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Regional and facility-type variations in infectious diseases in childcare and early childhood education facilities in Japan during the COVID-19 pandemic: A nationwide cross-sectional questionnaire survey

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Abstract: Young children are susceptible to infectious diseases due to their developing immune systems and close contact in group care settings. During the coronavirus disease 2019 (COVID-19) pandemic, infection prevention measures may have altered the epidemiology of common childhood infections, yet evidence on variations by facility type and region remains limited. In this study, the occurrence of COVID-19 and child-specific infectious diseases in childcare and early childhood education facilities in Japan was examined with particular focus on facility type and regional population density. A nationwide mail survey was conducted between January and April 2023 among 5,000 facility managers, and 710 valid responses were analysed. Over 90% of facilities reported at least one COVID-19 case within the previous year. The occurrence of child-specific infectious diseases, including adenovirus infection, hand, foot, and mouth disease, herpangina, streptococcal infection, norovirus infection, and respiratory syncytial virus infection, was lower in kindergartens serving children aged ≥ 3 years than in children in daycare centres or certified childcare centres ($p < 0.05$). Hand, foot, and mouth disease and influenza virus infection showed significant linear associations with population density, with lower reporting rates in less densely populated regions ($p < 0.05$). Conversely, rotavirus infection was more frequently reported in low-density regions ($p < 0.05$), whereas other child-specific infectious diseases exhibited heterogeneous and non-linear regional patterns, indicating that population density alone does not explain regional variation. These results highlight the importance of facility-, age-, and region-specific approaches to infection prevention in childcare settings beyond the COVID-19 pandemic.

***Keywords*:** infection surveillance, population density, infection prevention, early childhood health, childcare systems, public health measures

1. Introduction

Infectious diseases spread easily in childcare and early childhood education facilities, where young children spend extended periods in close contact during daily activities and rest. During the coronavirus disease 2019 (COVID-19) pandemic, children in Japan experienced substantial infection waves; notably, infections among children increased markedly during the sixth wave (January to March 2022) (*1*). Morimoto *et al.* reported that 30.5% of confirmed COVID-19 cases in Kyoto Prefecture during this period occurred in children aged ≤ 9 years (*2*). At the same time, widespread infection prevention measures implemented in childcare settings, such as mask-wearing, hand hygiene, and the use of alcohol-based sanitisers, were associated with a marked decline in other child-specific infectious diseases, including influenza, respiratory syncytial virus (RSV), norovirus, and adenovirus gastroenteritis (*3*).

Despite heightened interest in infection control during the pandemic, evidence regarding the occurrence of non–COVID-19 infectious diseases in childcare settings remains limited. Previous studies on infectious disease outbreaks in daycare centres in Japan were conducted before the pandemic (*4*), and no nationwide research has comprehensively examined child-specific infectious diseases across different types of childcare and early childhood education facilities during the COVID-19 pandemic.

The Japanese childcare and early childhood education system comprises three main facility types: kindergartens, daycare centres, and certified childcare

centres (*5*). Kindergartens, administered by the Ministry of Education, Culture, Sports, Science and Technology, admit children aged ≥ 3 years, regardless of parental employment status (*6,7*). Daycare centres, overseen by the Child and Family Agency, primarily serve children from infancy whose parents require childcare owing to employment or specific circumstances (*6,7*). Certified childcare centres integrate the functions of daycare centres and kindergartens, serving children from infancy to 5 years of age (*6,7*). Differences in age composition, operational structure, and daily routines across these facility types may differentially influence the occurrence and transmission of infectious diseases.

International studies suggest that infectious disease patterns among children vary by age group and regional characteristics. For example, Shen *et al.* reported age-related differences in the incidence of hand, foot, and mouth disease during the COVID-19 outbreak in China (*8*). In addition, Shirabe *et al.* demonstrated a strong association between population density and COVID-19 infection rates in Japan, indicating that regional context may also affect the occurrence of child-specific infectious diseases (*9*).

Understanding the occurrence of infectious diseases by facility type and region is essential for implementing timely and appropriate infection prevention measures. Prior research has shown that early recognition of infection trends within daycare centres facilitates prompt interventions and effective disease control (*10*). However, nationwide data examining child-specific infectious diseases, including COVID-19, across different childcare and early childhood education settings in Japan during the pandemic are lacking.

Therefore, the aim of this study was to clarify occurrence of COVID-19 and other child-specific infectious diseases in kindergartens, daycare centres, and certified childcare centres across Japan during the COVID-19 pandemic, with a particular focus on differences by facility type and regional population density.

2. Survey respondents and Methods

2.1. Study design

This study was a nationwide, cross-sectional survey conducted using self-administered questionnaires. Facilities were randomly selected from the 39,706 childcare and early childhood education facilities registered in the 2022 National School Data in Japan (*11*). The required sample size was calculated assuming a 95% confidence level, a 3% margin of error, and a population ratio of 0.5, resulting in a target sample of 1,040 facilities. Given the national childcare survey response rate of 23.9% (*12*), at least 4,426 facilities were required to achieve the target sample size; therefore, 5,000 facilities were contacted to account for a potential lower response rate caused by survey complexity.

2.2. Participants

In this study, managers of major Japanese childcare and early childhood education facilities were targeted, including kindergartens, daycare centres, and certified childcare centres. Self-administered questionnaires and return envelopes were mailed to the selected facilities.

2.3. Regional classification

Based on facility locations, the regions of Japan were divided into nine areas: Hokkaido, Tohoku, Kanto, Hokuriku/Koshinetsu, Tokai, Kinki, Chugoku, Shikoku, and Kyushu/Okinawa (Figure 1). The Hokkaido region comprised only the Hokkaido prefecture, while the Tohoku region included Aomori, Akita, Yamagata, Miyagi, Iwate, and Fukushima prefectures. The Kanto region comprised Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, and Kanagawa prefectures. Hokuriku/Koshinetsu region included Toyama, Ishikawa, Fukui, Yamanashi, Nagano, and Niigata prefectures; Tokai region comprised Gifu, Shizuoka, Aichi, and Mie prefectures; and the Kinki region included Shiga, Kyoto, Osaka, Hyogo, Nara, and Wakayama prefectures. The Chugoku region comprised Tottori, Shimane, Okayama, Hiroshima, and Yamaguchi prefectures; Shikoku region included Tokushima, Kagawa, Ehime, and Kochi prefectures; and Kyushu/Okinawa region included Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki,

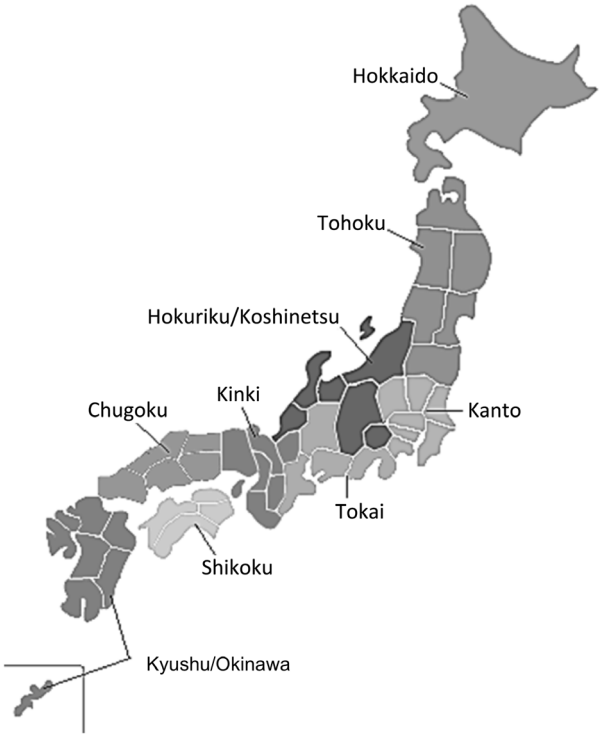

Figure 1. Regional classification of Japan used in this study.

Kagoshima, and Okinawa prefectures.

Furthermore, regions were classified into low, medium, and high density for the population density analysis. Population density (persons per km²) was calculated at the prefectural level using data obtained from the Japan Statistics e-Stat database (*13*). For each region, the median population density of the prefectures included was used as a representative value. Based on these median values, regions were classified into low-, medium-, and high-density categories. Low-density regions included Hokkaido, Tohoku, and Hokuriku/Koshinetsu; medium-density regions comprised Chugoku, Shikoku, and Kyushu/Okinawa; and high-density regions included Kanto, Tokai, and Kinki.

2.4. Questionnaire content

The questionnaire was used to collect information on managers' demographics, facility type and location, the number of childcare workers, and the number of children at each facility. In addition, data on whether each facility had reported cases of COVID-19 and other child-specific infectious diseases, including adenovirus, hand, foot, and mouth disease, herpangina, streptococcal infection, influenza virus, norovirus, rotavirus, RSV, and mumps, within the past year were obtained.

2.5. Statistical analysis

Categorical variables are presented as numbers and percentages (%), whereas continuous variables are expressed as means and standard deviations (SD). The proportion of facilities reporting each child-specific infectious disease was analysed based on facility type and region. Regional population density was defined using prefecture-level population density data obtained from official national statistics. Chi-square tests and residual analysis were performed to determine differences among facility types and regions within the 1-year period. Adjusted residuals greater than 1.96 or less than −1.96 were considered statistically significant. For analyses involving ordered population density categories (low, medium, and high), linear-by-linear association tests were additionally conducted to assess linear trends. All analyses were conducted using SPSS version 26.0, and a p-value < 0.05 was considered statistically significant.

2.6. Ethical considerations

The survey request documents, including questionnaires and return envelopes, were sent to all selected facilities. Informed consent was obtained when the managers read the request, completed the questionnaire, and returned it. This study was approved by the Research Ethics Review Board of Chukyogakuin University (Approval No. 22-04) and was conducted in accordance with the principles outlined in the Declaration of Helsinki.

3. Results

3.1. Basic information

In December 2022, questionnaires were randomly sent to 5,000 facility managers, and 776 responses (response rate: 15.4%) were received between January and April 2023. Of these, 66 responses with incomplete basic information or multiple uncertainties were excluded, resulting in 710 responses (valid response rate: 14.2%). Among the responses, 15.5% were from kindergartens, 53.5% from daycare centres, and 31.0% from certified childcare centres. By region, responses were as follows: 27.4% from Kanto, 13.0% from Kyushu/Okinawa, 12.1% each from Tohoku and Kinki, 10.7% from Tokai, 8.7% from Hokuriku/Koshinetsu, 7.0% from Chugoku, 5.5% from Hokkaido, and 3.5% from Shikoku (Table 1).

The mean age of the managers was 55.2 (SD 9.6) years. By facility type, the average ages were 55.7 (SD 9.3) years for kindergartens, 55.3 (SD 9.4) years for daycare centres, and 54.7 (SD 10.0) years for certified childcare centres. The average number of childcare workers per facility was 30.8 (SD 23.4): 19.3 (SD 15.3) in kindergartens, 31.9 (SD 22.9) in daycare centres,

Table 1. Regional distribution of childcare and early childhood education facilities by facility type (n = 710)

Region	Kindergartens *n* (%)	Daycare centres *n* (%)	Certified childcare centres *n* (%)	Total *n* (%)
Hokkaido	7 (18.0)	19 (48.7)	13 (33.3)	39 (5.5)
Tohoku	13 (15.1)	40 (46.5)	33 (38.4)	86 (12.1)
Kanto	35 (18.0)	124 (64.0)	35 (18.0)	194 (27.4)
Hokuriku/Koshinetsu	3 (4.8)	27 (43.6)	32 (51.6)	62 (8.7)
Tokai	15 (19.7)	36 (47.4)	25 (32.9)	76 (10.7)
Kinki	15 (17.4)	38 (44.2)	33 (38.4)	86 (12.1)
Chugoku	12 (24.0)	29 (58.0)	9 (18.0)	50 (7.0)
Shikoku	7 (28.0)	11 (44.0)	7 (28.0)	25 (3.5)
Kyushu/Okinawa	3 (3.2)	56 (60.9)	33 (35.9)	92 (13.0)
Total	110 (15.5)	380 (53.5)	220 (31.0)	710 (100)

Note: Values are presented as *n* (%). Percentages for facility types are calculated within each region, whereas percentages in the total column represent the proportion of all facilities.

and 34.8 (SD 25.8) in certified childcare centres. The average number of children per facility was 96.8 (SD 57.9). By type, kindergartens had a mean of 95.0 (SD 73.6) children, daycare centres had 83.8 (SD 43.5), and certified childcare centres had 120.3 (SD 63.7) (Table 2).

3.2. One-year facility-level reporting rates of infectious diseases

COVID-19 infections were reported in 96.9% of the facilities over the past year. However, norovirus and influenza virus infections, which are prevalent every year, were reported in 20.4% of the facilities. Adenovirus infection was reported in 52.8%, hand, foot, and mouth disease in 66.5%, herpangina in 36.2%, streptococcal infection in 48.7%, RSV infection in 63.8%, and mumps in 8.5% of the facilities.

3.3. One-year facility-reported infectious diseases by facility type

Statistical analysis revealed significant differences among facility types in the 1-year reporting rates for adenovirus infection, hand, foot, and mouth disease, herpangina, streptococcal, influenza virus, norovirus, rotavirus, and RSV infections (Table 3). Adjusted residuals greater than 1.96 or less than −1.96 indicated significantly higher or lower 1-year facility-level reporting rates than expected. Significant differences in 1-year facility-level reporting rates for adenovirus and hand, foot, and mouth disease were observed among facility types, as indicated by adjusted residuals. Residual analysis for adenovirus infection revealed values of −6.5 for kindergartens, 2.3 for daycare centres, and 2.6 for certified childcare centres. Regarding hand, foot, and mouth disease, adjusted residuals were −7.5 for kindergartens, 3.2 for daycare centres, and 2.4 for certified childcare centres. Significant differences in the 1-year facility-level reporting rates of herpangina and RSV infection were observed between kindergartens and daycare centres. Specifically, adjusted residuals for herpangina were −6.2 for kindergartens and 3.5 for daycare centres. For the RSV infection, the adjusted residuals were −5.2 for kindergartens and 2.7 for daycare centres. Residual analysis showed significant differences in 1-year facility-level reporting rates for streptococcal and norovirus infections between kindergartens and certified childcare centres, whereas for rotavirus infection, a significantly lower reporting rate was observed only in kindergartens. For streptococcal infections, the adjusted residual was −3.9 for kindergartens and 3.7 for certified childcare centres. Similarly, for norovirus infection, the adjusted residuals were −3.7 and 2.6 for kindergartens and certified childcare centres, respectively. For rotavirus infection, the adjusted residuals were −2.5 for kindergartens.

Table 2. Characteristics of facilities and managers by facility type (*n* = 710)

	Kindergartens (*n* = 110)	Daycare centres (*n* = 380)	Certified childcare centres (*n* = 220)	Total (*n* = 710)
Age of managers (years)	55.7 (9.3)	55.3 (9.4)	54.7 (10.0)	55.2 (9.6)
Number of childcare workers	19.3 (15.3)	31.9 (22.9)	34.8 (25.8)	30.8 (23.4)
Number of children	95.0 (73.6)	83.8 (43.5)	120.3 (63.7)	96.8 (57.9)

Note: Values are presented as mean (standard deviation).

Table 3. One-year facility-level reporting rates of child-specific infections (*n* = 710)

	Facilities reporting infection, *n* (%)			
	Kindergartens (*n* = 110)	Daycare centres (*n* = 380)	Certified childcare centres (*n* = 220)	Total (*n* = 710)
COVID-19 infection	106 (96.4)	367 (96.6)	215 (97.7)	688 (96.9)
Adenovirus infection*	27 (24.5)[#]	216 (56.8)[##]	132 (60.0)[##]	375 (52.8)
Hand, foot, and mouth disease*	39 (35.5)[#]	273 (71.8)[##]	160 (72.7)[##]	472 (66.5)
Herpangina*	11 (10.0)[#]	160 (42.1)[##]	86 (39.1)	257 (36.2)
Streptococcal infection*	35 (31.8)[#]	181 (47.6)	130 (59.1)[##]	346 (48.7)
Influenza virus infection*	9 (8.2)[#]	85 (22.4)	51 (23.2)	145 (20.4)
Norovirus infection*	8 (7.3)[#]	79 (20.8)	58 (26.4)[##]	145 (20.4)
Rotavirus infection*	2 (1.8)[#]	30 (7.9)	23 (10.5)	55 (7.7)
RSV infection*	46 (41.8)[#]	260 (68.4)[##]	147 (66.8)	453 (63.8)
Mumps	10 (9.1)	28 (7.4)	22 (10.0)	60 (8.5)

Note: Values are presented as *n* (%) of facilities reporting at least one case within 1 year. * Infections showing a significant overall difference based on the chi-square test. [#] Significantly lower values based on residual analysis following the chi-square test (adjusted residuals < −1.96). [##] Significantly higher values based on residual analysis following the chi-square test (adjusted residuals > 1.96). *Abbreviation*: RSV, respiratory syncytial virus.

3.4. Regional analysis of infectious diseases

Table 4 shows regional distribution of facilities reporting infectious diseases (1-year facility-level reporting rates). COVID-19 infections were reported in over 90% of facilities across all regions. Reports of other infections varied, with adenovirus infection reported in 40–68% of facilities. Hand, foot, and mouth disease, herpangina, streptococcal, influenza virus, norovirus infection, rotavirus, RSV, and mumps infections were reported in 36–72%, 16–44%, 28–61%, 9–33%, 16–27%, 0–15%, 48–75%, and 2–12% of facilities, respectively. Significant regional differences in 1-year facility-level reporting rates were observed for adenovirus, hand, foot, and mouth disease, streptococcal, influenza virus, and rotavirus infections. Residual analysis identified significant deviations in 1-year facility-level reporting rates for adenovirus infections in Tohoku (adjusted residuals: −2.4), Kanto (adjusted residuals: −2.3), and Kyushu/Okinawa (adjusted residuals: 3.2). For hand, foot, and mouth disease, significant differences were observed in Kanto (adjusted residuals 2.0) and Shikoku (adjusted residuals −3.3). The residuals for streptococcal infections were significantly different in Tohoku (adjusted residuals −3.2), Shikoku (adjusted residuals −2.1), and Kyushu/Okinawa (adjusted residuals 2.3). The residuals for influenza infection were −2.4 for Tohoku, −2.2 for Hokuriku/Koshinetsu, and 3.4 for Kyushu/Okinawa. The adjusted residual for rotavirus infection was −3.2 for Kanto.

3.5. Population density–based analysis of infectious diseases

Table 5 shows a summary of the 1-year facility-level reporting rates for child-specific infectious diseases by population density category. COVID-19 infection was reported in over 95% of facilities across all density categories, with no significant differences observed. Adenovirus infection showed a non-linear association with population density, characterised by a peak at medium density. Hand, foot, and mouth disease exhibited a significant increase with higher population density. Influenza virus infection showed a complex pattern, with a medium-density peak and a significant linear trend. Rotavirus infection showed an inverse association with population density, with higher reporting rates in low-density areas and lower rates in high-density areas. RSV infection also exhibited a non-linear pattern, characterised by a medium-density trough. In contrast, herpangina, streptococcal infection, norovirus infection, and mumps were not significantly associated with population density.

4. Discussion

In this study, facility-level reporting rates of child-

Table 4. One-year facility-level reporting rates of child-specific infections by region (n = 710)

	Hokkaido	Tohoku	Kanto	Hokuriku/Koshinetsu	Tokai	Kinki	Chugoku	Shikoku	Kyushu/Okinawa	Total
COVID-19 infection	38 (97.4)	84 (97.7)	188 (96.9)	62 (100.0)	74 (97.4)	79 (91.9)	47 (94.0)	25 (100.0)	91 (98.9)	688 (96.9)
Adenovirus infection*	25 (64.1)	35 (40.7)$^{\#}$	89 (45.9)$^{\#}$	34 (54.8)	36 (47.4)	53 (61.6)	27 (54.0)	13 (52.0)	63 (68.5)$^{\#\#}$	375 (52.8)
Hand, foot, and mouth disease*	24 (61.5)	53 (61.6)	140 (72.2)$^{\#\#}$	40 (64.5)	51 (67.1)	60 (69.8)	30 (60.0)	9 (36.0)$^{\#}$	65 (70.7)	472 (66.5)
Herpangina	15 (38.5)	29 (33.7)	81 (41.8)	22 (35.5)	24 (31.6)	24 (27.9)	17 (34.0)	4 (16.0)	41 (44.6)	257 (36.2)
Streptococcal infection*	24 (61.5)	28 (32.6)$^{\#}$	99 (51.0)	34 (54.8)	38 (50.0)	42 (48.8)	19 (38.0)	7 (28.0)$^{\#}$	55 (59.8)$^{\#\#}$	346 (48.7)
Influenza virus infection*	8 (20.5)	9 (10.5)$^{\#}$	38 (19.6)	6 (9.7)$^{\#}$	14 (18.4)	24 (27.9)	10 (20.0)	5 (20.0)	31 (33.7)$^{\#\#}$	145 (20.4)
Norovirus infection	8 (20.5)	16 (18.6)	32 (16.5)	17 (27.4)	15 (19.7)	21 (24.4)	8 (16.0)	5 (20.0)	23 (25.0)	145 (20.4)
Rotavirus infection*	6 (15.4)	7 (8.1)	5 (2.6)$^{\#}$	8 (12.9)	8 (10.5)	6 (7.0)	5 (10.0)	0 (0.0)	10 (10.9)	55 (7.7)
RSV infection	27 (69.2)	58 (67.4)	120 (61.9)	42 (67.7)	57 (75.0)	56 (65.1)	25 (50.0)	12 (48.0)	56 (60.9)	453 (63.8)
Mumps	1 (2.6)	6 (7.0)	16 (8.2)	5 (8.1)	7 (9.2)	10 (11.6)	2 (4.0)	3 (12.0)	10 (10.9)	60 (8.5)

Note: Values are shown as the number of facilities (% reporting at least one case per year). * Represents infections that were significantly different based on the chi-square test. $^{\#}$ Indicates significantly low values (adjusted residuals < −1.96) based on residual analysis following a chi-square test. $^{\#\#}$ Indicates significantly high values (adjusted residuals > 1.96) based on residual analysis following a chi-square test. *Abbreviation:* RSV, respiratory syncytial virus.

Table 5. One-year facility-level reporting rates of child-specific infectious diseases by population density category (*n* = 710)

	Low density (*n* = 187)	Medium density (*n* = 167)	High density (*n* = 356)	Overall pattern
COVID-19 infection	184 (98.4)	163 (97.6)	341 (95.8)	No association
Adenovirus infection*	94 (50.3)	103 (61.7)##	178 (50.8)	Medium-density peak
Hand, foot, and mouth disease†	117 (62.6)	104 (62.3)	251 (70.5)##	Increase toward high density
Herpangina	66 (35.3)	62 (37.1)	129 (36.2)	No association
Streptococcal infection	86 (46.0)	81 (48.5)	179 (50.3)	No association
Influenza virus infection*†	23 (12.3)#	46 (27.5)##	76 (21.3)	Complex pattern (significant linear trend)
Norovirus infection	41 (21.9)	36 (21.6)	68 (19.1)	No association
Rotavirus infection*†	21 (11.2)##	15 (9.0)	19 (5.3)#	Inverse density association
RSV infection*	127 (67.9)	93 (55.7)#	233 (65.4)	Medium-density trough
Mumps	12 (6.4)	15 (9.0)	33 (9.3)	No association

Note: Values are shown as the number of facilities (% reporting at least one case per year). * Represents infections that were significantly different based on the chi-square test. † Represents infections with a significant linear trend based on the linear-by-linear association test. ## Indicates significantly high values (adjusted residuals > 1.96) based on residual analysis following a chi-square test. # Indicates significantly low values (adjusted residuals < −1.96) based on residual analysis following a chi-square test. *Abbreviation*: RSV, respiratory syncytial virus.

specific infectious diseases, including COVID-19, in kindergartens, daycare centres, and certified childcare centres across Japan, were examined with a particular focus on differences by facility type and regional context. The findings revealed significant differences in occurrence of infections by facility type and region, indicating that the burden of infectious diseases in childcare and early childhood education settings varied across institutional and local contexts during the COVID-19 pandemic.

4.1. Overall trends in child-specific infectious diseases during the COVID-19 pandemic

Notably, COVID-19 was reported in nearly all facilities, highlighting its pervasive impact across childcare environments. This widespread reporting is consistent with national surveillance data indicating that the survey period coincided with the sixth and seventh waves, during which a substantial proportion of reported COVID-19 cases occurred among children aged ≤ 10 years in Japan (*14*).

In contrast, other child-specific infectious diseases, such as influenza and norovirus, typically show regular seasonal epidemics during non-pandemic periods. Reportedly, substantial reductions in several seasonal infectious diseases occurred during the COVID-19 pandemic. Specifically, Sakamoto *et al*. reported that incidence of seasonal influenza was markedly lower than pre-pandemic levels (*15*), and Fukuda *et al.* observed significant declines in influenza and rotavirus gastroenteritis among hospitalised children (*3*). Similar reductions were also reported in other countries during periods when COVID-19 control measures were widely implemented (*16*). These findings cannot be directly compared with pre-pandemic facility-level data; however, they provide important context for interpreting relatively low reporting rates of child-specific infectious diseases observed in the present study.

4.2. Facility-type differences in child-specific infectious diseases

By facility type, kindergartens showed significantly lower 1-year facility-level reporting rates for several infections, including hand, foot, and mouth disease, herpangina, adenovirus, streptococcal infection, influenza virus, norovirus, rotavirus, and RSV, than daycare centres and/or certified childcare centres. Several child-specific infectious diseases are known to occur more frequently in younger children approximately 2 years of age than in older preschool children aged 5–6 years, including adenovirus infection (*17,18*), hand, foot, and mouth disease (*19,20*), herpangina (*21,22*), influenza virus infection (*23,24*), norovirus gastroenteritis (*25,26*), rotavirus gastroenteritis (*27,28*), and RSV infection (*29,30*). Reports show that immunological maturity increases with age and that younger children have limited immune responses to common pathogens, whereas older preschool children are more likely to have developed partial immunity through prior exposures (*31,32*).

In contrast, with regard to streptococcal infections, which typically peak around early school age, particularly at approximately 5 years of age, in the pre-pandemic period in Japan (*33*), the different age distribution observed in the present study suggests that age-specific differences may have influenced occurrence of infection, thereby affecting effectiveness of infection prevention measures during the COVID-19 pandemic.

This interpretation is further supported by age-related differences in the feasibility of infection prevention behaviours. Kindergarten-aged children can generally understand and practice basic infection prevention behaviours, such as hand hygiene and mask use, enabling preventive strategies to be directly implemented at the child level. However, younger children in daycare and certified childcare centres have limited ability to independently practice such behaviours; hence, preventive measures rely largely on caregivers, which

may have reduced their overall effectiveness.

Consistent with this explanation, it has been previously demonstrated that non-pharmaceutical interventions introduced to prevent COVID-19 transmission also led to substantial reductions in many other childhood infectious diseases (*16,34*). Collectively, lower reporting rates observed in kindergartens likely reflect a combination of age-related biological factors, including increasing immunological maturity and accumulated immunity, and greater feasibility of implementing infection prevention behaviours at the child level.

4.3. Regional variation in child-specific infectious diseases

Regarding regional variation in child-specific infectious diseases, initial comparisons indicated lower 1-year facility-level reporting rates in less densely populated regions, such as Shikoku, Tohoku, and Hokuriku/Koshinetsu, whereas higher reporting rates were observed in more urbanised regions, including Kanto and Kyushu/Okinawa. However, further analyses stratified by population density revealed heterogeneous and pathogen-specific patterns, indicating that regional variation in child-specific infectious diseases cannot be explained by population density alone.

Specifically, the reporting rates of hand, foot, and mouth disease increased with higher population density, consistent with previous epidemiological reports indicating that close contact in urbanised settings facilitates transmission (*20*). Influenza virus infection also showed a significant linear trend across population density categories, consistent with reports indicating that population concentration and human mobility contribute to influenza transmission (*23,34*).

Nevertheless, several infections, including herpangina, norovirus infection, and mumps, showed no clear association with population density. Streptococcal infection showed significant regional differences but did not show a linear association with population density. Furthermore, rotavirus infection was inversely associated with higher reporting rates in low-density areas, whereas adenovirus and RSV infections exhibited non-linear patterns. These heterogeneous findings are consistent with previous findings suggesting that paediatric infectious diseases occurrence is strongly influenced by age distribution, childcare attendance patterns, facility characteristics, and local infection control practices, rather than by population density alone (*28,29,34*).

Collectively, the present results indicate that regional differences in child-specific infectious disease occurrence reflect a complex interplay between population density and disease-specific epidemiological characteristics, underscoring the importance of considering pathogen-specific transmission dynamics when interpreting regional patterns.

4.4. Research Limitations

This study has some limitations. First, the survey response rate was relatively low (15.4%; valid response rate: 14.2%), which may limit the generalisability of the findings. Facilities with higher awareness of infection control or greater interest in infectious disease issues may have been more likely to respond, potentially introducing selection bias.

Second, the survey was conducted between January and April 2023, a period characterised by high COVID-19 prevalence among children in Japan. Heightened awareness, increased testing, and enhanced reporting practices during this period may have influenced facility-level reporting rates for COVID-19 and other child-specific infectious diseases. Therefore, reported rates may differ from those observed after May 2023, when COVID-19 was reclassified as a category 5 infectious disease in Japan.

Third, detailed information on socioeconomic factors, such as parental employment status, household income, or access to healthcare, was not collected, which may influence childcare facility selection and infection reporting practices. Furthermore, population density was used as a proxy measure for regional characteristics associated with infection transmission and may not fully capture local childcare environments, including facility size, class composition, staff-to-child ratios, or patterns of interaction among children. Substantial heterogeneity may also exist within the same population density category.

Accordingly, regional differences in child-specific infectious diseases should be interpreted with caution. In future studies, response rates should be increased to improve representativeness, for example, by providing participating facilities with feedback on study findings; more detailed facility-level and community-level indicators should be incorporated. In addition, longitudinal research is needed to examine how changes in COVID-19 classification and infection control practices influence occurrence and reporting of child-specific infectious diseases over time in childcare and early childhood education facilities.

5. Conclusions

This study provides empirical evidence on how facility type and regional context shape occurrence of child-specific infectious diseases during the COVID-19 pandemic in Japan by examining facility-level reporting rates across different childcare settings nationwide. Facility type showed a particularly strong association with infection occurrence, with kindergartens consistently exhibiting lower 1-year facility-level reporting rates across multiple child-specific infectious diseases. This finding integrates age-related differences, feasibility of infection prevention behaviours, and the

aforementioned pandemic-related non-pharmaceutical interventions. At the regional level, while initial comparisons suggested higher reporting rates in more urbanised areas, population-density-stratified analyses revealed heterogeneous and pathogen-specific patterns, highlighting the importance of disease-specific epidemiological characteristics.

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