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Association of Age and Pediatric Household Transmission of SARS-CoV-2 Infection

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IMPORTANCE As a result of low numbers of pediatric cases early in the COVID-19 pandemic, pediatric household transmission of SARS-CoV-2 remains an understudied topic.

OBJECTIVE To determine whether there are differences in the odds of household transmission by younger children compared with older children.

DESIGN, SETTING, AND PARTICIPANTS This population-based cohort study took place between June 1 and December 31, 2020, in Ontario, Canada. Private households in which the index case individual of laboratory-confirmed SARS-CoV-2 infection was younger than 18 years were included. Individuals were excluded if they resided in apartments missing suite information, in households with multiple index cases, or in households where the age of the index case individual was missing.

EXPOSURES Age group of pediatric index cases categorized as 0 to 3, 4 to 8, 9 to 13, and 14 to 17 years.

MAIN OUTCOMES AND MEASURES Household transmission, defined as households where at least 1 secondary case occurred 1 to 14 days after the pediatric index case.

RESULTS A total of 6280 households had pediatric index cases, and 1717 households (27.3%) experienced secondary transmission. The mean (SD) age of pediatric index case individuals was 10.7 (5.1) years and 2863 (45.6%) were female individuals. Children aged 0 to 3 years had the highest odds of transmitting SARS-CoV-2 to household contacts compared with children aged 14 to 17 years (odds ratio, 1.43; 95% CI, 1.17-1.75). This association was similarly observed in sensitivity analyses defining secondary cases as 2 to 14 days or 4 to 14 days after the index case and stratified analyses by presence of symptoms, association with a school/childcare outbreak, or school/childcare reopening. Children aged 4 to 8 years and 9 to 13 years also had increased odds of transmission (aged 4-8 years: odds ratio, 1.40; 95% CI, 1.18-1.67; aged 9-13 years: odds ratio, 1.13; 95% CI, 0.97-1.32).

CONCLUSIONS AND RELEVANCE This study suggests that younger children may be more likely to transmit SARS-CoV-2 infection compared with older children, and the highest odds of transmission was observed for children aged 0 to 3 years. Differential infectivity of pediatric age groups has implications for infection prevention within households, as well as schools/childcare, to minimize risk of household secondary transmission. Additional population-based studies are required to establish the risk of transmission by younger pediatric index cases.

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Supplemental content

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The role of children in the transmission of SARS-CoV-2 infection requires further study. Early in the pandemic, when countries implemented lockdown measures, close contact was mostly limited to households and testing strategies tended to prioritize health care workers and symptomatic individuals.[1-4] As a result, there were relatively few diagnosed pediatric cases of COVID-19,[5] and it appeared that the proportion of children involved in the transmission of infection was small compared with adults.[2,6,7] Since many jurisdictions relaxed public health measures and reopened educational facilities in fall 2020, the number of pediatric COVID-19 cases has grown, providing the opportunity to better characterize the infectivity of children.

To date, household studies have typically only compared infectivity between young and old individuals, often grouping children with young adults[8-12] or dichotomizing age to older adults vs younger adults/children.[13,14] These studies have reported mixed results, with some finding that older age (≥20 years) was associated with increased infectivity,[6,8-10,15,16] 1 study finding younger age (<20 years),[12] and others finding no age effect.[11,13-15,17-19] Conversely, few household studies have examined differences in infectivity among children,[15,16,20-23] likely owing to insufficient sample size.[2,24] Two meta-analyses reported no significant differences between younger children and older children for household susceptibility to SARS-CoV-2[2,15]; however, it remains unclear if this holds true for infectivity. These findings warrant a closer look at household transmission of SARS-CoV-2 by children and whether there are any differences in the likelihood of transmission for particular age groups.

We sought to conduct an age analysis of residents aged 0 to 17 years in Ontario, Canada, who were the index case of SARS-CoV-2 infection in their household between June and December 2020. Pediatric index cases were divided into 4 age groups (0-3, 4-8, 9-13, and 14-17 years) to provide a more granular picture of any age differences. We were also interested in comparing characteristics of index cases by age group, exploring the direction of transmission by age, and assessing whether factors such as symptoms, school/childcare reopening, or school/childcare outbreaks were associated with differences in the odds of transmission from children to their household members.

Key Points

Question Are there differences in the odds of household transmission of SARS-CoV-2 by younger children compared with older children?

Findings In this cohort study of 6280 households with pediatric index cases, the adjusted odds of household transmission by children aged 0 to 3 years was 1.43 compared with children aged 14 to 17 years.

Meaning Younger children may have greater risk of transmitting SARS-CoV-2 to caregivers and siblings in the household than older children.

Methods

Study Population

We derived the study cohort from case data that were reported in provincial disease systems by public health units across Ontario, Canada's most populous province. All individuals with laboratory-confirmed SARS-CoV-2 infection (via positive nucleic acid amplification test) between June 1 and December 31, 2020, were included. We obtained ethics approval from Public Health Ontario's Research Ethics Board. Data were deidentified so informed consent was not required.

Identification of Private Households

Addresses of case individuals were reviewed and classified as either private households, defined as individual houses or apartments/suites within multiunit dwellings, or congregate settings (eg, homeless shelters or long-term care homes). We excluded any individuals with missing or incomplete address information, individuals residing in congregate settings, and individuals identified as residing in multiunit dwellings but missing suite information. Addresses were then matched between cases using a natural language processing algorithm from Python's "sklearn" library to identify multicase households. Details of the address matching process have been described previously.[25]

Outcomes

The outcome of interest was secondary household transmission of SARS-CoV-2 infection by a pediatric index case individual (aged 0-17 years). Index cases were defined as the earliest case of a household and were identified by comparing symptom onset dates of cases in the household.[2] If symptom onset date was missing, we used specimen collection date as a proxy; no cases were missing both dates. Secondary cases were defined as individuals (adult or pediatric) who had disease onset 1 to 14 days after the index case, per previous studies of household transmission.[2,21,22,25] We excluded households with index cases missing age (n = 12) and households with multiple index cases (ie, multiple cases occurring on the earliest case date of the household; n = 4335) because they would present challenges for estimating associations between household transmission and characteristics of the index case.

Individual-Level and Neighborhood-Level Characteristics of Index Cases

The main exposure of interest was age group of the index case: 0 to 3, 4 to 8, 9 to 13, and 14 to 17 years. We also a priori selected a group of individual-level and neighborhood-level characteristics of the index case to adjust for in the models. At the individual level, we included gender (which was reported in provincial disease systems), month of disease onset, and testing delay between symptom onset and specimen collection. For the testing delay, we additionally categorized individuals who were asymptomatic, identified as individuals who were missing symptom onset date (thus specimen collection date was used) and were reported as asymptomatic in provincial reportable disease systems. As we only had individual-level household size information reported for 59.6% of index cases,

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we also included mean family size for the neighborhood of the index case. Mean family size was available from 2016 Canadian census records for aggregate dissemination areas across Ontario, representing areas of approximately 5000 to 15 000 persons.

For stratified and sensitivity analyses, we additionally included information on the presence of symptoms, whether the index case was linked to a school/childcare outbreak (identified by public health units through their investigations), and whether the index case individual's disease onset was before or after school/childcare reopening (depending on the age of the index case individual). In Ontario, schools reopened in mid-September 2020 and childcare reopened mid-June 2020.

Statistical Analysis

We carried out descriptive analyses to assess the characteristics of pediatric index cases across the 4 age groups and included index case individuals older than 17 years for comparison. Direction of transmission from index case to secondary case by age was also examined. We then applied 3 logistic regression models to obtain odds ratios (OR) and 95% confidence intervals for the associations between index case age group and odds of transmitting SARS-CoV-2 to household contacts: (1) a crude, unadjusted model; (2) a model adjusted for gender and month of disease onset (adjusted model 1); and (3) a model adjusted for gender, month of disease onset, testing delay, and mean family size (adjusted model 2).

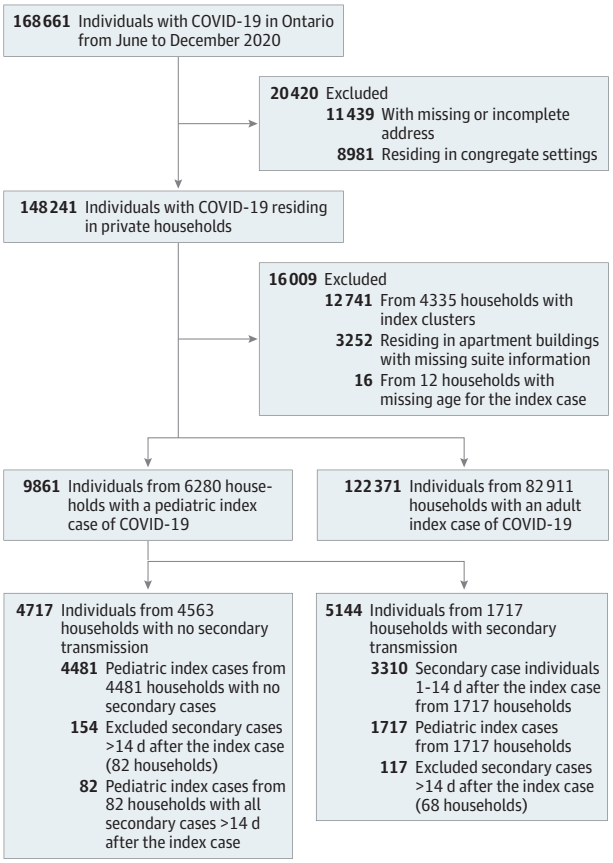
For stratified analyses, these models were refit to subsets of the data broken down by 3 additional index case characteristics: (1) presence of symptoms; (2) association with a school/childcare outbreak; and (3) disease onset before school/childcare reopening.

For sensitivity analyses, we first updated the definition of secondary cases to increase certainty of the direction of transmission from the index case; we reran the analyses with secondary case individuals who developed symptoms 2 to 14 days after the index case and 4 to 14 days after the index case. Second, we adjusted for individual-level household size instead of neighborhood-level mean family size in the subset of index cases that had this information available. Third, we ran the analysis on a symptomatic cohort, restricting to index case and secondary case individuals who had symptoms reported or a symptom onset date available. Last, we reran the symptomatic cohort analysis with the adjusted definitions for secondary cases (ie, 2-14 days and 4-14 days). Two-sided *P* values were statistically significant at .05. Analyses were performed using RStudio version 1.2.5033 (RStudio).

Results

Between June and December 2020, a total of 6280 private households had a pediatric index case (**Figure 1**). The mean (SD) age of index case individuals was 10.7 (5.1) years and 2863 (45.6%) were female individuals. Of 6280 households, 1717 (27.3%) experienced secondary household transmission, leading to a median of 2 secondary cases (25th percentile, 1 case; 75th percentile, 2 cases; 90th percentile, 3 cases). This corresponded with an overall crude rate of transmission of 27 341 per 100 000 households with pediatric index cases. Pediatric index cases most frequently transmitted infection to individuals aged 0 to 20 years or 30 to 50 years, with older children tending to transmit to older individuals in those age ranges (**Figure 2**).

Figure 1. Flow Diagram of Study Cohort



The proportion of index cases in each age group increased with age, with 12% (776 of 6280) aged 0 to 3 years, 20% (1257 of 6280) aged 4 to 8 years, 30% (1881 of 6280) aged 9 to 13 years, and 38% (2376 of 6280) aged 14 to 17 years (**Table 1**). Compared with index case indivudals in the oldest age group, younger index case individuals had a higher proportion associated with a school/childcare outbreak and shorter testing delays. Index case individuals aged 4 to 8 years and 9 to 13 years had higher proportion with no symptoms reported compared with index case individuals aged 14 to 17 years or aged 0 to 3 years. Across all age groups, more index case individuals had disease onset in the fall/winter (September-December) compared with the summer (June-August), which aligns with the trajectory of the second wave of the pandemic in Ontario.

Associations With Index Case Characteristics

Compared with index case individuals aged 14 to 17 years, those aged 0 to 3 years had higher odds of transmitting SARS-CoV-2 to household contacts in all 3 models (crude model: OR, 1.20;

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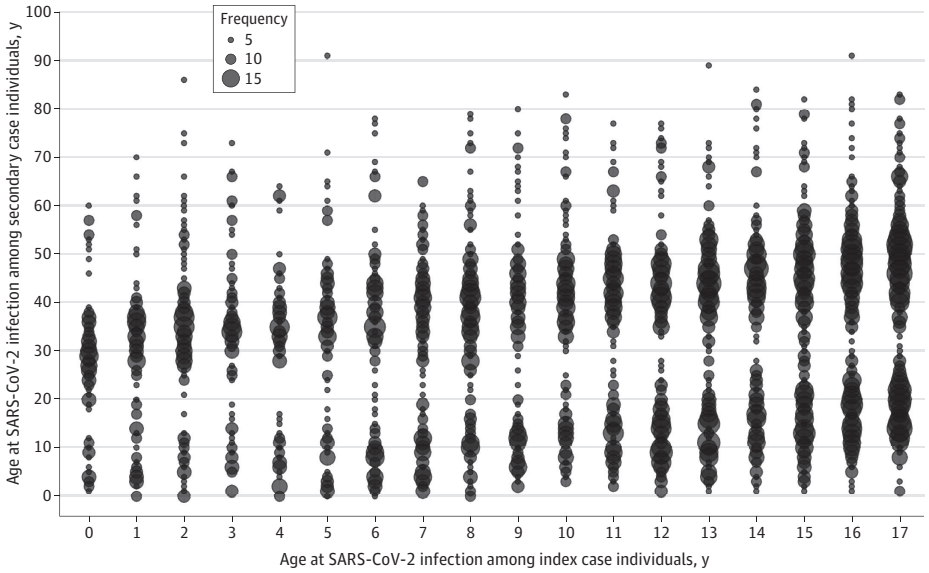
Figure 2. Bubble Plot of Age-to-Age Transmission



95% CI, 1.01-1.44; adjusted model 1: OR, 1.21; 95% CI, 1.01-1.45; adjusted model 2: OR, 1.43; 95% CI, 1.17-1.75) (**Table 2**). There were no significant differences in the odds of transmission by the 4- to 8-year and 9- to 13-year age groups, with the exception of adjusted model 2 for index case individuals aged 4 to 8 years (OR, 1.40; 95% CI, 1.18-1.67). Additionally, there were incremental odds of transmitting infection with longer testing delays compared with a 0-day delay (1-day delay: OR, 1.24; 2-day delay: OR, 1.59; 3-day delay: OR, 1.97; 4-day delay: OR, 2.38; ≥5-day delay: OR, 2.98), as well as increased odds with larger mean family size (OR, 1.63 per person increase; 95% CI, 1.43-1.86). No significant differences were observed by gender or by month of disease onset.

In stratified analyses, we did not observe significant heterogeneity in the odds of transmitting SARS-CoV-2 to household contacts between index case individuals with vs without symptoms reported, index case individuals not associated vs associated with a school/childcare outbreak, or index case individuals with disease onset before vs after school/childcare reopening (eTables 1 and 2 in the Supplement).

Sensitivity analyses of the crude model and adjusted model 1 resulted in the same direction of association for the 0- to 3-year age group, but confidence intervals widened (eTable 3 in the Supplement). In adjusted model 2, associations were largely unchanged with the 2- to 14-day definition, when controlling for individual-level household size, and in the symptomatic case analysis for the 0- to 3-year age group (adjusted model 2: OR, 1.43; 95% CI, 1.17-1.75; 2-14 days: OR, 1.37; 95% CI, 1.11-1.69; household size: OR, 1.31; 95% CI, 1.02-1.67; symptomatic: OR, 1.32; 95% CI, 1.06-1.64) and 4- to 8-year age group (adjusted model 2: OR, 1.40; 95% CI, 1.18-1.67; 2-14 days: OR, 1.33; 95% CI, 1.11-1.60; household size: OR, 1.31; 95% CI, 1.06-1.62; symptomatic: OR, 1.33; 95% CI, 1.10-1.61). Associations for the 0- to 3-year and 4- to 8-year age groups were also similar to adjusted model 2 in the combined 2- to 14-day definition and symptomatic case analysis (age 0-3 years: OR, 1.25; 95% CI, 1.00-1.57; age 4-8 years: OR, 1.23; 95% CI, 1.00-1.50), as well as for the 0- to 3-year age group with the 4- to 14-day definition (OR, 1.35; 95% CI, 1.07-1.70) and after further restricting to symptomatic cases (OR, 1.26; 95% CI, 0.96-1.64).

Discussion

In this study of 6280 pediatric index cases, we observed that children aged 0 to 3 years had greater odds of transmitting SARS-CoV-2 to household contacts compared with children aged 14 to 17 years. This association was observed irrespective of factors such as presence of symptoms, school/childcare reopening, or association with a school/childcare outbreak. We also observed some evidence of greater odds of household transmission by children aged 4 to 8 years after controlling for testing delays and neighborhood-level mean family size (as well as individual-level household size). We identified clustering in our age-to-age transmission plot, likely reflecting the age structure of households with younger individuals living with and transmitting to younger caregivers and siblings.

To date, there have been challenges with analyzing the role of children in household spread of SARS-CoV-2 owing to low numbers of pediatric index cases. We identified pediatric index case individuals younger than 18 years in approximately 7% of households (6280 of 89 191), which is similar to the proportions observed in international studies from Greece (9% of households with pediatric index cases; the study defined pediatric as age <18 years),[26] Switzerland (8% of households with pediatric index cases age <16 years),[27] Denmark (5% of households with pediatric index cases age <20 years),[21] Hunan, China (5% of households with pediatric index cases age <15 years),[19] and Guangzhou, China (5% of households with pediatric index cases age <20 years)[9]; higher than studies from South

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Table 1. Characteristics of Pediatric Index Cases by Age Group

Characteristic	Age, No. (%), y				
	0-3	4-8	9-13	14-17	>17
Total No.	766	1257	1881	2376	82 911
Age, median (IQR), y	2 (1-2)	6 (5-7)	11 (10-12)	16 (15-17)	40 (28-54)
Gender					
Female individuals	374 (49.1)	586 (46.9)	820 (43.9)	1083 (45.7)	39 891 (48.3)
Male individuals	385 (50.5)	663 (53.0)	1045 (55.9)	1283 (54.1)	42 572 (51.5)
Month of disease onset					
June	26 (3.4)	33 (2.6)	35 (1.9)	63 (2.7)	2945 (3.6)
July	18 (2.3)	30 (2.4)	31 (1.6)	69 (2.9)	2229 (2.7)
August	13 (1.7)	22 (1.8)	27 (1.4)	81 (3.4)	1744 (2.1)
September	87 (11.4)	155 (12.3)	167 (8.9)	227 (9.6)	8081 (9.7)
October	126 (16.4)	183 (14.6)	299 (15.9)	378 (15.9)	12 557 (15.1)
November	186 (24.3)	342 (27.2)	548 (29.1)	638 (26.9)	21 934 (26.5)
December	310 (40.5)	492 (39.1)	774 (41.1)	920 (38.7)	33 421 (40.3)
Testing delay, median (IQR), d[a]	1 (0-4)	1 (0-4)	2 (0-4)	2 (0-5)	2 (1-4)
Testing delay distribution, d					
Asymptomatic[b]	104 (15.3)	236 (22.5)	324 (20.1)	278 (13.1)	6541 (9.1)
<0[c]	37 (5.4)	71 (6.8)	72 (4.5)	107 (5.1)	3502 (4.9)
0	97 (14.3)	106 (10.1)	135 (8.4)	166 (7.8)	7069 (9.8)
1	113 (16.6)	149 (14.2)	219 (13.6)	298 (14.1)	11 137 (15.5)
2	84 (12.4)	124 (11.8)	223 (13.8)	283 (13.4)	11 242 (15.6)
3	69 (10.1)	97 (9.3)	153 (9.5)	242 (11.4)	8794 (12.2)
4	41 (6.0)	54 (5.2)	114 (7.1)	194 (9.2)	6122 (8.5)
≥5	135 (19.9)	211 (20.1)	372 (23.1)	548 (25.9)	17 619 (24.5)
Mean family size, median (IQR)[d]	3.2 (2.9-3.6)	3.2 (3.0-3.5)	3.3 (3.0-3.6)	3.3 (3.1-3.7)	3.3 (3.0-3.6)
Symptoms reported	586 (76.5)	822 (65.4)	1296 (68.9)	1856 (78.1)	65 964 (79.6)
Associated with a school/childcare outbreak	128 (16.7)	229 (18.2)	407 (21.6)	154 (6.5)	588 (0.7)
Before school/childcare reopening[e]	8 (1.0)	99 (7.9)	108 (5.7)	254 (10.7)	8189 (9.9)
Household size, median (IQR)	4 (3-5)	4 (4-5)	4 (4-5)	4 (4-5)	3 (2-4)

Abbreviation: IQR, interquartile range.

[a] A total of 778 pediatric index case individuals were excluded from the testing delay models who had no COVID-19 symptoms reported in provincial reportable disease systems, were missing symptom onset date, and were not reported as asymptomatic.

[b] Index case individuals who were asymptomatic were identified as cases that were missing symptom onset date (thus specimen collection date was used) and were reported as asymptomatic in provincial reportable disease systems.

[c] Index case individuals with a testing delay of <0 days were those who were tested prior to the onset of symptoms.

[d] Mean family size was derived from neighborhood-level census data.

[e] Reopening dates: June 12, 2020, for index cases aged 0-3 years; September 8, 2020, for index cases aged >3 years and residing outside Toronto, Canada; September 15, 2020, for index cases aged >3 years and residing in Toronto.

Korea (3% of households with pediatric index cases age <20 years)[20] and Wuhan, China (1% of households with pediatric index cases age <20 years)[12]; and lower than a study from the US (14% of households with pediatric index cases age <18 years).[23] Meta-analyses examining the age of household index cases additionally reported that 3% to 19% of households had pediatric index cases.[2,15] Further, in our study, presumed household transmission by a pediatric index case occurred in 27% of households using the 1- to 14-day definition of secondary transmission (24% and 16% using 2- to 14- and 4- to 14-day definitions, respectively), which is close to an estimate from Catalonia, Spain (28%).[16]

Of the aforementioned studies that included pediatric index cases, only a subset compared associations between pediatric age groups and household transmission with mixed findings. Our results align with 2 Danish studies that found that among children, there were increased odds of transmitting infection with younger age (age 0-5 years: OR, 1.11; 95% CI, 1.01-1.19 vs age 10-15 years: OR, 0.82; 95% CI, 0.78-0.85, compared with the age 30- to 35-year reference group).[21,22] One study from Spain also found that the highest OR for transmission was among younger index case individuals 0 to 2 years (OR, 2.27; 95% CI, 0.62-8.35 compared with the age 12- to 15-year reference group), but confidence intervals were wide.[16] Other studies instead compared secondary attack rates between pediatric age groups, including a study from South Korea that reported household contacts of index case individuals aged 10 to 19 years had the highest secondary attack rate at 18.6% (95% CI, 14.0%-24.0%) vs 5.3% (95% CI, 1.3%-13.7%) for index case individuals aged 0 to 9 years.[20] Conversely, a meta-analysis reported no significant difference in household secondary attack rates for index case individuals aged 10 to 19 years vs index case individuals aged 0 to 9 years.[15] Similarly, a study from Tennessee and Wisconsin observed higher household secondary attack rate for younger pediatric index case individuals, but confidence intervals were overlapping; the estimated secondary attack rates were 53% (95% CI, 31%-74%) for index case individuals younger than 12 years and 38% (95% CI, 23%-56%) for index case individuals aged 12 to 17 years.[23]

The differences in infectivity for pediatric age groups across studies may be explained by differences in viral shedding, symptom expression, and behavioral factors.[4,5,21,22] Viral load is suspected to be an important factor affecting the odds of SARS-CoV-2 transmission.[22,28,29] Several studies of age-specific viral shedding of SARS-CoV-2 have reported that vi-

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Table 2. Adjusted Odds Ratios and 95% Confidence Intervals for the Associations Between Index Case Age Group and Odds of Transmitting SARS-CoV-2 to Household Contacts

Characteristic	Index cases, No. (%)		Crude rate of transmission (per 100 000 households with pediatric index cases)	Odds ratio (95% CI)		
	Not associated with secondary cases in the household	Associated with secondary cases in the household		Crude model	Adjusted	
					Model 1[a]	Model 2[b]
Age, y						
0-3	532 (11.7)	234 (13.6)	30 548	1.20 (1.01-1.44)	1.21 (1.01-1.45)	1.43 (1.17-1.75)
4-8	909 (19.9)	348 (20.3)	27 685	1.05 (0.90-1.22)	1.06 (0.90-1.23)	1.40 (1.18-1.67)
9-13	1382 (30.3)	499 (29.1)	26 528	0.99 (0.86-1.13)	0.97 (0.85-1.11)	1.13 (0.97-1.32)
14-17	1740 (38.1)	636 (37.0)	26 768	1 [Reference]	1 [Reference]	1 [Reference]
Male	2433 (53.6)	943 (55.2)	27 932	NA	1.07 (0.95-1.19)	1.09 (0.96-1.23)
Female	2099 (46.2)	764 (44.7)	26 685	NA	1 [Reference]	1 [Reference]
Month of disease onset						
June	119 (2.6)	38 (2.2)	24 204	NA	1 [Reference]	1 [Reference]
July	113 (2.5)	35 (2.0)	23 649	NA	0.98 (0.58-1.66)	1.05 (0.58-1.89)
August	112 (2.5)	31 (1.8)	21 678	NA	0.89 (0.52-1.52)	0.93 (0.51-1.69)
September	482 (10.6)	154 (9.0)	24 214	NA	1.01 (0.67-1.51)	0.97 (0.62-1.51)
October	712 (15.6)	274 (16.0)	27 789	NA	1.22 (0.82-1.80)	1.20 (0.78-1.84)
November	1199 (26.3)	515 (30.0)	30 047	NA	1.37 (0.93-2.00)	1.38 (0.91-2.09)
December	1826 (40.0)	670 (39.0)	26 843	NA	1.16 (0.80-1.70)	1.14 (0.76-1.72)
Testing delay, d						
Asymptomatic	853 (18.8)	89 (5.2)	9448	NA	NA	0.34 (0.25-0.47)
<0	251 (5.5)	36 (2.1)	12 544	NA	NA	0.50 (0.33-0.75)
0	1076 (23.8)	206 (12.1)	16 069	NA	NA	1 [Reference]
1	570 (12.6)	209 (12.3)	26 829	NA	NA	1.24 (0.95-1.61)
2	488 (10.8)	226 (13.3)	31 653	NA	NA	1.59 (1.22-2.07)
3	361 (8.0)	200 (11.7)	35 651	NA	NA	1.97 (1.49-2.59)
4	238 (5.3)	165 (9.7)	40 943	NA	NA	2.38 (1.77-3.19)
≥5	692 (15.3)	574 (33.7)	45 340	NA	NA	2.98 (2.34-3.80)
Mean family size	3.3 (3.0-3.6)	3.4 (3.1-3.7)	NA	NA	NA	1.63 (1.43-1.86)

Abbreviation: NA, not applicable.

[a] Adjusted for gender and month of disease onset.

[b] Adjusted for gender, month of disease onset, testing delay, and mean family size. A total of 778 index case individuals were excluded from the model who had no COVID-19 symptoms reported in provincial reportable disease systems, were missing symptom onset date, and were not reported as asymptomatic.

ral loads in children are similar or higher than viral loads in adults.[22,30-33] In particular, 1 study reported that children younger than 5 years might carry more viral RNA in their nasopharynx than older children and adults.[30] Conversely, another study found no significant difference in viral loads for children 10 years or younger vs children aged 11 to 17 years.[34] Additionally, biases in testing practices, such as the preferential testing of symptomatic cases and contacts, inherently leads to underdetection of pediatric cases and challenges estimating their rates of transmission.[4,5,15] Studies have found younger children are more likely to be asymptomatic,[3,16,26] which has been postulated as a reason for lower infectivity because lower secondary attack rates have been reported for asymptomatic index cases compared with symptomatic index cases.[2,12,15,24] We found that asymptomatic status and testing delays had strong gradient effects on infectivity, similar to our previous study of household transmission.[25] However, even after adjusting for the lower odds of asymptomatic transmission and testing delays in our study, children aged 0 to 3 years and 4 to 8 years remained associated with higher odds of transmitting SARS-CoV-2 to household contacts than children aged 14 to 17 years. A possible explanation for this finding is that younger children are not able to self-isolate from their caregivers when they are sick, irrespective of the timing of testing.[21,35]

Limitations and Strengths

This study has some limitations that should be acknowledged. First, there is the possibility of misclassifying household transmission if secondary case infection was truly acquired outside the household or if the true index case individual of the household was untested. This is particularly relevant for pediatric cases owing to their increased probability of having mild or asymptomatic infection and thus increased probability of infection being missed. We attempted to account for this in sensitivity analyses by modifying the secondary case definition from 1 to 14 days to 2 to 14 and 4 to 14 days and by restricting analysis to symptomatic cases only. Second, this study used multiple evolving data systems for reporting COVID-19 cases in Ontario. As a result, there was some inconsistency regarding how symptoms were reported, which may result in some misclassification of symptomatic cases. We carefully examined the reporting practices over the months covered in the study and selected

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a combination of variables (symptoms reported, symptom onset date available, and/or asymptomatic flag) we felt reflected the most likely symptom status of cases. Third, we could not reliably calculate secondary attack rates in the study because we did not know the number of noninfected contacts in households for the full cohort. However, after controlling for individual-level household size within the subset of the cohort with this information available, our conclusions were unaltered.

This study also has several strengths. This is a large, population-based study of all individuals with confirmed SARS-CoV-2 infection in Canada's most populated province; thus, we had sufficient data to explore transmission within the understudied pediatric group. We were also able to include relevant covariates such as testing delays and household size; our results suggest that early testing of pediatric index cases and reduced household size/crowding may be useful strategies to minimize secondary household transmission by children. Second, the use of a natural language processing algorithm to perform address matching allowed us to reliably identify cases in the same household, rather than relying on contact tracing or other types of epidemiologic linkage that would be difficult to perform for a high volumes of cases. Third, our application of various sensitivity analyses for symptom status and the definition of secondary transmission increased our certainty of the direction of transmission from index case to secondary case, further supporting our findings.

Conclusions

As the number of pediatric cases increases worldwide, the role of children in household transmission will continue to grow. We found that younger children may be more likely to transmit SARS-CoV-2 infection compared with older children, and the highest odds of transmission were observed for children aged 0 to 3 years. Differential infectivity of pediatric age groups has implications for infection prevention controls within households and schools/childcare to minimize risk of household secondary transmission. Although children do not appear to transmit infection as frequently as adults, caregivers should be aware of the risk of transmission while caring for sick children in the household setting. As it is challenging and often impossible to socially isolate from sick children, caregivers should apply other infection control measures where feasible, such as use of masks, increased hand washing, and separation from siblings.

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Concept and design: Paul, Daneman, Schwartz, Science, Brown, Buchan.
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