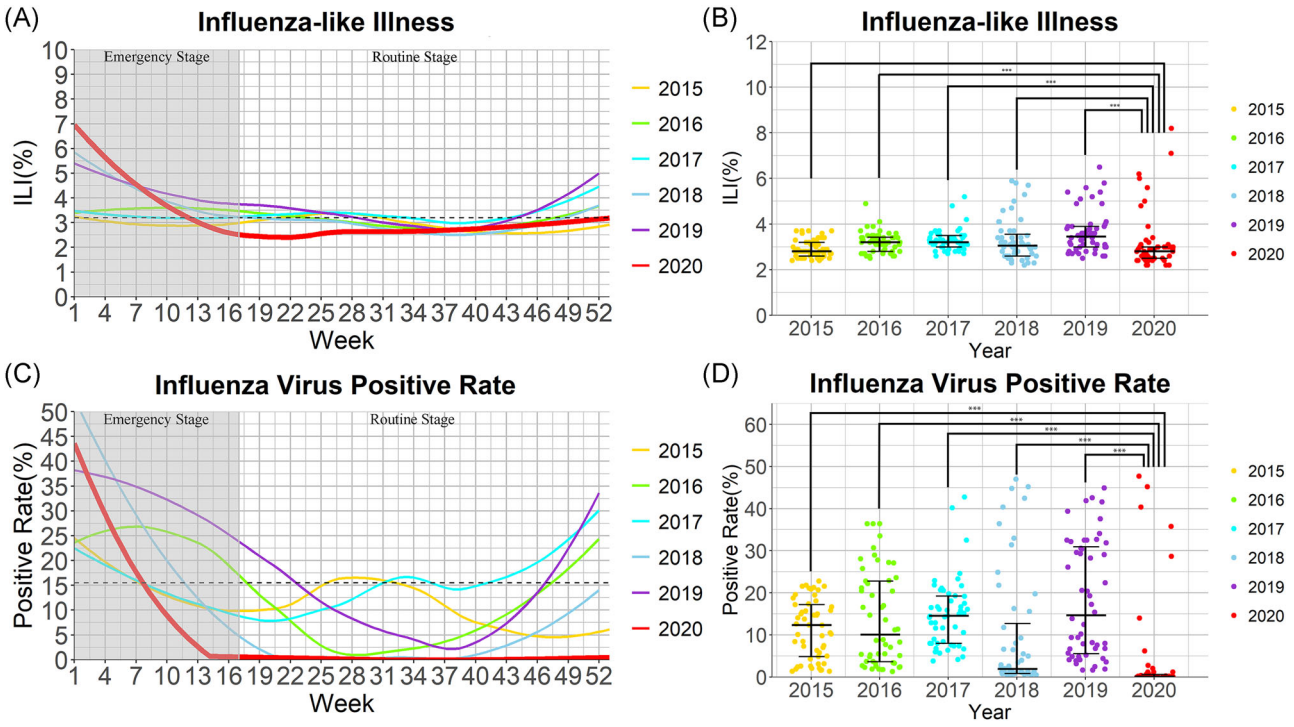

FIGURE 2 Comparison of weekly influenza-like illness percent and weekly influenza virus-positive rate between 2015, 2016, 2017, 2018, 2019, and 2020 in China. (A) Weekly influenza-like illness percent from 2015 to 2020; (B) weekly influenza-like illness percent in 2020 was compared to distributions in 2015–2019; (C) weekly influenza virus-positive rate from 2015 to 2020; (D) weekly influenza virus-positive rate in 2020 was compared to distributions in 2015–2019. (A,C) Black dashes note the average weekly influenza-like illness percent or weekly influenza virus-positive rate during 2015–2019; the gray rectangle represents the emergency response period in China in 2020 (January 1–April 30, 2020, Weeks 1–17, 2020); the white rectangle represents the routine stage (May 1–December 31, 2020, Weeks 18–52, 2020). (B,D) The weekly influenza-like illness percent and weekly influenza virus-positive rate in 2020 was compared to distributions in 2015–2019 using a Mann–Whitney test (***$p < 0.001$; **$0.001 < p < 0.01$; *$0.01 < p < 0.05$; no *$p < 0.1$); black lines indicate P25, P50, and P75, respectively, from the upper and lower quartiles; the dots indicate the weekly influenza-like illness percent and weekly influenza virus-positive rate from Week 1 to Week 52 or 53 in different years

In 2020, a total of 45 fatal cases of the seven GI diseases investigated were reported from China, while 754 deaths were reported during 2015–2019, see Table S7. The CFRs of the seven GI diseases in 2020 decreased by 46.12% (from 0.0431 to 0.0232 per 1000; $p < 0.001$) compared to those of 2015–2019 , see Figure 4 and Table S8.

3.6 | RI, ILI, and GI in emergency and routine response stage

The overall incidence and mortality rates for all RI diseases increased significantly by 51.57% and 400.51% (all $p < 0.001$), respectively, during the period of a state of emergency (January–April 2020), as compared to the same period in the previous 5 years; however, both suddenly decreased, by 44.73% and 20.58%, with the return to nonemergency conditions in May–December 2020 (all $p < 0.05$; Table 2).

The weekly percent of ILI increased by 5.71% during the state of emergency in 2020 and decreased by 9.68% during the nonemergency stage (all $p < 0.05$; Table 3). Similarly, the weekly positive influenza virus rate decreased by 28.06% and further decreased by 99.01% during the emergency and nonemergency periods in 2020 (all $p < 0.001$; Table 4). The same results were seen in the south and north of China.

For the GI diseases, the incidence and mortality both decreased substantially during both the emergency and the nonemergency periods in 2020, compared to the previous five years (Table 2).

4 | DISCUSSION

We found a marked decline in the overall yearly incidence rates of the ten RI, ILI activity, and the seven GI diseases, as well as GI mortality in 2020, compared to the previous 5 years in China. These indicated that the implementation and timing of COVID-19-related NPIs in China were very effective in mitigating the transmission of RI and GI infections. By contrast, the overall mortality rate and CFRs for the RI diseases increased in 2020, which might be contributed to by COVID-19 deaths, accounted for 66% (3344 deaths) in 5051 total deaths in China.

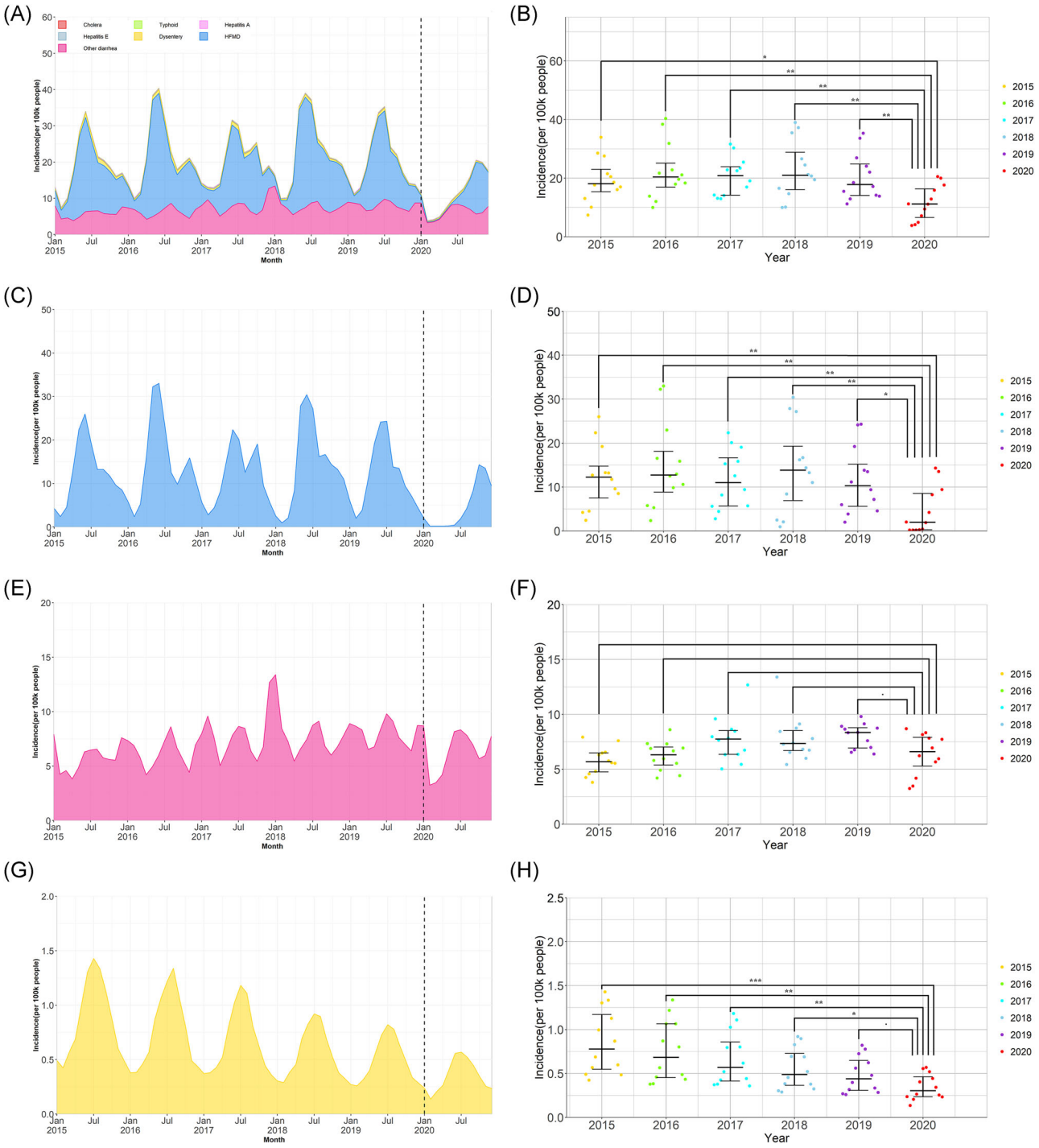

FIGURE 3 Monthly incidence rates and trends of seven gastrointestinal infectious diseases in 2020 (during the COVID-19 pandemic), compared with the five preceding years (2015–2019) in China. (A) Monthly incidence of overall GI; (B) the monthly incidence of overall GI in 2020 was compared to distributions in 2015–2019; (C) monthly incidence of HFMD; (D) the monthly incidence of HFMD in 2020 was compared to distributions in 2015–2019; (E) monthly incidence of other diarrhea. (F) The monthly incidence of other diarrhea in 2020 was compared to distributions in 2015–2019. (G) Monthly incidence of dysentery. (H) The monthly incidence of dysentery in 2020 was compared to distributions in 2015–2019. (B), (D), (F), (H) are generated by using a Mann–Whitney test (***$p < 0.0001$; no* denotes no change); black lines indicate P25, P50, and P75, respectively, from the upper and lower quartiles; the dots indicate the monthly incidence in different years

TABLE 1 Changes in the average yearly mortality rates for 10 respiratory and seven gastrointestinal infectious diseases in 2020, compared to the previous five years in China

Disease classification	Average yearly mortality rate (per 100 000)		Average yearly deaths		Changes (%) (95% CI)	*p* value
	2020	2015–2019	2020	2015–2019		
Respiratory infectious diseases						
Overall	0.36168	0.15829	5051	2184	128.49 (120.92–136.06)	<0.001
COVID-19	0.23945	0.00000	3344	0	NA	NA
Diphtheria	0.00000	0.00000	0	0	NA	NA
Influenza	0.01010	0.00804	141	111	25.50 (−2.34 to 53.34)	0.07
Measles	0.00000	0.00087	0	12	−100.00 (−156.58 to −43.42)	<0.001
Scarlet fever	0.00014	0.00000	2	0	NA	NA
Rubella	0.00000	0.00000	0	0	NA	NA
Pertussis	0.00007	0.00014	1	2	−50.60 (−219.66 to 118.46)	0.56
Meningitis	0.00021	0.00087	3	12	−75.30 (−138.40 to −12.19)	0.01
Mumps	0.00036	0.00007	5	1	393.99 (−81.30 to 869.28)	0.10
TB	0.11135	0.14829	1555	2046	−24.91 (−30.63 to −19.19)	<0.001
Gastrointestinal infectious diseases						
Overall	0.00322	0.01094	45	151	−70.56 (−88.68 to −52.43)	<0.001
HFMD	0.00029	0.00696	4	96	−95.88 (−116.29 to −75.48)	<0.001
Dysentery	0.00021	0.00036	3	5	−40.72 (−151.10 to 69.66)	0.47
Cholera	0.00000	0.00000	0	0	NA	NA
Typhoid	0.00043	0.00014	6	2	196.39 (−78.29 to 471.08)	0.16
Hepatitis E	0.00086	0.00130	12	18	−34.13 (−93.49 to 25.22)	0.26
Hepatitis A	0.00021	0.00043	3	6	−50.60 (−148.21 to 47.01)	0.31
Other diarrhea	0.00122	0.00174	17	24	−30.02 (−82.05 to 22.01)	0.26

Note: Changes = (x1−x2)/x2 × 100%; x1: average yearly mortality rate in 2020; x2: average yearly mortality rate in the previous 5 years (2015–2019). The *p* value was computed through two proportional tests.

Abbreviations: 95% CI, 95% confidence interval; COVID-19, coronavirus disease 2019; HFMD, hand, foot, and mouth disease; NA, not available; TB, tuberculosis; "+" = increased trend; "−" = decreased trend.

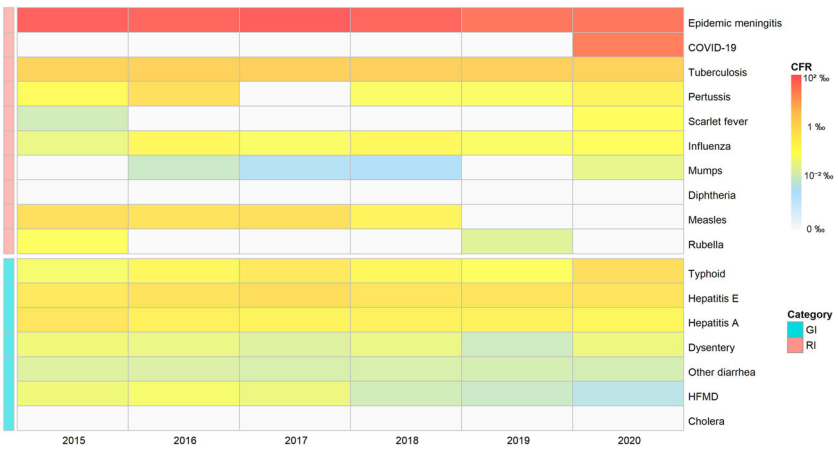

FIGURE 4 Yearly case fatality rates for notifiable RI and GI infectious diseases by year for 2015–2020 in China. CFR, case fatality rate; HFMD, hand, foot, and mouth disease; GI, gastrointestinal infectious diseases; RI, respiratory infectious diseases

TABLE 2 Changes in the average monthly incidence and mortality rates of 10 respiratory and 7 gastrointestinal infectious diseases in the emergency response stage (January to April 2020) and the routine response stage (May to December 2020), compared with the previous 5 years in China

	Emergency stage (January to April 2020)				Routine stage (May to December 2020)				
Disease classification	**2020**	**2015–2019**	**Changes (%) (95% CI)**	***p* value**	**2020**	**2015–2019**	**Changes (%) (95% CI)**	***p* value**	***p* value (Emergency vs. Routine)**
Respiratory infectious diseases									
Average monthly incidence rate (per 100 000)	26.63251	17.57151	51.57 (50.94–52.20)	<0.001	7.693814	13.9194	−44.73 (−45.28 to −44.17)	<0.001	<0.001
Average monthly mortality rate (per 100 000)	0.07012	0.01401	400.51 (366.13–434.88)	<0.001	0.01015	0.01278	−20.58 (−40.29 to −0.86)	0.04	<0.001
Gastrointestinal infectious diseases									
Average monthly incidence (per 100 000)	6.019745	13.49857	−55.40 (−55.95 to −54.86)	<0.001	14.34483	24.9666	−42.54 (−42.96 to −42.13)	<0.001	<0.001
Average monthly mortality (per 100 000)	0.000251	0.000641	−60.93 (−138.49 to 16.64)	0.12	0.000277	0.00105	−73.46 (−131.44 to −15.48)	0.01	0.80

Note: We defined monthly incidence (per 100 000) as the number of monthly incident cases divided by the population size, and overall monthly mortality (per 100 000) as the number of deaths per month divided by the total population size.

Changes = (x1−x2)/x2 × 100%; x1: average monthly incidence rate (mortality rate) in 2020; x2: average monthly incidence (mortality) rate in the previous 5 years (2015–2019). The *p* value for the emergency or routine stage was computed through two proportional tests; the *p* value for emergency versus routine was computed through a two-ratio *Z* test.

Abbreviations: 95% CI, 95% confidence interval; "+" = increased trend; "−" = decreased trend.

TABLE 3 Changes in weekly percent of influenza-like illness (ILI) in the emergency response stage (January–April 2020) and the routine response stage (May–December 2020), compared with the previous 5 years in China

	Emergency stage (January–April 2020)				Routine stage (May–December 2020)				
Areas	2020	2015–2019	Changes (%) (95% CI)	*p* value	2020	2015–2019	Changes (%) (95% CI)	*p* value	*p* value (emergency vs. routine stage)
Overall China	3.7	3.5	5.71 (0.14 to 6.92)	0.04	2.8	3.1	−9.68 (−12.71 to −5.74)	<0.001	<0.001
Southern China	3.6	3.5	2.86 (−3.41 to 5.70)	0.62	3.1	3.2	−3.13 (−8.11 to 0.79)	0.11	0.14
Northern China	3.7	3.5	5.71 (1.35 to 11.47)	0.01	2.3	2.8	−17.86 (−22.11 to −10.77)	<0.001	<0.001

Note: Changes = (*x*1−*x*2)/*x*2 × 100%; *x*1: average weekly ILI percent in 2020; *x*2: average weekly ILI percent in the previous five years (2015–2019).

The *p* value for the emergency or routine stage was computed through two proportional tests; the *p* value for emergency versus routine was computed through a two-ratio *Z* test.

Abbreviations: 95% CI, 95% confidence interval; "+" = increased trend; "−" = decreased trend.

TABLE 4 Changes in weekly positive influenza virus rate in emergency response stage (January–April 2020) and the routine response stage (May–December 2020), compared with the previous five years in China

	Emergency stage (January–April 2020)				Routine stage (May–December 2020)				
Areas	2020	2015–2019	Changes (%) (95% CI)	*p* value	2020	2015–2019	Changes (%) (95% CI)	*p* value	*p* value (emergency vs. routine stage)
Overall China	18.2	25.3	−28.06 (−33.69 to −22.63)	<0.001	0.1	10.1	−99.01 (−107.08 to −90.47)	<0.001	<0.001
Southern China	17.8	24.0	−25.83 (−33.69 to −18.06)	<0.001	0.2	11.0	−98.18 (−108.19 to −88.54)	<0.001	<0.001
Northern China	18.6	26.8	−30.60 (−38.52 to −22.88)	<0.001	0.0	8.3	−100.00 (−115.22 to −84.22)	<0.001	<0.001

Note: The *p*value for the emergency or routine stage was computed through two proportional tests; the *p* value for emergency versus routine was computed through a two-ratio *Z* test.

Changes = (*x*1−*x*2)/*x*2 × 100%; *x*1: average weekly positive influenza virus rate in 2020; *x*2: average weekly positive influenza virus rate in the previous 5 years (2015–2019).

Abbreviations: 95% CI, 95% confidence interval; "+" = increased trend; "−" = decreased trend.

As has been experienced globally, the implementation of public health control measures for COVID-19 has necessarily led to a considerable decline in such RI, ILI activity, and GI diseases and related effects, including nosocomial microorganism transmission [such as *Clostridium difficile* infection and multidrug-resistant (MDR)].[15–19] Several hypotheses have been proposed to explain the substantial decline in RI and GI. First and foremost, because RI diseases have similar modes of transmission as COVID-19 (i.e., through respiratory or contact routes), enteropathogenic agents are excreted in the respiratory and digestive tracts and can be transmitted from person to person by direct or indirect contact.[19,20] The general precautions used for COVID-19 prevention (e.g., lockdown, closure of schools, suspension of large events) have clearly reduced the frequency of other concurrent and seasonal viral respiratory infections and GI diseases.[4,10,15,21–26] Second, fewer visits to clinics for RI and GI diseases were possible due to the strict quarantine measures. People consequently altered their health-seeking behavior and there was reduced accessibility for patients to hospitals during the COVID-19 pandemic.[4,12,18] Third, people's hygiene habits have been greatly improved, including the wearing of masks, hand washing, and the implementation of proper ventilation.[22,27] Finally, viral interference, whereby innate immune responses to a viral infection can affect infection by a second virus, has been discussed as one reason for the low influenza virus circulation in human populations during the SARS-CoV-2 pandemic.[28]

In contrast to this, the incidence of influenza was much higher in China in 2020, in comparison to the previous 5 years. This escalation was driven by two major factors. First of all, the diagnosis standard of the confirmed influenza case was changed since 2019. According to the guidelines on the diagnosis and treatment of influenza (2019 edition) issued by the National Health Commission of the People's Republic of China, released at the end of 2019, the influenza antigen rapid test is included in the diagnosis standard of influenza confirmed cases since 2019. The second reason for this escalation was the higher testing rate due to the COVID alert, leading to improved national and local surveillance, testing, and diagnosis systems in 2020, especially in the state of emergency (January 1–April 30, 2020), compared to the previous five years.

Different from results in other research, respiratory deaths in China increased in 2020, particularly in the early state of emergency.[13] The increased mortality rate of RI was rooted in several reasons. One was that 66% of fatal cases were induced by COVID-19. Second, the COVID-19 pandemic's breach of China's healthcare capacity increased the RI deaths; the third reason was delays in patients visiting hospitals and delayed treatment due to their concerns about nosocomial infection. Additionally, the early Chinese studies showed that nearly one-half of COVID-19 patients having influenza co-infection, especially for influenza A variants, which are considered to be a multiorgan disease.[29] Meanwhile, there are many technical difficulties that may arise in defining diagnoses for co-infections of influenza, all these factors contributed to the increase in fatal outcomes.[15,17,29]

Our findings suggest that China's COVID-19 elimination/containment strategy has also been very effective in reducing the incidence rates of RI and GI diseases. However, we needed greater medical accessibility, capacity, and improvements in surveillance to decrease RI deaths during the COVID-19 epidemic. Although this study was limited in that it did not include province-specific data on RI and GI diseases, it can be of great benefit to the Chinese government as it can help them allocate resources to control common infectious diseases following the COVID-19 pandemic.

As COVID-19 vaccines are implemented and NPIs strategies become relatively relaxed, the general prevalence of seasonal respiratory and gastrointestinal pathogens will return. At which time, it may be anticipated that a co-epidemic with SARS-CoV-2 will increase, which will make the situation more complicated in future seasons.[15,30] It is very important to develop rapid dual or multiplex diagnostic tests to distinguish between these more common pathogens in the future. New surveillance technologies, pharmaceutical measures (vaccines and antivirus treatment), and NPIs must be developed to help preserve and boost the capacity and function of health systems, comprehensive strategies will be critical in controlling other classic, and emerging, infectious diseases.[3]

5 | CONCLUSION

China's COVID-19 elimination/containment strategy has been very effective in reducing the incidence rates of RI, ILI activity, and GI diseases, and mitigated the impact of the COVID-19 pandemic. However, the overall mortality rate and CFRs for the RI diseases increased significantly in 2020. Greater medical accessibility, capacity, and more rapid testing and diagnosis are needed to decrease RI deaths (especially COVID-19) during the COVID-19 epidemic in the future.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

ETHICS STATEMENT

This study was approved by the institutional review board of the Zhejiang Provincial Center for Disease Control and Prevention (No. 2020-026).

AUTHOR CONTRIBUTIONS

Lan Wang, Xiangyu Guo, Hui Jiang, and Shelan Liu contributed to the study design. Xiangyu Guo contributed to data analysis. Lan Wang and Na Zhao contributed to manuscript writing. Binghui Du, Wangli Xu, and Ta-Chien Chan contributed to manuscript revision. Hui Jiang and Shelan Liu contributed to data acquisition. All authors reviewed and approved the final version.

DATA AVAILABILITY STATEMENT

Individual patient data can be made available by the corresponding author on request.

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REFERENCES

1. Cucinotta D, Vanelli M. WHO declares COVID-19 a pandemic. *Acta Biomed*. 2020;91(1):157-160.
2. Mahase E. Covid-19: WHO declares pandemic because of "alarming levels" of spread, severity, and inaction. *BMJ*. 2020;368:m1036.
3. Liu WJ, Liu S. A tale of two cities: from influenza HxNy to SARS-CoV-z. *China CDC Wkly*. 2021;3(49):1052-1056.
4. Feng L, Zhang T, Wang Q, et al. Impact of COVID-19 outbreaks and interventions on influenza in China and the United States. *Nat Commun*. 2021;12(1):3249.
5. Lai S, Ruktanonchai NW, Carioli A, et al. Assessing the effect of global travel and contact restrictions on mitigating the COVID-19 pandemic. *Engineering*. 2021;7(7):914-923.
6. Brauner JM, Mindermann S, Sharma M, et al. Inferring the effectiveness of government interventions against COVID-19. *Science*. 2021;371(6531):eabd9338.
7. Ren R, Zhang Y, Li Q, et al. Asymptomatic SARS-CoV-2 infections among persons entering China from April 16 to October 12, 2020. *JAMA*. 2021;325(5):489-492.
8. Fong MW, Gao H, Wong JY, et al. Nonpharmaceutical measures for pandemic influenza in nonhealthcare settings-social distancing measures. *Emerg Infect Dis*. 2020;26(5):976-984.
9. Sakamoto H, Ishikane M, Ueda P. Seasonal influenza activity during the SARS-CoV-2 outbreak in Japan. *JAMA*. 2020;323(19):1969-1971.
10. Soo RJJ, Chiew CJ, Ma S, Pung R, Lee V. Decreased influenza incidence under COVID-19 control measures, Singapore. *Emerg Infect Dis*. 2020;26(8):1933-1935.
11. Trenholme A, Webb R, Lawrence S, et al. COVID-19 and infant hospitalizations for seasonal respiratory virus infections, New Zealand, 2020. *Emerg Infect Dis*. 2021;27(2):641-643.
12. Wong NS, Leung CC, Lee SS. Abrupt subsidence of seasonal influenza after COVID-19 outbreak, Hong Kong, China. *Emerg Infect Dis*. 2020;26(11):2753-2755.
13. Wormser GP. COVID-19 versus seasonal influenza 2019-2020: USA. *Wien Klin Wochenschr*. 2020;132(13–14):387-389.
14. Yang S, Wu J, Ding C, et al. Epidemiological features of and changes in incidence of infectious diseases in China in the first decade after the SARS outbreak: an observational trend study. *Lancet Infect Dis*. 2017;17(7):716-725.
15. Cimolai N. The complexity of co-infections in the era of COVID-19. *SN Compr Clin Med*. 2021:1-13.
16. Bentivegna E, Alessio G, Spuntarelli V, et al. Impact of COVID-19 prevention measures on risk of health care-associated Clostridium difficile infection. *Am J Infect Control*. 2021;49(5):640-642.
17. Bentivegna E, Luciani M, Arcari L, Santino I, Simmaco M, Martelletti P. Reduction of multidrug-resistant (MDR) bacterial infections during the COVID-19 pandemic: a retrospective study. *Int J Environ Res Public Health*. 2021;18(3).
18. Itaya T, Furuse Y, Jindai K. Does COVID-19 infection impact on the trend of seasonal influenza infection? 11 countries and regions, from 2014 to 2020. *Int J Infect Dis*. 2020;97:78-80.
19. Luciani L, Ninove L, Zandotti C, Nougairede A. COVID-19 pandemic and its consequences disrupt epidemiology of enterovirus meningitis, South-East France. *J Med Virol*. 2021;93(4):1929-1931.
20. Stoffel L, Agyeman PKA, Keitel K, et al. Striking decrease of enteroviral meningitis in children during the COVID-19 pandemic. *Open Forum Infect Dis*. 2021;8(6):ofab115.
21. Li Z, Chen Q, Feng L, et al. Active case finding with case management: the key to tackling the COVID-19 pandemic. *Lancet*. 2020;396(10243):63-70.
22. Nolen LD, Seeman S, Bruden D, et al. Impact of social distancing and travel restrictions on non-coronavirus disease 2019 (non-COVID-19) respiratory hospital admissions in young children in rural Alaska. *Clin Infect Dis*. 2021;72(12):2196-2198.
23. Iacobucci G. Covid lockdown: England sees fewer cases of colds, flu, and bronchitis. *BMJ*. 2020;370:m3182.
24. Jefferson T, Del Mar C, Dooley L, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review. *BMJ*. 2009;339:b3675.
25. Jefferson T, Del Mar CB, Dooley L, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses. *Cochrane Database Syst Rev*. 2020;11:CD006207.
26. Kwak J, Susan Wieland L. Physical interventions to interrupt or reduce the spread of respiratory viruses: summary of a Cochrane review. *Explore*. 2021;17(3):277-278.
27. Zhang J, Litvinova M, Liang Y, et al. Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China. *Science*. 2020;368(6498):1481-1486.
28. Li H, Zhao X, Zhao Y, et al. H1N1 exposure during the convalescent stage of SARS-CoV-2 infection results in enhanced lung pathologic damage in hACE2 transgenic mice. *Emerg Microbes Infect*. 2021;10(1):1156-1168.
29. Spuntarelli V, Luciani M, Bentivegna E, et al. COVID-19: is it just a lung disease? A case-based review. *SN Compr Clin Med*. 2020:1-6.
30. Morens DM, Fauci AS. Emerging pandemic diseases: how we got to COVID-19. *Cell*. 2020;183(3):837.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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