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# Household Transmission of Severe Acute Respiratory Syndrome Coronavirus 2 from Adults to Children

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Knowledge of transmission dynamics of severe acute respiratory syndrome coronavirus 2 from adults to children in household settings is limited. We found an attack rate among 213 children in 137 households to be 6.1% in households with confirmed adult 2019 novel coronavirus disease index case(s). Transmission from adult to child occurred in only 5.2% of households. Young children <5 years old were at lowest risk of infection (1.3%). Children were most likely to be infected if the household index case was the mother. (*J Pediatr* 2020;225:249-51).

Estimates of the basic reproduction number,  $R_0$ , for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes the 2019 novel coronavirus disease (COVID-19), have ranged from 2.2 to 2.7.<sup>1</sup> This value represents the theoretical number of cases generated by 1 infected person in a population in which all are susceptible. Data on attack rates in specific settings or populations might facilitate identification of drivers of the epidemic and thereby guide public health control or mitigation strategies. Population attack rates have been derived from mathematical modeling and contact tracing data in heterogeneous communities.<sup>2,3</sup> These methods are limited by the assumptions used, heterogeneous exposures, bias from transmission among contacts, and unidentified infection risk from untraced contacts. Investigating transmission in households can provide precise information on the transmissibility of an infectious pathogen.<sup>4,5</sup> Despite its importance, granular data on attack rates from detailed analysis of household transmission in children remain scarce.

Following detection of the first case of COVID-19 in Singapore on January 23, 2020,<sup>6</sup> a major systematic public health response strategy involving early identification, testing, and patient isolation was implemented. Patients with laboratory-confirmed COVID-19 were isolated in hospitals and their close contacts, including children in their households, were placed on strict quarantine for 14 days from the last day of exposure.<sup>6</sup> Beginning on March 5, because of concern that infected children might not display symptoms, the Ministry of Health Singapore implemented screening for SARS-CoV-2 by real-time reverse transcriptase polymerase chain reaction from nasopharyngeal swabs for all pediatric household contacts (regardless of symptoms) of persons with laboratory-confirmed COVID-19. This report

describes age-specific attack rates in children in households with confirmed COVID-19.

## Methods

KK Women's and Children's Hospital is an 830-bed hospital that provides care for approximately 500 children's emergency daily attendances and 12 000 deliveries per year. It was the designated hospital for evaluation of COVID-19 in pediatric household contacts of confirmed cases. A line list of pediatric household contacts of confirmed cases in Singapore who underwent evaluation of COVID-19 from March 5, 2020 to April 30, 2020 was extracted. All cases were assessed in the Children's Emergency Department of the hospital and a nasopharyngeal (NP) swab was collected to screen for SARS-CoV-2. If they were symptomatic and, thus, fulfilled the suspect case criteria, they were admitted for isolation and testing. If they were asymptomatic, they were sent back to home quarantine after the swabs were taken. These children were recalled for admission and isolation if their NP swabs subsequently confirmed presence of SARS-CoV-2. Laboratory confirmation was based on polymerase chain reaction testing of NP swabs.<sup>7</sup>

The study was approved by the institutional ethics review board. Written informed consent was waived in light of the need to inform public health outbreak control policies.

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SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
COVID-19	Coronavirus disease 2019
NP	Nasopharyngeal

## Results

During March and April, among 137 households with a total of 223 adults (index patients) with laboratory-confirmed COVID-19, 213 children age ≤16 years were tested for SARS-CoV-2; 13 cases were detected in 7 households, for an attack rate of 6.1% among children and 5.2% of households with confirmed exposure to COVID-19 (Table). One case child reported sore throat at the time of screening; one other had a single temperature reading of 100°F during hospitalization, but none had respiratory or any other symptoms.

In age-stratified analysis, the attack rate was 1.3% among children age <5 years, 8.1% among those age 5-9 years, and 9.8% among those age 10-16 years. Attack rates were similar, regardless of the sex of the child. The attack rate among children was highest when the household index case was the mother (11.1%), and lower and similar if the index case was the father (6.7%) or a grandparent (6.3%).

## Discussion

Based on systematic surveillance and screening of children who were household contacts of persons with confirmed COVID-19, the attack rate of SARS-CoV-2 infection in children was 6.1%. Transmission from adults to children was documented to have occurred in only 5.2% of households with confirmed exposure to COVID-19. Children age <5 years had lower rates of infection than did older children following exposure to a household member with COVID-19. The risk of secondary infection in children was highest if the index COVID-19 patient was the child's mother.

Modeled attack rates in Guangzhou, China were estimated to be 5.26%, 13.72%, and 17.69% among household contacts age <20 years, 20-59 years, and ≥60 years, respectively.<sup>4</sup> Detailed breakdown for the <20 years age group was not available. Another study from 2 local hospitals 150-250 km from Wuhan, China documented an attack rate of 2.3% in children age <5 years, 5.4% in children age 6-17 years, and 20.5% in adults age >18 years.<sup>5</sup> The sample size of children <18 years of age was limited to 100 contacts in this study. Because population susceptibility to SARS-CoV-2 is assumed to be universal, the attack rate in children would be expected to be similar to that in adults. Because transmission is known to be correlated with degree of contact, attack rates might be expected to be higher in younger children, who presumably have closer interactions with their parents than do older children; however, in our study the attack rate was lowest in the youngest age group. A recent study found a trend for increased expression of angiotensin-converting enzyme 2 (the receptor that SARS-CoV-2 uses for host entry) in nasal epithelium with increasing age<sup>8</sup>; thus, it is possible that younger children are more resistant to SARS-CoV-2 infection at a cellular level.

Multiple studies have suggested that children with COVID-19 may be less likely than adults to show symptoms such as fever, cough or shortness of breath, or to have severe

**Table. Attack rates among pediatric (age ≤16 years) household contacts of adults with diagnosed COVID-19—Singapore, March-April 2020**

Characteristics	Pediatric household contacts, (N = 213)		Attack rate, %
	Infected, n (%)	Not infected, n (%)	
Total	13 (100)	200 (100)	6.1
Households (n = 134)	7 (5.2)	127 (94.8)	5.2
Age, median y (range)	9.9 (2.1–13.1)	7.1 (0.1–13.7)	N/A
Age group (y)			
0-4	1 (7.7)	77 (38.5)	1.3
5-9	6 (46.2)	68 (34.0)	8.1
10-16	6 (46.2)	55 (27.5)	9.8
Sex			
Male	5 (38.5)	96 (48.0)	5.0
Female	8 (61.5)	104 (52.0)	7.1
Household index COVID-19 case*			
Father	7 (43.8)	97 (46.6)	6.7
Mother	7 (43.8)	56 (26.9)	11.1
Grandparent	1 (6.3)	15 (7.2)	6.3
Other (adult housemate)	1 (6.3)	39 (18.8)	2.5
Developed symptoms during quarantine			
Yes	1 (7.7)	7 (5.8)	N/A
No	12 (92.3)	193 (94.2)	N/A
Interval between last exposure to index patient and date of NP sample, mean d (range)	3.5 (1-6)	4 (1-12)	N/A

N/A, not applicable.

\*Total >213 as some households had more than 1 adult index case.

disease requiring hospitalization.<sup>9,10</sup> However, recently there have been reports detailing a new syndrome causing severe illness and death in some children.<sup>11,12</sup> Multisystem inflammatory syndrome in children have systemic inflammation, sharing some features of toxic shock and Kawasaki disease. The subpopulations of children at risk and the full spectrum of multisystem inflammatory syndrome in children remain unknown. Testing all children in households with COVID-19 cases regardless of symptom status could afford early case identification, isolation as well as close clinical monitoring. However, the very low attack rate among young children <5 years of age in households may suggest that young children <5 years of age are less likely to become infected than adults and may not be drivers of the epidemic. The low attack rate suggests that strict compliance with infection control may be able to eliminate or reduce the risk of transmission from adults to children in household settings.

The mean interval between last exposure and the single NP swab sample date of child cases (3.5 days), and noncases (4 days) were not biased. No serology was performed to assess the true burden of infection. High levels of herd immunity in children could have affected the findings, but this was unlikely based on seroprevalence data showing very low disease burden in children.<sup>13</sup> It was also unlikely that children in the household could have been infected and developed immunity prior to detection of the adult cases because the reported surveillance and case detection delay between onset to isolation was only 3.1 days in Singapore.<sup>1</sup> The risk of transmission in the household likely was reduced when the index adult case was admitted

for isolation in hospital. However, published data have shown viral shedding, environmental contamination, as well as transmission even during the asymptomatic phase.<sup>7,14</sup>

Generalizability of our data may not be appropriate to transmissibility in other settings or with another strain of SARS-CoV-2. Children in households could potentially be at risk of being infected with SARS-CoV-2 from home isolation of parents with COVID-19. However, the attack rate in children exposed to adult COVID-19 in household settings was especially low in children <5 years old. In the family household, children were at highest risk of acquiring SARS-CoV-2 if the index case was their mother. Understanding how COVID-19 affects children differently from adults will be important to guide clinical management of children with COVID-19, modeling the impact of children on community transmission and recommending appropriate prevention measures. ■

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