

SARS-CoV-2 transmission in kindergarten to grade 12 schools in the Vancouver Coastal Health region: a descriptive epidemiologic study

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Abstract

Background: There is an urgent need to assess the role of schools in the spread of SARS-CoV-2 in Canada to inform public health measures. We describe the epidemiology of SARS-CoV-2 infection among students and staff in the Vancouver Coastal Health (VCH) region in the first 3 months of the 2020/2021 academic year, and examine the extent of transmission in schools.

Methods: This descriptive epidemiologic study using contact tracing data included individuals aged 5 years and older with SARS-CoV-2 infection, reported between Sept. 10 and Dec. 18, 2020, who worked in or attended kindergarten to grade 12 (K–12) schools in person in the VCH region. We described case and cluster characteristics and reported the number of school-based transmissions.

Results: During the study period, 699 cases of SARS-CoV-2 infection were reported (55 cases per 10 000 VCH school population). Among cases in VCH resident staff and students, 52.5% (354/674) were linked to a household case or cluster; less than 1.5% (< 10) of infected individuals were hospitalized and none died. Out of 699 cases present at school, 26 clusters with school-based transmission resulted in 55 secondary cases. Staff members accounted for 53.8% of index cases (14/26) while making up 14.3% of the school population (17 742/123 647). Among clusters, 88.5% (23) had fewer than 4 secondary cases.

Interpretation: In our population during the study period, there were no deaths and severe disease was rare; furthermore, school-based SARS-CoV-2 transmissions were uncommon and clusters were small. Our results, which relate primarily to symptomatic disease, support the growing body of evidence that schools likely did not play a major role in SARS-CoV-2 spread in 2020.

Early in the pandemic, schools closed across Canada to help reduce the circulation of SARS-CoV-2 and decrease risks associated with infection among staff and students.¹ Evidence has since suggested that school closures and decreased in-person learning have had negative impacts on the mental health, well-being, educational attainment, social connection, health care access and health behaviours of students, families and staff.^{1–12} Combined with high socioeconomic tolls,^{13–15} these unintended consequences have compelled consideration of the efficacy of school closures in limiting morbidity and mortality associated with the COVID-19 pandemic.

Evidence now indicates that age is a risk factor for severe disease and children typically experience a mild course of illness.^{16–22} There is also a growing body of literature suggesting that children's in-person school attendance may not be an important driver of transmission; contact-tracing and test-based studies from other jurisdictions have identified little or no transmission in the school setting.^{23–34} Internation-

ally, studies illustrate that school reopening has not affected numbers of pediatric cases^{23,35,36} and that the risk of SARS-CoV-2 infection has not increased for educational staff working with children.^{30,36,37}

There are limited peer-reviewed data in Canada regarding risk of SARS-CoV-2 transmission in schools, although Ottawa Public Health has reported low rates of school-based transmission.³⁸ Given that transmission risk is influenced by community-level epidemiology, public health measures, health system infrastructure and other jurisdictional factors, this study contributes needed evidence within the Canadian

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context. We aimed to describe cases of SARS-CoV-2 infection among students and staff in the Vancouver Coastal Health (VCH) region who attended kindergarten to grade 12 (K–12) schools in person, assess the extent of SARS-CoV-2 transmission in schools and characterize clusters where school-based transmission was observed.

Methods

Study design and setting

This descriptive epidemiologic study using contact-tracing data was population-based and retrospective. We described the incidence and characteristics of cases of SARS-CoV-2 infection reported among K–12 staff and students in the Vancouver Coastal Health (VCH) region. The study period was from Sept. 10, 2020, to Dec. 18, 2020. Vancouver Coastal Health serves more than 1.2 million people³⁹ across urban, rural and remote geographies.

During the study period, although mass gatherings remained prohibited in British Columbia, schools and businesses were open with safety plans in place, and masks were encouraged but not required. Travel and gatherings in private residences were restricted gradually, starting in November 2020. There were no stay-at-home requirements.⁴⁰ Symptomatic testing was widely available, and contact tracing was conducted for all positive cases.⁴¹

Schools in BC reopened after summer holidays on Sept. 10, 2020, and closed for winter break after Dec. 18, 2020. Before reopening, schools implemented COVID-19 safety plans developed with support from public health officials across health authorities, which included public health measures (e.g., testing and contact-tracing protocols), environmental measures (e.g., enhanced cleaning and disinfection), administrative measures (e.g., scheduling and work practices, health and wellness policies, and cohorting), personal measures (e.g., staying home when sick, physical distancing, hand hygiene and respiratory etiquette) and personal protective equipment. Use of nonmedical masks was supported, but not always required (Appendix 1, available at www.cmajopen.ca/content/9/3/E810/suppl/DC1).⁴²

Cases

We extracted all laboratory-confirmed, probable-laboratory and probable-epidemiologically linked cases among individuals aged 5 years and older at the time of the case report between Sept. 10 and Dec. 18, 2020, who reported working in or attending a K–12 school within the VCH region during their incubation or infectious periods. We excluded cases of individuals who exclusively worked in or attended a daycare or postsecondary institution, attended school online or were home-schooled. School staff and student cases were categorized as either school-aged (age 5–17 yr) or aged 18 years and older.

Potential school-transmission events were defined as situations in which a case of SARS-CoV-2 infection was epidemiologically linked to another case at school, and transmission likely occurred in the school setting, whether in the course of

classroom or nonclassroom activities.^{27,31,33} To identify potential school-transmission events, we analyzed all clusters in which 2 or more cases were reported within a 14-day period in a school. Cases of individuals who did not interact with staff or students in the learning setting (e.g., building maintenance staff only present after school hours) were excluded from the cluster analysis.

Public health investigation and response

Nucleic acid amplification testing for SARS-CoV-2 was available for anyone with symptoms, and was advised for students or staff with fever or new symptoms persisting longer than 24 hours. Tests were generally processed within 24 hours. Positive tests were automatically reported to VCH's Office of the Chief Medical Health Officer, which investigated cases within 24 hours and identified contacts.⁴³

Contact tracing was conducted by health sciences professionals using a standardized electronic form adapted from the provincial COVID-19 case report form⁴⁴ via telephone interviews with the infected individuals or their proxies to obtain information including demographic characteristics, comorbidities, symptoms, school attendance or work details, activities during incubation and infectious periods, contacts with known confirmed or probable cases of SARS-CoV-2 infection, and exposures to clusters or outbreaks of SARS-CoV-2 infection.

Medical health officers performed qualitative individual risk assessments for each contact via a review of the contact-tracing data, integrating each infected individual's symptoms, ages of individuals and contacts, nature and duration of contact, setting (e.g., indoor or outdoor), and presence or absence of known SARS-CoV-2 transmission. Factors constituting high-risk exposures included direct contact with infectious body fluids (e.g., via sharing vapes or being coughed or sneezed on) and prolonged (> 15 min) contact with an individual with symptomatic infection, face to face or at close range;⁴³ thus, close contacts were identified among classmates. Factors constituting low-risk exposures included the absence of interactions or interactions outdoors of limited duration and at a distance (i.e., > 2 m).⁴³

Individuals with high-risk exposures were advised to self-isolate for 14 days and were monitored for emergence of symptoms during their incubation periods. Symptomatic individuals were directed to seek testing and few declined. Those with lower-risk exposures were advised to self-monitor for symptoms and present for testing accordingly. Asymptomatic individuals were tested at the discretion of the medical health officer.

Data sources and extraction

Vancouver Coastal Health's electronic COVID-19 case and contact tool is a custom, noncertified electronic medical record (EMR) built to EMR standards. It records first-hand information collected as a part of contact tracing, and is designed to capture relationships between cases, contacts, exposures, clusters and outbreaks. The public health team flags epidemiologic linkages between cases determined

through contact tracing on the EMR through a software feature. Staff members who chart in the EMR receive training and use standardized tools, including interview scripts and workflow guidance. Information such as age, sex and laboratory data are triangulated based on unique identifiers through integration with the provincial electronic health record platform, CareConnect. Data quality is assured through routine diagnostics and complaint-driven investigations.

Data used in the study were downloaded from the EMR in Excel format by M.S.-J. N.D. cleaned and verified the data; duplicate case entries were discarded based on unique identifiers, and cases with missing or incorrect Health Service Delivery Area fields were reclassified based on cities of residence or postal codes. For the temporally associated cases, D.B. verified school attendance or work status by chart review and excluded cases according to the selection criteria.

N.D. extracted the demographic characteristics, school name, grade, role (staff or student), attendance dates, comorbidities, symptoms and epidemiologic linkages to other cases within and outside of school, and the research team checked the data for accuracy. Hospitalizations and intensive care unit (ICU) admissions to VCH hospitals were determined using individual data linkages to acute care data. The Provincial Health Services Authority individually matched and provided hospitalization data for VCH staff and student cases hospitalized at BC Children's Hospital. Districts confirmed denominators of staff and students attending in person during the study period.

Data extraction for the cluster analysis was conducted by D.B. using a structured data abstraction tool and data dictionary (Appendix 2, Table A1, available at www.cmajopen.ca/content/9/3/E810/suppl/DC1). Cases' likely sources of infection were categorized as household, social, school or other. A case was determined to be a contact's likely source of viral acquisition if they had prolonged contact during the case's infectious period and the contact's incubation period.⁴³ If there was no contact with a positive case, this was recorded. All cases with multiple potential sources of acquisition were reviewed by D.B. and A.C., with high (93%) interrater reliability. The source of acquisition was attributed to the school if the nonschool source had an unclear symptom-onset date and no clear source of acquisition themselves. Index and secondary cases were categorized by symptom-onset date, and secondary cases' close contacts who became laboratory-confirmed or probable cases were categorized as tertiary cases.

Statistical analysis

All analyses were conducted via statistical computing software RStudio. We based *p* values on Pearson χ^2 and independent *t* tests for categorical and continuous variables, respectively.

Ethics approval

In consultation with the University of British Columbia Office of Research Ethics, this study did not require institutional research ethics review as it was completed as part of routine public health surveillance and operations.

Results

During the study period, 17 742 staff and 105 905 students worked in or attended school in person at a total of 358 schools (104 independent and 254 public) in the VCH region. In the same period, 699 cases of SARS-CoV-2 infection were reported among staff and students (Figure 1) in 270 unique VCH-region K-12 schools, representing an incidence of 55 cases per 10 000 population. During the study period, the weekly incidence peaked the week of Nov. 15–21, 10 weeks after school reopening (Figure 2; Appendix 2, Figures A1 and A2).

Of the 699 individuals with reported SARS-CoV-2 infection, 674 (96.4%) resided in the VCH region; these cases are described in Table 1. Notably, adults (≥ 18 yr) more frequently reported comorbidities and were less frequently linked to a confirmed case or cluster compared with children (5–17 yr) (*p* values < 0.01). The 25 (3.6%) staff and students with SARS-CoV-2 infection who resided outside the VCH region, while excluded from Table 1, were included in the cluster analysis.

Clusters of SARS-CoV-2 infection in schools

A total of 71 school clusters occurred, totalling 251 cases during the study period (Figure 3). No school-based transmission was suspected in 45 clusters (63.3%), with all 142 cases within these clusters likely acquiring SARS-CoV-2 infection outside of school. Within the 26 clusters containing at least 1 school-acquired case, a further 28 cases likely acquired infection outside of school. Of the 170 cases (19 staff and 151 students) temporally clustered but without evidence of school-based

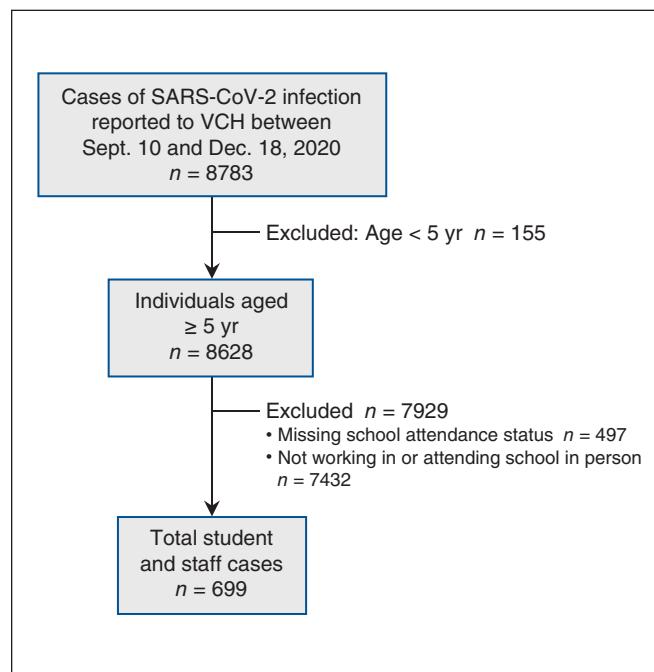


Figure 1: Flow diagram showing study population selection (including staff and students not residing in the Vancouver Coastal Health [VCH] region).

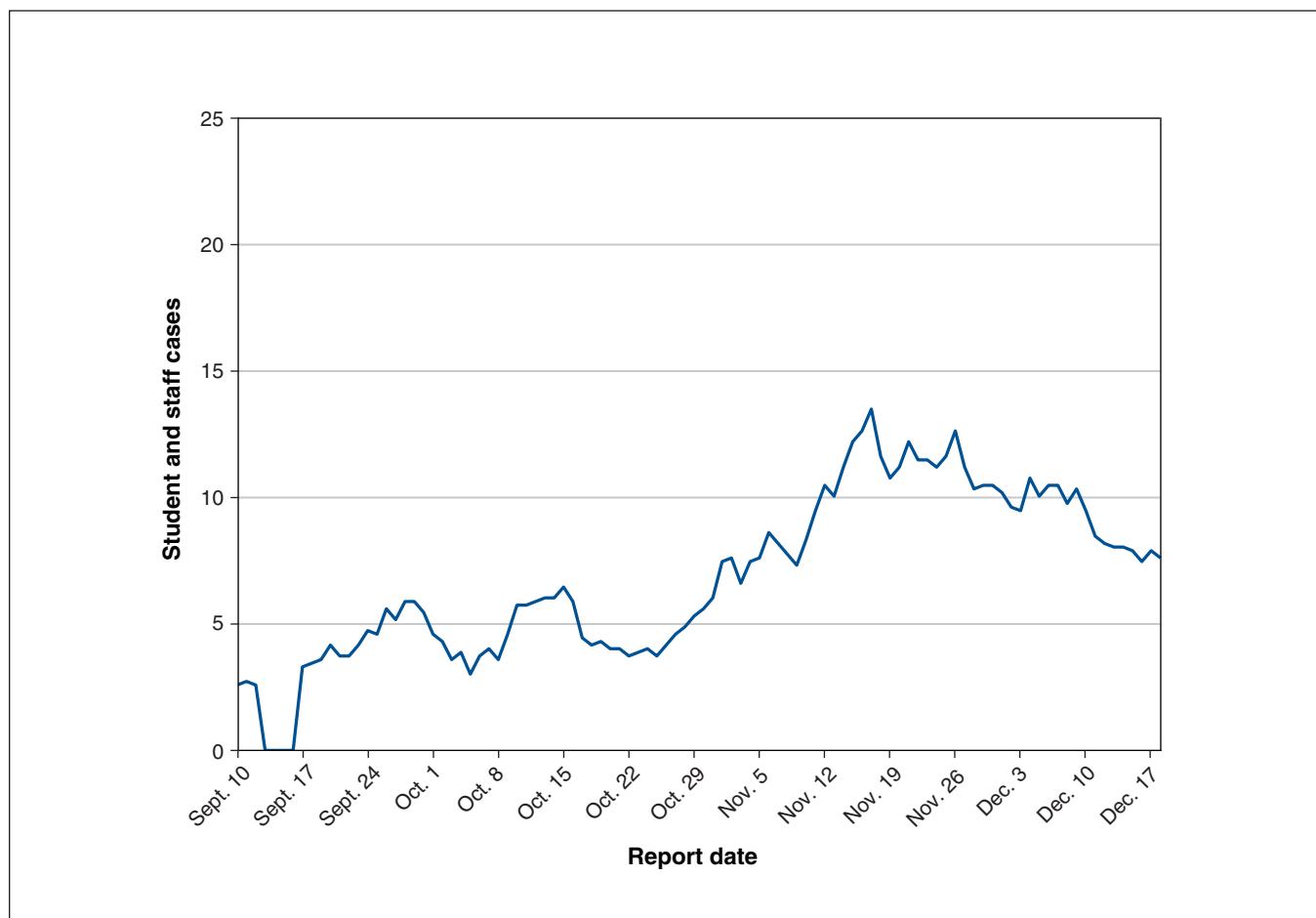


Figure 2: Seven-day average of new cases of SARS-CoV-2 infection among staff and students attending kindergarten to grade 12 schools in the Vancouver Coastal Health region reported during the study period (Sept. 10 to Dec. 18, 2020).

transmission, 107 (62.9%) were attributable to household contacts, 17 (10.0%) to social networks, 4 (2.4%) to sports teams and 2 (1.2%) to work outside of school. Forty students and staff (23.5%) had no known contact with another case inside or outside of school. There were no school closures because of SARS-CoV-2 transmission during the study period.

Cases with evidence of school-based transmission

Out of 699 cases present at school, likely transmission stemming from 26 (3.7%) index cases resulted in 55 secondary cases at school. A total of 237 close contacts were identified from these 55 secondary cases, and 10 became tertiary cases. Staff accounted for 53.8% of index cases (14/26) and 25.5% of secondary cases (14/55). Staff cases ($n = 28$) included 19 teachers, 6 support workers, and 3 principals or office staff members. Of the 81 index and secondary cases, 47 (58.0%) worked in or attended a K–7 school, 25 (30.9%) a grade 8–12 school and 9 (11.1%) a K–12 school. The ratio of secondary cases to total primary cases was 0.09.

The characteristics of clusters with school-based transmission are presented in Table 2. Among 26 total clusters, 13 (50.0%) had 1 secondary case, 10 (38.5%) had 2–3 secondary cases and 3 (11.5%) had 4 or more secondary cases. All clusters

with 4 or more secondary cases had an index staff case and occurred in grades K–7. The median size of clusters was 3 (range 2–8) when the index case was a staff member compared with 2 (range 2–3) when the index case was a student. There were 8 (30.8%) clusters involving students only, all among grades 4–12, and 4 clusters (15.4%) involving staff members only. Of the 14 clusters including both staff and students, 9 (64.3%) occurred in grades K–7 and 5 (35.7%) in grades 8–12.

School-based activities where transmission may have occurred are presented in Table 3. Evidence of transmission was most commonly found in a shared classroom, but no specific class type was more frequently identified. For some cases, there were multiple exposures settings within the school, notably through socializing with a classmate.

Interpretation

During the study period, the number of cases of SARS-CoV-2 infection reported among K–12 students and staff in the VCH region gradually increased in the context of broader societal reopening, reaching a peak incidence 10 weeks (about 5 incubation periods) after school reopening and declining thereafter in the context of increasingly restrictive public

Table 1: Characteristics of cases of SARS-CoV-2 infection among 674 students and staff residing in the Vancouver Coastal Health region reported between Sept. 10 and Dec. 18, 2020*

Characteristic	No. (%) of cases†		
	Adults (≥ 18 yr) <i>n</i> = 157	Children (5–17 yr) <i>n</i> = 517	Total <i>n</i> = 674
Age at time of report, yr, median (range)	39 (18–73)	12 (5–17)	14 (5–73)
Age ≥ 65 yr at time of report	2 (1.3)	NA	2 (0.3)
Sex			
Female	104 (66.2)	224 (43.3)	328 (48.7)
Male	53 (33.8)	292 (56.5)	345 (51.2)
Health service delivery area			
Coastal rural	6 (3.8)	33 (6.4)	39 (5.8)
Coastal urban	29 (18.5)	107 (20.7)	136 (20.2)
Richmond	29 (18.5)	99 (19.1)	128 (19.0)
Vancouver	93 (59.2)	278 (53.8)	371 (55.0)
Linked to confirmed case or cluster			
No	62 (39.5)	114 (22.1)	176 (26.1)
Yes, non-household contact	50 (31.8)	94 (18.2)	144 (21.4)
Yes, household contact	45 (28.7)	309 (59.8)	354 (52.5)
Case status			
Recovered and removed from isolation	157 (100)	517 (100)	674 (100)
Deceased	0 (0)	0 (0)	0 (0)
Ever hospitalized	—	—	< 10 (< 1.5)
Ever admitted to ICU	—	—	< 10 (< 1.5)
One or more comorbidity	36 (22.9)	37 (7.2)	73 (10.8)
Comorbidity type‡			
Cancer	2 (1.3)	0 (0)	2 (0.3)
Cardiac	5 (3.2)	1 (0.2)	6 (0.9)
Diabetes	7 (4.5)	3 (0.6)	10 (1.5)
Immunocompromised	3 (1.9)	8 (1.5)	11 (1.6)
Pregnant	3 (1.9)	0 (0)	3 (0.4)
Respiratory	2 (1.3)	6 (1.2)	0 (0)
Smoking or vaping	27 (17.2)	22 (4.3)	49 (7.3)
One or more COVID-19 symptoms	155 (98.7)	501 (96.9)	656 (97.3)

Note: ICU = intensive care unit, NA = not applicable, VCH = Vancouver Coastal Health.
*Data accurate as of Jan. 12, 2021. Excludes 25 cases who resided outside of the VCH region but worked in or attended school in person in the VCH region. Although VCH followed up on all school cases, clusters and exposures at schools within the VCH region, long-term follow-up of individual cases is typically completed in the health authority in which the individual resides. Therefore, complete information from long-term follow-up (e.g., hospitalization data) was available only for individuals residing within the VCH region.
†Unless stated otherwise.
‡Comorbidity types were not mutually exclusive.

health measures. The trend in new cases among the school population mirrored that of the general population in the VCH region.⁴⁵ Hospitalizations and ICU admissions were rare, and there were no deaths.

Although as many as 251 cases were temporally clustered with another case in the same school within a 14-day period, 170 (68%) of these cases had no evidence of school-based transmission. When school-based transmissions occurred, the

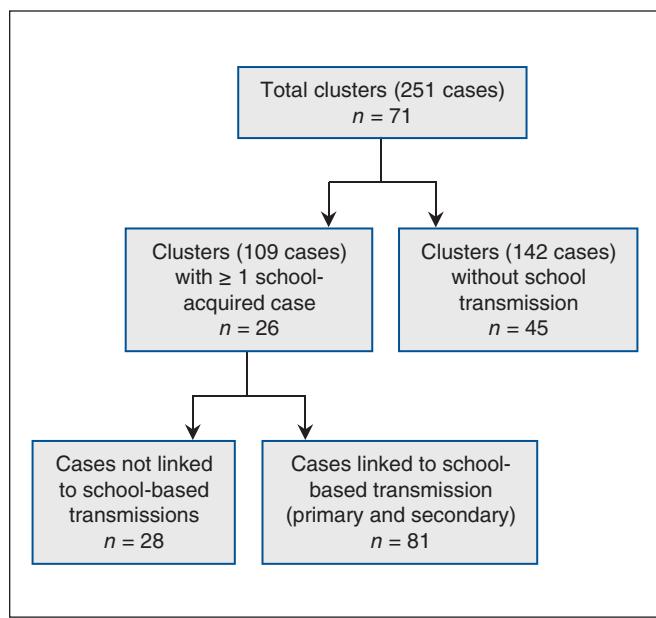


Figure 3: Flow diagram showing characteristics of school cluster transmission.

number of identified secondary cases was small; a total of 55 school-acquired cases represented 0.04% of individuals working in or attending a K–12 school in the VCH region. Staff members were disproportionately identified as the index cases compared with their makeup of the school population. A shared classroom accounted for most transmissions; no particular class or activity was noticeably higher risk.

Our findings support the growing body of evidence that schools are likely not an important driver of SARS-CoV-2 spread.^{23,35,36} In concordance with other studies, we found that a household case was the most common source of infection for school-aged children^{30,32} and that school-based acquisitions were uncommon.^{29,30,32,33} Individuals with SARS-CoV-2 infection seldom infected others at school; out

of 699 student and staff cases, we identified likely school-based transmissions stemming from 26 index cases (3.7%). The ratio of secondary cases to total primary cases was 0.09 in the school setting, compared with 0.27 observed in Luxembourg,³⁰ 0.08 in Germany³² and 0.02 in South Korea.²³ Although we did not systematically track the number of school contacts per index case, the secondary attack rate is likely to be very low given the low number of identified secondary cases, in concordance with prior studies across several countries.^{24,25,28,30} As observed elsewhere, when school-based transmission occurred, the number of secondary cases was limited,^{23,31,46} although one large high school outbreak was described in Israel⁴⁷ in the context of crowding and a concurrent heat wave. We observed a larger number of secondary cases when the index case was an adult, similar to the experience in England³¹ and Singapore.²⁶ Our findings reinforce the observation that numerous cases in a school can reflect multiple introductions from the community rather than school-based transmissions.²

Of note, our study was conducted in the context of limited circulation of SARS-CoV-2 variants of concern, strong collaboration between the public health and education sectors, good school-based infection prevention and control measures, and rapid access to testing and contact tracing. Contact tracing within 24 hours and regular monitoring of cases and contacts may have prevented transmission to tertiary cases. Further studies will be required to evaluate the impact of individual infection prevention and control measures.

Caution should be taken in generalizing our results owing to differences in underlying epidemiology, public health measures, health system infrastructure and culture, among other factors that may differ by jurisdictions. However, our findings suggest that schools may be able to safely remain open in settings with moderate community transmission (i.e., weekly incidence of 10–100 cases per 100 000 as observed in this study) with infection prevention and control measures in place and sufficient public health capacity for rapid testing and contact tracing.

Table 2: Characteristics of 26 clusters with evidence of school-based transmission

Characteristic	No. (%)*			
	Grades K–7 n = 13 clusters	Grades 8–12 n = 9 clusters	Staff only n = 4 clusters	All grades n = 26 clusters
No. of cases per cluster, median (range)	2 (2–8)	3 (2–4)	2.5 (2–4)	2.5 (2–8)
Role of index cases, n = 26 cases				
Staff	7 (53.8)	3 (33)	4 (100)	14 (54)
Student	6 (46.2)	6 (67)	0 (0)	12 (46)
Role of secondary cases, n = 55 cases				
Staff	4 (12.1)	3 (20.0)	7 (100)	14 (25.5)
Student	29 (87.9)	12 (80.0)	0 (0)	41 (74.5)

Note: K = kindergarten.
*Unless stated otherwise. Percentage reflects the proportion of cases per grade grouping or staff status.

Table 3: School settings where transmission may have occurred for 55 cases of school-acquired SARS-CoV-2 infection*

Exposure setting	No. of cases			No. (%) of cases All grades <i>n</i> = 59 exposure settings
	Grades K–7 <i>n</i> = 35 exposure settings	Grades 8–12 <i>n</i> = 17 exposure settings	Staff only <i>n</i> = 7 exposure settings	
Class	28 (26 students, 2 staff)	11 (10 students, 1 staff)	2 (2 staff)	41 (69.5)
Office, meeting or staff room	2 (2 staff)	1 (1 staff)	3 (3 staff)	6 (10.2)
Socializing at school	3 (3 students)	2 (2 students)	0	5 (8.5)
Unspecified interaction	0	1 (1 student)	2 (2 staff)	3 (5.1)
Field trip	0	2 (1 student, 1 staff)	0	2 (3.4)
Cohort†	2 (2 students)	0	0	2 (3.4)

Note: K = kindergarten.

*There were multiple potential exposure settings for some cases; an assessment of which within-school exposure setting was most likely responsible for transmission was not included as part of this study.

†A cohort is a group of students and staff who remain together throughout a school term, the composition of which is consistent for all activities that occur in schools.

Limitations

Our analysis was limited by reliance on routinely collected data and by potential recall bias owing to the self-reported nature of contact-tracing interview data, although case and proxy report was supplemented with information from school administrators as needed. Although medical health officers could request asymptomatic testing for the purposes of public health investigation, universal testing was not required. Transmissions to undetected (e.g., asymptomatic and not tested) secondary and tertiary cases were therefore not examined, which could disproportionately affect groups more likely to experience asymptomatic infection. However, studies that employed asymptomatic testing of school contacts reported low levels of transmission.^{24,25,28} Class sizes were not measured; thus, any association with school-based transmissions was not assessed.

Data extraction for the cluster analysis was not done in duplicate, except for cases with multiple exposures; the potential for misclassification of the likely source of acquisition for these cases was minimized via independent review by 2 members of the research team. This study was limited to descriptive statistics, and causal inferences cannot be drawn.

Conclusion

From Sept. 10 to Dec. 18, 2020, we detected minimal clusters and low rates of secondary transmission in schools; these findings relate primarily to symptomatic disease. There were no deaths, and severe disease was rare in our study population. In-person school attendance may not expose students and staff to higher risks than those experienced in the community when infection prevention and control measures are in place,

and adequate case and contact management capacity is available. Acknowledging harms associated with decreased school attendance, policy-makers should focus on the implementation of measures to safely facilitate in-person learning, and consider school closures and widespread quarantine of students and staff with great caution.

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