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Impact of the COVID-19 pandemic on the epidemiology of other communicable diseases in Japan

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A B S T R A C T

Objectives: To elucidate the impact of the COVID-19 pandemic on the epidemiology of other infectious diseases.
Design: We investigated the epidemiology of 36 communicable diseases during 2015-2021 in Japan and compared the number of cases in each disease between the prepandemic (2015-2019) and intrapandemic (2020-2021) periods. Relationships between the incidence of the infectious diseases and the COVID-19 pandemic were also investigated.
Results: Of 36 communicable diseases, the number of cases in the 27 diseases (75%) mainly caused by pathogens transmitted by droplet or contact was lower intrapandemic than prepandemic, and the cases of 21 diseases (58%) continued to decrease intrapandemic. The number of cases of six diseases (17%) was higher intrapandemic than prepandemic, and the cases of two diseases (5.6%), Japanese spotted fever and syphilis, continued to increase intrapandemic. Time trend analyses revealed a positive correlation between case numbers of communicable diseases and the COVID-19 pandemic, whereas the case numbers of hand-foot-and-mouth disease and respiratory syncytial virus infection rebounded in 2021 after decreasing in 2020.
Conclusion: The COVID-19 pandemic has greatly impacted the epidemiology of communicable diseases, suggesting that countermeasures against COVID-19 and lifestyle changes might be involved in these epidemiological changes.

Introduction

The COVID-19 pandemic has affected >600 million patients, with over 6.4 million deaths reported worldwide as of September 1, 2022 [1,2]. Mortality rates for COVID-19 differ between Western countries (1.1% in the United States, 0.8% in the United Kingdom) and Asian countries (0.5% in China, 0.2% in Japan) [1,2]; although, the reasons remain uncertain. National governments have been faced with various challenges in balancing attempts to control the COVID-19 pandemic with the stabilization of economic activity.

In response to the COVID-19 pandemic, various strategies have been used in each country, based on the differing economic, cultural, and health care system situations [3,4]. The mitigation strategy for COVID-19 in Japan can be characterized by the prevention of cluster formation and unenforced self-restraint. After the first case of COVID-19 was confirmed in Japan on January 16, 2020, the Japanese government and the expert committee recommended avoidance of "the 3Cs" of close-contact settings, crowded places, and closed places with poor ventilation as public preventive measures, in addition to individual preventive measures, including handwashing, disinfection, and wearing masks.

The COVID-19 pandemic has led to the implementation of public health measures and lifestyle changes and has affected the epidemiology of other infectious diseases worldwide [5–7], with a marked decrease in respiratory infections [8–10]. However, the effects of these measures and lifestyle changes under the mitigation policy on major communicable diseases in Japan remain unclear.

In this study, we investigated the impact of the COVID-19 pandemic on the epidemiology of other communicable diseases in Japan and discuss the potential role of COVID-19 countermeasures and lifestyle changes in the epidemiological trends identified.

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Methods

Data source and endemic levels of infectious diseases in Japan

We used the data for 105 communicable diseases during 2015-2021 from the National Institute of Infectious Diseases, which monitors the weekly incidence of 87 notifiable infectious diseases and 18 sentinel surveillance diseases included in the clinical sentinel surveillance system in Japan. The notifiable disease and sentinel surveillance systems in Japan are pursuant to the Infectious Disease Control Law [11]. Diagnostic methods differ according to the category of infectious disease, such as polymerase chain reaction testing, antigen testing, or clinical diagnosis [11]. The diagnostic methods for each infectious disease included in the surveillance did not change during the study period. Laboratory-based diagnosis was confirmed for all notifiable diseases and approximately 10% of sentinel surveillance diseases, in addition to laboratory tests performed in hospitals or clinics [11]. Sentinel surveillance sites consist of over 5000 hospitals and clinics (60% pediatrics, 40% internal or general medicine clinics). Data were extracted on 41 highly reported infectious diseases with an average of ≥100 reported cases per year during 2015-2019 in Japan for 23 notifiable diseases and for 18 sentinel surveillance diseases. Five infectious diseases caused by multiple species of pathogen, including infectious gastroenteritis, acute encephalitis, bacterial meningitis, aseptic meningitis, and carbapenem-resistant *Enterobacteriaceae* infection, were excluded from the study. As a result, the incidences of 36 infectious diseases, including 21 notifiable diseases and 15 sentinel surveillance diseases, from 2015 to 2021 in Japan were investigated in the study.

The mean annual numbers of cases of each communicable disease in 2015-2019 (prepandemic) were calculated and compared with those in 2020-2021 (intrapandemic), respectively. The 36 infectious diseases examined are listed in Table 1 and Supplementary Figure 1. The estimated annual incidences of the 36 infectious diseases during 2020-2021 were compared between the state-of-emergency period and the nonstate-of-emergency period to assess the effects of nonpharmaceutical interventions on the incidences of communicable diseases. From January to September 2021, strict countermeasures against COVID-19 were implemented in metropolises but not in other areas in Japan. In this period, the estimated annual incidences of the top five common infectious diseases among the 36 diseases were compared between Tokyo, the largest metropolis in Japan, and Shikoku or Kyushu regions to assess the effects of nonpharmaceutical interventions on the incidences of communicable diseases in different areas.

Statistical analysis

For each of the 36 infectious diseases, we calculated the mean annual number of reported cases prepandemic (2015-2019) and intrapandemic (2020-2021). The hypothesis that the number of reported cases would not differ significantly between the two periods was tested using Poisson regression modeling. Observational period- and population-adjusted Poisson regression models were used to compare the incidence of infectious diseases between different periods and between different areas. The ratio of the number of reported cases in 2020 to the mean annual number of reported cases during 2015-2019 and the ratio of the number of reported cases in 2021 to that in 2020 were calculated for each of the 36 infectious diseases. The correlation between these two ratios in each disease was assessed to analyze time trends using Spearman rank correlation coefficients and linear regression. Values of $P < 0.05$ were considered indicative of statistical significance. All statistical analyses were performed using SPSS statistics version 24.0 software (IBM Corp, Armonk, NY, USA).

Ethical approval

The permission to use surveillance data for the study was obtained from the National Institute of Infectious Diseases Japan. The study protocol was approved by the institutional review board at Beppu Medical Center (approval no. 2022-03). The study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement [12].

Results

Epidemiology of COVID-19 and public interventions in Japan

Figure 1 shows the daily confirmed COVID-19 cases in Japan during 2020-2021. Five different waves of the outbreak occurred in Japan during this period. The first endemic wave was dominated by the B.1.1.114 lineage, the second wave by B.1.1.284, the third wave by B.1.1.214, the fourth wave by B.1.1.7, and the fifth wave by AY.29 [13]. In Japan, public health and social measures against COVID-19 have been implemented since January 2020 (Supplementary Table 1), including wearing masks, cleaning the hands, and avoiding the 3Cs (close-contact settings, crowded places, and closed spaces). From March to May 2020, schools were temporarily closed and entry from 73 countries was banned [14,15]. COVID-19 vaccination was started for medical workers in February 2021 and for individuals aged ≥65 years in April 2021. During 2020-2021, the Japanese government declared a state of emergency four times (Figure 1), representing mild lockdown. In periods of a declared state of emergency, residents were strongly recommended to stay at home, wash hands, conduct disinfection, wear masks, and avoid the 3Cs. After 2020, these nonpharmaceutical interventions have been gradually relaxed. The entry ban to Japan was lifted on June 2022.

Time series trends in epidemiology of 36 infectious diseases in Japan during the COVID-19 pandemic

Table 1 lists the 36 infectious diseases investigated in the study and shows the causative pathogens, principal modes of transmission, and the comparison of the time series trends in each number of reported cases in Japan. The mean annual number of reported cases was significantly lower ($P < 0.001$) intrapandemic than prepandemic for 27 infectious diseases (75.0%), with decreased percentage differences >50% for 19 infectious diseases (52.8%). Conversely, the mean number of reported cases was significantly higher (P ranging from <0.001 to <0.05) intrapandemic than prepandemic for six infectious diseases (16.7%).

The ratio of the number of reported cases in 2020 to the mean annual number of cases prepandemic and the ratio of cases in 2021 to cases in 2020 for each infectious disease are shown in Figure 2. A significant positive correlation was confirmed between the two ratios among 36 infectious diseases (Figure 2a), showing a continuous trend of either increase or decrease during the COVID-19 pandemic.

The estimated annual incidences of the 36 infectious diseases in 2020-2021 (intrapandemic period) were compared between the period with strict countermeasures (state-of-emergency period) and the period without strict countermeasures (nonstate-of-emergency period) to assess the effects of nonpharmaceutical interventions on the incidences of communicable diseases (Supplementary Table 2). Observational period-adjusted Poisson regression analyses showed a significantly decreased incidence in 24 of the 36 infectious diseases (66.7%) during the state-of-emergency period and a significantly increased incidence in two diseases (5.6%), mumps and respiratory syncytial virus (RSV) infection. A significant decrease in incidence during the state-of-emergency period

Table 1
Characteristics of the 36 infectious diseases and comparison of the mean annual number of reported cases between 2015-2019 (prepandemic) and 2020-2021 (intrapandemic).

Infectious disease	Causative pathogen	Main mode of transmission	Mean number of reported cases		Percent difference
			2015-2019	2020-2021	2020-2021 vs 2015-2019
AIDS[a]	HIV	Sexual transmission	1347	1061	-21.2 ***
Acute hemorrhagic conjunctivitis[b]	Enterovirus 70, Coxsackievirus A24	Direct contact transmission	434	160	-63.1 ***
Amoebic dysentery[a]	*Entamoeba histolytica*	Fecal-oral transmission	998	570	-42.9 ***
Bacillary dysentery[a]	*Shigella*	Fecal-oral transmission	166	47	-71.7 ***
Chlamydial pneumonia[b]	*Chlamydia pneumoniae, Chlamydia trachomatis*	Droplet transmission	254	39	-84.6 ***
Creutzfeldt-Jakob disease[a]	Scrapie prion protein	Unknown	193	164	-15.0
Dengue fever[a]	Dengue virus	Vector-borne transmission	308	27	-91.2 ***
Disseminated cryptococcosis[a]	*Cryptococcus neoformans, Cryptococcus gattii*	Inhalation of basidiospore	144	155	+7.6
Enterohemorrhagic *Escherichia coli* infection[a]	Enterohemorrhagic *E. coli*	Fecal-oral transmission	3735	3142	-15.9 ***
Epidemic keratoconjunctivitis[b]	Adenovirus	Direct contact transmission	26,097	7880	-69.8 ***
Erythema infectiosum[b]	Human parvovirus B19	Droplet transmission	63,970	10,211	-84.0 ***
Exanthem subitum[b]	Human herpesvirus 6 and 7	Droplet transmission	73,675	62,547	-15.1 ***
Group A streptococcal pharyngitis[b]	*Streptococcus pyogenes*	Direct contact transmission	3,68,619	1,46,766	-60.2 ***
Hand-foot-and-mouth disease[b]	Enterovirus 71, Coxsackievirus, Echovirus	Direct contact transmission	2,65,034	47,536	-82.1 ***
Hepatitis A[a]	Hepatitis A virus	Fecal-oral transmission	429	95	-77.9 ***
Hepatitis E[a]	Hepatitis E virus	Fecal-oral transmission	361	451	+24.9 **
Herpangina[b]	Coxsackievirus, Enterovirus 71, Echovirus	Direct contact transmission	1,00,823	31,201	-69.1 ***
Influenza[b]	Influenza virus A and B	Droplet transmission	16,54,510	2,81,500	-83.0 ***
Invasive group A streptococcal disease[a]	*S. pyogenes*	Direct contact transmission	622	699	+12.4 *
Invasive *Haemophilus influenzae* infection[a]	*H. influenzae*	Droplet transmission	390	222	-43.1 ***
Invasive pneumococcal infection[a]	*Streptococcus pneumoniae*	Droplet transmission	2963	1506	-49.2 ***
Japanese spotted fever[a]	*Rickettsia japonica*	Vector-borne transmission	289	453	+56.7 ***
Legionellosis[a]	*Legionella pneumophilia*	Inhalation of contaminated aerosol	1869	2072	+10.9 **
Measles[a]	Measles virus	Airborne transmission	282	10	-96.5 ***
Mumps[b]	Mumps virus	Droplet transmission	71,113	7648	-89.2 ***
Mycoplasma pneumoniae pneumonia[b]	*M. pneumoniae*	Droplet transmission	9737	2029	-79.2 ***
Pertussis[a]	*Bordetella pertussis*	Droplet transmission	14,366	1839	-87.2 ***
Pharyngoconjunctival fever[b]	Adenovirus	Direct contact transmission	75,897	34,436	-54.6 ***
Respiratory syncytial virus infection[b]	Respiratory syncytial virus	Droplet transmission	1,24,167	1,21,549	-2.1 ***
Rotavirus gastroenteritis[b]	Rotavirus	Fecal-oral transmission	4419	170	-96.2 ***
Rubella[a]	Rubella virus	Droplet transmission	1121	56	-95.0 ***
Scrub typhus[a]	*Orientia tsutsugamushi*	Vector-borne transmission	442	523	+18.3 **
Syphilis[a]	*Treponema pallidum*	Sexual transmission	5290	6829	+29.1 ***
Tetanus[a]	*Clostridium tetani*	Transmission through skin wound	126	99	-21.4
Tuberculosis[a]	*Mycobacterium tuberculosis*	Airborne transmission	22,710	16,454	-27.5 ***
Varicella [b]	Varicella-zoster virus	Airborne transmission	62,636	24,680	-60.6 ***

Statistical analyses were performed using Poisson regression modeling.
[a] Notifiable disease
[b] Sentinel surveillance disease
* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$.

compared with the nonstate-of-emergency period was observed in all three diseases with vector-borne transmission (100%), six of seven diseases with direct contact transmission (85.7%), eight of 11 diseases with droplet transmission (72.7%), two of three diseases with airborne transmission (66.7%), and three of six diseases with fecal-oral transmission (50.0%).

The estimated annual incidences of the five most common infectious diseases, RSV infection, herpangina, group A streptococcal pharyngitis, hand-foot-and-mouth disease (HFMD), and influenza, among the 36 diseases during January-September 2021 were compared between Tokyo, as the largest metropolis in Japan, with strict countermeasures and the Shikoku or Kyushu regions without strict countermeasures to assess the effects of nonpharmaceutical interventions on the incidences of communicable diseases in different areas (Supplementary Table 3). The population-adjusted Poisson regression analyses showed significantly increased incidences of RSV infection, herpangina, group A streptococcal pharyngitis, and HFMD in the Shikoku and Kyushu regions compared with those in Tokyo.

Characteristics of infectious diseases with decreased incidence intrapandemic

Of the 27 infectious diseases with a significant decrease in the mean number of reported cases during the COVID-19 pandemic, 21 infectious diseases (77.8%), except for acquired immunodeficiency syndrome, enterohemorrhagic *Escherichia coli* infection, HFMD, herpangina, measles, and RSV infection, continued to

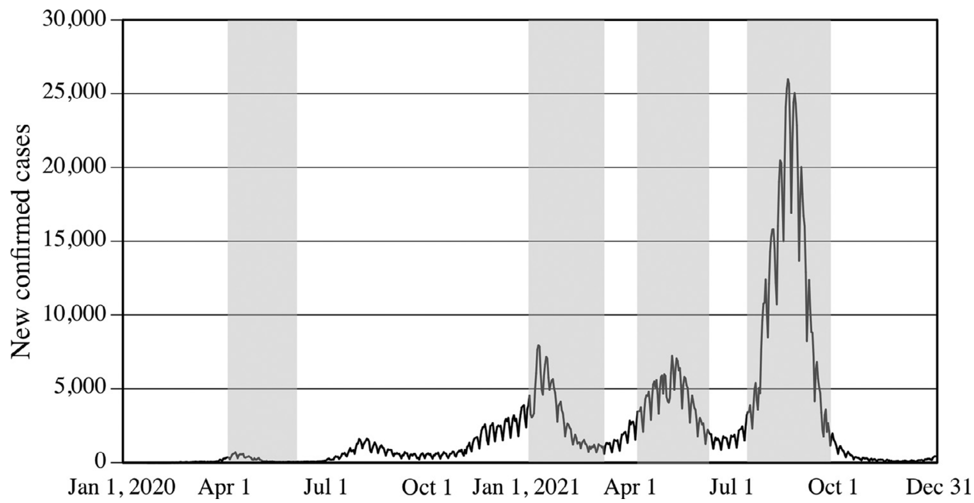

Figure 1. The number of daily confirmed new cases of COVID-19 during 2020–2021 in Japan. Gray zones indicate periods of a state of emergency declared by the government of Japan.

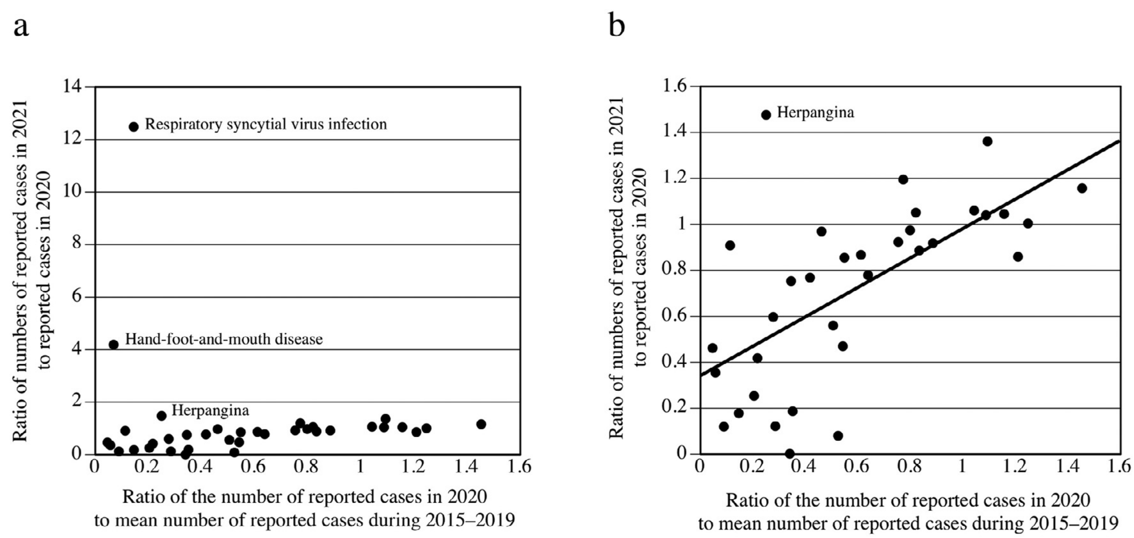

Figure 2. Correlation analyses between the ratio of the number of reported cases in 2020 to the mean number of reported cases in 2015-2019 (prepandemic) and the ratio of the number of reported cases in 2021 to that in 2020 for each of the 36 infectious diseases. Correlations were examined using Spearman rank correlation coefficients. (a) A positive correlation between the two ratios was confirmed among 36 infectious diseases (Spearman's $\rho = 0.450$, $P = 0.006$). (b) A more significant positive correlation was confirmed between the two ratios when hand-foot-and-mouth disease and respiratory syncytial virus infection were excluded (Spearman's $\rho = 0.674$, $P <0.001$). A straight line indicates a positive linear association between the two ratios, calculated by linear regression modeling ($R^2 = 0.401$, $P <0.001$).

decrease through 2020-2021 (Supplementary Figure 1). Of those 27 infectious diseases, 20 infectious diseases (74.1%) are characterized by airborne, droplet, or direct contact transmission (Table 1), and five infectious diseases (18.5%) are considered imported infections, with the source of infection identified to be overseas, including amoebic dysentery, bacillary dysentery, dengue fever, hepatitis A, and measles. In Japan, public health and social measures to prevent infection have been implemented nationwide, and entry to Japan was banned until June 2022, after the COVID-19 pandemic began.

Characteristics of infectious diseases with increased incidence intrapandemic

A significant increase in the mean number of reported cases during the COVID-19 pandemic was observed for six infectious diseases, including hepatitis E, invasive group A streptococcal disease, Japanese spotted fever, legionellosis, scrub typhus, and syphilis (Table 1). Japanese spotted fever and scrub typhus are vector-borne diseases and are transmissible during outdoor activity. Hepatitis E is also transmitted during outdoor activity through untreated water from natural sources, berries, and meat products. A camping boom occurred in Japan during the COVID-19 pandemic as a 3Cs-compliant leisure activity [16]. No vaccinations are available for these six infectious diseases; conversely, none of the 12 vaccine-preventable diseases included in the study showed increased incidences during the COVID-19 pandemic.

Infectious diseases with rebound outbreak in 2021 after decreased incidence in 2020

HFMD and RSV infection showed outbreaks in 2021 after decreased incidences in 2020 (Figures 2a, 3). Herpangina exhibited a similar but weaker (P <0.001) trend (Figure 2a). Although the number of cases of HFMD and RSV infection in 2020 was significantly lower than the mean annual numbers of those prepandemic, the number of cases of these two diseases was significantly higher in 2021 than in 2020 (Figure 3). In particular, the number of cases of RSV infection in 2021 was significantly higher than

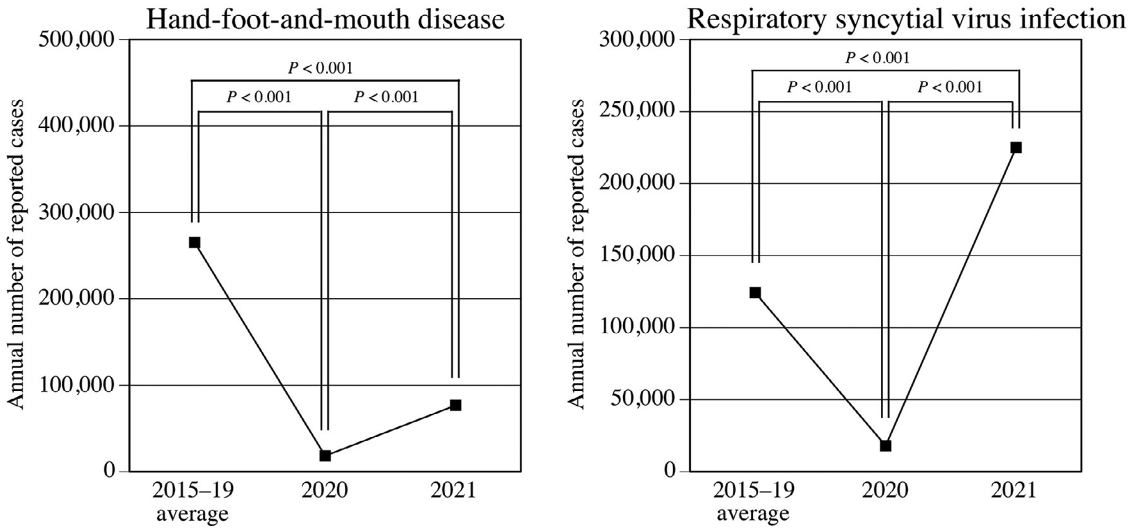

Figure 3. Sequential analyses of the incidences of hand-foot-and-mouth disease and respiratory syncytial virus infection during 2015-2021 in Japan. Each box indicates the annual number of reported cases during 2020-2021(intrapandemic) and the average in 2015-2019 (prepandemic). Statistical analyses were performed using Poisson regression modeling.

that of prepandemic (Figure 3). Changes in the number of reported cases of HFMD and RSV infection differed from those of other 34 infectious diseases (Figure 2a). After excluding HFMD and RSV infection, a more significant positive correlation was confirmed between the COVID-19 pandemic and subsequent changes in number of reported cases of other 34 infectious diseases (Figure 2b). The Japanese government did not recommend the use of face masks by children aged <2 years, and outbreaks of HFMD and RSV infection were subsequently observed in early childhood after the reopening of childcare facilities.

Discussion

In this time series analysis during 2015-2021 in Japan, we reported the impact of the COVID-19 pandemic on the endemic status of other 36 infectious diseases. Of these diseases, the annual reported number of 27 diseases (75%) was significantly lower intrapandemic than prepandemic. In contrast, the number of six diseases (17%) showed a significant increase intrapandemic. The COVID-19 pandemic has led to lifestyle changes worldwide. Individual and public health measures against COVID-19 are considered to have contributed to the control of many infectious diseases [5–10]. Preferences in terms of entertainment and leisure activities have also changed due to the COVID-19 pandemic and may be associated with the increased incidences of some infectious diseases [16–18]. Our findings may be important in understanding the effects of public health measures and behavioral changes during global pandemics on the incidences of infectious diseases.

Similar to the current findings, decreased incidences of communicable diseases in 2020 were confirmed in other observational studies conducted in Asian countries [6,7,19,20], Australia [5], European countries [21,22], and the United States [9,23]. Such reports suggest that the COVID-19 strategy has led to similar control of other infectious diseases, mainly comprising those transmitted by airborne/droplet or contact, in many countries. The incidences of these infectious diseases may remain suppressed as long as public health and social measures are implemented, including mask wearing, cleaning the hands, and social distancing. The incidences of imported infectious diseases, including amoebic dysentery, bacillary dysentery, dengue fever, hepatitis A, and measles, decreased by 47-95% in Japan during the COVID-19 pandemic, probably caused by the ban on entry into Japan. A state of emergency strongly recommending staying at home, handwashing, disinfection, wearing masks, and avoidance of the 3Cs led to decreases in the incidences of infectious diseases through vector-borne, direct contact, droplet, and airborne transmissions, with >70% reductions. These nonpharmaceutical interventions were shown to have significant impacts on the epidemiology of communicable diseases other than COVID-19.

This study demonstrated increased incidences of six infectious diseases during the COVID-19 pandemic, including hepatitis E, invasive group A streptococcal disease, Japanese spotted fever, legionellosis, scrub typhus, and syphilis. The incidence of hepatitis E during the COVID-19 pandemic was reportedly decreased in China and increased in Taiwan [6,19]. Hepatitis E is mainly transmitted through untreated water from natural sources, berries, and meat products [24]. During the COVID-19 pandemic, a boom in camping was seen in Japan, as well as in the United States [16]. A significant increase in patients with hepatitis E during the COVID-19 pandemic in Japan may be caused by the consumption of contaminated water and food during camping, such as undercooked pork, venison products, and clams [25]. Age ≥65 years and preceding skin lesion are considered risk factors for developing invasive group A streptococcal disease [26]. An aging society and a reduction in visits to the hospital after minor trauma in Japan may have led to increased numbers of invasive group A streptococcal disease during the COVID-19 pandemic. Increased number of cases of Japanese spotted fever and scrub typhus in Japan may also be attributable to the camping boom during the COVID-19 pandemic. Outbreaks of other vector-borne diseases were reported to occur during educational camping and outdoor activity in the United States [27,28]. Other locally transmitted diseases in Japan showed different epidemiological changes during the COVID-19 pandemic. The annual number of reported cases of Zika virus infection and severe fever with thrombocytopenia syndrome in 2020 were statistically unchanged compared with each mean annual number of reported cases during 2015-2019, whereas the annual number of reported cases of chikungunya fever significantly decreased in 2020 compared with the mean annual number of reported cases during 2015-2019 (data not shown). The incidence of legionellosis has been increasing in Japan, the United States, and European countries [29–31]. The increased number of patients with legionellosis in Japan can be explained by improved detection rates with the increased use of the urinary *Legionella* antigen test, in addition to the aging of society, particularly in the population aged ≥70 years [29]. The epidemiological changes to syphilis in Japan were inconsistent with the results of epidemiological studies reporting a decreased incidence of syphilis in 2020 in China, Switzerland, Taiwan, and the United States [6,7,22,32]. However, an increased incidence of syphilis was also observed in Australia [5]. In addition, a resurgence of syphilis was observed in the United States after a statewide executive order, such as Policies that Assure Uniform Safety for Everyone, particularly among females and African-Americans [32,33]. These reports indicate underestimations of syphilis case numbers during the COVID-19 pandemic, probably attributable to the limitations on access to testing and health care [32,33]. The increase in the reported number of syphilis cases in Japan is attributed to increased transmission through sexual activity with the use of dating apps and female sex workers [17,18].

Our result revealed consistent trends in the incidences of infectious diseases during the COVID-19 pandemic in Japan. This constant trend is considered to be associated with preventive interventions against COVID-19, including border restrictions, quarantine and isolation, social distancing, wearing masks, and other changes in population behavior [34]. Counter to this trend, the incidences of HFMD and RSV infection showed a significant rebound in 2021 after a significant decrease in 2020. Nonetheless, the incidences of adenovirus infection, influenza, and *Mycoplasma pneumoniae* infection, all of which are droplet-transmissible diseases similar to HFMD and RSV infection, continued to decrease during the COVID-19 pandemic. One possible reason for this is that children aged ≤2 years accounted for 60% and 42% of patients with HFMD and RSV infection, respectively, which were higher than the 18%, 5%, and 2% among patients with adenovirus infection, influenza, and *M. pneumoniae* infection, respectively [35–38]. The temporary closure of childcare facilities and physical distancing during 2020 in Japan may have contributed to the lack or waning of immunity against communicable diseases in early childhood. The government of Japan did not recommend the use of face masks for children aged ≤2 years because of the risk of choking and struggling to breathe, which probably contributed to the spread of HFMD and RSV infections in this naïve population after the reopening of childcare facilities. Another possible reason is that the basic reproduction numbers of HFMD (4.8-5.9) and RSV infection (4.5) seem to be higher than those of adenovirus infection (2.3), *M. pneumoniae* infection (1.7), and influenza (1.2-1.4) [39–42]. The increased incidence of mumps during the state-of-emergency period may be due to the lack of universal mumps vaccination in Japan.

This nationwide epidemiological study in Japan has several limitations that should be kept in mind. First, routine immunization services and coverage rates differ among countries. The outbreak risk of vaccine-preventable disease depends on vaccination coverage rates and herd immunity [43]. A measles outbreak occurred during 2021 in Pakistan, one of the five countries with the lowest vaccination coverage against measles [44,45]. In Japan, the measles vaccination coverage rate is approximately 95% among those aged 5-24 years [46]. Childhood immunization programs were disrupted by the COVID-19 pandemic in 2020 in at least 68 countries, with these countries facing increased risks of measles and yellow fever outbreaks if catch-up immunization is delayed [47]. Second, different from notifiable diseases, this study did not include the total number of cases of sentinel surveillance diseases. One sentinel surveillance site per 30,000 population was randomly selected in Japan based on the Infectious Diseases Control Law, and over 5000 sentinel sites exist nationwide [11]. This study was conducted based on data from these sentinel sites. Third, the incidences of infectious diseases with small numbers of reported cases could have been affected by the sporadic outbreaks. Finally, the legal systems and public compliance behaviors against COVID-19 vary among countries [48]. After the public recommendations were issued regarding measures, such as 3Cs and individual preventive behaviors, 80% of residents were reported to routinely wear face masks and 70-80% canceled or postponed travel and leisure events at least once in Japan [49,50]. The direct generalizability of our results to other countries with different compliance and immunization program is thus likely to be limited. Further study is needed to evaluate the effect of public health and social measures on the incidences of infectious diseases in low- and middle-income countries and to clarify the cost-effectiveness of preventive measures.

In conclusion, the implementation of nonpharmaceutical interventions against COVID-19 led to significant decreases in the incidences of 75% of communicable diseases mainly caused by pathogens transmitted by droplet or direct contact in Japan during the COVID-19 pandemic, whereas continuous increases in the incidences of Japanese spotted fever and syphilis were confirmed. Overall, the increasing or decreasing trends in the incidence of each communicable disease remained during the COVID-19 pandemic. However, HFMD and RSV infection showed significant rebounded incidences in 2021, mainly among children aged ≤2 years. Even in Japan, with its mitigation policy, the COVID-19 pandemic has had a marked impact on the epidemiology of communicable diseases.

Declaration of competing interest

The authors have no competing interests to declare.

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Ethical approval

The study protocol was approved by the institutional review board of Beppu Medical Center (approval no. 2022-03).

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Author contributions

HK led the study conceptualization and the development of the research question, supported by KH and TH. KH and HK were responsible for data collection. TH accessed and verified the data. TH and HK developed the statistical analysis plan and performed the analyses. KH and HK wrote the first draft of the paper. All authors contributed to the interpretation and discussion of the results, critically revised the manuscript, and approved the final version and the submission of the manuscript. The corresponding author had final responsibility for the decision to submit for publication.

Data sharing

The data included in this study are publicly available from the Infectious Disease Surveillance System of the National Institute of Infectious Diseases in Japan (https://www.niid.go.jp/niid/ja/idwr.html).

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijid.2023.01.013.

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