Impact of non-pharmaceutical interventions on the incidence of respiratory infections during the COVID-19 outbreak in Korea: a nationwide surveillance study

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Summary: In this ecological study using a nationwide notifiable diseases database and a sample surveillance, the implementation of NPIs was associated with significantly lower incidences of chickenpox, mumps, and respiratory virus infections compared to the prediction model or the pre-intervention period.

Abstract

Background. Many countries have implemented non-pharmaceutical interventions (NPIs) to slow the spread of coronavirus disease 2019 (COVID-19). We aimed to determine whether NPIs led to the decline in the incidences of respiratory infections.

Methods. We conducted a retrospective, ecological study using a nationwide notifiable diseases database and a respiratory virus sample surveillance collected from January 2016 through July 2020 in the Republic of Korea. Intervention period was defined as February–July 2020, when the government implemented NPIs nationwide. Observed incidences in the intervention period were compared to the predicted incidences by autoregressive integrated moving average model and the 4-year mean cumulative incidences (CuIs) in the same months of the pre-intervention period.

Results. Five infectious diseases met the inclusion criteria: chickenpox, mumps, invasive pneumococcal disease, scarlet fever, and pertussis. The incidences of chickenpox and mumps during the intervention period were significantly lower than the prediction model. The CuIs of chickenpox and mumps were 36.4% (95% CI, 23.9–76.3) and 63.4% (95% CI, 48.0–93.3) of the predicted values. Subgroup analysis showed that the decrease in the incidence was universal for chickenpox, while mumps showed a marginal reduction among those aged <18 years, but not in adults. The incidence of respiratory viruses was significantly lower than both the predicted incidence (19.5%; 95% CI, 11.8–55.4%) and the 4-year mean CuIs in the pre-intervention period (24.5%; $P<0.001$).

Conclusions. The implementation of NPIs was associated with a significant reduction in the incidences of several respiratory infections in Korea.

Keywords: non-pharmaceutical intervention; social distancing; COVID-19; respiratory infection; South Korea

Introduction

Non-pharmaceutical interventions (NPIs) have been implemented widely to control the global spread of coronavirus disease 2019 (COVID-19) since February 2020.[1] While specific practices vary across individual countries and settings, most public health strategies share the core elements of NPIs: social distancing, "test and isolate" symptomatic people, hand hygiene, respiratory etiquette, and environmental cleaning.[2] Social distancing measures aim to reduce the transmission of disease by decreasing the frequency and duration of social contact. They include avoiding physical contact and mass gatherings, school and workplace closures, and travel restrictions. The universal use of facemasks was added to mandates later during the epidemic, as more evidence of its benefit emerged.[3] These elements of NPIs are not novel; they have been studied and prepared for decades as an important strategy to slow the spread of novel respiratory virus infections, such as a novel influenza A.[4-6] However, they have never been applied so broadly in modern times before this pandemic, thus providing the opportunity to examine the effects at a societal level.

The Republic of Korea has been able to flatten the curve so far, in stark contrast to other countries with a comparable population and economy. The first case of COVID-19 in South Korea was confirmed on January 20, 2020; a month later, a regional outbreak originated from a church gathering, which led to an explosive increase in the number of cases over the next two months. In response, the health authorities of South Korea implemented nationwide NPIs to slow down the spread of the epidemic (Figure 1). High compliance to NPIs, combined with widespread testing and effective contact tracing led to a decline in the number of daily new cases since late April.[7] Considering that these interventions were successful in containing the spread of COVID-19, it provided a unique opportunity for us to investigate the effect of NPIs on the incidence of other respiratory infections.

We compared the incidence of other infectious diseases that are transmitted via respiratory secretions before and after the implementation of NPIs in South Korea to examine their effect on these diseases.

Methods

Data source

The monthly numbers of reported cases were obtained from the notifiable diseases database curated by the Korea Center for Disease Control and Prevention (KCDC). Physicians who diagnosed diseases designated as notifiable are required by law to report them without delay. The number of cases was divided by annual mid-year population obtained from the Korean Statistical Information Service (http://kosis.kr) to calculate the monthly incidence per 1,000,000 population. The number of respiratory viruses and enteroviruses identified from respiratory specimens by polymerase chain reaction (PCR) were collected weekly through the national sample surveillance for acute respiratory infections, which is managed by the Korea Influenza and Respiratory Viruses Surveillance System (KINRESS) operated by the KCDC. Participating institutions reported the number of positive results from patients with acute respiratory illnesses on a weekly basis. As the sample surveillance was not based on population-based data, crude numbers of positive cases were analyzed. All surveillance data are accessible to public through the KCDC website (http://cdc.go.kr/npt).

Study design

This study was a retrospective, ecological study examining the change in the incidence of various respiratory infections after the implementation of NPIs against COVID-19. Target infectious diseases were selected from among notifiable diseases using the following criteria:

1) the principal mode of transmission is respiratory (droplet or airborne), 2) clinical course is acute or subacute, 3) annual incidence exceeds 100 cases. The pre-intervention period was designated as Jan 2016–Jan 2020, and the intervention period was Feb–Jul 2020.

We constructed models to predict incidences in the intervention period from the trends of incidences in the pre-intervention period using an autoregressive integrated moving average (ARIMA) model. The actual incidences and model predictions were visually examined to determine whether the observed incidences during the intervention period lay within the 95% confidence intervals (CIs) of the predicted values. Furthermore, the observed cumulative incidence (CuI) during the intervention period was compared against the expected CuI in the prediction models and the mean CuI during the same period (Feb–Jul) in the pre-intervention period. Subgroup analyses were performed for three age groups (0–6, 7–17, ≥18 years) for notifiable diseases, which was planned *a priori*.

To exclude the possibility of underreporting or a lapse of surveillance during the COVID-19 epidemic, the incidences of notifiable non-respiratory infections were examined using the same methods stated above. Notifiable diseases with ≥1,000 cases per year were included; however, zoonotic diseases were excluded as they occur predominantly in summer and fall in South Korea.

There have been two distinct regional clusters of COVID-19 cases in South Korea: one in the Daegu/Gyeongbuk area that experienced a regional outbreak from February through early April and one in the Seoul/Gyeonggi/Incheon metropolitan area, the most densely populated area in South Korea, that saw a steady increase of confirmed cases with multiple small clusters since May. Difference-in-difference analysis was conducted to evaluate the difference in the effect of NPI among these regions. This research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki, and the study protocol was approved by the institutional review board of the Severance Children's Hospital, Yonsei University College of Medicine, Republic of Korea (No. 4-2020-0820).

Statistical analysis

Seasonal ARIMA models were constructed to forecast incidences during the intervention period. Parameters were determined by comparing multiple candidate models in terms of residuals, autocorrelation coefficients, and Akaike information criterion. Mean absolute percentage error was calculated to examine the predictive accuracy of the ARIMA models. The difference between CuIs was tested using Student's *t*-test. Difference-in-difference was estimated as previously described; detailed statistical methods are described in the Supplementary Methods.[8] All tests were two-tailed, and *P*-values <0.05 was considered statistically significant. Statistical analyses were performed using R version 3.6.2 (R Foundation for Statistical Computing, Vienna, Austria) and SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

Incidences of notifiable diseases

Five infectious diseases that met the inclusion criteria were included in our analysis: chickenpox, mumps, invasive pneumococcal disease (IPD), scarlet fever, and pertussis. Seasonal ARIMA models were constructed, and the parameters and model characteristics are shown in Supplementary Table 1. Compared with predicted incidences, the actual incidences of chickenpox and mumps during the intervention period were significantly lower (Figure 2). The incidences of IPD, scarlet fever, and pertussis were also lower than predicted values, but lay within 95% CIs of the predicted values. Actual CuIs during the intervention period of chickenpox and mumps were 278.01 and 111.01, respectively, which were 36.4% (95% CI, 23.9–76.3) and 63.4% (95% CI, 48.0–93.3) of the predicted incidences (Table 1A). CuIs of study diseases during the intervention period were universally lower than the mean CuIs during the same months of the pre-intervention period. Scarlet fever (15.8% of the mean pre-intervention CuI), pertussis (34.2%), and chickenpox (38.4%) showed a larger reduction in CuIs, while those of mumps (58.7%) and IPD (57.6%) were smaller. However, they all showed statistically significant reduction in CuIs.

Subgroup analysis showed an age-specific effect of NPIs on the incidences of respiratory infections (Supplementary Figures 1–3 and Table 1). The incidence of chickenpox was substantially lower during the intervention period all age groups. Mumps showed a marginal reduction in incidence among those aged 0–6 and 7–17 years, but not in adults. IPD, scarlet fever, and pertussis also showed decreased incidence, but the difference was small and not statistically significant. The incidence of chickenpox declined to the largest extent among persons in the age group of 7–17 years (28.5% of the predicted CuI; 95% CI, 19.2–54.9), followed by that in the 0–6 age group (43.9%; 95% CI, 26.9–118.6) and then among those aged ≥18 years (57.3%; 95% CI, 45.6–77.4). The CuIs of all diseases were significantly lower than the mean pre-intervention CuIs, except that of IPD among those aged 7–17 years (Table 1A).

We examined whether there exists a difference in the degree of decreasing trends in the incidences of respiratory infections by region (Supplementary Table 2). However, the difference-in-differences regression indicated no significant difference between Daegu/Gyeongbuk area and the remaining regions, despite more stringent NPIs employed during a large regional outbreak in the area. Similarly, there was no difference in the degree of decreasing incidences between Seoul/Gyeonggi/Incheon metropolitan area, which is the most populous region with the largest number of cases of COVID-19, compared to elsewhere.

Sample surveillance for respiratory viruses

The weekly incidence of respiratory viral infections was significantly lower than both the predicted incidence (19.5%; 95% CI, 11.8–55.4%) and the 4-year mean incidence in the pre-intervention period (24.5%; P<0.001; Figure 3 and Table 1B). When examined separately by species, the number of specimens that tested positive for bocavirus, parainfluenza virus, rhinovirus, and metapneumovirus were significantly lower during the intervention period, while those of respiratory syncytial virus (RSV) and coronavirus were comparable to both the predicted incidence and 4-year mean incidence. The relative CuIs were smaller (4.0–19.6% of the mean pre-intervention CuIs) compared to those of notifiable diseases (29.4–63.4%).

Incidences of notifiable non-respiratory infections

Hepatitis A, hepatitis C, and carbapenem-resistant Enterobacterales (CRE) infections met the inclusion criteria for notifiable non-respiratory infections. The observed incidences of all three diseases during the intervention period remained within the 95% CIs of model predictions (Figure 4). Hepatitis C and CRE were newly designated as notifiable diseases in Jul 2017; thus, the observed CuIs were compared against the mean CuIs in 2018–2019 (Table 1C). The CuIs of hepatitis C and CRE during the intervention period were 112.3% and 124.9% of the pre-intervention mean CuIs, respectively. A large surge of hepatitis A was observed in 2019, which led to a relatively smaller CuI in the intervention period (31.9% of the pre-intervention mean). However, the observed CuI of hepatitis A lied within the 95% CI of the predicted value.

Discussion

This nationwide study demonstrates a remarkable reduction in the incidence of highly transmissible infections following the implementation of NPIs that were enforced to control COVID-19. This trend may vary by age, suggesting that these transmissible diseases may be affected differently depending on the degree of NPI implementation and age-specific factors. Even as the COVID-19 pandemic continues, the reduction in the incidence of other respiratory infections may provide secondary benefits as this can decrease the efforts put into screening and isolation and reduce medical expenses related to COVID-19, especially since it is difficult to distinguish this disease from other respiratory infections.[9]

The monthly incidence rates of notifiable diseases decreased remarkably to 26–63% of the predicted values, regardless of their high infectivity (e.g., chicken pox R_0 = 6.3–13.8, pertussis R_0 = 7.3–18.5, mumps R_0 = 4.3–11.2, scarlet fever R_0 = 3.7–8.0).[10] In particular, chickenpox and mumps showed a significant reduction in both the prediction models and the CuIs compared to that in the past 4 years. Meanwhile, the incidences of pertussis and IPD were not high enough to detect any difference and that of scarlet fever has shown a downward trend in recent years. These are limitations in analyzing the effects of NPIs.

Interestingly, the incidence of notifiable diseases began to decline even before late February, which was when NPIs were officially recommended by health authorities. This finding suggests that voluntary social distancing and behavior changes by individuals had begun before the government-led mandates in Korea. Based on mobile big data, the daily movement of people in February 2020 was seen to decrease by up to 38% compared to that during January 2–20, 2020 (before the first Korean COVID-19 confirmed case).[11] The authors of the study also reported that the daily number of passengers at major subway stations in Seoul was also significantly lower. Similar study results were recently published in the US.[12, 13] Nolen et al. reported that hospitalization rates for non-COVID-19 respiratory illnesses had begun to decline before mandatory social distancing in Alaska.[12] Another study comparing the diagnosis rates of common infectious diseases in children (aged 0–17 years), before and after imposing strong social distancing measures, including movement restrictions in Massachusetts, reported a significant reduction in several respiratory illnesses by 10–101%.[13] Unlike the above two studies in the United States, our data shows that less stringent means of social distancing without movement restrictions or remote working (commonly called “lockdown”) can also reduce the spread of highly transmissible infections.

Decreased incidence of infectious diseases by enforcing NPIs is not characteristic of some respiratory infections but appears to be a common phenomenon in transmissible pathogens, mainly represented by respiratory viruses, which are transmitted by droplets or direct contact. Previous studies evaluating the effects of social distancing have reported a reduction in nonspecific acute respiratory illnesses, including influenza-like illness and pneumonia.[12-15] However, respiratory viruses included in our study were identified through a PCR-based test, and we demonstrated numbers showing that all the respiratory viruses recorded by the KINRESS had a decreasing trend. In particular, enterovirus infections, which are most prevalent during the summer in temperate climates, remarkably reduced to 3% of the last four-year mean. A recent Taiwanese study reported a reduction of enterovirus infections along with influenza during the 2019–20 winter season after wearing masks and social distancing during the COVID-19 outbreak.[16] However, this study did not include similar data for the summer season. Our study included data for the summer season (June to July) as well, which allowed us to distinctly observe the continued decline of enterovirus infections.[16] Meanwhile, in countries in the Southern Hemisphere, influenza activity was very low during the typical influenza season, June-August 2020.[17] Since the NPIs against COVID-19 have stayed in place in South Korea, we would be able to observe whether the decline in infections caused by respiratory viruses such as RSV and influenza (which are prevalent in the winter season) continues in the coming winter months in the Northern Hemisphere.

Mumps and rhinovirus infections tended to increase after May 2020 when social distancing measures were relaxed, while the incidence of other transmissible diseases remained at low levels during the whole period. One of the reasons for this could be increased exposure among vulnerable children of that age as schools or day-care centers opened, but it is unclear why only infections due to these two respiratory viruses increased. In addition, a low cross-immunity to heterogeneous subtypes of rhinovirus and waning herd immunity against mumps could be potential causes, but more long-term surveillance data are required to clarify the certainty and persistence of these results.[18-21]

The degree of reduction of notifiable diseases after NPIs were enforced differed by age group. In general, the decrease in all notifiable diseases in children was greater than that in adults; particularly, chickenpox and mumps decreased by 40–66% compared to the last four-year mean in children, but only by 22–26% in adults. One of the possible explanations is that NPI was enforced more strongly among children than adults. While adults were not forced to work from home, on-site school reopening had been delayed until May 20. After that, it was opened as follows: high school (age 16–18) first, then kindergarten (age 3–6), middle school (age 13–15), and elementary school (age 7–12). This judgment was made considering the need for child care, the possibility of poor compliance with infection control policies among young children, the high-density facilities, and the possibility of transmission of SARS-CoV-

2 to grandparents who are at higher risk for severe illness from COVID-19.[22, 23] Along with the delay in reopening schools, multifaceted interventions such as restrictions on the use of indoor play facilities and large academies may have also contributed in reducing the likelihood of transmission.

This study, nevertheless, has some limitations. First, although physicians are obliged to report notifiable diseases to the health authorities, there are possibilities of over- or under-reporting as well as misdiagnosis. However, we also examined the incidences of three common non-respiratory infections. Their incidences during the COVID-19 pandemic were similar or larger compared to baseline or model predictions, suggesting the absence of under-reporting. Second, even though only notifiable diseases with more than 100 cases per year were included, these numbers may be insufficient to detect differences to a statistically significant degree, particularly in subgroups. Third, we could not exclude imported cases due to limitations of the database. However, the number of imported cases included in the study was very small (<20 cases per year), so it would not exert a meaningful effect on the results. Finally, factors indirectly related to NPIs (i.e., healthcare-seeking behaviors) could not be accounted for in the analysis.

We demonstrated that the implementation of NPIs was associated with a significant reduction in the incidences of several respiratory infections in South Korea. As NPI measures continue to be in place during the COVID-19 pandemic, further research is needed to determine if this associated decreased trend is sustained in the coming winter months.

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Author contributions

Drs. Huh and Kang had full access to the study data and take responsibility for its integrity and accuracy of analysis. Drs. Huh and Jung contributed equally to this study.

Concept and design: Huh, Jung, Kang

Acquisition, analysis, or interpretation of data: Huh, Kim, Hong, Jung, Ahn, Kim, Kang

Drafting of the manuscript: Huh, Kang

Statistical analysis: Huh, Hong, Jung

Conflict of Interest Disclosures

The authors have no conflicts of interest to declare.

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References

1. Hartley DM, Perencevich EN. Public Health Interventions for COVID-19: Emerging Evidence and Implications for an Evolving Public Health Crisis. JAMA **2020**; 323(19): 1908-9.

2. Qualls N, Levitt A, Kanade N, et al. Community Mitigation Guidelines to Prevent Pandemic Influenza - United States, 2017. MMWR Recomm Rep **2017**; 66(1): 1-34.

3. Brooks JT, Butler JC, Redfield RR. Universal Masking to Prevent SARS-CoV-2 Transmission—The Time Is Now. JAMA **2020**; 324(7): 635-7.

4. U.S. Department of Health and Human Services. Pandemic Influenza Plan: 2017 Update. Washington, DC, **2017**.

5. Markel H, Lipman HB, Navarro JA, et al. Nonpharmaceutical Interventions Implemented by US Cities During the 1918-1919 Influenza Pandemic. JAMA **2007**; 298(6): 644-54.

6. 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): 976-84.

7. Choi S, Ki M. Analyzing the Effect of Social Distancing for Novel Coronavirus Disease 2019(COVID-19) in South Korea. Epidemiol Health **2020**: e2020064.

8. Lyu W, Wehby GL. Comparison of Estimated Rates of Coronavirus Disease 2019 (COVID-19) in Border Counties in Iowa Without a Stay-at-Home Order and Border Counties in Illinois With a Stay-at-Home Order. JAMA Network Open **2020**; 3(5): e2011102-e.

9. Emanuel EJ, Persad G, Upshur R, et al. Fair Allocation of Scarce Medical Resources in the Time of Covid-19. N Engl J Med **2020**; 382(21): 2049-55.

10. Huang SZ. A new SEIR epidemic model with applications to the theory of eradication and control of diseases, and to the calculation of R0. Math Biosci **2008**; 215(1): 84-104.

11. Park IN, Yum HK. Stepwise Strategy of Social Distancing in Korea. J Korean Med Sci **2020**; 35(28): e264.

12. Nolen LD, Seeman S, Bruden D, et al. Impact of Social Distancing and Travel Restrictions on

non-COVID-19 Respiratory Hospital Admissions in Young Children in Rural Alaska. Clin Infect Dis **2020**.

13. Hatoun J, Correa ET, Donahue SMA, Vernacchio L. Social Distancing for COVID-19 and Diagnoses of Other Infectious Diseases in Children. Pediatrics **2020**.

14. Lee H, Lee H, Song KH, et al. Impact of Public Health Interventions on Seasonal Influenza Activity During the SARS-CoV-2 Outbreak in Korea. Clin Infect Dis **2020**.

15. Boelle PY, Souty C, Launay T, et al. Excess cases of influenza-like illnesses synchronous with coronavirus disease (COVID-19) epidemic, France, March 2020. Euro Surveill **2020**; 25(14).

16. Chiu NC, Chi H, Tai YL, et al. Impact of Wearing Masks, Hand Hygiene, and Social Distancing on Influenza, Enterovirus, and All-Cause Pneumonia During the Coronavirus Pandemic: Retrospective National Epidemiological Surveillance Study. J Med Internet Res **2020**; 22(8): e21257.

17. Olsen SJ, Azziz-Baumgartner E, Budd AP, et al. Decreased Influenza Activity During the COVID-19 Pandemic - United States, Australia, Chile, and South Africa, 2020. MMWR Morb Mortal Wkly Rep **2020**; 69(37): 1305-9.

18. Fields VS, Safi H, Waters C, et al. Mumps in a highly vaccinated Marshallese community in Arkansas, USA: an outbreak report. Lancet Infect Dis **2019**; 19(2): 185-92.

19. Glanville N, Johnston SL. Challenges in developing a cross-serotype rhinovirus vaccine. Curr Opin Virol **2015**; 11: 83-8.

20. Park SH. Resurgence of mumps in Korea. Infect Chemother **2015**; 47(1): 1-11.

21. Palmenberg AC, Spiro D, Kuzmickas R, et al. Sequencing and analyses of all known human rhinovirus genomes reveal structure and evolution. Science **2009**; 324(5923): 55-9.

22. Sugaya N, Takeuchi Y. Mass vaccination of schoolchildren against influenza and its impact on the influenza-associated mortality rate among children in Japan. Clin Infect Dis **2005**; 41(7): 939-47.

23. Towers S, Feng Z. Social contact patterns and control strategies for influenza in the elderly. Math Biosci **2012**; 240(2): 241-9.

Table 1. Cumulative incidences (CuI) of respiratory infections from February through July of each year. Observed CuI in 2020, CuI predicted by autoregressive integrated moving average model, and mean CuI in the past 4 years (2016–2019) are shown.

(A) Respiratory infections from the national notifiable diseases database

Disease	N, Feb–Jul 2020	Cumulative incidence, Feb–Jul (per 1,000,000)			% predicted (95% CI)	% mean (2016–2019)	P
		Observed (2020)	Predicted	Mean (2016–2019)			
Overall							
Chickenpox	14412	278.01	764.38	723.47	36.37 (23.88–76.30)	38.43	<0.001
Mumps	5755	111.01	175.15	189.22	63.38 (47.98–93.34)	58.67	<0.001
Invasive pneumococcal disease	166	3.20	5.71	5.56	56.09 (31.55–220.50)	57.63	0.013
Scarlet fever	1341	25.87	98.94	163.57	26.14 (10.62–∞)	15.81	<0.001
Pertussis	65	1.25	4.26	3.66	29.43 (11.30–∞)	34.24	0.026
Age 0–6							
Chickenpox	7170	2727.18	6218.14	6491.43	43.86 (26.90–118.64)	42.01	<0.001
Mumps	2142	814.73	1358.76	1468.13	59.96 (42.10–104.15)	55.49	<0.001
Invasive pneumococcal disease	11	4.18	7.40	8.67	56.52 (26.78–902.18)	48.25	0.016

Scarlet fever	1016	386.45	1409.76	2267.63	27.41 (11.59–1263.35)	17.04	<0.001
Pertussis	15	5.71	10.31	15.98	55.31 (10.31–∞)	35.71	0.012
Age 7–17							
Chickenpox	5688	129.13	453.29	376.19	28.49 (19.23–54.90)	34.33	<0.001
Mumps	2451	55.65	82.41	92.50	67.52 (48.07–113.42)	60.16	<0.001
Invasive pneumococcal disease	1	0.02	0.11	0.08	19.98 (5.91–∞)	28.19	0.078
Scarlet fever	268	6.08	14.78	37.21	41.17 (11.91–∞)	16.35	<0.001
Pertussis	19	0.43	2.37	2.07	18.22 (4.88–∞)	20.80	0.029
Age ≥18							
Chickenpox	1554	35.28	61.54	47.79	57.33 (45.55–77.35)	73.83	0.013
Mumps	1162	26.38	32.29	33.85	81.71 (62.69–117.30)	77.93	0.005
Invasive pneumococcal disease	154	3.50	6.49	5.95	53.85 (30.36–238.09)	58.79	0.021
Scarlet fever	57	1.29	2.07	2.35	62.40 (38.23–169.60)	55.13	0.003
Pertussis	31	0.70	2.10	1.21	33.51 (18.75–153.20)	57.95	0.242

(B) Respiratory virus infections reported from the national sample surveillance network

Disease	Cumulative incidence, Feb–Jul			% predicted (95% CI)	% mean (2016–2019)	P
	Observed (2020)	Predicted	Mean (2016–2019)			
Enterovirus	39	1146.82	1229.25	3.40 (0.54–∞)	3.17	<0.001
Respiratory viruses (except enterovirus)	8409	43074.79	34354.00	19.52 (11.77–55.38)	24.48	<0.001
Adenovirus	914	4704.96	4827.50	19.43 (8.81–685.04)	18.93	<0.001
Bocavirus	336	4102.29	3587.00	8.19 (5.10–16.45)	9.37	<0.001
Parainfluenzavirus	316	7952.53	5482.75	3.97 (2.83–6.67)	5.76	<0.001
Respiratory syncytial virus	1718	2773.57	2232.75	61.94 (11.94–377.64)	76.95	0.451
Rhinovirus	2989	15265.41	11299.25	19.58 (14.99–28.22)	26.45	<0.001
Metapneumovirus	470	6965.98	5014.75	6.75 (4.34–13.85)	9.37	<0.001
Coronavirus	1666	1786.83	1910.00	93.24 (28.49–351.24)	87.23	0.667

CI, confidence interval.

(C) Non-respiratory infections from the national notifiable diseases database

Disease	N, Feb–Jul 2020	Cumulative incidence, Feb–Jul (per 1,000,000)			% predicted (95% CI)	% mean (2018–2019)	P
		Observed (2020)	Predicted	Mean (2018–2019)			
Hepatitis A	1890	36.46	25.70	114.35	141.87 (20.86–∞)	31.88	0.031
Hepatitis C	5896	113.73	101.76	101.31	111.77 (88.44–151.82)	112.27	0.021
Carbapenem-resistant Enterobacterales	7719	148.90	162.95	119.25	91.38 (80.61–105.46)	124.86	0.006

CI, confidence interval.

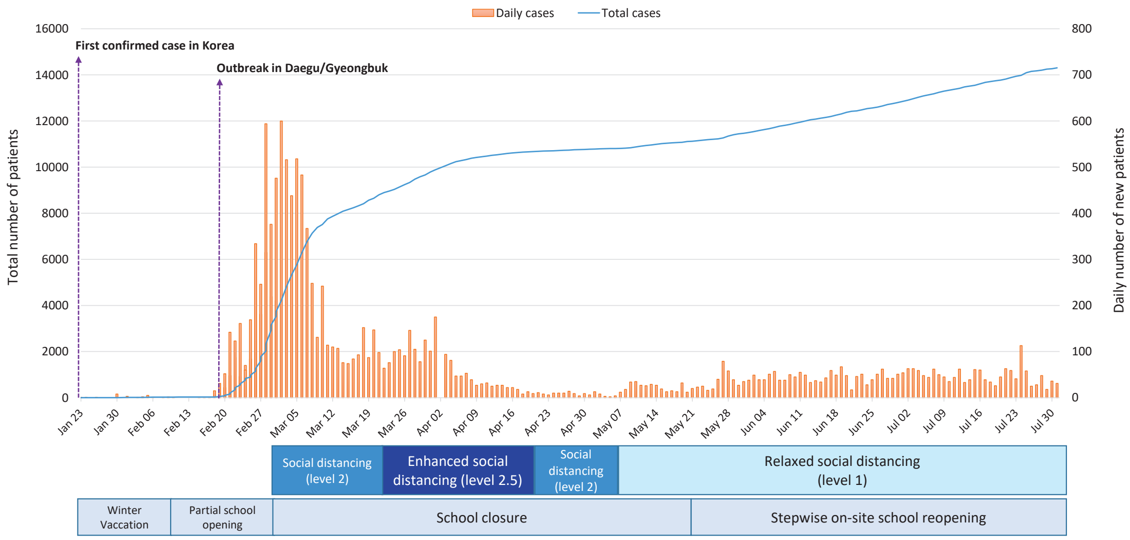
Figure Legends

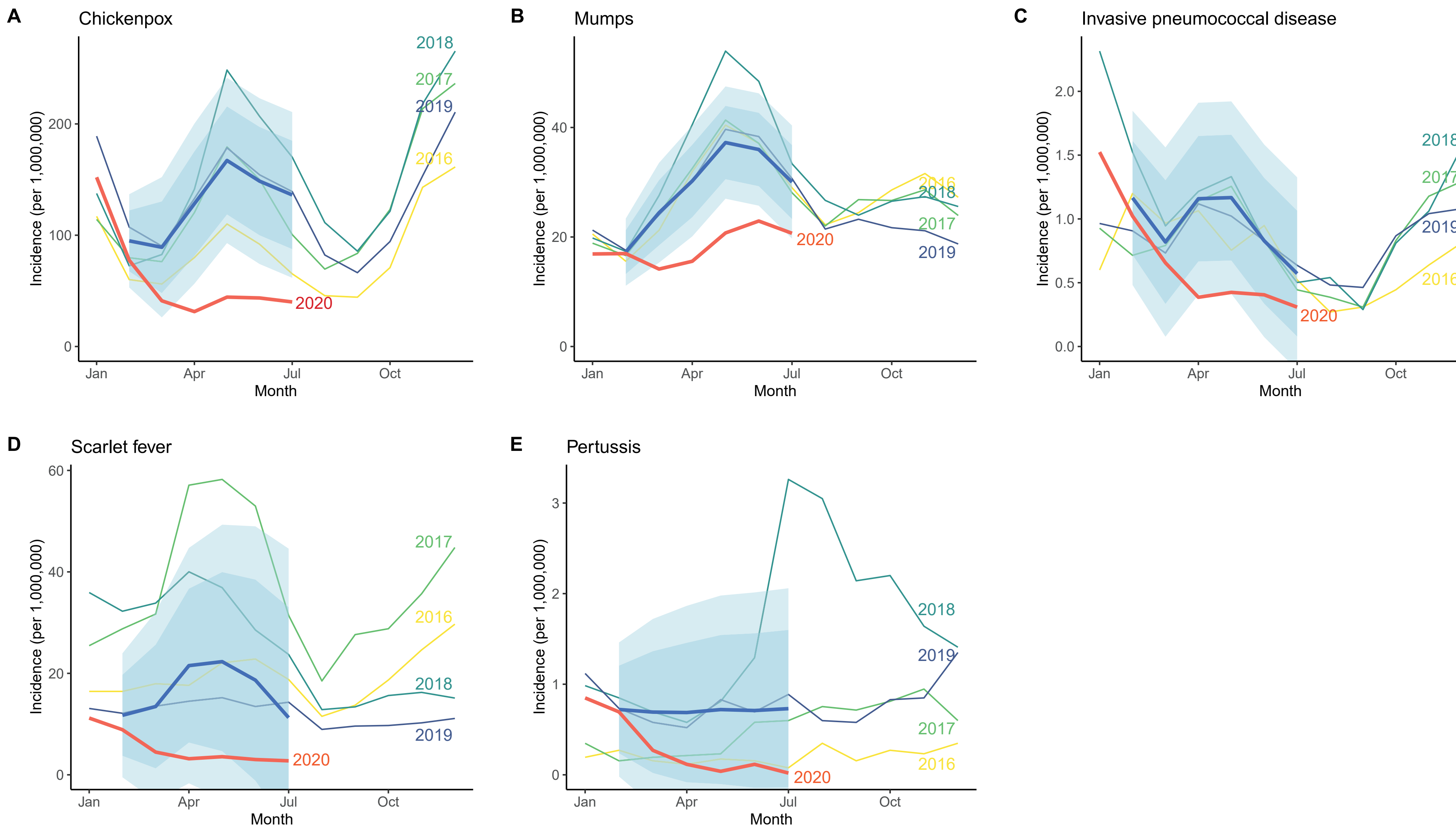
Figure 1. Daily number of confirmed cases of coronavirus diseases 2019 (COVID-19) and non-pharmaceutical interventions.

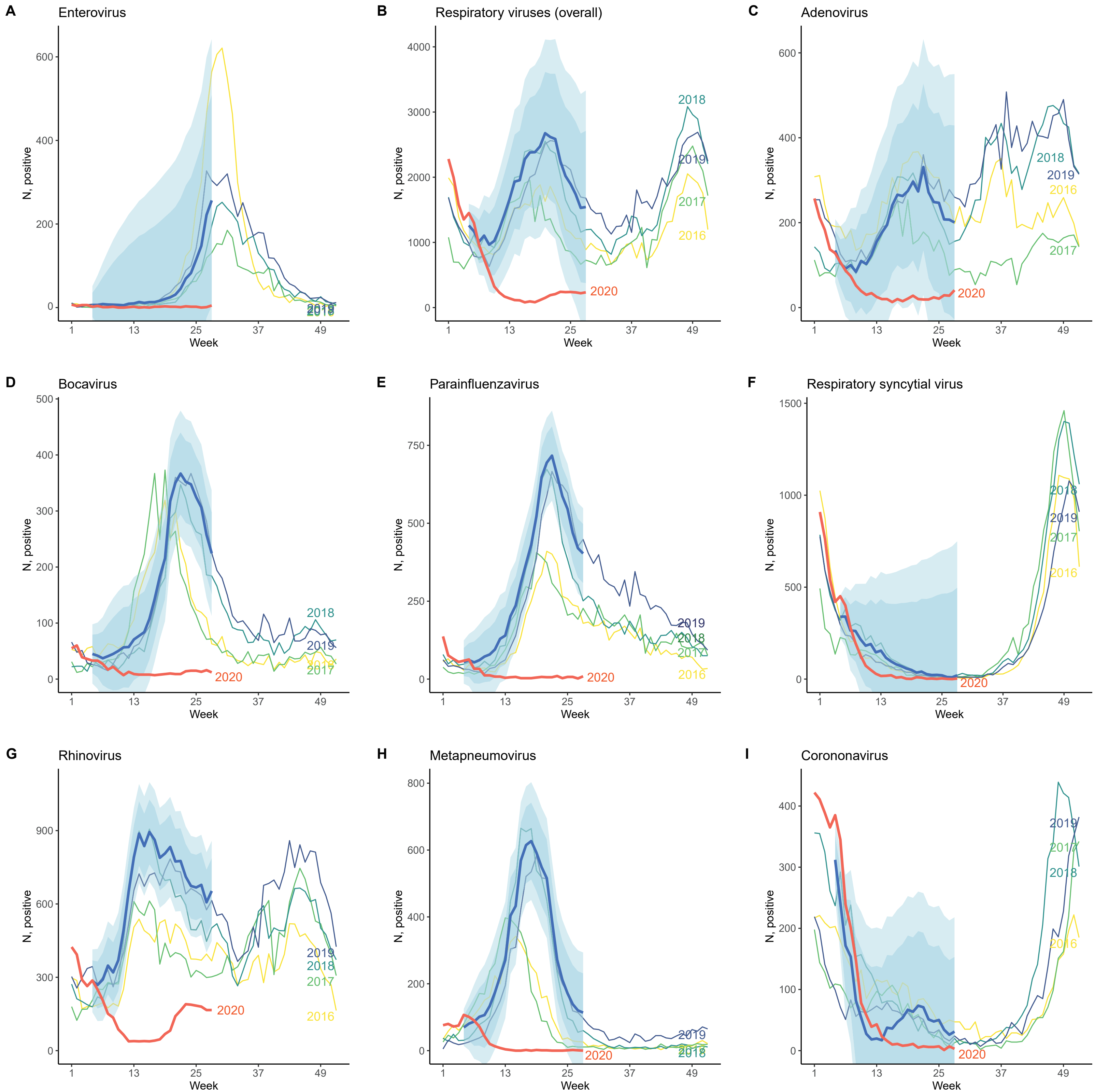
Figure 2. Monthly incidence of notifiable respiratory infections and predicted incidence by autoregressive integrated moving average (ARIMA) model. Thick red lines denote the observed incidence in the intervention period; thick blue line, the predicted incidence; blue shades, 80% and 95% confidence intervals of the predicted incidence.

Figure 3. Weekly reported cases of respiratory virus infections from a nationwide sample surveillance network. Thick red lines denote the observed incidence in the intervention period; thick blue line, the predicted incidence; blue shades, 80% and 95% confidence intervals of the predicted incidence.

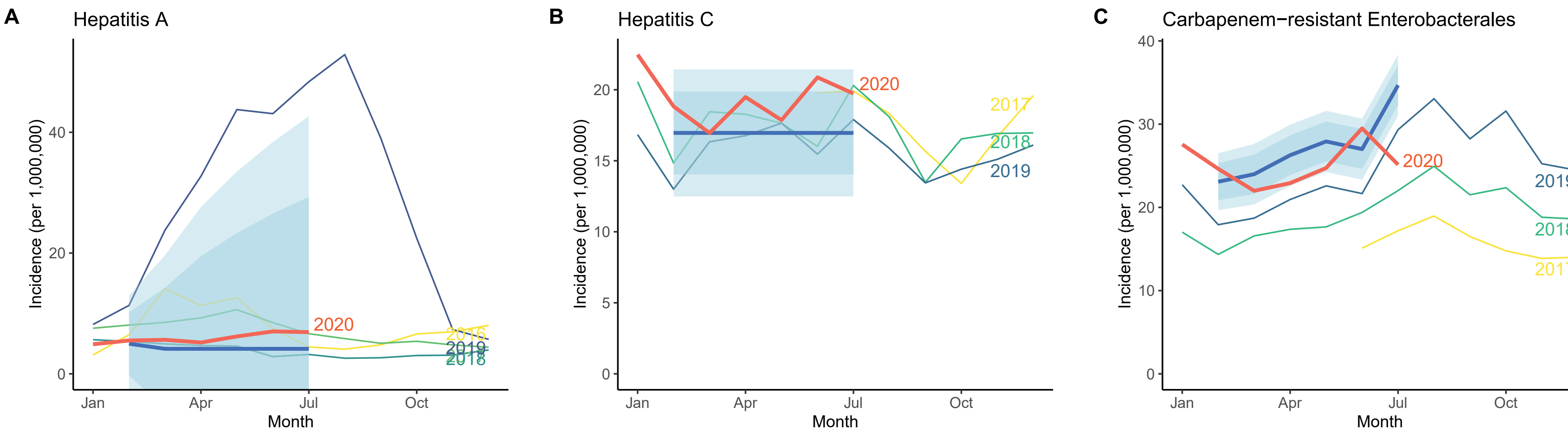
Figure 4. Monthly incidence of notifiable non-respiratory infections and predicted incidence by autoregressive integrated moving average (ARIMA) model. Thick red lines denote the observed incidence in the intervention period; thick blue line, the predicted incidence; blue shades, 80% and 95% confidence intervals of the predicted incidence.


Daily cases
Total cases
First confirmed case in Korea
Outbreak in Daegu/Gyeongbuk
Total number of patients
Daily number of new patients
Social distancing (level 2)
Enhanced social distancing (level 2.5)
Social distancing (level 2)
Relaxed social distancing (level 1)
Winter Vaccation
Partial school opening
School closure
Stepwise on-site school reopening


A
Chickenpox
B
Mumps
C
Invasive pneumococcal disease
D
Scarlet fever
E
Pertussis
Incidence (per 1,000,000)
Month
Jan
Apr
Jul
Oct
2016
2017
2018
2019
2020



A
Enterovirus
B
Respiratory viruses (overall)
C
Adenovirus
D
Bocavirus
E
Parainfluenzavirus
F
Respiratory syncytial virus
G
Rhinovirus
H
Metapneumovirus
I
Corononavirus
N, positive
Week
2020
2019
2018
2017
2016


A
Hepatitis A
Incidence (per 1,000,000)
0
20
40
Jan
Apr
Jul
Oct
Month
2020
2016
2019
2018
B
Hepatitis C
Incidence (per 1,000,000)
0
5
10
15
20
Jan
Apr
Jul
Oct
Month
2020
2017
2018
2019
C
Carbapenem−resistant Enterobacterales
Incidence (per 1,000,000)
0
10
20
30
40
Jan
Apr
Jul
Oct
Month
2020
2019
2018
2017