Trends in gastrointestinal infections before and during nonpharmaceutical interventions in Korea in comparison with the United States

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ABSTRACT

OBJECTIVES: To examine how the trends in the weekly frequencies of gastrointestinal infectious diseases changed before and during the COVID-19 pandemic in Korea, and to compare them with the trends in the United States.

METHODS: We compared the weekly frequencies of gastrointestinal infectious diseases (16 bacterial and 6 viral diseases) in Korea during weeks 5-52 before and after COVID-19. In addition, the weekly frequencies of five gastrointestinal infectious diseases in the United States (data from the Centers for Disease Control and Prevention) that overlapped with those in Korea were compared.

RESULTS: The mean weekly number of total gastrointestinal infectious diseases in Korea showed a significant decrease (from 522 before COVID-19 to 245 after COVID-19, $P < 0.01$). Only bacterial gastrointestinal infectious diseases caused by *Campylobacter* increased significantly; other bacterial gastrointestinal infectious diseases showed either a decrease or no change. All other viral diseases decreased. In the United States, the weekly numbers of *Salmonella*, *Campylobacter*, typhoid, shigellosis, and hepatitis A virus sharply decreased after the COVID-19 outbreak. The weekly numbers of all viral diseases markedly decreased in both countries; however, the bacterial gastrointestinal infectious diseases showed a different pattern.

CONCLUSIONS: Most gastrointestinal infectious diseases decreased after the COVID-19 outbreak. In contrast, *Campylobacter* infections showed an increasing trend in Korea, but a decreasing trend in the United States. Further studies are needed to elucidate the different trends in bacterial and viral infectious diseases before and after NPIs and between different countries.

KEY WORDS: COVID-19, Gastrointestinal infection, Nonpharmaceutical intervention

INTRODUCTION

On March 11, 2020, the World Health Organization (WHO) declared coronavirus disease 2019 (COVID-19) as a pandemic. After the WHO declaration, nonpharmacological interventions (NPIs) against COVID-19 have been implemented in several countries [1]. NPIs such as movement restrictions and isolation measures began in March 2020 worldwide [2], and Korea also started implementing nationwide NPIs in March 2020 [3, 4]. As a result of NPIs, the weekly positivity rates of viral respiratory infections significantly decreased in 2020 compared with those in the same weeks in 2010-2019 [5]. Interventions, including personal hygiene and social distancing measures, might affect infectious diseases other than respiratory infectious diseases. However, whether NPIs could influence the development of other infectious diseases is unknown owing to the limited number of studies. Therefore, we examined how the trends in the weekly frequencies of gastrointestinal infectious diseases changed before and during the COVID-19 pandemic in Korea, considering the COVID-19 trend, and compared them with the trends in the United States.

METHODS

We analyzed the weekly number of gastrointestinal infectious diseases from the Infectious Disease Surveillance System established by the Korea Disease Control and Prevention Agency (KDCA). Physicians reported this surveillance system based on Infectious Disease Control and Prevention Act [6]. After collecting data from the local health authorities, these data were transferred to the Korea Centers for Disease Control and Prevention (KCDC). A report of national statistics was then published using these confirmed data from the KCDC [7]. According

to reporting guidelines, reported infectious disease is classified into three groups; pathogen identified, suspected infection, or a pathogen carrier [8]. The infectious disease surveillance system in Korea is composed of a mandatory surveillance system and a sentinel surveillance system [6, 9]. The mandatory surveillance system requires obligatory reporting from all health centers immediately or within 24 hours of identifying 64 types of infectious diseases. The sentinel surveillance system receives weekly reports on 23 types of infectious diseases from designated health institutions. In this study, we considered gastrointestinal infectious diseases, including cholera, shigellosis, typhoid, paratyphoid, enterohemorrhagic *Escherichia coli* (EHEC), and hepatitis A virus, which are collected through the mandatory surveillance system: *Salmonella*, enteroinvasive *E. coli* (EIEC), *Yersinia enterocolitica*, *Clostridium perfringens*, *Vibrio parahaemolyticus*, enteropathogenic *E. coli* (EPEC), *Bacillus cereus*, *Campylobacter*, enterotoxigenic *E. coli* (ETEC), *Listeria monocytogenes*, *Staphylococcus aureus*, group A rotavirus, astrovirus, adenovirus, norovirus, and sapovirus infections, which are collected through the sentinel surveillance system [9]. For a cross-country comparison with the United States, we used weekly reports from the Nationally Notifiable Diseases Surveillance System (NNDSS) by the US Centers for Disease Control and Prevention (CDC) [10], to which infectious and contagious diseases are immediately reported by healthcare providers [11, 12]. The NNDSS is collected from all 50 states and the District of Columbia and monitors about 120 diseases classified by the main transmission: sexually transmitted, foodborne or waterborne, vectorborne, injection drug use–associated, and respiratory [13]. As a result, the types of infectious agents reported in the KDCA in Korea and the CDC in the United States differed. Thus, we selected infectious diseases from the CDC that overlapped with those in the KDCA for comparison: salmonellosis, *Campylobacter* infection, typhoid, shigellosis, and hepatitis A virus

infection. For the period before COVID-19, the mandatory surveillance system used the mean weekly number from 2015 to 2019, which was calculated as the sum of all weekly numbers divided by five (the number of years). The sentinel surveillance system used data from July 30, 2017 to 2019, considering the expansion of medical centers for sentinel surveillance in July 2017. For the period after COVID-19, we used the weekly number of each type of gastrointestinal infectious disease from weeks 5 to 52 of 2020. We then compared the mean weekly number for the same weeks before and after COVID-19 on the mandatory surveillance system and the sentinel surveillance system using a paired t-test.

We excluded 1-4 weeks from each year to reflect the incidence of COVID-19 because the first COVID-19 patient was identified in Korea on January 20, 2020. Data on the number of weekly COVID-19 cases from the CDC in the United States [14] and from the KDCA in Korea [15] were used. For visualization, we plotted the trends in the weekly number of new COVID-19 cases together with the mean weekly number of each gastrointestinal infectious disease for two periods, before and after COVID-19. All statistical analyses were conducted using Microsoft Excel (version 2016; Microsoft, Redmond, WA, USA).

RESULTS

Table 1 shows the mean weekly number of gastrointestinal infectious diseases during weeks 5-52 before COVID-19 compared with that after COVID-19 in Korea and the United States. In Korea, the weekly number of total gastrointestinal infectious diseases showed a significant decrease (from 522 before COVID-19 to 245 after COVID-19, $P < 0.01$). Statistically significant decreases were observed for all types of viral gastrointestinal infectious diseases

(range of decrease -55.2 to -5.8, $P < 0.01$). The decreases for total bacterial gastrointestinal infectious diseases were not statistically significant ($P = 0.12$). In contrast, the total viral gastrointestinal infectious diseases markedly decreased after COVID-19 compared with the period before COVID-19. Meanwhile, in the United States, both of total bacterial gastrointestinal and total viral gastrointestinal significantly decreased. In particular, in Korea, a statistically significant decrease was observed for *Salmonella*, *V. parahaemolyticus*, enterotoxigenic *E. coli* (ETEC), enteroinvasive *E. coli* (EIEC), *S. aureus*, *B. cereus*, typhoid, and shigellosis. A statistically significant increase was observed for *Campylobacter* infections. There were no statistically significant differences in *C. perfringens*, *Y. enterocolitica*, *Listeria monocytogenes*, EHEC, cholera, paratyphoid, and enteropathogenic *E. coli* (EPEC) infections. In the United States, salmonellosis (-151.8), *Campylobacter* infection (-163.9), typhoid (-1.5), shigellosis (-71.9), and hepatitis A virus infection (-15.5) were significantly decreased after COVID-19 compared before COVID-19 ($P < 0.01$ all).

Figures 1 and 2 present the epidemic curves of each type of gastrointestinal infectious disease determined by sentinel surveillance and mandatory surveillance during weeks 5–52 before and after COVID-19 in Korea with the weekly number of new COVID-19 cases. After the start of the COVID-19 outbreak followed by the establishment of NPIs in Korea, the frequency of the six types of viral diseases decreased, especially group A rotavirus, astrovirus, adenovirus, norovirus, and sapovirus infections. In particular, the frequency of astrovirus and sapovirus infections reached nearly zero from week 41. The epidemic patterns of bacterial diseases did not show a dramatic decrease after COVID-19.

Figure 3 shows that the weekly number of *Salmonella* infection, *Campylobacter* infection, typhoid, shigellosis, and hepatitis A virus infection sharply decreased after the

COVID-19 outbreak in the United States. The decrease in the number of shigellosis cases was most pronounced, from 124 on week 9 to 9 on week 18.

DISCUSSION

With respect to the five gastrointestinal infections that were collected in both countries, not only the weekly numbers of each bacterial and viral diseases but also the total number of bacterial and viral gastrointestinal diseases markedly decreased in the United States. However, Korea showed a different pattern compared to the US. Specifically, the total number of viral gastrointestinal diseases decreased significantly while the total number of bacterial gastrointestinal did not significantly decrease. In addition, each bacterial gastrointestinal disease had various trends.

Infectious diseases are expected to decrease after the COVID-19 pandemic due to worldwide NPIs. In Korea, the total viral gastrointestinal infections showed a considerable decrease, but the decreases in the total bacterial gastrointestinal infections did not reach a statistically significant level. Unlike the viral gastrointestinal infectious disease, there were fluctuations in the bacterial gastrointestinal infections trends (downward, stable, and then upward) in 2020 compared with the previous years. A significant decrease was observed in *Salmonella*, *V. parahaemolyticus*, *ETEC*, *EIEC*, *S. aureus*, *B. cereus*, typhoid, and shigellosis. However, only the increase in *Campylobacter* infections was statistically significant. Although NPIs, such as hand hygiene and wearing a mask, can decrease viral disease [16], and these viral gastrointestinal infectious diseases also show a significant decrease like the respiratory viruses did, suggesting the existence of a foodborne or waterborne infection route in the case of

gastrointestinal viruses [17, 18]. However, *C. perfringens* and EHEC are not significantly increased. It is probably due to an unstable small number. In the case of EHEC, the outbreak in 2019 may affect the increase of EHEC [19]. Bacterial gastrointestinal infections are difficult to identify both before and after the COVID-19 outbreak. Bacterial pathogens propagate through rotten food or water, especially during the summer [20, 21].

As the types of gastrointestinal infections collected in Korea and the United States differed, a direct comparison would be limited; however, there are several potential reasons for this divergence. First, the United States issued a stay-at-home order between March and April 2020. In Korea, personal hygiene measures, such as mask-wearing, were used. Second, compared to the United States, Korea issued a less strict social distancing policy, and therefore, accessibility to medical care may have been lower in the United States than in Korea [22].

Despite these potential reasons, *Campylobacter* infections showed obviously different patterns between Korea and the United States. Gastrointestinal infectious diseases have a wide range of infection pathways. Agents of *Campylobacter* infections are animals, including dogs, cats, pigs, sheep, rodents, birds, and poultry [9]. According to a Korean study, retail raw chickens were confirmed about 68% for *Campylobacter*. After the COVID-19 outbreak, the annual consumption of chicken per adult increased 1.2kg compared to COVID-19 [23]. Thus, *Campylobacter* infections are a zoonotic contagious disease that can infect humans through food based on these assumptions. Additionally, cluster outbreaks in restaurants were the highest number before COVID-19, however, after COVID-19, the highest place of cluster outbreaks is changed to Korean's pre-primary [9]. Additionally, even though restaurants used to be the locations with the highest number of cluster outbreaks, this has been changed to pre-primary schools after COVID-19. In Korea, kindergartens and pre-primary have different purposes.

Kindergartens focus on education, and pre-primary schools focus on childcare. Therefore, this could explain the poor control of *Campylobacter* due to the coronavirus. Consequently, people who had gastrointestinal infectious diseases with less severe symptoms might have had limited accessibility to the medical center during the COVID-19 pandemic than the period before it, which could be more impacted in the United States than in Korea. Thus, despite the possibility of under-reporting followed by underestimation of actual infection numbers in both countries, this would be more impactful in the United States [24]. Our data, including the mandatory surveillance and sentinel surveillance, and, in the case of sentinel surveillance, the number of hospitals, including public hospitals collecting data, increased from July 30, 2017 [25]. Thus, we compared the periods before and after COVID-19, depending on the surveillance system.

In conclusion, while viral gastrointestinal diseases, including hepatitis A, prominently decreased after COVID-19, bacterial diseases showed different trends in Korea and a decreasing trend in the United States. Further studies are needed to elucidate the different trends in bacterial and viral infectious diseases before and after NPIs and between different countries as well as considering the characteristics of each pathogen

Conflict of interest

The authors have no conflicts of interest to declare for this study.

Acknowledgments

This research was supported by the Government-wide R&D Fund Project for Infectious Disease Research (GFID), Republic of Korea (grant number: HG18C00880).

This study was conducted under the research project “Research and Development on Integrated Surveillance System for Early Warning of Infectious Diseases” (RISEWIDs).

Author Contributions

Conceptualization: BYP and SYK Data curation: SYK and JHK Formal analysis: SKY. Funding acquisition: BYC. Methodology: BYP and SYK Project administration: BYP and BYC visualization: SYK. Writing – original draft: SYK, BYP Writing – review & editing: SYK, BYP, BYC

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Table 1. Mean weekly number of gastrointestinal infectious diseases during weeks 5-52 in before COVID-19 compared with that after COVID-19 in Korea and the United States

Figure 1. Mean weekly number of gastrointestinal infections by the sentinel surveillance in Korea before COVID-19 compared with after COVID-19. Red dotted line indicates the mean weekly incidence in Korea before COVID-19. Black line shows the weekly incidence after COVID-19. Blue zone indicates the coronavirus disease 2019 (COVID-19) incidence in Korea. (A) Total gastrointestinal infectious diseases. (B) *Bacillus cereus*. (C) *Campylobacter*. (D) *Clostridium perfringens*. (E) Enteroinvasive *E. coli*. (F) Enteropathogenic *E. coli*. (G) Enterotoxigenic *E. coli*. (H) *Listeria monocytogenes*. (I) *Salmonella*. (J) *Staphylococcus aureus*. (K) *Vibrio parahaemolyticus*. (L) *Yersinia enterocolitica*. (M) Adenovirus. (N) Astrovirus. (O) Group A rotaviruses. (P) Norovirus. (Q) Sapovirus.

Figure 2. Mean weekly number of gastrointestinal infections by mandatory surveillance in Korea before COVID-19 compared with after COVID-19. Red dotted line indicates the mean weekly incidence in Korea before COVID-19. Black line shows the weekly incidence after COVID-19. Blue zone indicates the coronavirus disease 2019 (COVID-19) incidence in Korea. (A) Cholera. (B) Enterohemorrhagic *Escherichia coli*. (C) Paratyphoid. (D) Shigellosis. (E) Typhoid. (F) Hepatitis A.

268 Figure 3. Mean weekly number of gastrointestinal infections in the United States during 2015-
269 2019 compared with that in 2020. Red dotted line indicates the mean weekly incidence in the
270 United States before COVID-19. Black line shows the weekly incidence after COVID-19. Blue
271 zone indicates the coronavirus disease 2019 (COVID-19) incidence in the United States. (A)
272 *Campylobacter*. (B) Hepatitis A. (C) *Salmonella*. (D) Shigellosis. (E) Typhoid.

Epub ahead of print

Table 1. Mean weekly number of gastrointestinal infectious diseases during weeks 5-52 in before COVID-19 compared with that after COVID-19 in Korea and the United States

	Korea				United States			
	Weekly number ($\pm$ SD)		Differ ence	P	Weekly number ($\pm$ SD)		Differ ence	P
	Before COVID-19	After COVID-19			Before COVID-19	After COVID-19		
Total number of gastrointestinal infectious diseases	522.1($\pm$ 83.3)	245.0($\pm$ 98.2)	-277.1	< 0.01	1021.0($\pm$ 257.0)	616.0($\pm$ 205.0)	-405	< 0.01
Total	190.7($\pm$ 70.8)	182.0($\pm$ 91.6)	-8.7	0.12	965.5($\pm$ 252.5)	576.2($\pm$ 193.6)	-389.3	< 0.01
Sentinel surveillance ^a								
<i>Salmonella</i>	52.4($\pm$ 32.2)	38.0($\pm$ 27.2)	-14.4	< 0.01	350.8($\pm$ 132.9)	199.0($\pm$ 94.1)	-151.8	< 0.01
<i>Vibrio</i> <i>parahaemolyticus</i>	2.6($\pm$ 2.6)	1.0($\pm$ 1.4)	-1.6	< 0.01	-	-	-	-
Enterotoxigenic <i>Escherichia coli</i>	1.8($\pm$ 1.6)	1.0($\pm$ 1.4)	-0.8	< 0.01	-	-	-	-
Enteroinvasive <i>E. coli</i>	0.3($\pm$ 0.6)	0.1($\pm$ 0.3)	-0.2	0.02	-	-	-	-
<i>Campylobacter</i>	57.1($\pm$ 38.3)	67.0($\pm$ 55.1)	9.9	< 0.01	497.3($\pm$ 126.4)	333.4($\pm$ 104.5)	-163.9	< 0.01
<i>Clostridium</i> <i>perfringens</i>	57.9($\pm$ 9.9)	59.0($\pm$ 13.9)	1.1	0.35	-	-	-	-
<i>Staphylococcus</i> <i>aureus</i>	3.7($\pm$ 2.2)	1.0($\pm$ 1.2)	-2.7	< 0.01	-	-	-	-
<i>Bacillus cereus</i>	0.6($\pm$ 0.6)	0.2($\pm$ 0.5)	-0.4	< 0.01	-	-	-	-
<i>Yersinia</i> <i>enterocolitica</i>	2.2($\pm$ 1.0)	2.0($\pm$ 1.6)	-0.2	0.73	-	-	-	-
<i>Listeria</i> <i>monocytogenes</i>	0.2($\pm$ 0.3)	0.1($\pm$ 0.5)	-0.1	0.84	-	-	-	-
Enteropathogenic <i>E. coli</i>	2.3($\pm$ 1.9)	2.0($\pm$ 2.5)	-0.3	0.60	-	-	-	-
Mandatory surveillance ^b								
Cholera	0.1($\pm$ 0.1)	0.1($\pm$ 0.1)	-0.1	0.15	-	-	-	-
Typhoid	2.6($\pm$ 1.1)	0.7($\pm$ 0.9)	-1.8	< 0.01	2.1($\pm$ 1.0)	0.6($\pm$ 0.9)	-1.5	< 0.01
Paratyphoid	1.1($\pm$ 0.6)	1.1($\pm$ 1.3)	0.0	0.88	-	-	-	-
Shigellosis	2.4($\pm$ 1.1)	0.4($\pm$ 0.7)	-2.0	< 0.01	115.2($\pm$ 13.7)	43.3($\pm$ 29.0)	-71.9	< 0.01
Enterohemorrhagic <i>E. coli</i>	2.7($\pm$ 1.9)	5.5($\pm$ 10.8)	2.8	0.06	-	-	-	-
Total	371.3($\pm$ 87.9)	147.7($\pm$ 80.1)	-223.6	< 0.01	54.6($\pm$ 10.9)	39.1($\pm$ 18.4)	-15.5	< 0.01
Sentinel surveillance ^a								
Group A rotaviruses	73.0($\pm$ 48.3)	23.0($\pm$ 16.8)	-50.0	< 0.01	-	-	-	-
Astrovirus	15.4($\pm$ 6.0)	2.0($\pm$ 5.1)	-13.4	< 0.01	-	-	-	-
Adenovirus	18.5($\pm$ 6.0)	3.0($\pm$ 2.6)	-15.5	< 0.01	-	-	-	-
Norovirus	95.2($\pm$ 66.1)	40.0($\pm$ 59.5)	-55.2	< 0.01	-	-	-	-
Sapovirus	6.5($\pm$ 3.0)	0.7($\pm$ 1.0)	-5.8	< 0.01	-	-	-	-
Mandatory surveillance ^b								
Hepatitis A	124.0($\pm$ 42.4)	77.6($\pm$ 17)	-46.3	< 0.01	54.6($\pm$ 10.9)	39.1($\pm$ 18.4)	-15.5	< 0.01

^a The weekly number of each type of gastrointestinal infectious disease in weeks 5-52 of 2020 with the mean of the same weeks during 2017.7.30-2019 in Korea or during 2015-2019 in United States.

^b The weekly number of each type of gastrointestinal infectious disease in weeks 5-52 of 2020 with the mean of the same weeks during 2015-2019 in Korea and United States

..... Before COVID-19
 — After COVID-19
 ■ COVID-19