Review Article
Clinical Microbiology

Ann Lab Med 2026;46:124-135
https://doi.org/10.3343/alm.2025.0226
ISSN 2234-3806 • eISSN 2234-3814

ANNALS OF LABORATORY MEDICINE

Seasonal Trends of Major Respiratory, Gastrointestinal, and Other Viral Infections in Korea: An Analysis Before, During, and After the Coronavirus Disease 2019 Pandemic

Su-Kyung Lee, M.S.*, Ji Hyun Kim, B.S.*, and Hyun Soo Kim, M.D., Ph.D.
Department of Laboratory Medicine, Hallym University Dongtan Sacred Heart Hospital, Hallym University College of Medicine, Hwaseong, Korea

Some viral infections display distinct seasonal patterns influenced by factors such as climate, human behavior, and viral characteristics. In this review, we investigated the seasonality of 15 viral infections in Korea. We analyzed viruses for which national surveillance data are available from the Korea Disease Control and Prevention Agency, including influenza virus, respiratory syncytial virus (RSV), rhinovirus, parainfluenza virus, metapneumovirus, human bocavirus, seasonal coronaviruses, enterovirus, adenovirus, norovirus, rotavirus, Japanese encephalitis virus, Hantaan virus, varicella–zoster virus, and mumps virus. In temperate climates, such as that in Korea, winter peaks are commonly observed for influenza, RSV, and norovirus infections, whereas enteroviruses are more prevalent in summer and early autumn. Parainfluenza viruses exhibit type-specific seasonality (circulating in warmer months from spring to autumn). During the coronavirus disease 2019 pandemic (2020–2021), the incidence of most respiratory and gastrointestinal viral infections analyzed in this study declined substantially owing to non-pharmaceutical interventions, such as social distancing and mask-wearing. After the preventive measures were relaxed, many viruses initially exhibited delayed or atypical seasonal peaks. However, by 2024, the seasonality of most, but not all, viral infections had largely returned to their pre-pandemic patterns. We also reviewed factors influencing viral seasonality, including climatic conditions, vector activity, human behavior, immunity, and viral genetic variation. These findings highlight the dynamic nature of viral seasonality and reinforce the importance of timely surveillance and flexible public health responses tailored to each country's epidemiological landscape.

Key Words: Coronavirus disease 2019, Korea, Seasons, Viral infection

Received: May 1, 2025
Revision received: September 4, 2025
Accepted: November 6, 2025
Published online: December 1, 2025

Corresponding author:
Hyun Soo Kim, M.D., Ph.D.
Department of Laboratory Medicine,
Hallym University Dongtan Sacred Heart
Hospital, Hallym University College of
Medicine, 7 Keunjaebong-gil,
Hwaseong 18450, Korea
E-mail: hskim0901@empas.com

*These authors contributed equally to this study as co-first authors.

© Korean Society for Laboratory Medicine
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (https://creativecommons.org/licenses/by-nc/4.0) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Viral seasonality is a well-established phenomenon with distinct seasonal patterns in the incidence and transmission of viral infections [1, 2]. The seasonality of viral infections is influenced by various factors, including environmental conditions, host behavior, and viral characteristics. In temperate regions, many respiratory viruses show distinct winter peaks, whereas in tropical regions these patterns are less pronounced [2]. Korea, a temperate country with cold, dry winters and hot, humid summers, demonstrates distinct seasonal trends. For example, influenza and respiratory syncytial virus (RSV) typically peak between December and February, whereas enteroviruses are more prevalent from late summer to early autumn. Understanding these seasonal patterns is essential for predicting outbreaks, optimizing healthcare resource allocation, and implementing timely preventive measures. These measures include planning influenza vaccination campaigns ahead of the winter peak or scheduling RSV prophylaxis for infants at high risk [3].

Several groups have analyzed the seasonal trends of individual viruses, highlighting fluctuations in their incidence rates [4–6]. However, few studies have systematically reviewed the seasonal trends of multiple viruses that display seasonal variations. This lack of integrated research represents a gap in understanding the broader landscape of viral seasonality, which is crucial for improving public health preparedness and response strategies. Comprehensive reviews of viral seasonality in Korea are lacking, limiting insights into local patterns and their public health implications. Viral seasonality varies between regions and countries, emphasizing the need for country-specific studies to inform local health policies and interventions [1].

This review provides an integrated description of the seasonality of common viral infections in Korea before, during, and after the coronavirus disease 2019 (COVID-19) pandemic. Concurrently, we provide a more comprehensive understanding of viral activity, which can contribute to the development of more effective disease prevention and control strategies.

COMMON VIRUSES SHOWING SEASONALITY IN KOREA

Influenza virus

Influenza viruses, belonging to the *Orthomyxoviridae* family, are seasonal respiratory pathogens that cause epidemics during winter and early spring in temperate regions. Multiple strains of influenza viruses, such as H3N2, H1N1, and influenza B, can circulate concurrently within the same season [7]. In most temperate regions, influenza A viruses tend to peak earlier in the season than influenza B viruses [7]. In the Northern Hemisphere, influenza activity typically peaks between October and April, with the highest incidence occurring from December to February, whereas in the Southern Hemisphere, influenza activity peaks from April to October. However, substantial variation exists, and the seasonality of influenza viruses varies according to the region and climate [8]. Subtropical regions show less pronounced seasonality than temperate regions but still tend to have higher influenza incidences during winter months. In tropical regions, influenza viruses circulate year-round without seasonality, although viral activity may be higher during the rainy season. Typically, viral seasonality is more pronounced at higher latitudes than at lower latitudes. However, this relationship is modulated by other geographical and climatological factors, such as continental climate effects and ocean currents, which may alter the timing and intensity of seasonal peaks [1, 9]. This seasonality gradient is closely related to climatic (e.g., temperature, humidity, and precipitation) and human behavioral (e.g., population density and social interaction patterns) factors.

In Korea, seasonal influenza epidemics traditionally occur between December and April [10]. In the 2018–2019 season, two distinct peaks occurred in December 2018 and April 2019. However, the COVID-19 pandemic altered this seasonal pattern. During the 2020–2021 and 2021–2022 seasons, influenza activity remained below the epidemic threshold because of social distancing and non-pharmaceutical interventions. The typical winter epidemic pattern returned in the 2022–2023 season,

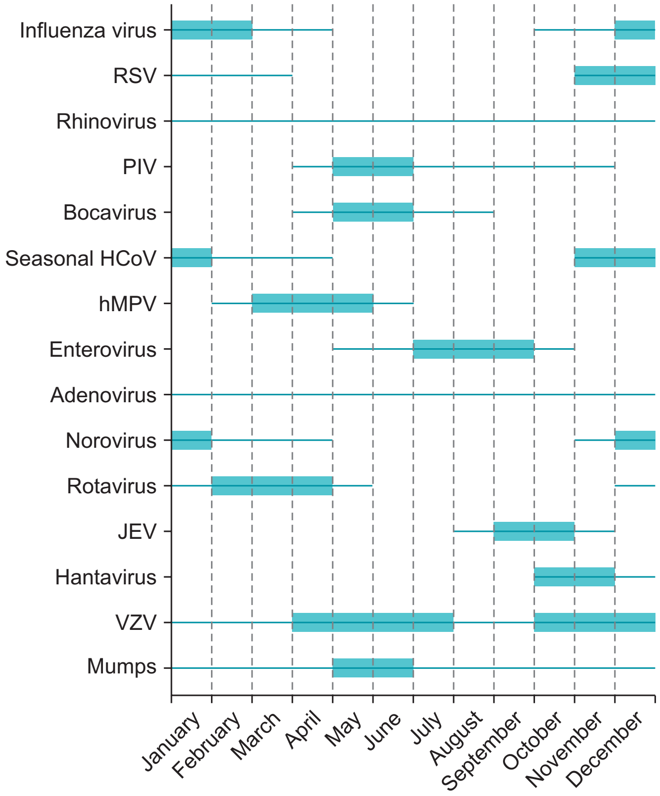

Fig. 1. Seasonal patterns of common viral infections in Korea before the coronavirus disease 2019 pandemic (2015–2019) (https://dportal.kdca.go.kr/). The horizontal lines indicate the months with increased incidence during this 5-year period, and the horizontal boxes represent the months within these periods when peak incidence was observed.

Abbreviations: RSV, respiratory syncytial virus; PIV, parainfluenza virus; HCoV, human coronavirus; hMPV, human metapneumovirus; JEV, Japanese encephalitis virus; VZV, varicella–zoster virus.

and the incidence rates were higher in the summer and autumn than in previous years [10–12]. In other temperate countries, such as the United States, Japan, and several European countries, influenza activity also showed atypical seasonal patterns during the COVID-19-recovery phase, with some countries experiencing off-season peaks in summer or autumn before returning to the usual winter epidemic timing [13].

These seasonal dynamics are illustrated in Fig. 1, which presents the periods of increased and peak incidence for each virus before the COVID-19 pandemic. Table 1 presents a summary of the seasonal trends before, during, and after the COVID-19 pandemic.

RSV

RSV, a member of the *Pneumoviridae* family, is a major cause of respiratory infection in infants and young children. Along with influenza, RSV is one of the most prominent viruses displaying seasonality [14, 15]. In temperate regions, RSV circulates during

Table 1. Seasonal patterns of common viral infections in Korea before, during, and after the COVID-19 pandemic (https://dportal.kdca.go.kr/)

Virus (family)	Primary site of infection	Increased incidence before COVID-19	Peak incidence before COVID-19	Peak incidence during and after COVID-19
Influenza virus (*Orthomyxoviridae*)	Respiratory tract	Winter (October–April) Influenza A tended to increase in winter, whereas influenza B tended to increase from late winter to spring (April). The 2018–2019 season had two peaks in December 2018 and April 2019.	Winter (December-February) Bimodal peak in December 2018 and April 2019	2020–2021: incidence markedly decreased 2022: incidence increased in winter and continuously increased in other seasons 2023–2024: increased in winter, returned to pre-pandemic pattern
RSV (*Pneumoviridae*)	Respiratory tract	Winter (November–March)	November–December	2020–2021: incidence markedly decreased 2022: bimodal peak in January and October 2023: April peak 2024: incidence returned to pre-pandemic pattern
Rhinovirus (*Picornaviridae*)	Respiratory tract	Year-round, with increases in spring and autumn when school terms start	No consistent peak	2020–2022: incidence decreased but present year-round 2023: large peak in April 2024: incidence returned to pre-pandemic pattern
PIV (*Paramyxoviridae*)	Respiratory tract	April–November	May–June	2020: incidence markedly decreased 2021: large peak in October–November 2022: bimodal peak in June and November 2023: bimodal peak in April and July 2024: returned to pre-pandemic pattern
Bocavirus (*Parvoviridae*)	Respiratory tract, gastrointestinal tract	April–August	May–June	2020: incidence markedly decreased 2021: peak in May 2022: peak in July–August 2023–2024: returned to pre-pandemic pattern
Seasonal coronavirus (*Coronaviridae*)	Respiratory tract	Winter (November–April)	November–January	2020–2021: incidence markedly decreased 2022–2024: increased incidence in winter, with gradual return to pre-pandemic pattern
hMPV (*Pneumoviridae*)	Respiratory tract	Spring (February–June)	March–May	2020–2021: incidence markedly decreased 2022: peak in October 2023: peak in June 2024: gradual return to pre-pandemic pattern
Enterovirus (*Picornaviridae*)	Central nervous system, skin, myocardium, conjunctiva, respiratory tract, gastrointestinal tract	Late spring to autumn (May–October)	July–September	2020–2021: incidence markedly decreased 2022–2024: incidence decreased, with return to pre-pandemic pattern

(Continued to the next page)

Table 1. Continued

Virus (family)	Primary site of infection	Increased incidence before COVID-19	Peak incidence before COVID-19	Peak incidence during and after COVID-19
Adenovirus (*Adenoviridae*)	Respiratory tract, gastrointestinal tract, conjunctiva, urinary tract	Year-round	No consistent peak	2020–2022: incidence markedly decreased 2023: large peak in August 2024: decreased incidence of respiratory adenoviral infection, with the pre-pandemic pattern of year-round occurrence maintained
Norovirus (*Caliciviridae*)	Gastrointestinal tract	Winter (November–April)	December–January	2020: increased incidence in early 2020 followed by a rapid decrease 2021: incidence increased in winter 2022: bimodal peak (January and June) 2023–2024: return to pre-pandemic pattern
Rotavirus (*Sedoreoviridae*)	Gastrointestinal tract	Late winter to spring (December–May)	February–April	2020–2023: incidence decreased 2023: incidence decreased with gradual return to pre-pandemic pattern
JEV (*Flaviviridae*)	Central nervous system	Late summer to autumn (August–Nov)	September–October	Similar to pre-pandemic pattern
Hantaan virus (*Hantaviridae*)	Kidney	Autumn (October–December)	October–November	2020–2021: incidence slightly decreased but increased in October–December, similar to pre-pandemic pattern
VZV (*Orthoherpesviridae*)	Skin, nervous system	Year-round, with bimodal seasonal peaks (April–July and October–December)	Bimodal peak (April–July and October–December; highest in December)	Year-round
Mumps virus (*Paramyxoviridae*)	Salivary glands (parotid glands)	Year-round	May–June	Year-round
Measles virus (*Paramyxoviridae*)	Respiratory tract, skin	Rare, with small outbreaks in 2014 and 2019		Continued low incidence 2024: slight increase from February–May

Abbreviations: COVID-19, coronavirus disease 2019; RSV, respiratory syncytial virus; PIV, parainfluenza virus; hMPV, human metapneumovirus; JEV, Japanese encephalitis virus; VZV, varicella–zoster virus.

the winter months, although the timing, extent, and duration of incidence surges vary annually. In the Northern Hemisphere, RSV activity begins in early November and persists until early March of the following year [8]. In contrast, in subtropical and tropical regions, seasonality is less distinct, and the seasonal patterns are more diverse. RSV tends to circulate continuously year-round, with epidemic periods often lasting over 6 months. RSV activity often increases during the rainy season, peaking between July and November in some regions [16, 17]. In the Southern Hemisphere, the RSV epidemic period is opposite that of the Northern Hemisphere, with increased activity from May to September. RSV seasonality becomes more pronounced with increasing distance from the equator. However, accurately predicting the timing of RSV epidemics based solely on geographic location and climatic factors is challenging. Even within a single country or region, the incidence of RSV infections may vary substantially. For example, in Korea, differences in outbreak timing and peak activity have been reported across regions [18].

Before the COVID-19 pandemic, RSV displayed a distinct seasonal pattern in Korea, with increased incidence during the winter months [10] (Fig. 1). However, this pattern changed during the COVID-19 pandemic. Non-pharmaceutical interventions, such as mask-wearing and social distancing during the pandemic, disrupted the typical RSV seasonality. During the 2020–2021 season, no winter RSV epidemics occurred, and atypical RSV B outbreaks occurred outside the traditional winter season. Furthermore, during the COVID-19 pandemic, RSV activity peaked approximately 2 months later than it did before the pandemic [18] (Table 1). Similar changes were reported in other temperate countries, although the magnitude and timing varied by country [5, 6]. RSV activity shifted to different seasons (e.g., summer or autumn) in some countries, while in others it showed an unusually prolonged seasonal epidemic, and demonstrated a delayed peak by several months in some, influenced by the timing and intensity of non-pharmaceutical interventions, travel restrictions, and immunity gaps [13]. In other temperate countries, such as the United States, Japan, and several European nations, influenza activity similarly reemerged at atypical times during the COVID-19-recovery phase, with some countries experiencing off-season peaks in summer or autumn before returning to the usual winter epidemic timing.

Rhinovirus

Human rhinoviruses, belonging to the *Picornaviridae* family, are a major cause of upper respiratory tract infections. Rhinovirus infections can occur year-round but generally display a seasonal cycle in temperate regions, with two seasonal peaks in spring and autumn [19, 20]. In contrast, seasonality tends to be less distinct in subtropical and tropical regions, where temperatures are relatively high year-round [20]. In Oahu, Hawaii and Ho Chi Minh City, Vietnam, several rhinovirus peaks occur each year [21, 22]. Close contact among students appears to facilitate the rhinovirus transmission, making its incidence associated with school terms [23].

In Korea, rhinovirus occurs year-round and tends to increase in spring (March–May) and autumn (September–November) [10, 24] in association with school reopening and seasonal changes. This pattern changed during the COVID-19 pandemic. During 2020–2022, rhinovirus activity decreased but remained constant year-round. In 2023, a large peak occurred in April 2023, and the incidence subsequently returned to the pre-pandemic pattern [10, 25] (Fig. 1, Table 1). Similar patterns were observed in other temperate countries during the COVID-19 pandemic, where rhinovirus circulation persisted year-round and often increased shortly after the relaxation of non-pharmaceutical interventions or around school reopening [13].

Human parainfluenza virus (HPIV)

HPIVs, members of the *Paramyxoviridae* family, are important respiratory pathogens. The seasonality of HPIVs is not as distinct as that of influenza viruses or RSV and varies significantly by HPIV type and region [8]. In temperate regions, such as the United States, Europe, and Japan, the incidence of HPIV-1 infection tends to peak every 2 yrs in the autumn, whereas the incidence of HPIV-2 infection tends to peak in the autumn but is less predictable. HPIV-3 consistently peaks in the spring and summer, and HPIV-4 typically peaks in late summer and early autumn [25–28]. However, in China, the incidence of HPIV-4 has peaked in spring and summer in some years, differing from its typical seasonal pattern in more temperate regions [29]. The seasonality of HPIV-1, HPIV-2, and HPIV-3 appears to be similar across hemispheres. For example, in western Australia, PIV-3 peaks annually around September (corresponding to spring in the Southern Hemisphere), whereas HPIV-1 peaks in April during the autumn [30]. In tropical regions, the seasonal patterns are less distinct, and some reports have demonstrated no clear seasonality [31]. In southeast Asian countries (including Singapore, Malaysia, and Vietnam), the incidences of HPIV-1 and HPIV-3 generally peak between January and May, with HPIV-3 peaking from February to May and HPIV-1 peaking from March to May [27].

In Korea, HPIV displays a distinct seasonal pattern, peaking in late spring and gradually declining, although seasonal peaks can persist through the summer and autumn [10]. This pattern appears to reflect the seasonality of HPIV-3, the most frequently occurring type. As in most temperate regions, HPIV-3 in Korea shows a distinct peak in the spring and summer, whereas HPIV-1 and HPIV-2 display less distinct seasonality and tend to circulate in autumn [25, 32]. The seasonality of HPIV-4 is difficult to define owing to limited research. During the COVID-19 pandemic, stringent infection-control measures led to a significantly lower incidence of HPIV infection in 2020–2021 [18]. In 2021, HPIV-3 demonstrated an autumn peak from October to November, differing from pre-pandemic patterns [18, 33, 34]. In 2022, HPIV displayed a bimodal peak in June and November [10]. In 2023, the bimodal peak shifted to April and July. In 2024, the HPIV infections peaked in late spring, similar to the seasonal pattern observed in the pre-pandemic period (Fig. 1, Table 1). Similar atypical HPIV seasonality has been reported in other temperate countries during the COVID-19 pandemic, with some regions experiencing delayed peaks or extended activity periods following the relaxation of non-pharmaceutical interventions.

Human bocavirus (HBoV)

HBoV is a member of the *Parvoviridae* family that primarily causes respiratory tract infections in children. HBoV infection occurs year-round, with peak timing differing across countries [35]. In temperate climates, a higher incidence has been observed during the winter months [35, 36], although other reports showed a higher incidence during the spring or summer months [37, 38]. Data from a study conducted in Sweden showed that 62% of HBoV1 infections occurred between December and March, whereas research from Spain indicated that HBoV activity increased in December and January. However, data from China, Japan, and Korea showed higher HBoV-positivity rates during spring and summer [37, 38]. HBoV seasonality is less pronounced in subtropical and tropical regions. For example, no distinct seasonal patterns were observed in Mexico [39].

In Korea, HBoV displays distinct seasonal patterns, with peak incidence during the spring and summer months (April–August) [10, 38, 40]. However, recent data suggest that the COVID-19 pandemic influenced the seasonality of respiratory viruses. The incidence of HBoV infection decreased markedly in 2020; peaked in May of 2021, July–August of 2022; and returned to the pre-pandemic seasonal pattern in 2023–2024 [10] (Fig. 1, Table 1).

Seasonal human coronaviruses (HCoVs: 229E, NL63, OC43, and HKU1)

Seasonal HCoVs 229E, NL63, OC43, and HKU1, members of the *Coronaviridae* family, primarily cause upper respiratory infections. These four common HCoVs display clear seasonal patterns, particularly in temperate regions [41]. Before the COVID-19 pandemic, these coronaviruses typically circulated from October to April, peaking in January or February, with activity waning by late spring [41]. This pattern is similar to that of other respiratory viruses, such as influenza virus and RSV, suggesting a strong association with colder and drier conditions, which favor coronavirus persistence and transmission [42, 43]. Although most HCoVs (including NL63) peak in winter, NL63 shows greater seasonal variability than that of other seasonal coronaviruses. In some temperate countries, NL63 peaks in late summer to early autumn, diverging from the winter trend [44]. In tropical and subtropical regions, such as Hong Kong and Zambia, HCoV seasonality is less distinct [45, 46], suggesting that higher temperatures and humidity in tropical climates contribute to more variable and less predictable HCoV seasonality.

In Korea, HCoV seasonality is similar to that in other temperate regions, with peaks in winter and early spring (December–March) [10, 47]. HCoVs 229E, OC43, and NL63 are detected predominantly in winter, although specific data on the seasonality of HKU1 in Korea remain unavailable. Because HKU1 was first identified in 2004, global data are relatively limited, and information from Korea is scarce. In 2020–2021, during the COVID-19 pandemic, the circulation of HCoVs markedly decreased owing to the implementation of stringent public health measures to control the spread [10]. However, from 2022 to 2024, the incidence of HCoV infection increased during the winter months and gradually returned to the pre-pandemic seasonal pattern (Fig. 1, Table 1).

Human metapneumovirus (hMPV)

hMPV, a member of the *Pneumoviridae* family, primarily causes respiratory infections. In temperate regions, the incidence of hMPV infection typically increases from late winter to spring, although its seasonality may vary slightly from year to year and according to the circulating strains and regions [8, 48]. However, in subtropical and tropical regions, hMPV seasonality is less pronounced, displaying diverse patterns depending on the location. For example, in countries such as Vietnam and Bangladesh, hMPV circulates year-round [49, 50]. In Kuala Lumpur, Malaysia, hMPV activity increases during the monsoon season from November to April, similar to the patterns observed in temperate regions [51]. In Senegal, hMPV activity is associated with the rainy season [52].

In Korea, the incidence of hMPV infection shows a distinct seasonal pattern, with an increased incidence in late winter and spring (February–June), peaking in March–May [10, 53]; however, the seasonality of hMPV infection changed significantly during the COVID-19 pandemic [54]. During the 2020–2021 period, the incidence of hMPV infection decreased markedly. In 2022, the incidence peaked in October, deviating from the pre-pandemic pattern. In 2023, the incidence peaked in June. By 2024, the occurrence of hMPV returned to its pre-pandemic seasonal pattern (Fig. 1, Table 1).

Enterovirus

Enteroviruses, members of the *Picornaviridae* family, are associated with a wide spectrum of clinical manifestations, including respiratory infections, meningitis, encephalitis, hand-foot-and-mouth disease, and myocarditis. According to the International Committee on Taxonomy of Viruses (https://ictv.global/taxonomy), the *Enterovirus* genus comprises 15 species, including enterovirus A–L and rhinovirus A–C, and over 100 different types that can infect humans. Each type causes distinct infections, and the clinical manifestations can differ [4, 55]. However, comprehensive studies have not been conducted that describe the diseases and seasonality of all types collectively, owing to the large number of enterovirus types. In practice, enterovirus typing is not performed routinely in most laboratories. Because enteroviruses and rhinoviruses share high genetic similarity, many commercial assays detect them together as “enterovirus/rhinovirus,” without differentiating between them. Consequently, most studies evaluating enterovirus seasonality rely on aggregated data, and not all genotypes are detected simultaneously.

In temperate climates, enterovirus infections occur predominantly during summer and early autumn, typically between June and October [4, 55]. In the United States, the peak incidence occurs between July and September [56]. This seasonal pattern aligns with increases in temperature and humidity, which facilitate viral transmission. In tropical and subtropical climates, enterovirus seasonality is less pronounced. In southern China (which has a subtropical climate), two distinct peaks in enterovirus infections have been observed and are commonly associated with EV-A71 and CV-A16, the primary causes of hand-foot-and-mouth disease [57]. No distinct seasonal pattern has been reported in tropical Asian countries.

In Korea, enterovirus infections follow seasonal patterns typical of those found in temperate regions, with an increased incidence from summer to early autumn (May–October) [10, 58, 59]. The incidence typically peaks between July and September. During the COVID-19 pandemic, no seasonal peak of enterovirus was observed in 2020–2021; however, this absence should be interpreted with caution, as it likely reflects overall low circulation due to extensive social distancing and public health measures, rather than a true loss of seasonality. Since 2022, the typical summer peak has returned, resembling the pre-pandemic pattern [10] (Fig. 1, Table 1).

Adenovirus

Human adenoviruses are members of the *Adenoviridae* family and cause various diseases, including respiratory infections, conjunctivitis, and gastroenteritis. They consist of seven species (A–G) and over 100 genotypes (http://hadvwg.gmu.edu/), with overlapping clinical manifestations across species [60]. Unlike influenza and RSV infections, respiratory adenovirus infections generally do not exhibit strong seasonality [61]. Although adenoviruses tend to circulate year-round without distinct seasonal peaks, some reports have shown small seasonal variations in their prevalence. For example, in temperate climates, a slight increase in incidence during winter and early spring has been reported [62, 63]. Pharyngoconjunctival fever, often associated with swimming pools, is more prevalent in summer [64]. Adenoviral gastroenteritis does not exhibit a specific seasonal pattern [65, 66].

In Korea, respiratory adenoviruses circulate year-round, with small peaks commonly observed in spring and autumn [10, 67, 68]. During the COVID-19 pandemic (2020–2022), the incidence of respiratory adenovirus infections decreased markedly owing to the implementation of stringent public health measures to control the spread of COVID-19 [68]. However, in 2023, an atypical summer peak of respiratory adenoviral infection occurred, with detection rates peaking at 42.2% in late August, driven primarily by an increased incidence of HAdV-B3 infection [68]. By 2024, the incidence of respiratory adenoviral infections was lower than that in 2023 and had returned to the pre-pandemic pattern of year-round circulation (Fig. 1, Table 1).

Norovirus

Norovirus, a member of the *Caliciviridae* family, is a leading cause of acute viral gastroenteritis. Norovirus seasonality peaks during winter in temperate regions (December–February in the Northern Hemisphere and June–August in the Southern Hemisphere) [69, 70]. In the United States, the norovirus season occurs between October and May, with more pronounced winter seasonality in the eastern United States [70]. In subtropical and tropical climates, such as those in Bangladesh, Vietnam, and India, norovirus displays less distinct seasonality and occurs year-round, with incidence rates tending to increase during the rainy season [69, 71, 72]. The incidence of norovirus infection is higher at low temperatures and relative humidity levels [73, 74]. However, the results of one study conducted in western India showed that norovirus detection peaked in March, when humidity and rainfall were low, but temperatures were relatively high [75].

In Korea, the incidence of norovirus infection increases during winter (November–April), peaking in December and January [10]. During the COVID-19 pandemic (2020–2021), the relative proportion of cases occurring in winter remained higher than that in other seasons; however, the absolute incidence was lower than that during the pre-pandemic period. In 2022, a bimodal peak occurred in January and June, with a summer peak from May to July, driven primarily by the GII.4 genotype. Since 2023, norovirus activity has returned to its pre-pandemic pattern, with a winter peak (Fig. 1, Table 1).

Rotavirus

Rotavirus, a member of the *Sedoreoviridae* family, is a major cause of severe gastroenteritis in infants and young children. In temperate regions, the incidence of rotavirus infection is higher during winter and spring, although the peak incidence varies widely from autumn to spring, depending on the geographical location [76]. This seasonal pattern persisted after the introduction of rotavirus vaccines; however, the reduction in incidence rates made the peaks less pronounced. [76] In subtropical and tropical climates, the seasonality of rotavirus is less distinct, and infection can occur year-round; however, the incidence is generally higher during the dry season or periods of lower temperatures [76, 77]. Increased temperature, precipitation, and relative humidity are associated with a lower incidence of rotavirus infection [77].

In Korea, rotavirus outbreaks peaked primarily during winter but have shifted toward early spring in recent years, with incidence rates decreasing following the introduction of rotavirus vaccines [78, 79]. Similar shifts in peaks from winter to early spring have been reported in other countries, such as Japan and the United States. These changes may be attributable to climate change or vaccine-induced changes in the transmission dynamics. During the COVID-19 pandemic (2020–2022), the incidence of rotavirus infection decreased markedly, with a gradual return to the pre-pandemic seasonal patterns [10] (Fig. 1, Table 1).

Other viruses

Japanese encephalitis virus infections occur predominantly from late summer to autumn (August–October), suggesting a temporal association with the activity of mosquito vectors in Korea [10, 80]. Hantavirus infections, which cause hemorrhagic fever with renal syndrome, show a clear autumn predominance, with most cases occurring between October and December, peaking in October and November [10, 81]. This timing aligns with increased human–rodent interactions during the harvest season, and the incubation period of approximately 2–4 weeks aligns with the seasonal link between environmental exposure and disease onset. Varicella–zoster virus occurs year-round, with bimodal peaks from April to July and October to December [10, 82]. Mumps occurred year-round, showing two peaks in May–June and November–December during 2010–2014, whereas in 2015–2019 the highest incidence was observed in May–June. [10, 83, 84] (Fig. 1, Table 1).

FACTORS INFLUENCING THE SEASONALITY OF VIRUSES

Climate factors: temperature, humidity, and precipitation

The seasonality of viruses is primarily influenced by climatic factors such as temperature, humidity, and precipitation. For example, low temperature and low absolute humidity enhance the stability and transmission of the influenza virus, a representative winter-predominant respiratory virus [2, 85]. These conditions also impair mucociliary clearance and the interferon response, reduce vitamin D synthesis due to limited sunlight, and thereby increase host susceptibility [86–88]. Cold weather further drives people indoors, facilitating droplet and aerosol spread. In contrast, enteroviruses causing respiratory infections, hand-foot-and-mouth disease, and meningoencephalitis spread predominantly during the summer months, as higher temperatures and humidity favor their stability and transmission. Published studies demonstrated that enteroviruses persist in warm and humid environments [4, 89]. The incidence of norovirus infection, a major cause of gastroenteritis that occurs mainly in winter, is higher under conditions of low temperature and low relative humidity [73, 74]. Precipitation also influences virus prevalence. For example, although RSV, influenza, and norovirus infections occur year-round in tropical regions, their incidence tends to be higher during the rainy season [2, 75, 90].

Vectors and transmission factors

Vector-borne and environmental factors play significant roles in the seasonality of viral infections. Mosquito-borne diseases, such as dengue fever and Japanese encephalitis, occur predominantly in summer when mosquito populations are most active [91]. Increased mosquito activity during warmer and wetter summers creates favorable conditions for virus transmission [92]. Tick-borne severe fever with thrombocytopenia syndrome (SFTS), caused by the SFTS virus and transmitted primarily by *Haemaphysalis longicornis*, occurs mainly between May and October in Korea, with a peak incidence in summer to early autumn, reflecting the seasonal activity of the tick vector [93]. In contrast, hantavirus infections, which are transmitted by rodents, tend to peak in autumn, when rodent activity is highest [94].

Environmental factors also contribute to the seasonal patterns of viral transmission. For example, increased participation in recreational indoor and outdoor water activities during summer can lead to outbreaks of adenovirus-associated conjunctivitis [60]. Conversely, norovirus infections tend to peak in winter and may be associated with the consumption of raw or undercooked shellfish, such as oysters [95].

Social distancing, environment, and immunity

The timing of school reopening is associated with the spread of various viruses [2]. For example, in Korea, increases in rhinovirus activity in spring and autumn appear to coincide with the timing of the start of the school term; however, these peaks are also observed at other times of the year, unrelated to school terms, suggesting that other climatic or behavioral factors may contribute. Additionally, travel can facilitate the spread of viruses, with outbreaks occurring in densely populated environments, such as cruise ships [9]. Outbreaks on cruise ships are considered event-driven transmissions and do not reflect the true seasonal patterns of viruses. Similarly, during winter, lower temperatures and higher indoor crowding contribute to increased viral transmissions [2].

Conversely, reduced exposure opportunities may lead to decreased antibody levels over time and a lack of immune boosting due to reduced exposure, resulting in sudden outbreaks of certain viruses. Before the COVID-19 pandemic, temperature was considered as the most critical determinant in the seasonality of viral infections. Subsequent research has demonstrated that for certain respiratory viruses, such as influenza, low absolute humidity, rather than relative humidity, plays a more important role in enhancing viral stability and transmission [85]. However, during the COVID-19 pandemic, social distancing measures implemented during 2020 and 2021 drastically reduced the incidence of both respiratory and gastrointestinal infections, indicating that behavioral factors play important roles in determining seasonality [96]. Even after these measures were lifted, the seasonality of several viral infections differed from the pre-COVID-19 pattern. This phenomenon could be attributable to prolonged social distancing, which led to reduced immunity (including lower antibody levels), causing sudden spikes in viral infections or outbreaks outside their typical seasonal patterns.

Vaccination and immunity

Vaccination can significantly reduce the incidence of viral infections and the distinct seasonality of certain viral infections. For example, the incidence of measles, which displayed a peak incidence from late winter to spring in temperate climates, has dramatically decreased due to widespread vaccination. In Korea, following the introduction of the measles vaccine in 1965 and its inclusion in the national immunization program in 1983, the number of cases decreased significantly. Measles currently occurs sporadically, making it difficult to discern a clear seasonal pattern [97].

Genetic variation of viruses

The emergence of new genetic variations of existing viruses can trigger new pandemics. For example, influenza viruses and noroviruses undergo seasonal antigenic drift, which can result in the emergence of new variants that evade immunity, leading to outbreaks [98, 99]. Furthermore, novel coronaviruses, such as the Middle East respiratory syndrome coronavirus (MERS-CoV) and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), may exhibit seasonal patterns that differ from those of endemic seasonal HCoVs, such as HCoV 229E, NL63, OC43, and HKU1. Although the emergence of MERS-CoV and SARS-CoV-2 is best explained by species jumps or zoonotic spillover events, these processes are ultimately based on underlying genetic variations. These novel variants can potentially disrupt the established seasonal patterns of other viruses, as demonstrated during the COVID-19 pandemic (Table 1).

CONCLUSION

The emergence of SARS-CoV-2 in 2019 and the subsequent COVID-19 pandemic significantly disrupted the previously established seasonal patterns of viral infections. Between 2020 and 2021, social distancing measures led to marked declines in the rates of multiple viral infections. However, starting in 2022, the incidence of some viral infections rebounded, and some viruses showed shifts in their seasonal patterns. By 2024, most viral infections had returned to their pre-pandemic seasonal patterns. These findings suggest that the seasonality of viral infections is not solely influenced by environmental factors, such as temperature and humidity, but is also affected by factors, such as social distancing and reduced immunity. Continuous surveillance of viral diseases is essential for understanding and responding to these evolving patterns effectively. These findings also underscore important public health implications, particularly for the timely allocation of healthcare resources and the optimization of vaccination schedules in anticipation of seasonal surges. Future studies should focus on long-term monitoring of viral seasonality, evaluating the effects of climate change and shifts in the immune landscape, and applying advanced modeling tools to better predict emerging seasonal trends. Although this review is centered on Korea, its insights are broadly relevant, offering a framework for understanding global viral seasonality and supporting international preparedness efforts.

ACKNOWLEDGEMENTS

None.

AUTHOR CONTRIBUTIONS

Kim HS contributed to conception and drafting of the study and funding acquisition. Lee SK and Kim JH contributed to investigation and methodology. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

None declared.

RESEARCH FUNDING

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean Government (MSIT; Grant No. RS-2023-00241658) and by the Hallym University Research Fund.

REFERENCES

1. Neumann G and Kawaoka Y. Seasonality of influenza and other respiratory viruses. EMBO Mol Med 2022;14:e15352.
2. Moriyama M, Hugentobler WJ, Iwasaki A. Seasonality of respiratory viral infections. Annu Rev Virol 2020;7:83–101.
3. Grohskopf LA, Ferdinands JM, Blanton LH, Broder KR, Loehr J. Prevention and control of seasonal influenza with vaccines: Recommendations of the Advisory Committee on Immunization Practices — United States, 2024–25 influenza season. MMWR Recomm Rep 2024;73:1–25.
4. Baker RE, Yang W, Vecchi GA, Takahashi S. Increasing intensity of enterovirus outbreaks projected with climate change. Nat Commun 2024;15:6466.
5. Bermúdez Barrezueta L, Matías Del Pozo V, López-Casillas P, Brezmes Raposo M, Gutiérrez Zamorano M, Pino Vázquez MA. Variation in the seasonality of the respiratory syncytial virus during the COVID-19 pandemic. Infection 2022;50:1001–5.
6. Hamid S, Winn A, Parikh R, Jones JM, McMorrow M, Prill MM, et al. Seasonality of respiratory syncytial virus — United States, 2017–2023. MMWR Morb Mortal Wkly Rep 2023;72:355–61.
7. Zanobini P, Bonaccorsi G, Lorini C, Haag M, McGovern I, Paget J, et al. Global patterns of seasonal influenza activity, duration of activity and virus (sub)type circulation from 2010 to 2020. Influenza Other Respir Viruses 2022;16:696–706.
8. Li Y, Reeves RM, Wang X, Bassat Q, Brooks WA, Cohen C, et al. Global patterns in monthly activity of influenza virus, respiratory syncytial virus, parainfluenza virus, and metapneumovirus: A systematic analysis. Lancet Glob Health 2019;7:e1031–45.
9. Kakoullis L, Steffen R, Osterhaus A, Goeijenbier M, Rao SR, Koiso S, et al. Influenza: Seasonality and travel-related considerations. J Travel Med 2023;30:taad102.
10. Korea Disease Control and Prevention Agency. Infectious disease portal https://dportal.kdca.go.kr (Updated on Jan 2025).
11. Kwon SL and Kim BI. How COVID-19 shifted the seasonal flu in Korea. Influenza Other Respir Viruses 2023;17:e13113.
12. Cho HJ, Rhee JE, Kang D, Choi EH, Lee NJ, Woo S, et al. Epidemiology of respiratory viruses in Korean children before and after the COVID-19 pandemic: A prospective study from national surveillance system. J Korean Med Sci 2024;39:e171.
13. Zhao C, Zhang T, Guo L, Sun S, Miao Y, Yung CF, et al. Characterising the asynchronous resurgence of common respiratory viruses following the COVID-19 pandemic. Nat Commun 2025;16:1610.
14. Wang L, Berger N, Davis PB, Kaelber DC, Volkow N, Xu R. Time trend and seasonality in medically attended respiratory syncytial virus (RSV) infections in US children aged 0–5 years, January 2010–January 2023. Fam Med Community Health 2023;11:e002453.
15. Guo L, Deng S, Sun S, Wang X, Li Y. Respiratory syncytial virus seasonality, transmission zones, and implications for seasonal prevention strategy in China: a systematic analysis. Lancet Glob Health 2024;12:e1005–16.
16. Chadha M, Hirve S, Bancej C, Barr I, Baumeister E, Caetano B, et al. Human respiratory syncytial virus and influenza seasonality patterns-early findings from the WHO global respiratory syncytial virus surveillance. Influenza Other Respir Viruses 2020;14:638–46.
17. Bloom-Feshbach K, Alonso WJ, Charu V, Tamerius J, Simonsen L, Miller MA, et al. Latitudinal variations in seasonal activity of influenza and respiratory syncytial virus (RSV): A global comparative review. PLoS One 2013;8:e54445.
18. Kim YK, Song SH, Ahn B, Lee JK, Choi JH, Choi SH, et al. Shift in clinical epidemiology of human parainfluenza virus type 3 and respiratory syncytial virus B infections in Korean children before and during the COVID-19 pandemic: A multicenter retrospective study. J Korean Med Sci 2022;37:e215.
19. Price RHM, Graham C, Ramalingam S. Association between viral seasonality and meteorological factors. Sci Rep 2019;9:929.
20. Monto AS. The seasonality of rhinovirus infections and its implications for clinical recognition. Clin Ther 2002;24:1987–97.
21. Marcelo RZ, Lustik MB, Jones MU. Seasonality and climatic factors associated with human rhinovirus/enterovirus nasopharyngeal sample positivity on Oahu, Hawai'i, 2016-2019. Mil Med 2024;189:e34–9.
22. Tran DN, Trinh QD, Pham NT, Pham TM, Ha MT, Nguyen TQ, et al. Human rhinovirus infections in hospitalized children: Clinical, epidemiological and virological features. Epidemiol Infect 2016;144:346–54.
23. Berginc N, Sočan M, Prosenc Trilar K, Petrovec M. Seasonality and genotype diversity of human rhinoviruses during an eight-year period in Slovenia. Microorganisms 2024;12:341.
24. Lim DK, Jung BK, Kim JK. Climate factors and their effects on the prevalence of rhinovirus infection in Cheonan, Korea. Microbiol Biotechnol Lett 2021;49:425–31.
25. Han JY, Suh W, Han SB. Seasonal epidemiological and clinical characteristics of pediatric patients with human parainfluenza virus infection by serotype: A retrospective study. Virol J 2022;19:141.
26. Maykowski P, Smithgall M, Zachariah P, Oberhardt M, Vargas C, Reed C, et al. Seasonality and clinical impact of human parainfluenza viruses. Influenza Other Respir Viruses 2018;12:706–16.
27. Soh S, Loo LH, Jamali N, Maiwald M, Aik J. Climate variability and seasonal patterns of paediatric parainfluenza infections in the tropics: An ecological study in Singapore. Int J Hyg Environ Health 2022;239:113864.
28. Abedi GR, Prill MM, Langley GE, Wikswo ME, Weinberg GA, Curns AT, et al. Estimates of parainfluenza virus-associated hospitalizations and cost among children aged less than 5 years in the United States, 1998–2010. J Pediatric Infect Dis Soc 2016;5:7–13.
29. Ren L, Gonzalez R, Xie Z, Xiong Z, Liu C, Xiang Z, et al. Human parainfluenza virus type 4 infection in Chinese children with lower respiratory tract infections: A comparison study. J Clin Virol 2011;51:209–12.
30. Greiff DRL, Patterson-Robert A, Blyth CC, Glass K, Moore HC. Epidemiology and seasonality of human parainfluenza serotypes 1-3 in Australian children. Influenza Other Respir Viruses 2021;15:661–9.
31. Gregianini TS, Seadi CF, Zavarize Neto LD, Martins LG, Muller GC, Straliotto SM, et al. A 28-year study of human parainfluenza in Rio Grande do Sul, Southern Brazil. J Med Virol 2019;91:1423–31.
32. Gu YE, Park JY, Lee MK, Lim IS. Characteristics of human parainfluenza virus type 4 infection in hospitalized children in Korea. Pediatr Int 2020;62:52–8.
33. Lee H, Kim SH, Cho SJ, Lee YU, Lee K, Lee YP, et al. Genetic analysis of HPIV3 that emerged during the SARS-CoV-2 pandemic in Gwangju, South Korea. Viruses 2022;14:1446.
34. Park K, Sung H, Kim MN. Reemergence of parainfluenza virus type 3 and respiratory syncytial virus infections during the COVID-19 pandemic. Ann Lab Med 2023;43:114–6.

35. Christensen A, Kesti O, Elenius V, Eskola AL, Døllner H, Altunbulakli C, et al. Human bocaviruses and paediatric infections. Lancet Child Adolesc Health 2019;3:418–26.
36. Oldhoff E, Bennet R, Eriksson M, Allander T. Human bocavirus 1 epidemiology in children in relation to virus load and codetection. Acta Paediatr 2023;112:1049–55.
37. Lu QB, Wo Y, Wang HY, Huang DD, Zhao J, Zhang XA, et al. Epidemic and molecular evolution of human bocavirus in hospitalized children with acute respiratory tract infection. Eur J Clin Microbiol Infect Dis 2015;34:75–81.
38. Ahn JG, Choi SY, Kim DS, Kim KH. Human bocavirus isolated from children with acute respiratory tract infections in Korea, 2010–2011. J Med Virol 2014;86:2011–8.
39. Gamiño-Arroyo AE, Arellano-Galindo J, Del Carmen Guerra-de-Blas P, Ortega-Villa AM, Mateja A, Llamosas-Gallardo B, et al. Clinical and molecular characterization of children and adults with respiratory bocavirus infection in Mexico: A cross-sectional nested study within the ILI002 prospective observational study. Lancet Reg Health Am 2024;29:100647.
40. An TJ, Lee J, Shin M, Rhee CK. Seasonality of common respiratory viruses: Analysis of nationwide time-series data. Respirology 2024;29:985–93.
41. Shah MM, Winn A, Dahl RM, Kniss KL, Silk BJ, Killerby ME. Seasonality of common human coronaviruses, United States, 2014–2021. Emerg Infect Dis 2022;28:1970–6.
42. Gerna G, Campanini G, Rovida F, Percivalle E, Sarasini A, Marchi A, et al. Genetic variability of human coronavirus OC43-, 229E-, and NL63-like strains and their association with lower respiratory tract infections of hospitalized infants and immunocompromised patients. J Med Virol 2006;78:938–49.
43. Gaunt ER, Hardie A, Claas EC, Simmonds P, Templeton KE. Epidemiology and clinical presentations of the four human coronaviruses 229E, HKU1, NL63, and OC43 detected over 3 years using a novel multiplex real-time PCR method. J Clin Microbiol 2010;48:2940–7.
44. Li Y, Wang X, Nair H. Global seasonality of human seasonal coronaviruses: A clue for postpandemic circulating season of severe acute respiratory syndrome coronavirus 2? J Infect Dis 2020;222:1090–7.
45. Lau SK, Woo PC, Yip CC, Tse H, Tsoi HW, Cheng VC, et al. Coronavirus HKU1 and other coronavirus infections in Hong Kong. J Clin Microbiol 2006;44:2063–71.
46. Baillie VL, Moore DP, Mathunjwa A, Park DE, Thea DM, Kwenda G, et al. Epidemiology and seasonality of endemic human coronaviruses in South African and Zambian children: A case-control pneumonia study. Viruses 2021;13:1513.
47. Choi YY, Kim YK, Choi EH. Clinical and epidemiological characteristics of common human coronaviruses in children: A single center study, 2015-2019. Pediatr Infect Vaccine 2021;28:101–9.
48. Williams JV, Harris PA, Tollefson SJ, Halburnt-Rush LL, Pingsterhaus JM, Edwards KM, et al. Human metapneumovirus and lower respiratory tract disease in otherwise healthy infants and children. N Engl J Med 2004;350:443–50.
49. Otomaru H, Nguyen HAT, Vo HM, Toizumi M, Le MN, Mizuta K, et al. A decade of human metapneumovirus in hospitalized children with acute respiratory infection: Molecular epidemiology in central Vietnam, 2007–2017. Sci Rep 2023;13:15757.
50. Rahman MZ, Sumiya M, Sahabuddin M, Pell LG, Gubbay JB, Rahman R, et al. Genetic characterization of human metapneumovirus identified through community and facility-based surveillance of infants in Dhaka, Bangladesh. J Med Virol 2019;91:549–54.
51. Chow WZ, Chan YF, Oong XY, Ng LJ, Nor'E SS, Ng KT, et al. Genetic diversity, seasonality and transmission network of human metapneumovirus: Identification of a unique sub-lineage of the fusion and attachment genes. Sci Rep 2016;6:27730.
52. Jallow MM, Fall A, Kiori D, Sy S, Goudiaby D, Barry MA, et al. Epidemiological, clinical and genotypic features of human metapneumovirus in patients with influenza-like illness in Senegal, 2012 to 2016. BMC Infect Dis 2019;19:457.
53. Lim YK, Kweon OJ, Kim HR, Kim TH, Lee MK. Clinical features, epidemiology, and climatic impact of genotype-specific human Metapneumovirus infections: Long-term surveillance of hospitalized patients in South Korea. Clin Infect Dis 2020;70:2683–94.
54. Nam EJ, Kim DJ, Ham JY, Song KE, Lee NY. Recent changes in the human metapneumovirus outbreak at a university hospital in Korea. Clin Lab 2023;69.
55. Rueca M, Vairo F, Spaziante M, Fabeni L, Forbici F, Berno G, et al. Molecular genotyping of circulating enterovirus in the Lazio region from 2012 to 2023. Viruses 2024;16:1013.
56. Pons-Salort M, Oberste MS, Pallansch MA, Abedi GR, Takahashi S, Grenfell BT, et al. The seasonality of nonpolio enteroviruses in the United States: Patterns and drivers. Proc Natl Acad Sci U S A 2018;115:3078–83.
57. Koh WM, Bogich T, Siegel K, Jin J, Chong EY, Tan CY, et al. The epidemiology of hand, foot and mouth disease in Asia: A systematic review and analysis. Pediatr Infect Dis J 2016;35:e285–300.
58. Kang HJ, Yoon Y, Lee YP, Kim HJ, Lee DY, Lee JW, et al. A different epidemiology of enterovirus A and enterovirus B co-circulating in Korea, 2012–2019. J Pediatric Infect Dis Soc 2021;10:398–407.
59. Jeon JS, Kim JK, Yu J, Kim JW. Epidemic trends of enterovirus infections from pediatric patients in Cheonan, Korea. J Clin Lab Anal 2016;30:161–4.
60. Ghebremedhin B. Human adenovirus: Viral pathogen with increasing importance. Eur J Microbiol Immunol (Bp) 2014;4:26–33.
61. Binder AM, Biggs HM, Haynes AK, Chommanard C, Lu X, Erdman DD, et al. Human adenovirus surveillance — United States, 2003–2016. MMWR Morb Mortal Wkly Rep 2017;66:1039–42.
62. Pscheidt VM, Gregianini TS, Martins LG, Veiga ABGD. Epidemiology of human adenovirus associated with respiratory infection in southern Brazil. Rev Med Virol 2021;31:e2189.
63. Videla C, Carballal G, Misirlian A, Aguilar M. Acute lower respiratory infections due to respiratory syncytial virus and adenovirus among hospitalized children from Argentina. Clin Diagn Virol 1998;10:17–23.
64. Lee J, Bilonick RA, Romanowski EG, Kowalski RP. Seasonal variation in human adenovirus conjunctivitis: A 30-year observational study. Ophthalmic Epidemiol 2018;25:451–6.
65. Dong JX, Li T, Chao S, Gao Y, Zhou LX, Zhao XY. [Fecal rotavirus and adenovirus antigen detection and clinical analysis of children with acute gastroenteritis in a hospital of Beijing City from 2019 to 2022]. Zhonghua Yu Fang Yi Xue Za Zhi 2023;57:566–71.
66. Guga G, Elwood S, Kimathi C, Kang G, Kosek MN, Lima AAM, et al. Burden, clinical characteristics, risk factors, and seasonality of adenovirus 40/41 diarrhea in children in eight low-resource settings. Open Forum Infect Dis 2022;9:ofac241.
67. Kim TH, Yim CH, Ahn SY, Kang KJ, Choi YM, Ko JH, et al. Clinical features of respiratory adenovirus infections in pediatric inpatients in a single medical center. Allergy Asthma Respir Dis 2015;3:402–9.
68. Lee NJ, Woo S, Rhee JE, Lee J, Lee S, Kim EJ. Increased trend of adenovirus activity after the COVID-19 pandemic in South Korea: Analysis of national surveillance data. Ann Lab Med 2024;44:581–5.
69. Ahmed SM, Lopman BA, Levy K. A systematic review and meta-analysis of the global seasonality of norovirus. PLoS One 2013;8:e75922.

70. Kambhampati AK, Calderwood L, Wikswo ME, Barclay L, Mattison CP, Balachandran N, et al. Spatiotemporal trends in Norovirus outbreaks in the United States, 2009–2019. Clin Infect Dis 2023;76:667–73.
71. Rahman M, Rahman R, Nahar S, Hossain S, Ahmed S, Golam Faruque AS, et al. Norovirus diarrhea in Bangladesh, 2010–2014: Prevalence, clinical features, and genotypes. J Med Virol 2016;88:1742–50.
72. Mans J. Norovirus infections and disease in lower-middle- and low-income countries, 1997–2018. Viruses 2019;11:341.
73. Lopman B, Armstrong B, Atchison C, Gray JJ. Host, weather and virological factors drive norovirus epidemiology: Time-series analysis of laboratory surveillance data in England and Wales. PLoS One 2009;4:e6671.
74. Colas de la Noue A, Estienney M, Aho S, Perrier-Cornet JM, de Rougemont A, Pothier P, et al. Absolute humidity influences the seasonal persistence and infectivity of human norovirus. Appl Environ Microbiol 2014;80:7196–205.
75. Chhabra P, Dhongade RK, Kalrao VR, Bavdekar AR, Chitambar SD. Epidemiological, clinical, and molecular features of norovirus infections in western India. J Med Virol 2009;81:922–32.
76. Patel MM, Pitzer VE, Alonso WJ, Vera D, Lopman B, Tate J, et al. Global seasonality of rotavirus disease. Pediatr Infect Dis J 2013;32:e134–47.
77. Levy K, Hubbard AE, Eisenberg JN. Seasonality of rotavirus disease in the tropics: A systematic review and meta-analysis. Int J Epidemiol 2009;38:1487–96.
78. Yoon HS, Sohn YH, Chae JD, Lim J, Kim SY. Characterization of rotavirus infection in hospitalized children under 5 with acute gastroenteritis 5 years after introducing the rotavirus vaccines in South Korea. Children (Basel) 2022;9:1633.
79. Cho SR, Chae SJ, Jung S, Choi W, Han MG, Yoo CK, et al. Trends in acute viral gastroenteritis among children aged ≤5 years through the national surveillance system in South Korea, 2013–2019. J Med Virol 2021;93:4875–82.
80. Sunwoo JS, Jung KH, Lee ST, Lee SK, Chu K. Reemergence of Japanese encephalitis in South Korea, 2010–2015. Emerg Infect Dis 2016;22:1841–3.
81. Noh JY, Cheong HJ, Song JY, Kim WJ, Song KJ, Klein TA, et al. Clinical and molecular epidemiological features of hemorrhagic fever with renal syndrome in Korea over a 10-year period. J Clin Virol 2013;58:11–7.
82. Kim EY, Park C, Lee G, Jeong S, Song J, Lee DH. Epidemiological characteristics of varicella outbreaks in the Republic of Korea, 2016–2020. Osong Public Health Res Perspect 2022;13:133–41.
83. Park SH. Resurgence of mumps in Korea. Infect Chemother 2015;47:1–11.
84. Choe YJ, Min K, Cho SI. Spatial distribution of mumps in South Korea, 2001–2015: identifying clusters and population risk factors. Epidemiol Infect 2017;145:2122–8.
85. Shaman J, Pitzer VE, Viboud C, Grenfell BT, Lipsitch M. Absolute humidity and the seasonal onset of influenza in the continental United States. PLoS Biol 2010;8:e1000316.
86. Kudo E, Song E, Yockey LJ, Rakib T, Wong PW, Homer RJ, et al. Low ambient humidity impairs barrier function and innate resistance against influenza infection. Proc Natl Acad Sci U S A 2019;116:10905–10.
87. Foxman EF, Storer JA, Vanaja K, Levchenko A, Iwasaki A. Two interferon-independent double-stranded RNA-induced host defense strategies suppress the common cold virus at warm temperature. Proc Natl Acad Sci U S A 2016;113:8496–501.
88. Uyeki TM, Hui DS, Zambon M, Wentworth DE, Monto AS. Influenza. Lancet 2022;400:693–706.
89. Jiang X, Ma Y, Lv Q, Liu Y, Zhang T, Yin F, et al. Influence of social and meteorological factors on hand, foot, and mouth disease in Sichuan Province. BMC Public Health 2023;23:849.
90. Tamerius JD, Shaman J, Alonso WJ, Bloom-Feshbach K, Uejio CK, Comrie A, et al. Environmental predictors of seasonal influenza epidemics across temperate and tropical climates. PLoS Pathog 2013;9:e1003194.
91. Lee H, Halverson S, Ezinwa N. Mosquito-borne diseases. Prim Care 2018;45:393–407.
92. Ciota AT and Keyel AC. The role of temperature in transmission of zoonotic arboviruses. Viruses 2019;11:1013.
93. Park SW, Ryou J, Choi WY, Han MG, Lee WJ. Epidemiological and clinical features of severe fever with thrombocytopenia syndrome during an outbreak in South Korea, 2013–2015. Am J Trop Med Hyg 2016;95:1358–61.
94. Tian HY, Yu PB, Luis AD, Bi P, Cazelles B, Laine M, et al. Changes in rodent abundance and weather conditions potentially drive hemorrhagic fever with renal syndrome outbreaks in Xi'an, China, 2005–2012. PLoS Negl Trop Dis 2015;9:e0003530.
95. Lowther JA, Gustar NE, Powell AL, Hartnell RE, Lees DN. Two-year systematic study to assess norovirus contamination in oysters from commercial harvesting areas in the United Kingdom. Appl Environ Microbiol 2012;78:5812–7.
96. Jeon K, Lee SK, Jeong S, Song W, Kim HS, Kim JS, et al. Trends in the detection of viruses causing gastroenteritis over a 10-year period and impact of nonpharmaceutical interventions. J Clin Virol 2024;172:105676.
97. Kang JH. Review of measles in Korea: Quarantine and elimination. Infect Chemother 2020;52:113–22.
98. Javanian M, Barary M, Ghebrehewet S, Koppolu V, Vasigala V, Ebrahimpour S. A brief review of influenza virus infection. J Med Virol 2021;93:4638–46.
99. Kim HS, Hyun J, Kim HS, Kim JS, Song W, Lee KM. Emergence of GII.4 Sydney norovirus in South Korea during the winter of 2012–2013. J Microbiol Biotechnol 2013;23:1641–3.