Human Mobility and Droplet-transmissible Pediatric Infectious Diseases During the Coronavirus Disease-2019 Pandemic

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Abstract

Background: The number of children with common pediatric infectious diseases (PIDs) other than coronavirus disease-2019 (COVID-19) decreased in 2020 compared with those in previous years worldwide. The present study tested the hypothesis that human mobility may be a potential factor contributing to reductions in PIDs that can be transmitted by droplets among children.

Methods: An ecological study was conducted using two publicly available datasets: surveillance on infectious diseases collected by the Japanese government and COVID-19 community mobility reports presented by Google. Among common PIDs, we focused on focused on respiratory syncytial virus (RSV) infection, pharyngoconjunctival fever (PCF), group A streptococcal (GAS) pharyngitis, hand-foot-and-mouth disease (HFMD), and herpangina because of their nature as droplet-transmissible PIDs. The COVID-19 community mobility reports demonstrated percent decreases in the movement of people over time in groceries and pharmacies, parks, and transit stations. We compared the weekly trends in numbers of patients with PIDs identified in 2020 with those identified in the previous years 2015–2019. We then determined the associations between numbers of patients with PIDs and percentage decreases in human mobility during 2020 using Pearson correlation analysis.

Results: Despite experiencing their peak seasons, dramatic reductions were observed in the numbers of patients with PCF and GAS pharyngitis after the 10th week in 2020. Beyond the 20th week, no seasonal peaks were observed in the numbers of patients with all PIDs identified in 2020. Significant correlations were found between percentage decreases in human mobility in transit stations and numbers of patients with HFMD (Pearson correlation coefficient [95% confidence interval]: 0.65 [0.44–0.79]), PCF (0.47 [0.21–0.67]), RSV infection (0.45 [0.19–0.66]), and GAS pharyngitis (0.34 [0.06–0.58]). No significant correlations were found between numbers of patients with PIDs and human mobility in parks.

Conclusions: The highest correlations were found for the associations between numbers of patients with PIDs and human mobility in transit stations, suggesting that adult-to-child transmission may be a primary factor associated with increased numbers of patients with PIDs, rather than cross-transmission among children. A reduction in human mobility for adults may contribute toward decreases in the numbers of children with droplet-transmissible PIDs.

Background

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection has been spreading worldwide since the original outbreak in China in 2019. To address the rapid increases in patients with coronavirus disease-2019 (COVID-19) during the pandemic, many countries have carried out citywide lockdown measures to minimize spreading of the infection, resulting in great restriction on the movement of people [1–4]. Social distancing and mask-wearing have also been required, based on increasing evidence for their effectiveness in protecting against SARS-CoV-2 infection [4–11].

Studies have shown that the numbers of children with common pediatric infectious diseases (PIDs) other than COVID-19 decreased in 2020 compared with previous years [12–21]. One study suggested that social distancing may have had the greatest impact on decreasing the numbers of children with PIDs during the SARS-CoV-2 pandemic [14]. However, to our knowledge, no studies have determined the specific potential factors contributing to the reductions in PIDs. We hypothesized that human mobility may be a potential factor affecting reductions in PIDs that can be transmitted by droplets among children. To test this hypothesis, we evaluated the associations between human mobility and trends in PIDs, using datasets from Japanese infectious disease surveillance and nationwide human mobility reports.

Methods

Data sources and study design

An ecological study was conducted using two publicly available datasets: (1) Japanese surveillance of infectious diseases and (2) COVID-19 community mobility reports. Institutional review board approval was not required for the study because the data did not contain individual personal information and were publicly available through internet websites.

The Japanese government conducts the National Epidemiological Surveillance of Infectious Diseases program and has obtained information on the diseases specified in the Infectious Diseases Control Law since 1999. The numbers of patients with the specific infectious diseases are updated and publicized weekly on a website presented by the National Institute of Infectious Diseases [22]. Although some infectious diseases are notifiable and reported immediately upon occurrence by every medical facility throughout Japan, common PIDs are reported by approximately 3,000 sentinel medical facilities across Japan (sentinel surveillance) [23]. Common PIDs comprise respiratory syncytial virus (RSV) infection, pharyngoconjunctival fever (PCF), group A streptococcal (GAS) pharyngitis, infectious gastroenteritis, chicken pox, hand-foot-and-mouth disease (HFMD), erythema infectiosum, roseola infantum, herpangina, and mumps [23]. Among these 10 diseases, the present study focused on RSV infection, PCF, GAS pharyngitis, HFMD, and herpangina because of their nature as droplet-transmissible PIDs. Chicken pox and mumps were excluded from the analysis because specific vaccinations are available for these diseases.

COVID-19 community mobility reports provided by Google LLC are also publicly available [24]. These reports offer insights into how national human mobility has changed in response to policies aimed at combating COVID-19 in 131 countries worldwide. Google distills these insights from data on users who opted-in for “Location History” in their Google Account based on support for public health policy [25]. The datasets demonstrate the human mobility trends over time. Specifically, the datasets reveal how people visiting categorized places change compared with baseline days, with the data presented as percent changes. A baseline day provides a standard value for that day of the week, and represents the median value for that day over a 5-week period (January 03 to February 06, 2020) [26]. The six categorized places

are retail and recreation areas, groceries and pharmacies, parks, transit stations, workplaces, and residential areas. Among these categorized places, the present study focused on groceries and pharmacies, parks, and transit stations, assuming that these areas mainly reflect the movement of people. Percent decreases in human mobility become larger when the movement of people is more greatly restricted.

Statistical analysis

First, we evaluated the weekly trends in numbers of patients with PIDs as well as the percentage decreases in human mobility for every week in the year 2020 (52 weeks). We also evaluated the differences in trends of numbers of patients with PIDs between the year 2020 and the previous years (2015–2019). The numbers of patients with PIDs identified during 2015–2019 were presented as mean and minimum–maximum numbers for each week using error bars in charts. The human mobility data were originally obtained as daily data, and subsequently changed into weekly data representing the mean values for each week. The Japanese government announced the State of Emergency in response to the rapid COVID-19 outbreak inside Japan during the period encompassing the 15th–19th weeks in 2020. The State of Emergency is highlighted in the charts because the movement of people across Japan was largely restricted during this period.

Second, we evaluated the associations between numbers of patients with PIDs and percentage decreases in human mobility using Pearson correlation analysis. Scatter plots were created to determine the distributions of the associations between these variables. We further created a heat map to clarify the strengths of the correlation coefficients between variables according to the specific PIDs and categorized places. The correlation coefficients were determined to be significant when the absolute values of the lowest limit of the 95% confidence intervals (CIs) were higher than zero. The 2.5 and 97.5 percentiles were used to express the 95% CIs. All analyses were performed using Python version 3.7.4 (The Python Software Foundation, 2020, Beaverton, OR, USA).

Results

Figure 1 shows the weekly trends in percentage decreases in human mobility and numbers of patients with PIDs in the 1-year (52-week) period. Compared with the standard values defined as mean human mobility in the baseline period (1st to 5th weeks), human mobility in transit stations rapidly decreased from the 14th week, reached the lowest percentage of > 50% decrease at the 19th week, rebounded toward an increase, and subsequently remained at approximately 20% decrease until the end of the year 2020 (Fig. 1A). Human mobility in groceries and pharmacies as well as parks remained almost unchanged throughout the observation period.

For all five specific PIDs, the numbers of patients identified after the 13th week in 2020 were consistently smaller than the minimum numbers of patients identified in 2015–2019 (Fig. 1B). The trends in the numbers of patients with PIDs differed according to the seasonal variation types. PIDs with a single peak in annual seasonality after the 20th week (HFMD, RSV infection, and herpangina) had consistently

smaller numbers of infected patients in 2020 compared with the previous years without showing the peak trends in their annual epidemic seasons, although the number of patients with herpangina moderately increased during the peak season. The number of patients with herpangina identified after the 41st week in 2020 was similar to those identified during the same period in the previous years. Meanwhile, PIDs with multiple peaks in annual seasonality (PCF and GAS pharyngitis) showed different trends. Specifically, the numbers of patients with PCF and GAS pharyngitis identified in 2020 were similar to those identified in the previous years until the 10th week, and then dramatically decreased after the 11th week to much smaller numbers without subsequent increases during their peak seasons, although the number of patients with PCF showed a moderate increase in the peak season after the 41st week in 2020. Actually, school closures occurred nationwide in Japan from the 10th week in 2020 in response to the increased number of patients with COVID-19.

Scatter plots shows associations between percentage decreases in human mobility in transit stations and numbers of patients with PIDs (Fig. 2). Similar associations are shown in groceries and pharmacies (Supplementary Fig. 1) and parks (Supplementary Fig. 2). The correlation coefficients are summarized in Fig. 3, which also shows a heatmap of the correlations between numbers of patients with PIDs and percentage decreases in human mobility in specific places. Among the PIDs, the Pearson correlation coefficients were highest for human mobility in transit stations, followed by groceries and pharmacies and then parks (Fig. 3). Significant correlations were found between percentage decreases in human mobility in transit stations and numbers of patients with HFMD (Pearson correlation coefficient [95% CI]: 0.65 [0.44–0.79]), PCF (0.47 [0.21–0.67]), RSV infection (0.45 [0.19–0.66]), and GAS pharyngitis (0.34 [0.06–0.58]). No significant correlations were found between numbers of patients with PIDs and human mobility in parks.

Discussion

The present study provided four main findings. First, despite experiencing their peak seasons, dramatic reductions were observed in the numbers of patients with PCF and GAS pharyngitis after the 10th week in 2020 as prompt responses to the national school closure. Furthermore, the rapid decreases in human mobility in transit stations from the 14th week enhanced the reductions in numbers of patients with PCF and GAS pharyngitis throughout 2020, with the smallest weekly numbers among the examined years since 2015. Second, no seasonal peaks after the 20th week were observed in the numbers of patients with all PIDs identified in 2020. In particular, the numbers of patients with HFMD and RSV infection, which have single seasonal peaks during the 30th–40th weeks in average years, were consistently minimized without any surge trends during the peak seasons. Third, the approximately 20% decrease in human mobility (in transit stations) appeared to have contributed to consistent reductions in the numbers of patients with PIDs. Finally, human mobility in transit stations had the highest correlations with reduced numbers of patients with PIDs compared with those in groceries and pharmacies and parks. To our knowledge, this is the first study that demonstrate that human mobility may be a potential factor affecting reductions in droplet-transmissible PIDs.

In Japan, the government formally started to close schools nationwide from the 10th week in 2020. The school closure continued until the State of Emergency was officially lifted in the 19th week. The numbers of patients with PIDs just in the middle of a peak season (PCF and GAS pharyngitis) were clearly reduced from the 10th week, coinciding with the start of the nationwide school closure. The numbers of patients with PCF and GAS pharyngitis were consistently decreased during the period of school closure (10th–19th weeks) with much smaller numbers than those identified in the previous years. Even after the 20th week when schools reopened throughout Japan, the numbers of patients with PCF and GAS pharyngitis identified in 2020 retained the large reductions and presented the smallest numbers since 2015. Furthermore, the numbers of children with HFMD, RSV infection, and herpangina identified after school reopening were also greatly reduced after the 20th week, even during the annual peak seasons. A study focusing on SARS-CoV-2 infection indicated that the numbers of children with COVID-19 did not rapidly increase after school reopening, while easing of restrictions on large-scale gatherings had a major influence on rapid increases [27]. After the 20th week in Japan, the fact that school children adhered to social distancing and standard infection control and prevention measures, such as thorough hand-washing and mask-wearing, may have resulted in the moderate increases in numbers of patients with PIDs as well as COVID-19. A study conducted before the SARS-CoV-2 pandemic reported that hand-washing by children and their caregivers had a significant protective effect against community-acquired HFMD and herpangina [28]. Other studies documented that increased compliance with social distancing measures can be a cost-effective strategy to mitigate the transmission of infectious diseases [29, 30]. These studies support our explanations for the present findings.

The highest correlation coefficients were found for the associations between numbers of patients with PIDs and human mobility in transit stations. The primary users of transit stations are typically adults. Therefore, the present findings indicate that greater reductions in the movements of adults with less potential human-to-human contacts may contribute to large decreases in the numbers of children with droplet-transmissible PIDs. For these reasons, our findings suggest that parent-to-child transmission may be a primary factor associated with increasing numbers of patients with PIDs, rather than cross-transmission among children. For example, RSV infection among children was greatly reduced without an annual peak season during 2020. Young infants are the dominant patients for RSV infection-associated hospital visits and hospitalizations [31]. Previous studies indicated that parents most often introduced RSV into households, leading to infection in infants [31–34], which could support our explanations for the present findings. The present results also suggested that an approximately 20% decrease in human mobility in transit stations (for adults) may contribute to reductions in the numbers of patients with droplet-transmissible PIDs.

The study had some limitations. First, children with PIDs who lacked severe signs and symptoms would have refrained from visiting hospitals during the study period to avoid the potential risk for hospital-related asymptomatic transmission of SARS-CoV-2 [35], and this may have affected the decreased numbers of patients with PIDs identified throughout 2020. Second, the human mobility reports typically represented the activity of adults because the reports were based on data from Google users [24–26]. Therefore, the study did not include accurate information on the movements of children. Finally, our data

only reflected weekly data on patients with PIDs from limited hospitals, although approximately 3,000 hospitals throughout Japan participate in the surveillance of PIDs. The small samples comprising only 52 weeks of data may have introduced statistical inaccuracy to the correlation coefficients between numbers of patients with PIDs and human mobility.

Conclusions

We evaluated the associations between human mobility and trends in PIDs identified in 2020 in Japan. The highest correlations were found for the associations between numbers of patients with PIDs and human mobility in transit stations, suggesting that adult-to-child transmission may be a primary factor associated with increased numbers of patients with PIDs. A reduction in human mobility for adults may contribute toward decreases in the numbers of children with droplet-transmissible PIDs.

Abbreviations

SARS-CoV-2: severe acute respiratory syndrome coronavirus 2

COVID-19: coronavirus disease-2019

PID: pediatric infectious disease

RSV: respiratory syncytial virus

PCF: pharyngoconjunctival fever

GAS pharyngitis: group A streptococcal pharyngitis

HFMD: hand-foot-and-mouth disease

Declarations

Ethics approval and consent to participate

All methods were performed in accordance with the Declaration of Helsinki. Institutional review board approval was not required for the study because the data did not contain individual personal information and were publicly available through internet websites.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are publicly available through internet websites.

Competing interests

The authors declare that they have no competing interests.

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None.

Authors' contributions

RA, YS, TF, and HH conceptualized and designed the study, carried out the analyses, drafted the initial manuscript, and reviewed and revised the manuscript.

RA, TS, YN, and HH conceptualized and designed the study and critically reviewed the manuscript for important intellectual content.

RA, YS, and TF designed the data collection instruments, coordinated and supervised the data collection, and critically reviewed the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Figures

Figure. 1

Figure 1

Weekly trends in the numbers of patients with pediatric infectious diseases and percentage decreases in human mobility in the 1-year (52-week) period. The numbers of patients identified in the years 2015–2019 are presented as mean and minimum–maximum numbers in each week using error bars. The percentage decreases in human mobility represent the mean values for each week compared with the baseline 5-week period (January 03 to February 06, 2020). In all panels, the initiation of the nationwide school

closure at the 10th week is highlighted by black dashed lines and the national State of Emergency from the 16th to 19th weeks is shown by red dashed lines. The schools typically reopened after the State of Emergency was officially lifted in the 19th week.

Figure. 2

Figure 2

Correlations between numbers of patients with pediatric infectious diseases and percentage decreases in human mobility in transit stations The percent decreases in human mobility become larger when the

movement of people is more greatly restricted. *Significant correlation.

Figure. 3

Figure 3

Heatmap of correlations between numbers of patients with pediatric infectious diseases and percentage decreases in human mobility *Significant correlation.

Supplementary Files

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