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Low SARS-CoV-2 seroprevalence among Vancouver public school staff in British Columbia, Canada in the context of widespread community transmission

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Abstract

Objectives: There are limited school data accounting for asymptomatic SARS-CoV-2 infections in the school setting, particularly late in the 2020/21 school year, and in the context of uninterrupted in-person schooling. The objective was to determine the COVID-19 rates among all students and staff within Vancouver public schools, and the SARS-CoV-2 seroprevalence among the school staff.

Design: Incident COVID-19 cases among students and school staff using public health data, with an embedded cross-sectional serosurvey among school staff sampled from February 10 to May 15, 2021, comparing to period, age, sex and geographic location-weighted data from blood donors.

Setting: Vancouver School District (British Columbia, Canada) from kindergarten to grade 12.

Participants: Active school staff enrolled from February 3 to April 23, 2021.

Main outcome measures: SARS-CoV-2 antibodies in a sample of school staff using spike (S)-based testing (unvaccinated staff) or N-based serology testing (vaccinated staff).

Results: Incident COVID-19 cases among students attending in-person was 9.8 per 1,000 students (N = 47,280 students), and was 13 per 1,000 among staff (N = 7,071 active school staff). Of 1,689 school staff in study sample, 78.2% had classroom responsibilities, and spent a median of 17.6 hours in class per week [IQR: 5.0 – 25 hours]. Although 21.5% (363/1,686) reported close contact with a COVID-19 case, only 5 likely acquired the infection at school, based on viral testing. Adjusted seroprevalence in 1,556 staff (92.1%) was 2.3% [95%CI: 1.6–3.2%] compared to 2.6% [95%CI: 2.2–3.1%] in 5417 blood donors.

Conclusion: We found no detectable increase in seroprevalence among staff of this school district above a representative sample of blood donors from the same community. These findings show that it was possible to maintain in-person schooling without significantly increasing risk for school staff in the 2020/2021 school year, in the context of widespread community transmission and mitigation measures.

Article Summary:

Strengths:

- Largest Canadian study in one of the few, if not only jurisdiction in North America that maintained schools opened for in-person school during the 2020-2021 school year.
- Robust testing and reporting of seroprevalence, including reference data from entire school population, to allow to assess the possibility of a selection bias.

Limitations:

- Non-random participant selection, implying that a selection bias cannot be entirely excluded, although it is unlikely based on comparison with entire population.
- Limited power to detect small increase in seroprevalence over representative community reference group of blood donors.
- Study pre-dates the emergence of most variants of concerns in Canada, including the delta variant.

Introduction

SARS-CoV-2 forced over a billion students out-of-school globally in the Spring 2020. Decisions to close schools, motivated by high case mortality in populations, had serious implications for children's emotional, social, physical and educational outcomes [1]. The risk of secondary SARS-CoV-2 transmission within schools has been heavily debated. On one hand, viral culture studies suggest that children may be less infectious than adults [2], contact tracing studies show low rates of in-school transmission [3-13], and surveillance studies demonstrate little increased transmission when schools re-opened [14-19]. On the other hand, seroprevalence studies have been conducted to account for asymptomatic transmission, but many studies have reported data early in the pandemic, or in the setting of partial school closure [15 20-22].

In the spring of 2020, Public Health authorities in British Columbia (BC) ordered a cessation of in-person schooling provincially, with a transition to remote learning from home. Like most of the world, the province went under a nearly complete lockdown between March and early June when most sectors of the economy were paused. While BC reported relatively low community viral transmission early in the first pandemic wave, roughly >50 times more COVID-19 cases were reported (121,762 cases reported in a population of 5,017,000) between July 1, 2020 and April 23, 2021, compared to February to May 2020. Despite increasing cases in late summer, BC was unique within Canada in that it maintained in-person schooling for the entire duration of the 2020/2021 school year starting September 8, 2020, except for winter (December 18, 2020 to January 4, 2021) and spring (March 12 to March 29, 2021) breaks.

The main goal of this study was to determine the SARS-CoV-2 seroprevalence in school staff in Vancouver public schools during the 2020/21 school year. The secondary objectives were to compare the seroprevalence in school staff to a reference population of matched Canadian blood donors, and to report on the incidence of COVID-19 cases among all students and school staff.

Materials and Methods

Study design: This study used prospectively collected cross-sectional blood samples and questionnaire data collected between Feb 10 and May 15 2021 among active school staff of the Vancouver School District (the District). Seroprevalence data were compared to data obtained from Canadian blood donors screened prior to donation, to ensure they were in good health, including questions about COVID-19. People were ineligible to donate blood if they had a recent COVID-19 infection two weeks after symptoms resolved, or were hospitalized within 3 weeks before.

Participants: *School staff* self-enrolled from February 3 to April 23, 2021 after receiving an introduction email from school principals from the District in early February 2021, inviting them to register online at: https://www.bcchr.ca/COVIDatschools, for both a questionnaire and to provide blood for serology testing. A flyer was posted on the District website, and reminder emails were also sent. Interested participants completed a screener to identify whether they met eligibility criteria. Staff were included if they were a current, full or part-time staff member (confirmed by District email address). Staff who reported being temporary staff, on-leave, or on-call with no reported classroom time were excluded. Informed consent was obtained from all school staff. The study was approved by the University of British Columbia Children's and Women's Research Ethics Board (H20-03593).

Study setting: The District is a large, urban school district with 89 elementary schools and 18 secondary schools (47,280 students and 7,071 school staff) located in the city of Vancouver (BC, Canada ~600,000 population in the city of Vancouver with 2.6 million population in the urban area). Following a complete closure in March 2020, schools opened in a limited fashion, except for students who use English as a

second language and those with complex learning needs who were able to attend in-person 5 days/week until June 30, 2020. On September 8, 2020 schools reopened for the 2020/21 school year, except for a winter break from December 18, 2020 to January 4, 2021, and spring break from March 12 to 29, 2021. COVID-19 mitigations measures implemented in District schools as well as indications for viral testing are detailed in **Appendix 1**.

Data Collection: Data was collected from school staff using a questionnaire that asked, among others, about risk factors for COVID-19, household structure, physical distancing behavior, close contacts with COVID-19 cases (defined by asking: *"someone diagnosed with COVID-19 with whom you'd been within two meters of for greater than two minutes"*), history of viral testing (including dates and symptoms) and vaccination, etc [23]. A second questionnaire about mental health and vaccine perception was also administered but not reported in this paper. COVID-19 vaccination status in blood donors was also collected by asking at the time of blood donation.

To estimate the degree of exposure to known COVID-19 cases, we also obtained data from Vancouver Coastal Health (VCH)'s Case and Contact Management Interface. The District provided student and staff lists to VCH, which linked the data to determine the incidence of SARS-CoV-2 infection among all students and staff in District schools. The adult education staff was excluded. Staff and students affiliated with Vancouver Alternate Secondary School programs were counted as attending a single school for the purposes of incidence calculations.

Given that the history of viral testing in the prospective school staff sample was obtained via questionnaires, we selected the median date of questionnaire completion (March 4, 2021) as the end date for data extraction. We extracted all lab-confirmed, probable, and epidemiologically-linked COVID-19 cases reported to VCH. To assess the incidence of known infection among staff over the course of the pandemic, we calculated the incidence of reported staff cases from January 15, 2020 (corresponding to the first case reported to VCH) to March 4, 2021. Similarly, exposure to student cases during the school year was estimated by calculating the incidence from September 8, 2020 to March 4, 2021.

Serology testing: Blood samples were collected from February 10 to May 15 2021, at clinics set-up in various participating Vancouver schools, at the BC Children's Hospital or outpatient clinical laboratories in metro Vancouver. The presence of antibodies against SARS-CoV-2 was used as a marker of prior COVID-19 infection, using dual S- and N-based serology testing, where S-based serology was used in unvaccinated participants and N-based serology testing was used with vaccinated participants (**Supplemental Figure 1**), or for blood donors in whom we did lacked reliable data on vaccination status.

Antibodies directed against the spike (S1) protein were detected using the Ortho T *VITROS*^{TM} Anti-SARS-CoV-2 *Total antibody assay* (Ortho IgG; Ortho Clinical Diagnostics, Rochester, NY), a Health Canada and FDA-licensed qualitative assay which detects all types of antibodies (IgA, IgG and IgM). S-based serology testing was done on a Vitros 5600 analyser at the BC Children's & Women's Hospital Laboratory, which is accredited for clinical testing. Literature and in-house validation demonstrated this assay can identify both symptomatic and asymptomatic infected individuals >7 days post illness onset with a sensitivity between 90.7% and 97.7%, and specificities between 99.4% and 100% [24 25]. Specimens were considered reactive at a cut-off index ≥1.00. All S-tested negative samples with S-antibody indexes >99th centile were also confirmed to be negative on the Roche assay. Testing for anti-nucleocapsid (N) protein SARS-CoV-2 antibodies was performed using the Roche Elecsys^{TM} Anti-SARS-CoV-2 (Roche T; Roche, USA). This qualitative total antibody assay is Health Canada and FDA-licensed with reported sensitivity of 88.5% – 100% at least 14 days post-COVID-19 onset and specificity of 99.8% –100% [26-28]. Testing was performed on a Cobas e601 analyzer at St. Paul's Hospital Laboratory.

Blood donors were tested for both SARS-CoV-2 spike and N antibodies using the Roche Elecsys™ Anti-SARS-CoV-2 S and Anti-SARS-CoV-2 (Roche, USA) assays, respectively, on a Cobas e801 analyzer, and assigned using a similar S/N strategy for vaccinated / unvaccinated cases (**Supplemental Figure 1**).

Statistical analyses: The Rogan-Gladen estimator was used to calculate the true prevalence adjusting for test specificity and sensitivity, with 95% confidence intervals estimated using Blaker's method [29]. For seroprevalence in school staff and blood donors, sensitivity of 95.3% and specificity of 100% was used for the S-based assay [25 30]. Seroprevalence in blood donors was obtained weighting the data from the nucleocapsid-based Roche Elecsys™ Anti-SARS-CoV-2 (Roche T; Roche, USA) by collection month, postal code, sex and age and also adjusted for sensitivity and specificity of the N-based test using the Rogan-Gladen method (**Supplemental Data**). The geographical distribution of the school staff and the weighted blood donor data based on three postal code digits is shown in **Supplemental Figure 3**.

Data statement: The study data will be made available through the COVID-19 Immunity Task Force.

Results

COVID-19 cases from VCH contact tracing data in District schools (N = 47280 students and N = 7071 school staff): During the 2020-2021 school year (Sept 2020 to June 2021) 46879 students attended District schools in-person, and 401 students attended an Alternate District School (total of 47280 students). As shown in **Figure 1**, the overall weekly rates of reported COVID-19 cases among staff and students during the pandemic followed a trend similar to the weekly rates among Vancouver residents.

The population-level incidence of COVID-19 cases among students (including Vancouver Alternate Secondary Schools) during the 2020/21 school year was 9.8 cases per 1000 students, ranging from 0 to 63 cases per 1000 between schools (**Supplemental Figure 2**). Among schools with at least 1 student case, the median number of student cases was 3, and the median school population was 376 students.

In addition, 67 out of the 107 schools (62.6%) had no staff members diagnosed as confirmed, probable, or epidemiologically-linked COVID-19 cases since the beginning of the pandemic. Twenty-six of the 40 schools (65%) with staff cases had only one staff case. Including staff of Vancouver Alternate Secondary Schools, the incidence of reported cases from January 15, 2020 to March 4, 2021 among staff within specific schools ranged from 0 cases per 1000 staff to a maximum of 167 COVID-19 cases per 1000 staff. Among schools with at least 1 staff case, the median number of staff cases was 1, and the median size of each school's staffing complement was 46.5 staff members. All schools with incidences higher than 80 COVID-19 cases per 1000 staff had only 1 or 2 staff cases among a staffing complement of under 25 staff. The incidence of reported COVID-19 cases from January 15, 2020 to March 4, 2021 was 13 cases per 1000 classroom staff, and 14 cases per 1,000 non-classroom staff (**Supplemental Table 1**).

COVID-19 cases self-reported in school staff sample (N = 1689): Staff COVID-19 cases reported to VCH were compared to questionnaire data. In total, there were 2162 access to the screener, of which 1743 staff identified themselves, provided contact information and consented on-line (**Figure 2**). The characteristics of 1689 staff who completed the questionnaire, corresponding to 23.9% of eligible staff (**Table 1**).

Notably, 63.7% of study participants were elementary school staff and 28.1% were secondary school staff (**Table 1**), which align with District data (not shown). Overall, a majority (78.2%; n = 1320) of school staff were classroom staff, and spent a median of 17.6 hours of contact time with students per week (**Table 1**). The District estimated that 5091 staff have classroom responsibilities. Therefore, based on self-reported classroom duties, we estimate that the study enrolled ~26% of all eligible classroom staff.

About one third (37%) of school staff lived with an essential worker, predominantly in the social services, education/research/healthcare, construction, maintenance and skilled trades, and food sectors (**Table 2**). Among the school staff who completed the questionnaire, 51 reported a positive viral test among their household members (**Table 2**). In total, 363 (21.5%) reported a history of close contact with a COVID-19 case at or outside school, but only 24 of all 1689 school staff self-reported a positive viral test which represents an incidence rate of COVID-19 case of 1.4% (**Table 2**). Four (16.7%) tested positive by nucleic acid testing prior to the beginning of classes in September 2020.

Of the 24 school staff who reported a positive viral test, 5 (21%) reported close contact with a student or co-worker case, including one who required hospitalization during the 2020/21 school year. Seven (29%) reported close contact with a friend or family member with COVID-19, and one reported close contact with both a co-worker and family member with COVID-19. Eleven had unknown sources of acquisition and were not aware of any close contact with a COVID-19 case.

SARS-CoV-2 seroprevalence in school staff (N = 1556): Of 1689 school staff with prospective questionnaire data, 1556 completed serology testing (median date: March 11, 2021). Serology results for vaccinated and SARS-CoV-2-infected staff are shown in **Supplemental Table 2** and **3**, respectively. In total, 35 tested positive for SARS-CoV-2 by serology. Therefore, the unadjusted prevalence was 2.2% (95%CI: 1.6 – 3.1%), and the seroprevalence after adjusting for the sensitivity and specificity of the test was 2.3% (95%CI: 1.6 to 3.2%). Of the 35 school staff who were seropositive, 29 worked in a classroom setting and one did not work in a classroom setting, but reported more than 20 hours of contact time with students per week, for a seroprevalence also of 2.3% (95%CI: 1.5 – 3.1%). The proportion of staff who tested positive for SARS-CoV-2 by serology between secondary and elementary schools (**Table 3**) corresponded to the proportion of staff in each school level (**Table 1**). In comparison, the adjusted, weighted seroprevalence among 5417 blood donors was 2.6% (95%CI: 2.2 – 3.1%).

Discussion

This study found that the seroprevalence among staff in Vancouver public schools was relatively low after a period of widespread community transmission. Results were consistent with both self-reported infection as well as COVID-19 cases reported by VCH. Findings are in keeping with modelling studies [31 32] and data from the UK where low seroprevalence was also measured in teachers, but this was earlier in the pandemic [15]. To the best of our knowledge, this study is one of the largest to report seroprevalence estimates in the school setting in the later phases of the pandemic in the context of in-person schooling and widespread viral transmission. Despite that the seroprevalence in this study was approximately three-fold higher relative to previous estimates of 0.55% to 0.6% obtained from Vancouver residents in spring 2020 [33-35], it remained comparable to the community, as determined from blood donors.

Since this study was completed, only one other study reported seroprevalence in the school setting in North America[36]. A major advantage of the current study is that it was conducted in BC, one of the few jurisdictions in North America that maintained in-person schooling during the 2020/21 school year. About one quarter of the ~132,444 COVID-19 cases reported in BC during this period were located in the regional health authority where the city of Vancouver and its District are located. Study results are drawn from a large sample of staff, including a majority of those exposed to COVID-19 in the classroom. The use of S-based serology assays identified COVID-19 cases up to a year before. The study utilized sensitive serology testing to identify cumulative SARS-CoV-2 cases that may have not come to clinical attention, but could still contribute to the transmission chain [37]. Conversely, the N-based serology test allowed us to assess for infections in vaccinated staff towards the end of recruitment.

Among our study participants, 21.5% (363) of school staff reported a close contact with a COVID-19 case, and the majority (76.6%, 278/363) identified contact with a COVID-19 case at school. These data alone could reinforce the perception that schools are a risky environment. However, we could not find evidence to substantiate the perception that a large number of asymptomatic infections have been missed through contact tracing, and thus we were able to provide a more accurate depiction of viral transmission. Despite the high frequency of school staff who reported symptoms (**Table 2**), 90.1% (598/664) had no serological evidence of infection using a sensitive testing strategy. Under-ascertainment by viral testing could have been related to the use of targeted testing up until April 2020. However, the relatively high proportion (60%) of cases diagnosed by nucleic acid testing who tested positive via serology suggests good access to viral testing in this specific setting, during the study period.

Mitigation strategies employed in BC schools have been shown elsewhere to minimize risk in educators to a level comparable to the risk in the community [38 39]. Although non-medical masks were encouraged, but not required for students in schools until February 2021 (grades 8-12) and end of March 2021 (grades 4-12) (**Appendix**), and are still not required for K-3 students – a situation that is unique in Canada - we also did not detect any meaningful difference in seroprevalence between elementary and secondary school staff. Of note all school staff from the District were required to mask indoor (which is reflected in our survey results) and this intervention has been associated with lower risk of infection [38].

This study has limitations. First, study volunteers are typically healthier, raising a possibility that seroprevalence estimates were underestimated. To estimate this bias, the incidence of COVID-19 cases based on self-report (1.4%) was compared to the contact tracing data in classroom staff across the entire District (1.3%) and suggests that we did not under sample those who are in direct contact with students. Second, the seroprevalence of school staff was compared to matched blood donors which may not be a reliable estimate of community seroprevalence. However, blood donors are healthier, non-pregnant and may be more representative of the school staff enrolled in this study compared to other socio-economically-deprived populations at higher risk of COVID-19 [40 41]. Third, the study had limited power to detect small differences between seroprevalence in school staff and the community. Lastly, this study was conducted before any significant introduction of the delta variant of SARS-CoV-2 which has clearly been shown to be more transmissible when compared with prior variants [42]. In this context, follow-up studies are needed to determine its effect on seroprevalence estimates in the future.

In conclusion, this study shows no detectable increase in SARS-CoV-2 infections in school staff working in Vancouver public schools following a period of widespread community transmission (October – May 2021). Vaccination of school staff and older student age groups, together with the introduction of more transmissible variants requires ongoing evaluation of COVID-19 infections within the school community.

Authors' contributions: LCM and PML obtained funding as Co-PIs; DMG, AW, MAI, DC, PML and LCM designed the original study concept; SH was involved in the earliest stages of the study, helping with funding applications, study design, ethics applications and data interpretation; FR helped review the literature; EB constructed and managed the data collection database with support from LCM and AW; LM set-up and coordinated the recruitment of participants; SS and HRR processed all blood samples; VEB supervised the collection of blood samples; AC supervised the analysis of VCH case data among students and school staff; MAI advised statistical study design and analyzed the main seroprevalence estimates; SO provided and analysed matched data from Canadian blood donors; AW performed all other data analyses; CO facilitated communications within the District during the study; RYX helped with data analysis; MS contributed to the design of the study; DMG & PML drafted the first manuscript with specific sections written by AW, SH, VEB, MAI, AC, CO and LCM. All authors revised the manuscript and approved its final version.

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Conflicts of interest: CO is an employee of the Vancouver School District, but the District was not involved in the design, analysis, interpretation of the data, or the drafting of this manuscript; MS has been an investigator on projects funded by GlaxoSmithKline, Merck, Pfizer, Sanofi-Pasteur, Seqirus, Symvivo and VBI Vaccines. All funds have been paid to his institute, and he has not received any personal payments; Authors declare no relevant conflicts of interest.

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Table 1: Baseline characteristics of school staff sample

Variable	n[#]	Completed questionnaire (n=1689)	n[#]	Completed serology testing (n=1556)
Age (mean ± SD)	1684	45.4 ± 10.4	1556	45.7 ± 10.3
Sex, % female, n (%)	1681	1355 (80.6%)	1550	1257 (81.1%)
Canadians of indigenous origin, n (%)	1688	31 (1.8%)	1555	31 (2.0%)
Ethnicity, n (%)	1689		1556	
White, Caucasian		1175 (69.6%)		1084 (69.7%)
South Asian		65 (3.9%)		57 (3.7%)
Chinese		277 (16.4%)		257 (16.5%)
Black		12 (0.7%)		12 (0.8%)
Filipino		35 (2.1%)		33 (2.1%)
Latin American		26 (1.5%)		26 (1.7%)
Arab		4 (0.2%)		3 (0.2%)
Southeast Asian		32 (1.9%)		27 (1.7%)
West Asian		1 (0.1%)		1 (0.1%)
Korean		11 (0.7%)		9 (0.6%)
Japanese		39 (2.3%)		36 (2.3%)
Other/no answer		62 (3.7%)		57 (3.7%)
Classroom workers*, n (%)	1688	1320 (78.2%)	1555	1212 (77.9%)
Contact time with students (hrs/wk, median [IQR])	1684	17.6 [5.0-25.0]	1552	17.5 [4.6-25.0]
School level, n (%)	1689		1556	
Elementary		1076 (63.7%)		992 (63.8%)
Secondary		474 (28.1%)		436 (28.0%)
Work at multiple levels		55 (3.3%)		48 (3.1%)
School district office only		84 (5.0%)		80 (5.1%)
No. people living in household (median [IQR])	1685	3 [2-4]	1552	3 [2-4]
No. people in household is essential worker (median [IQR])	1671	0 [0-1]	1541	0 [0-1]
At least one co-morbidity¶, n (%)	1689	409 (24.2%)	1556	379 (24.4%)
Smoker, n (%)	1686	46 (2.7%)	1553	41 (2.6%)
Travelled outside BC since Jan '20, n (%)	1687	278 (16.5%)	1554	252 (16.2%)

[#]N with data available.

* Those who reported being a Teacher, Teacher Librarian, Resource Teacher, Student Support Worker, or Family and Youth Worker in response to the question: *What is your job title*? *Teacher/Teacher Librarian/Resource Teacher/Student Support Worker/Family and Youth Worker/Administrator (Principal, Vice Principal)/Administrative Assistant/Maintenance Staff/School Board Office Staff/Other.*

¶any the following: hypertension, diabetes, asthma, chronic lung disease, chronic heart disease, chronic kidney disease, liver disease, cancer, chronic blood disorder, immunosuppressed, chronic neurological disorder.

Table 2: Reported COVID-19 exposures and PCR outcomes among school staff

Variable	n[#]	Completed CITF questionnaire (n=1689)
COVID-19-like symptoms*, n (%)	1688	664 (39.3%)
Number tested for COVID-19 (PCR), n (%)	1688	760 (45.0%)
At least one positive COVID-19 viral test		24 (1.4%)
More than one positive COVID-19 viral test		1 (0.01%)
All negative COVID-19 viral test		715 (42.4%)
Did not know/could not remember test result		21 (1.2%)
Hospitalized for COVID-19, n (%)	1683	3 (0.2%)
Type of occupation for essential worker living in household, n (%)	1671	619 (37.0%)
Agriculture & food production		7 (0.4%)
Community services (sewage & water treatment, waste disposal)		10 (0.6%)
Construction, maintenance, skilled trades		77 (4.6%)
Consumer products (hardware, safety, vehicle, sales, garden centres)		9 (0.5%)
Financial services (banking, real estate, insurance)		19 (1.1%)
Food (grocery, convenience, liquor, restaurant)		67 (4.0%)
Health care		99 (5.9%)
Social services, education, research		244 (14.6%)
Manufacturing, resources, energy, utilities		21 (1.3%)
Services (pharmacy, gas station, delivery, funeral, vet, etc.)		13 (0.8%)
Sports (professional)		0
Supply chain & transportation		19 (1.1%)
Telecommunications & IT (including the media)		16 (1.0%)
Other		84 (5.0%)
COVID-19 case among other household members[δ], % Yes, n (%)	1688	51 (3.0%)
Reported close contact with a COVID-19 case outside household (within 2 meters and for >2 minutes), n (%)	1686	363 (21.5%)
Another school staff member / work colleague		133 (7.9%)
Student in classroom setting		145 (8.6%)
Family (non-household member)		46 (2.7%)
Friend		84 (5.0%)
Unknown		26 (1.5%)
Wear a mask in public places[τ], % Always or Often, n (%)	1685	1677 (98.5%)
Co-workers wear masks[τ], % Always or Usually, n (%)	1682	1635 (97.2%)
Students wear masks[τ], % Always or Usually, n (%)		
Elementary	1058	359 (33.9%)
Secondary	465	431 (92.7%)
Completed serology testing, n (%)	1689	1556 (92.1%)

[#]N with data available.

*Any of the following: cough, fever, shortness of breath, sore muscles, headache, sore throat, diarrhea, decrease sense of smell [specify period]. "Did you have any of the following symptoms between January 2020 and present?".

[δ]"Has anyone in your household (not counting yourself) ever tested positive for COVID-19? ([Yes], [Not applicable, I live alone], [No one has been tested], [No, they tested negative], [Not sure, waiting for the result])".

[τ]Questions about masking were as follows: How often have you worn a mask in public places in the past three months? (Never, Rarely, Occasionally, Often, Always); To the best of your knowledge, how often do your co-workers wear a mask in your presence? (Never, Occasionally, Usually, Always); To the best of your knowledge, how often do students in your school wear a mask in your presence? (Never, Occasionally, Usually, Always).

Table 3: Seropositive cases according to school education level where school staff teaches/assists

School	Frequency	Percent cases
Elementary	19	54.3
Secondary	9	25.7
Multiple / mixed	3	8.57
School board office	4	11.4

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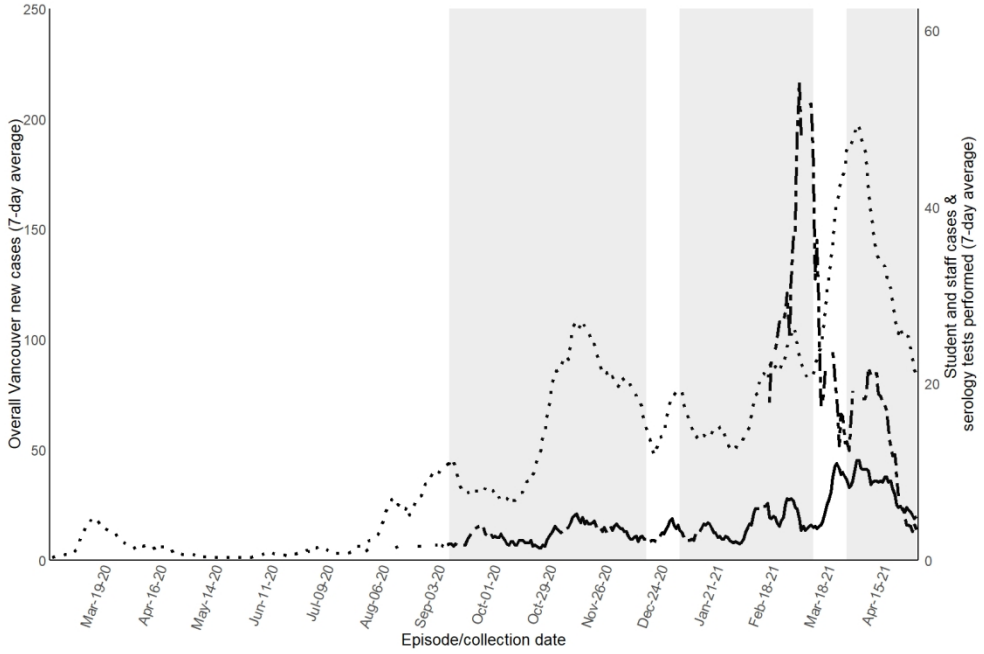


Figure 1: Weekly reported COVID-19 cases among all school staff and students of the Vancouver School District, compared to all Vancouver residents. Seven-day average of new SARS-CoV-2 cases among Vancouver residents and dates of serology collection. Median date of completion of questionnaire was March 4th. Dotted line shows total weekly Vancouver resident COVID-19 cases. Plain line shows total weekly cases among all students and staff from the Vancouver School District. Dashed line shows cumulative weekly serology tests performed among school staff sample. Gray background denotes when public school was in session.

288x192mm (150 x 150 DPI)

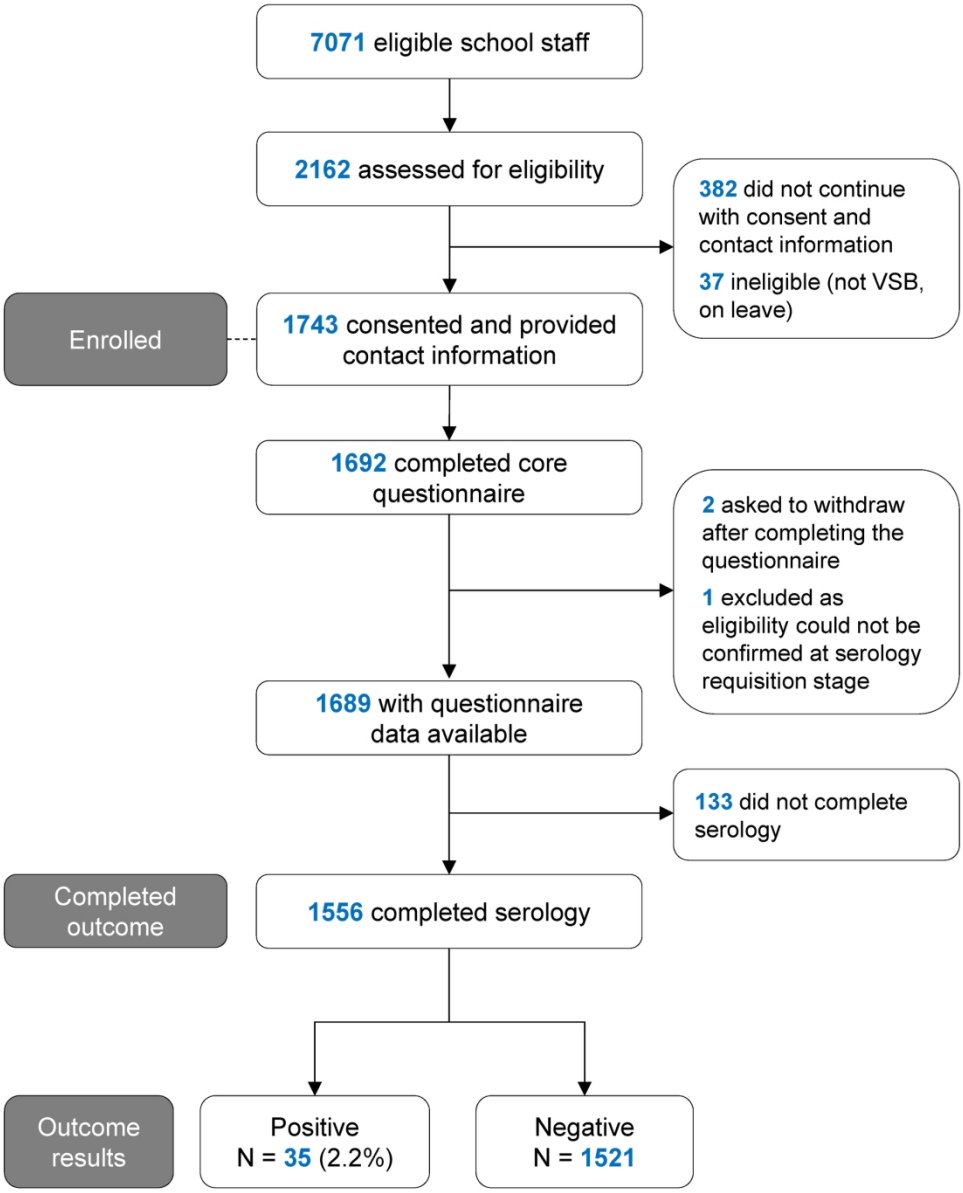
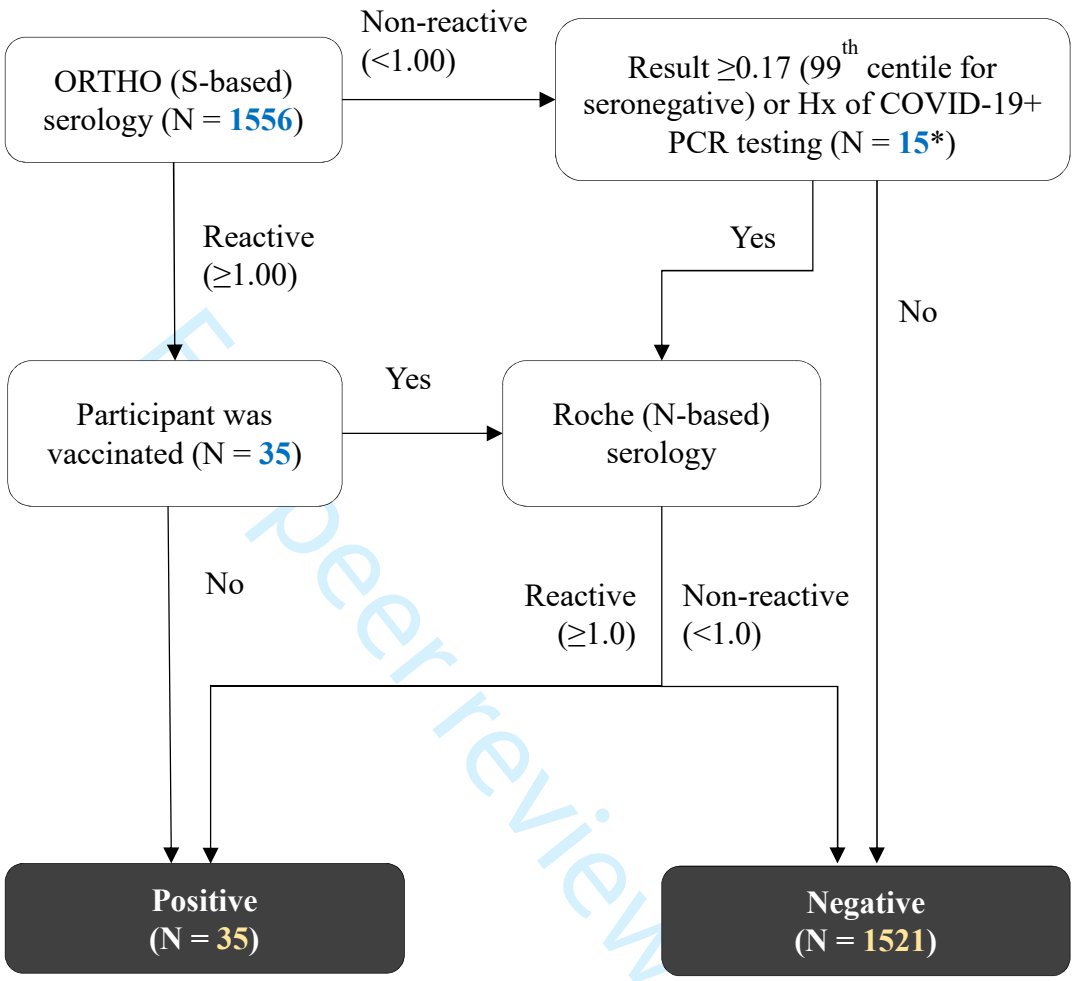


Figure 2: Flow diagram for enrollment of school staff study sample.

163x201mm (300 x 300 DPI)

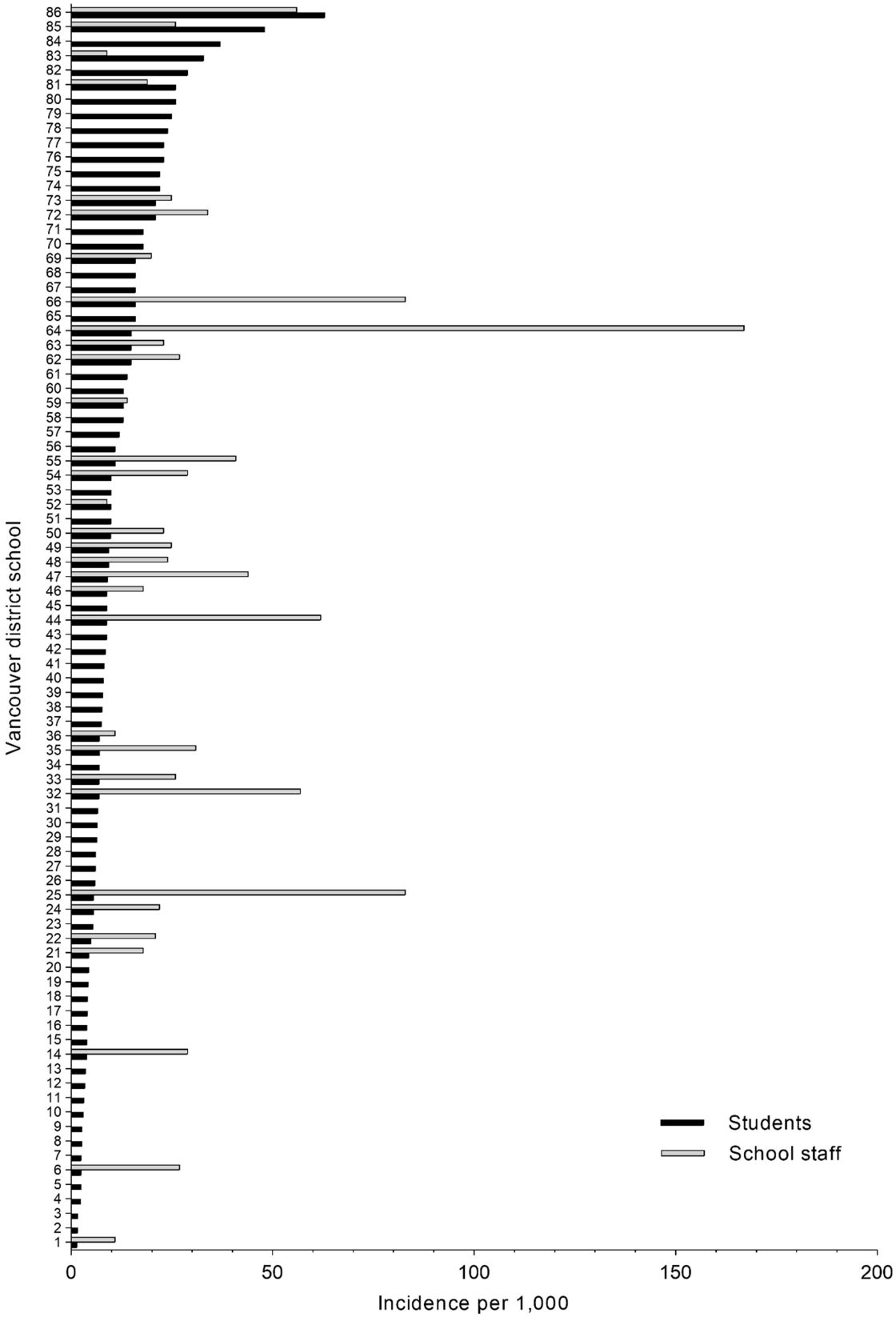
Supplemental Figure 1: Seroprevalence case assignment strategy



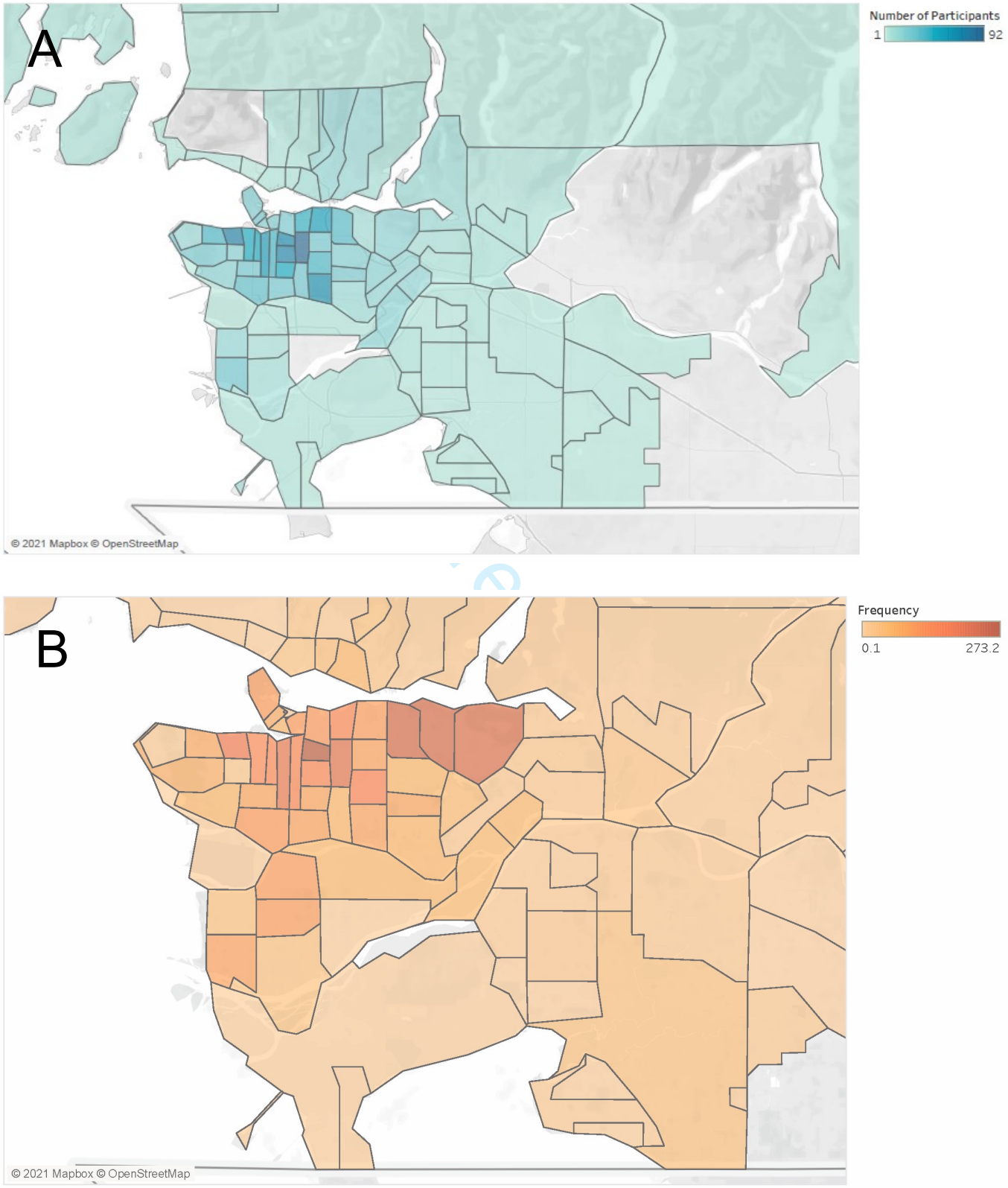
To distinguish between antibodies due to COVID-19 versus antibody responses to vaccination, a dual, stepwise serology testing strategy was employed, where more sensitive S-based testing (using ORTHO assay) was used in unvaccinated school staff who composed the majority of our study sample, and virus-specific N-based antibody testing (using Roche assay) was used in vaccinated school staff.

*One case reported PCR positive testing had subthreshold S-based serology reactivity of 0.39.

Supplemental Figure 2: Incidence of reported COVID-19 cases (Vancouver Coastal Health) per students (n = 47,280) and staff (n = 7,071) between schools of the Vancouver School District (21 of 107 schools had zero COVID-19 cases among students and staff, and are not included in this graph).



Supplemental Figure 3: Comparison of the geographical distribution of school staff included in study (A) versus the reference blood donor group (B) by first 3 postal code digit areas.



Map based on Longitude (generated) and Latitude (generated). Color shows sum of Frequency. Details are shown for FSA.

Supplemental Table 1: Reported positive viral testing among entire Vancouver School District staff

Reporting period	Classroom staff* N = 5091	Non-classroom staff** N = 1408	Other school staff*** N = 572	Overall N = 7071
Up to and including September 9th, 2020	7	1	1	9
Between September 10th 2020 and March 4th 2021 inclusive (median date of completion of study questionnaires)	58	18	8	84
Between March 5th 2020 and April 23rd 2021	34	8	4	46

*Teachers, Teacher Librarians, Resource Teachers, Student Support Workers, Family and Youth Workers, and Counsellors, including staff who are on call for these positions.

**Principals/VPs, Office Administrative Assistants, Facilities Staff, Building Engineers, and Custodians, including staff who are on call for these positions.

***Food services, Supervision Aides, and District staff, including staff who are on call for these positions.

Supplemental Table 2: Results of ORTHO (Spike-based) or ROCHE (N-based) serology testing, and according to self-reported viral PCR, for Spike-POSITIVE, VACCINATED cases (n=35)

Antibody detection				Self-reported COVID-19 PCR result?	Days between vaccine and serology	Final case assignment
Spike reactivity	Spike (index)	N reactivity	N (index)			
R	4.8	NR	0.082	Not tested	16	Negative
R	73.6	NR	0.089	No	14	Negative
R	252	R	150.7	Yes	1	Positive
R	142	NR	0.088	No	24	Negative
R	69.9	R	99.09	Yes	20	Positive
R	31.1	NR	0.084	Not tested	20	Negative
R	279	NR	0.144	Not tested	15	Negative
R	27.8	NR	0.09	Not tested	15	Negative
R	13.7	NR	0.088	Not tested	56	Negative
R	47.3	NR	0.087	No	32	Negative
R	163	NR	0.089	Not reported	11	Negative
R	10.5	NR	0.091	No	2	Negative
R	2.64	NR	0.09	Not tested	17	Negative
R	15.3	NR	0.092	Not tested	16	Negative
R	285	NR	0.082	Not tested	16	Negative
R	7.95	NR	0.085	No	?	Negative
R	16.8	NR	0.086	Not tested	31	Negative
R	114	NR	0.087	Not tested	17	Negative
R	90	NR	0.082	Not tested	16	Negative
R	15.9	NR	0.096	Not tested	18	Negative
R	486	R	44.52	Yes	88	Positive
R	63.5	NR	0.09	Not tested	?	Negative
R	1.07	NR	0.093	No	14	Negative
R	3.78	NR	0.095	Not tested	20	Negative
R	20.5	NR	0.212	No	21	Negative
R	132	NR	0.088	No	57	Negative
R	20.7	NR	0.095	Not tested	20	Negative
R	147	NR	0.085	No	21	Negative
R	61.5	NR	0.093	Not tested	24	Negative
R	106	NR	0.096	Not tested	23	Negative
R	73.6	NR	0.091	Not tested	?	Negative
R	79.9	NR	0.094	No	35	Negative
R	2.47	NR	0.095	Not tested	16	Negative
R	9.71	NR	0.098	No	15	Negative
R	8.56	NR	0.094	Not tested	28	Negative

R: reactive; NR: non-reactive; the only 3 vaccinated staff that tested positive by both S- and N-based assays also reported a history of COVID-19 by positive PCR viral test, and none of the vaccinated school staff who tested negative by the N-based serology assay reported a positive PCR viral test. All spike (S)-reactive cases were contacted by phone or email to confirm the date they received a COVID-19 vaccine between the date of survey completion and blood sampling. Three participants indicated that they had received a COVID-19 vaccine, but omitted to indicate the date in the questionnaire or email response.

Supplemental Table 3: Results of ORTHO (Spike-based) or ROCHE (N-based) serology testing, and according to self-reported viral PCR, for seropositive, INFECTED cases (n=35)

Antibody detection				Self-reported COVID-19 PCR result?	Time between PCR test and serology	Vaccinated? [days between vaccine and serology]
Spike reactivity	Spike (index)	N reactivity	N (index)			
R	6.2	R	1.44	Yes	2 months	No
R	224	R	57.99	Not tested	-	No
R	129	R	5.99	Not tested	-	No
R	112	R	127	Yes	1.9 month	No
R	226	R	125.3	Yes	3.2 months	No
R	433	R	64.64	Not tested	-	No
R	270	R	166.7	Yes	2.5 months	No
R	8.73	NR	0.483	Yes	3 weeks	No
R	272	R	6.41	Yes	3 months	No
R	3.22	NR	0.074	Not tested	-	No
NR	0.39	R	8.61	Yes	11.25 months	No
R	445	R	2.84	No	-	No
R	242	R	1.99	Not tested	-	No
R	52.4	R	4.58	Yes	5.5 months	No
R	138	NR	0.564	Not tested	-	No
R	318	R	42.54	Not tested	-	No
R	2.27	R	117.6	Yes	2.75 months	No
R	562	R	28.92	Yes	~7 months	No
R	216	R	119.3	Yes	2.3 months	No
R	381	R	193.3	Not tested	-	No
R	142	R	11.03	Yes	1.5 month	No
R	331	R	3.54	Not tested	-	No
R	69.7	R	16.88	Not tested	-	No
R	252	R	150.7	Yes	2 months + 6 days	Yes [1]
R	69.9	R	99.09	Yes	4.25 months	Yes [20]
R	4.44	R	4.26	Not tested	-	No
R	45.1	R	4.22	Not tested	-	No
R	581	R	44.07	Yes	1 year + 2 weeks	No
R	503	R	45.95	Yes	6.75 months	No
R	10.3	R	1.01	Yes	2.75 months	No
R	211	R	130.5	Yes	1.84 month	No
R	310	R	80.05	Yes	4.5 months	No
R	224	R	15.64	Not tested	-	No
R	327	R	57.04	Yes	4 months + 2 days	No
R	486	R	44.52	Yes	3.75 months	Yes [8]

R: reactive; NR: non-reactive; One school staff who tested positive for COVID-19 by PCR viral test tested negative by serology ~5 months later both by S- and N-based assays. Another who reported a positive PCR test did not complete the serology testing.

SUPPLEMENTAL DATA: Weighted seroprevalence analysis in Canadian blood donors

Create weight according to month*fsa2*sex*agegroup distribution in study sample.

By removing samples without complete information, 1527 left in study sample, which made 104 groups. Samples from Feb were treated as Jan sample. There are data from 16407 samples from British Columbia blood donors, which made 410 groups.

The weighted analysis involve: 1526 school staff and 5417 blood donor samples.

Comparison between British Columbia and weighted blood donor data:

School staff data					Blood donor data		
		N	%			Weighted N	Weighted %
Total		1526	100			5417	100.0
Month	1	267	17.5		1	947.8	17.50
	3	873	57.21		**3**	3099.0	57.21
	4	347	22.74		**4**	1231.8	22.74
	5	39	2.56		**5**	138.4	2.56
FSA2	**V0**	5	0.33		**V0**	17.7	0.33
	V1	1	0.07		**V1**	3.5	0.07
	V2	4	0.26		**V2**	14.2	0.26
	V3	108	7.08		**V3**	383.4	7.08
	V4	28	1.83		**V4**	99.4	1.83
	V5	788	51.64		**V5**	2797.2	51.64
	V6	463	30.34		**V6**	1643.6	30.34
	V7	128	8.39		**V7**	454.4	8.39
	V9	1	0.07		**V9**	3.5	0.07
Sex	**F**	1238	81.13		**F**	4394.7	81.13
	M	288	18.87		**M**	1022.3	18.87
Age	**17-24**	11	0.72		**17-24**	39.0	0.72
	25-	431	28.24		**25-**	1530.0	28.24
	40-	967	63.37		**40-**	3432.7	63.37
	60-	117	7.67		**60-**	415.3	7.67
Roche N					**Neg**	5276.7	97.41
					Pos	140.3	2.59 (95%CI: 2.17- 3.11)

APPENDIX 1: COVID-19 mitigations measures in Vancouver schools (2020/21 school year)

Prior to reopening, the District implemented COVID-19 safety plans consistent with the British Columbia Centre for Disease Control (BCCDC) COVID-19 Public Health Guidance for K-12 School Settings: http://www.bccdc.ca/Health-Info-Site/Documents/COVID_public_guidance/Guidance-k-12-schools.pdf. and Provincial COVID-19 Health & Safety Guidelines for K-12 Settings: https://www2.gov.bc.ca/assets/gov/education/administration/kindergarten-to-grade-12/safe-caring-orderly/k-12-covid-19-health-safety-guidlines.pdf with support from Public Health.

COVID-19 safety plans included public health measures (e.g., protocols for testing and contact tracing), environmental measures (e.g., maximization of distance in classrooms, enhanced cleaning and disinfection, improved fresh air intake), administrative measures (e.g., staggered scheduling, assigning students and staff cohorts), personal measures (e.g., daily symptom checks, physical distancing, hand hygiene, respiratory etiquette), and personal protective equipment.

At the beginning of the school year (late August/September), parents were given the option of: 1) full time in-person schooling, 2) home schooling, 3) online learning and 4) a temporary online learning with return to full time schooling with re-entry dates offered later in fall and in January 2021.

During the entire school year, daily health assessments were required by all staff and students (via parents) prior to arriving at school and again upon arrival. Anyone with even minor symptoms of cold or flu-like illness was to stay home or go home if these symptoms developed mid-day. Classrooms and other spaces were arranged to maximize distance between students and staff. Class sizes were set by grades: 20 students / class for kindergarten; 22 for grades 1 to 3; 30 for grades 4 to 12. School staff and their students were assigned specific classrooms which were between 75 m^2 – 83 m^2 for elementary students (K to grade 7) and 75 m^2 – 80 m^2 for secondary students (grades 8 to 12) with larger spaces available for elective courses (e.g., physical education, food studies, metal, woodworking, automotive). In addition, secondary classrooms were divided into two separate groupings (AM and PM) of 15 students.

The plan also included revising school schedules and learning groups where students also had staggered recess and lunch breaks, and were assigned specific outside areas. Elementary students (K-7) received full day in-class instruction in their assigned learning groups/cohorts. Secondary students (grades 8 to 12) had both in-class instruction and remote learning and their schedules shifted to a quarter system with maximum two in-person classes a day with further instruction given remotely.

Ventilation measures included opening windows to promote fresh air flow to classrooms as well as indoor air ventilation improved with the HVAC systems running longer during the day, recirculating less air and the filters changed to higher efficiency (MERV13) filters.

Other measures included, the addition of hand sanitizer to classrooms and common areas, directional traffic flow within the school, provision of plexiglass as needed for certain staff roles, and the training of all staff on the safety plan and protocols. In addition to the regular daily cleaning by custodial staff, twice daily disinfection of all high touch frequency items was conducted. Shared items in classrooms were limited and the teachers, or if in secondary school, the students disinfected those used. Initially, masking was encouraged, but not required. Non-medical mask use was encouraged but not required early in the school year, and then in February 2021 masks were required for all staff and students in grades 6-12 in common spaces, and ultimately from April onward for students grades 4-12 at all times while indoors at school. This guidance did not apply if staff or students did not tolerate a mask for health or behavioural reasons. Masks remained recommended for K-3 students. Two reusable cloth masks were distributed to

all staff and students in September 2020 and again in January 2021. The vast majority of enrolled staff did not wear face shields. Face shields were made available to student support staff who work in close proximity to students with diverse needs and to first aid attendants.

SARS-CoV-2 nucleic acid amplification (PCR) was available for anyone with symptoms through the provincial health system, and advised for students or staff with fever or new symptoms which persisted for over 24 hours. Tests were generally processed within 24 hours, and positive tests were automatically reported to Public Health which investigated cases within 24 hours, and initiated contact tracing. Symptomatic close contacts were asked to seek testing; asymptomatic testing was not used to release contacts from isolation on an earlier timeline. All close contacts, including close contacts at school, were isolated for at least 14 full days. Entire classes were not isolated unless all members were identified as close contacts. School closures to control transmission were not required during the study period. Also, at the time, vaccination programs had not substantially reached working-age people until April 14, and the majority of school staff vaccinations occurred in May. Last day of classes was June 29th, 2021 and June 30th was the last day for staff (administrative day).

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*
Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any pre-specified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3,4 + Appendix 1
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	3
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	3, and Supplementary file, Page 7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*3*
Bias	9	Describe any efforts to address potential sources of bias	3, 7 (limitation section: "To estimate this bias,…")
Study size	10	Explain how the study size was arrived at	3,4 (population-based + convenience sample for seroprevalence estimates)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5

Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA (descriptive analysis)
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	3
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5 + flow chart (Fig. 2)
		(b) Give reasons for non-participation at each stage	Fig 2
		(c) Consider use of a flow diagram	Fig 2
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA (cross-sectional)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	6 and Supp Fig 1, Supp Table 2 & 3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6, Supp Fig 1
		(*b*) Report category boundaries when continuous variables were categorized	Tables
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplemental Data
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6,7
Generalisability	21	Discuss the generalisability (external validity) of the study results	7

Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	8

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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SARS-CoV-2 seroprevalence among Vancouver public school staff in British Columbia, Canada: A cross-sectional study

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SARS-CoV-2 seroprevalence among Vancouver public school staff in British Columbia, Canada: A cross-sectional study

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Abstract

Objectives: Few studies reported COVID-19 cases in schools, in a setting of uninterrupted in-person schooling during the 2020/21 academic year. The main objective was to determine the SARS-CoV-2 seroprevalence and incidence of COVID-19 cases among school staff in Vancouver public schools.

Design: Cumulative incident COVID-19 cases among all students and school staff based on public health data, with an embedded cross-sectional serosurvey among a school staff sample, comparing to period, age, sex and geographical location-weighted data from blood donors.

Setting: Vancouver School District (British Columbia, Canada) from kindergarten to grade 12.

Participants: Active school staff enrolled from February 3 to April 23, 2021 with serology testing from February 10 to May 15, 2021.

Main outcome measures: SARS-CoV-2 antibodies in a sample of school staff using spike (S)-based testing (unvaccinated staff) or N-based serology testing (vaccinated staff).

Results: Public health data showed the cumulative incidence of COVID-19 among students attending in-person was 9.8 per 1,000 students (N = 47,280), and 13 per 1,000 among school staff (N = 7,071). In a representative sample of 1,689 school staff, 78.2% had classroom responsibilities, and spent a median of 17.6 hours in class per week [IQR: 5.0 – 25 hours]. Although 21.5% (363/1,686) of surveyed staff self-reported close contact with a COVID-19 case outside of their household (16.5% contacts were school-based), 5 likely acquired the infection at school based on viral testing. Sensitivity/specificity-adjusted seroprevalence in 1,556/1,689 staff (92.1%) was 2.3% [95%CI: 1.6–3.2%], comparable to a sex, age, date and residency area-weighted seroprevalence of 2.6% [95%CI: 2.2 – 3.1%] among 5,417 blood donors.

Conclusion: Seroprevalence among staff was comparable to a reference group of blood donors from the same community. These data show that in-person schooling could be safely maintained during the 2020/21 school year with mitigation measures, in a large school district in Vancouver, Canada.

Article Summary:

Strengths:

- Largest Canadian study in one of the few, if not only jurisdiction in North America that maintained schools opened for in-person school during the 2020-2021 school year.
- Reference data from entire school population, and robust reporting of seroprevalence based on accurate serology testing on a representative school sample.

Limitations:

- Non-random participant selection, implying that a selection bias cannot be entirely excluded, although it is unlikely based on comparison with entire population.
- Limited power to detect small increase in seroprevalence over representative community reference group of blood donors.
- Study pre-dates the emergence of most variants of concerns in Canada, including the delta variant.

Introduction

SARS-CoV-2 forced over a billion students out-of-school globally in the Spring 2020. Decisions to close schools, motivated by high case mortality in populations, had serious implications for children's emotional, social, physical and educational outcomes [1]. The risk of secondary SARS-CoV-2 transmission within schools has been heavily debated. On the one hand, data support low rates of in-school secondary SARS-CoV-2 transmission [2-12], with little increased transmission when schools re-opened [13-18]. On the other hand, few studies have accounted for asymptomatic transmission using antibody testing, but most have reported data early in the pandemic, or in the setting of partial school closure [14 19-21].

In the spring of 2020, BC health authorities ordered a cessation of in-person schooling provincially, with a transition to remote learning from home. Like most of the world, the province went under a nearly complete lockdown between March and early June 2020 when most sectors of the economy were paused. In the global context, British Columbia (BC) and Canada observed relatively low incident COVID-19 cases compared to other areas of the world [22]. While BC reported relatively low community transmission, roughly >50 times more cases were reported between July 1, 2020 and May 15, 2021 (136,291 cases in a population of 5,017,000), compared to the first pandemic wave from February to May 2020 [23]. Despite increasing cases in late summer, BC was unique within Canada in that it maintained in-person schooling for the entire duration of the 2020-2021 school year starting September 8, 2020, except for regular winter (December 18, 2020 to January 4, 2021) and spring (March 12 to March 29, 2021) breaks.

The main goal of this study was to determine the SARS-CoV-2 seroprevalence in school staff in Vancouver public schools during the 2020-2021 school year. The secondary objective was to compare the seroprevalence in school staff to a reference population of matched Canadian blood donors.

Materials and Methods

Study design: This study used baseline, cross-sectional data from a prospective study collected by questionnaire among active school staff of the Vancouver School District (the District) between February 10 and May 15 2021, with blood samples for serology testing collected from the same school staff between February 10 to May 15 2021, and serology data obtained between January 1st and May 31, 2021 from Canadian blood donors during the same period, age, sex and geographical area of residency.

Participants: *School staff* self-enrolled from February 3 to April 23, 2021 after receiving an introduction email from school principals from the District in early February 2021, inviting them to register online at: https://www.bcchr.ca/COVIDatschools, for both a questionnaire and to provide blood for serology testing. A flyer was posted on the District website, and reminder emails were also sent. Interested participants completed a screener to identify whether they met eligibility criteria. Staff were included if they were a current, full or part-time staff member (confirmed by District email address). Staff who reported being temporary staff, on-leave, or on-call with no classroom time, or working exclusively in an adult education setting were ineligible. Informed consent was obtained from all school staff. The study was approved by the University of British Columbia Children's and Women's Research Ethics Board (H20-03593).

Study setting: The District is a large, urban school district with 89 elementary schools and 18 secondary schools (47,280 students and 7,071 school staff) located in the city of Vancouver (BC, Canada ~600,000 population in the city of Vancouver with a population of 2.6 million in urban area). Following a complete closure in March 2020, schools opened in a limited fashion, except for students who use English as a second language and those with complex learning needs who were able to attend in-person 5 days/week until June 30, 2020. On September 8, 2020 schools reopened for the 2020/21 school year, except for a regularly scheduled winter break from December 18, 2020 to January 4, 2021, and spring break from

March 12 to 29, 2021. COVID-19 mitigations measures implemented in District schools as well as indications for viral testing are detailed in **Appendix 1**.

Data Collection: To estimate the degree of exposure to known COVID-19 cases, we obtained data from Vancouver Coastal Health (VCH)'s Case and Contact Management Interface. The District provided student and staff lists attending the District as of May 17, 2021 to VCH, which linked the data to determine the cumulative incidence of COVID-19 cases among all students and staff in District schools (excluding the adult education staff). Staff and students affiliated with Vancouver Alternate Secondary School programs were counted as attending a single school for the purposes of incidence calculations.

Given that the history of viral testing in the prospective school staff sample was obtained via questionnaires, we selected the median date of questionnaire completion (i.e. March 4, 2021) as the end date for data extraction. We extracted all lab-confirmed, probable, and epidemiologically-linked COVID-19 cases reported to VCH. To assess the incidence of known infection among staff over the course of the pandemic, we calculated the incidence of reported staff cases from January 15, 2020 (corresponding to the first case reported to VCH) to March 4, 2021. Similarly, exposure to student cases during the school year was assessed using the incidence of confirmed, probable, or epidemiologically-linked COVID-19 cases from the beginning of the school year (September 8, 2020) to March 4, 2021. Data from (smaller size) school annexes were combined to their corresponding attachment schools, as long as the school staff was shared between the two, for a total of 77 elementary and 18 secondary schools in the analysis.

Data was collected from the school staff sample using a questionnaire that asked, among others, about risk factors for COVID-19, household structure, physical distancing behavior, close contacts with COVID-19 cases (defined by asking: *"someone diagnosed with COVID-19 with whom you'd been within two meters of for greater than two minutes"*), history of viral testing (including dates and symptoms) and vaccination, etc. [24]. Analyses on risk factors for COVID-19 and data from a second questionnaire about mental health and vaccine perception are not reported in this paper. For blood donors, we only had access to age, sex, postal code of residence and COVID-19 vaccination status at the time of blood donation using questionnaires administered by Canadian Blood Services as part of the routine donation process.

Serology testing: Blood samples were collected at clinics set-up in various participating Vancouver schools, at the BC Children's Hospital or outpatient clinical laboratories in the Vancouver area. The presence of antibodies against SARS-CoV-2 was used as a marker of prior COVID-19 infection, using dual S- and N-based serology testing, where S-based serology was used in unvaccinated participants and N-based serology testing was used with vaccinated participants, or for blood donors in whom we did lack reliable data on vaccination status (**Supplemental Figure 1**). Vaccines used in Canada elicit a spike (S) antibody response, whereas natural infection elicits both an S and a nucleocapsid (N) response. Thus N responses can be used to determine if a participant has had prior infection regardless of vaccination status.

Antibodies directed against the spike (S1) protein were detected using the Ortho T *VITROS*^{TM} Anti-SARS-CoV-2 *Total antibody assay* (Ortho IgG; Ortho Clinical Diagnostics, Rochester, NY), a Health Canada and FDA-licensed qualitative assay which detects all types of antibodies (IgA, IgG and IgM). S-based serology testing was done on a Vitros 5600 analyser at the BC Children's & Women's Hospital Laboratory, which is accredited for clinical testing. Literature and in-house validation demonstrated this assay can identify both symptomatic and asymptomatic infected individuals >7 days post illness onset with a sensitivity between 90.7% and 97.7%, and specificities between 99.4% and 100% [25 26]. Specimens were considered reactive at a cut-off index ≥1.00. All S-tested negative samples with S-antibody indexes >99th centile were also confirmed to be negative on the Roche assay. Testing for anti-nucleocapsid (N) protein SARS-CoV-2 antibodies was performed using the Roche Elecsys^{TM} Anti-SARS-CoV-2 (Roche T; Roche, USA). This qualitative total antibody assay is Health Canada and FDA-licensed with reported

sensitivity of 88.5% – 100% at least 14 days post-COVID-19 onset and specificity of 99.8% –100% [27-29]. Testing was performed on a Cobas e601 analyzer at St. Paul's Hospital Laboratory.

Blood donors were screened prior to donation, to ensure they were in good health. People were ineligible to donate blood if they had a recent COVID-19 infection two weeks after symptoms resolved, or were hospitalized within 3 weeks before. Blood donors were tested for N antibodies using the Roche Elecsys™ Anti-SARS-CoV-2 assay (Roche, USA) on a Cobas e801 analyzer. N antibodies have been shown to persist in blood after infection with assay sensitivity maintained until at least a year post-infection [30].

Bias minimization strategies: Because enrollment was non-random, a number of measures were taken to facilitate/encourage participation: i) Strong buy-in from schools (see *Patient and Public Involvement* section below); ii) Easy participation: blood collection sites were set-up in schools over lunch and after work, in four geographically dispersed, centrally located area within the Vancouver School District area to ensure that the blood collection was readily accessible to participants. Other blood collection sites also included partnerships with hundreds of private community clinics in Vancouver (opened on weekends), the St-Paul's Hospital (high sampling volume, located in downtown Vancouver) and the British Columbia Children's Hospital (located west of the District); iii) Facilitation on the ground: we hired a full-time study coordinator to maintain contact and answer emails 7 days per week, and ensure a smooth study flow, facilitate bookings at blood collection sites with flexible hours, etc. (including driving around the city to meet the few participants who were unable to attend the multiple blood clinics); iv) Participant incentives: Participants were offered a $20 incentive and serology results were returned to them.

Patient and Public Involvement: Right from the study design stage, District leaders, Teacher and Student Support Worker, and parent Associations were engaged to obtain support and seek feedback on study feasibility. Weekly meetings occurred from study launching until publication of findings with a District leadership representative (CO) and a District liaison (Kathy O'Sullivan) to adjust study advertisement and procedures to maximize recruitment. At the end, results were shared immediately, initially with study participants, followed by BC Public Health and government authorities, and in other Canadian provinces.

Statistical analyses: In absence of data available at the time on COVID-19 transmission in schools, our initial sample size was set based on an anticipated increase in seroprevalence compared to earlier phases of the pandemic. We estimated that 2,410 school staff would achieves 80% power to detect a 2.2-fold increase in prevalence estimates available from April to June 2020 [31]. The Rogan-Gladen estimator was used to calculate the true prevalence adjusting for test specificity and sensitivity, with 95% confidence intervals estimated using Blaker's method [32]. For the school staff sensitivity of 95.3%, and specificity of 100% were used for the S-based assay [26 33], ignoring the small proportion of N-based assays used for outcome classification. For the blood donors, sensitivity of 98.8% and specificity of 99.6% were used for the nucleocapsid-based Roche Elecsys™ Anti-SARS-CoV-2 assay (Roche T; Roche, USA), weighting the data by collection month, postal code, sex and age (**Supplemental Data**). Uncertainty of the serology tests was approached incorporating the uncertainty in test parameters using a Bayesian approach with no meaningful changes to 95% confidence intervals (not shown). All analyses were done on complete cases.

Data statement: De-identified data will be made available through the COVID-19 Immunity Task Force.

Results

District-wide COVID-19 exposure from students: During the 2020-2021 school year (September 2020 to June 2021) 46879 students attended District schools in-person and 401 students attended an Alternate District School. As shown in **Figure 1**, overall weekly rates of reported COVID-19 cases among staff and students during the pandemic followed a trend similar to the weekly rates among Vancouver residents.

Population-level cumulative incidence of COVID-19 cases among students (total of 47280 students) during the 2020/21 school year was 9.8 cases per 1000 students (median 8.2; range 0 to 63 cases per 1000 between schools). Each school had between 0 and 36 cases. Twelve schools had zero student cases. District-wide COVID-19 cumulative incidence among school staff: The cumulative incidence of COVID-19 cases from January 15, 2020 to March 4, 2021 among the 5091 classroom school staff was 13 cases per 1000, and was 14 cases per 1,000 among 1980 other and non-classroom staff (**Supplemental Table 1**). When looking at COVID-19 cases since the beginning of the pandemic, 54 of 95 schools had no staff COVID-19 case, with a maximum of 3 staff cases per school. The cumulative incidence of COVID-19 case among 4.5% staff members assigned to more than one schools was 21 per 1,000 staff.

Characteristics of school staff sample: In total, 2162 school staff accessed the initial study screening website, of which 1743 staff provided contact information and consented for serology testing. The characteristics of 1689 staff who completed the questionnaire are shown in **Table 1**. This corresponds to 23.9% of all eligible staff. The age and sex of school staff in the sample was representative of the District population (mean age ± SD: 47.4 ± 11.2 years; 69.5% female [76.2% female among classroom staff]; N = 6751 with data available). The proportion of school staff sampled for serology was evenly distributed among low vs. high COVID-19 incidence schools (**Supplemental Figure 2**). The residency distribution of the school staff sample was also geographical similar to the District population (**Supplemental Data**).

A total of 78.2% (n = 1320) of our sample were classroom staff, who spent a median of 17.6 hours of contact time with students per week (**Table 1**). In comparison, the District estimated that 71.9% (n = 5091) of the 7071 eligible staff, had classroom responsibilities. Notably, the distribution of the school staff sample between elementary and secondary schools (**Table 1**), as well as the distribution of occupations of the school staff sample also reflected all staff in the District (**Supplemental Table 2**).

About one third (37%) lived with an essential worker, predominantly in the social services, education/research/healthcare, construction, maintenance and skilled trades, and food sectors (**Table 2**). In total, 363 (21.5%) school staff reported close contact with a COVID-19 case at or outside school, including 51 who reported close contact with a COVID-19 case in their household (**Table 2**).

SARS-CoV-2 prevalence in school staff sample by viral testing: Only 24 self-reported having had COVID-19 based on nucleic acid amplification tests, for a cumulative incidence of 1.4% of school staff (**Table 2**). Of the 24 school staff who reported a positive viral test, 4 (16.7%) tested positive prior to the beginning of classes in September 2020. Five (21%) reported that the most likely source of infection was a close contact with a student or co-worker case, including one who required hospitalization during the 2020/21 school year. Seven (29%) reported close contact with a friend or family member with COVID-19, and one reported close contact with both a co-worker and family member with COVID-19. Eleven had unknown sources of acquisition and were not aware of any close contact with a COVID-19 case.

SARS-CoV-2 seroprevalence in school staff sample by serology: Of 1689 school staff who completed the prospective questionnaire, 1556 completed serology testing (median blood collection date: March 11, 2021). In total, 35 tested positive for SARS-CoV-2 by serology. Therefore, this corresponded to 46% more infections diagnosed by serology compared to infections diagnosed by viral testing.

Thirty-five staff (2.2%) of the 1556 school staff who completed serology were vaccinated at the time of blood testing. Individual serology results are shown in **Supplemental Table 3** and **4** for vaccinated and SARS-CoV-2-infected staff, respectively. Accounting for vaccination status, 35 school staff had a serology profile indicative of a previous COVID-19 infection (**Supplemental Figure 1**). Of the 35 school staff who had a positive serology indicative of infection, 29 worked in a classroom setting and one did not work in a classroom setting, but reported more than 20 hours of contact time with students per week. The

proportion of staff who tested positive for SARS-CoV-2 by serology between secondary and elementary schools (**Table 3**) corresponded to the proportion of staff in each school level (**Table 1**).

Among the school staff sample, the unadjusted prevalence was 2.2% (95%CI: 1.6 – 3.1%), and the seroprevalence adjusted for the sensitivity and specificity of the test was 2.3% (95%CI: 1.6 to 3.2%). In comparison, the adjusted seroprevalence among 5417 blood donors was 2.6% (95%CI: 2.2 – 3.1%). Importantly, the postal code area distribution of the school staff sample closely matched the age-, sex-, period- and residency location-weighted blood donor data (**Supplemental Figure 3**).

Post-stratification seroprevalence analyses: The proportion of female overall was slightly higher in the school sample compared to the District population. However, the seroprevalence in the school sample was similar, 2.6% (95%CI: 1.9% - 3.6%), after post-stratifying for sex. Additionally, if we had sampled equally among schools the post-stratification seroprevalence would be 2.5% (95%CI: 1.8% – 3.5%), so not statistically different than the actual original estimate in the school staff sample presented above.

Discussion

This study found that the seroprevalence among staff in Vancouver public schools was relatively low after a period of widespread community transmission pre-dating the emergence of Variants of Concerns. Results were consistent with COVID-19 cases reported by VCH. Findings are in keeping with modelling studies [34 35] and data from the UK where low seroprevalence was also measured in teachers, but this was earlier in the pandemic [14]. To the best of our knowledge, this study is the largest Canadian study and one of the largest to report seroprevalence estimates in the context of continuously maintained in-person schooling and widespread viral transmission late in the 2020 to 2021 academic year. Despite that the seroprevalence in this study was approximately three-fold higher relative to previous estimates of 0.55% to 0.6% obtained from Vancouver residents in spring 2020 [31 36 37], it remained comparable to the community, as determined from blood donors of the same age, sex, and living in the same community.

Since this study was completed, only one other study reported seroprevalence in the school setting in North America [38]. A major advantage of the current study is that it was conducted in BC, one of the few jurisdictions in North America that maintained in-person schooling during the 2020-2021 school year. About one quarter of the ~132,444 COVID-19 cases reported in BC during this period were located in the regional health authority where the city of Vancouver and its District are located. Study results are drawn from a large sample of staff, including a majority of those exposed to COVID-19 in the classroom. The use of S-based serology assays identified COVID-19 cases up to a year before. The study utilized sensitive serology testing to identify cumulative SARS-CoV-2 cases that may have not come to clinical attention, but could still contribute to the transmission chain [39]. Conversely, the N-based serology test allowed us to assess for infections in vaccinated staff towards the end of recruitment.

The high proportion (60%) of cases diagnosed viral testing who tested positive via serology contrasts with a recent review finding that on average the ratio of antibody to viral detection of cases up to over 18 [40]. Our findings would suggest good access to viral testing in this specific setting, during the study period.

Among our study participants, 21.5% (363) of school staff reported a close contact with a COVID-19 case, and the majority (76.6%, 278/363) identified contact with a COVID-19 case at school. These data alone could reinforce the perception that schools are a risky environment. However, despite the high frequency of school staff who reported close contacts, but also symptoms (**Table 2**), 90.1% (598/664) had no serological evidence of infection using a sensitive testing strategy. Thus, we were able to provide a more accurate depiction of viral transmission and could not find evidence to substantiate the perception that a large number of asymptomatic infections have been missed through contact tracing.

Mitigation strategies employed in BC schools have been shown elsewhere to minimize risk in educators to a level comparable to the risk in the community [41 42]. Although non-medical masks were encouraged, but were not required for students in schools until February 2021 (grades 8-12) and end of March 2021 (grades 4-12), we did not observe any difference in seroprevalence between elementary and secondary school staff. Of note all school staff from the District were required to mask indoors (which is reflected in our survey results) and this intervention has been associated with lower risk of infection [41].

This study has limitations. First, non-random participant selection amongst the school staff population implies a potential volunteer bias. However, the similar incidence of COVID-19 cases among the school staff sample (1.4%) compared to the entire District (1.3%) suggests that we did not under-sample those at risk. Second, blood donors are healthier and therefore, may not be a reliable estimate of community seroprevalence though there are likely representative of school staff compared to other socioeconomic-deprived populations at higher risk of COVID-19 [43 44]. Effectively, underestimation of the seroprevalence in blood donors would only reinforce our conclusion. Third, this study was conducted before the more transmissible delta or omicron variants. Based on contact tracing data, we recently showed that secondary transmission in District schools remained infrequent even in the delta era [45]. Further serology testing is planned in the spring of 2022 to determine if these conclusions will hold true during the omicron era.

In conclusion, this study shows no detectable increase in SARS-CoV-2 infections in school staff working in Vancouver public schools following a period of widespread community transmission (October 2020 to May 2021), compared to a reference group of blood donors from the same age, sex and community area. Vaccination of school staff and older student age groups, together with the introduction of more transmissible variants requires ongoing evaluation of COVID-19 infections within the school community.

Authors' contributions: LCM and PML obtained funding for this study; DMG, AW, SH, MAI, DC, PML and LCM designed the original study concept; SH further contributed to data interpretation; FR reviewed the literature; EB constructed and managed the data collection database; LM set-up and coordinated the recruitment of participants; SS and HRR processed blood samples, under the supervision of VEB; ND analyzed the population-level data from students and school staff, under the supervision of AC; MAI performed statistical analyses; SO provided and analysed matched data from Canadian blood donors; AW performed all other data analyses; CO facilitated communications within the District during the study; RYX helped with data analysis; MS contributed to the design of the study; DMG & PML drafted the first manuscript with specific sections written by AW, SH, VEB, MAI, AC, CO and LCM. All authors revised the manuscript and approved its final version.

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Conflicts of interest: CO is an employee of the Vancouver School District, but the District was not involved in the design, analysis, interpretation of the data, or the drafting of this manuscript; MS has been an investigator on projects funded by GlaxoSmithKline, Merck, Pfizer, Sanofi-Pasteur, Seqirus, Symvivo and VBI Vaccines. All funds have been paid to his institute, and he has not received any personal payments; Authors declare no relevant conflicts of interest. LifeLabs and Dynacare played no role in the study other than providing a service for the collection of blood samples.

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Figure Legends

Figure 1: Weekly reported COVID-19 cases among all school staff and students of the Vancouver School District, compared to all Vancouver residents. Seven-day average of new SARS-CoV-2 cases among Vancouver residents and dates of serology collection. Median date of completion of questionnaire was March 4th. Dotted line shows total weekly Vancouver resident COVID-19 cases. Plain line shows total weekly cases among all students and staff from the Vancouver School District. Dashed line shows cumulative weekly serology tests performed among school staff sample. Gray background denotes when public school was in session.

Figure 2: Flow diagram for enrollment of school staff study sample.

Table 1: Baseline characteristics of school staff sample

Variable	n[#]	Completed questionnaire (n=1689)	n[#]	Completed serology testing (n=1556)
Age (mean ± SD)	1684	45.4 ± 10.4	1556	45.7 ± 10.3
Sex, % female, n (%)	1681	1355 (80.6%)	1550	1257 (81.1%)
Canadians of indigenous origin, n (%)	1688	31 (1.8%)	1555	31 (2.0%)
Ethnicity, n (%)	1689		1556	
White, Caucasian		1175 (69.6%)		1084 (69.7%)
South Asian		65 (3.9%)		57 (3.7%)
Chinese		277 (16.4%)		257 (16.5%)
Black		12 (0.7%)		12 (0.8%)
Filipino		35 (2.1%)		33 (2.1%)
Latin American		26 (1.5%)		26 (1.7%)
Arab		4 (0.2%)		3 (0.2%)
Southeast Asian		32 (1.9%)		27 (1.7%)
West Asian		1 (0.1%)		1 (0.1%)
Korean		11 (0.7%)		9 (0.6%)
Japanese		39 (2.3%)		36 (2.3%)
Other/no answer		62 (3.7%)		57 (3.7%)
Classroom workers*, n (%)	1688	1320 (78.2%)	1555	1212 (77.9%)
Contact time with students (hrs/wk), median (IQR)	1684	17.6 [5.0-25.0]	1552	17.5 [4.6-25.0]
School level, n (%)	1689		1556	
Elementary		1076 (63.7%)		992 (63.8%)
Secondary		474 (28.1%)		436 (28.0%)
Work at multiple levels		55 (3.3%)		48 (3.1%)
School district office only		84 (5.0%)		80 (5.1%)
No. people living in household, median (IQR)	1685	3 [2-4]	1552	3 [2-4]
Living with an essential worker in household, n (%)	1671	619 (37.0%)	1541	565 (36.7%)
At least one co-morbidity¶, n (%)	1689	409 (24.2%)	1556	379 (24.4%)
Smoker, n (%)	1686	46 (2.7%)	1553	41 (2.6%)
Travelled outside BC since Jan 1st '2020, n (%)	1687	278 (16.5%)	1554	252 (16.2%)

[#] N with data available.

* Those who reported being a Teacher, Teacher Librarian, Resource Teacher, Student Support Worker, or Family and Youth Worker in response to the question: "What is your job title? (Teacher, Teacher Librarian, Resource Teacher, Student Support Worker, Family and Youth Worker, Administrator [Principal, Vice Principal], Administrative Assistant, Maintenance Staff, School Board Office Staff, Other). "

¶ any the following: hypertension, diabetes, asthma, chronic lung disease, chronic heart disease, chronic kidney disease, liver disease, cancer, chronic blood disorder, immunosuppressed, chronic neurological disorder.

Table 2: Reported COVID-19 exposures and PCR outcomes among school staff

Variable	n[#]	Completed questionnaire (n=1689)
COVID-19-like symptoms*, n (%)	1688	664 (39.3%)
Number tested for COVID-19 (PCR), n (%)	1688	760 (45.0%)
At least one positive COVID-19 viral test		24 (1.4%)
More than one positive COVID-19 viral test		1 (0.01%)
All negative COVID-19 viral test		715 (42.4%)
Did not know/could not remember test result		21 (1.2%)
Hospitalized for COVID-19, n (%)	1683	3 (0.2%)
Type of occupation for essential worker living in household, n (%)	1671	619 (37.0%)
Agriculture & food production		7 (0.4%)
Community services (sewage & water treatment, waste disposal)		10 (0.6%)
Construction, maintenance, skilled trades		77 (4.6%)
Consumer products (hardware, safety, vehicle, sales, garden centres)		9 (0.5%)
Financial services (banking, real estate, insurance)		19 (1.1%)
Food (grocery, convenience, liquor, restaurant)		67 (4.0%)
Health care		99 (5.9%)
Social services, education, research		244 (14.6%)
Manufacturing, resources, energy, utilities		21 (1.3%)
Services (pharmacy, gas station, delivery, funeral, vet, etc.)		13 (0.8%)
Sports (professional)		0
Supply chain & transportation		19 (1.1%)
Telecommunications & IT (including the media)		16 (1.0%)
Other		84 (5.0%)
COVID-19 case among other household members[δ], % Yes, n (%)	1688	51 (3.0%)
Reported close contact with a COVID-19 case outside household (within 2 meters and for >2 minutes), n (%)	1686	363 (21.5%)
Another school staff member / work colleague		133 (7.9%)
Student in classroom setting		145 (8.6%)
Family (non-household member)		46 (2.7%)
Friend		84 (5.0%)
Unknown		26 (1.5%)
Wear a mask in public places[τ], % Always or Often, n (%)	1685	1677 (98.5%)
Co-workers wear masks[τ], % Always or Usually, n (%)	1682	1635 (97.2%)
Students wear masks[τ], % Always or Usually, n (%)		
Elementary	1058	359 (33.9%)
Secondary	465	431 (92.7%)
Completed serology testing, n (%)	1689	1556 (92.1%)

[#] N with data available.

* Any of the following: headache, cough, fever, sore throat, shortness of breath, sore muscles, diarrhea, decrease sense of smell [specify period]. "Did you have any of the following symptoms between January 2020 and present?".

[δ] "Has anyone in your household (not counting yourself) ever tested positive for COVID-19? ([Yes], [Not applicable, I live alone], [No one has been tested], [No, they tested negative], [Not sure, waiting for the result])".

[τ] Questions about masking were as follows: “How often have you worn a mask in public places in the past three months? (Never, Rarely, Occasionally, Often, Always)”; “To the best of your knowledge, how often do your co-workers wear a mask in your presence? (Never, Occasionally, Usually, Always)”; “To the best of your knowledge, how often do students in your school wear a mask in your presence? (Never, Occasionally, Usually, Always)”.

Table 3: Seropositive cases according to school education level where school staff teaches/assists

School	Frequency	Percent cases
Elementary	19	54.3
Secondary	9	25.7
Multiple / mixed	3	8.6
School board office	4	11.4
Total	**35**	**100.0%**

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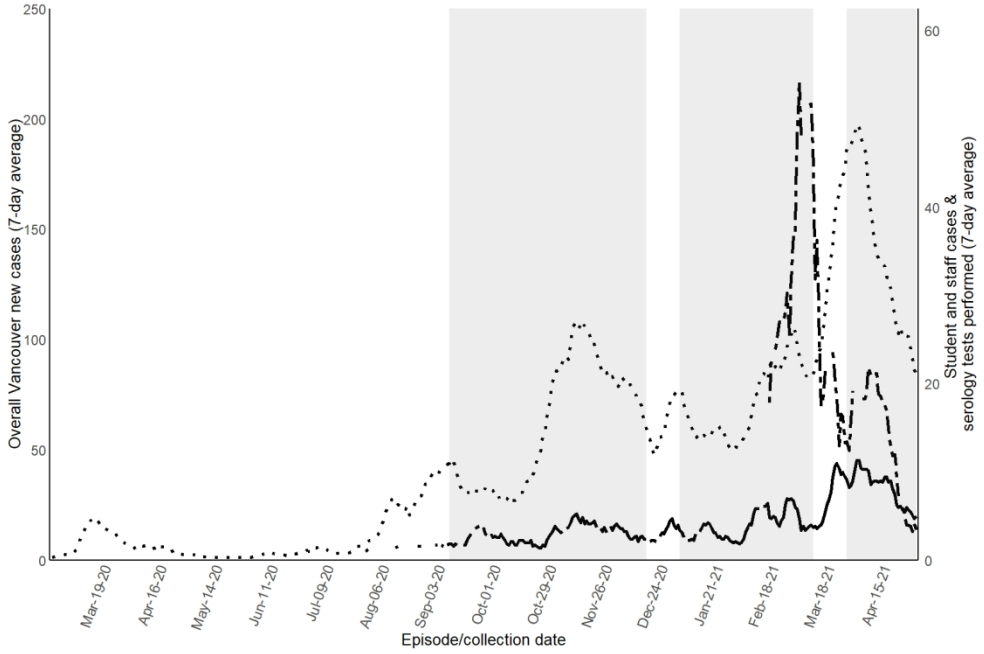


Figure 1: Weekly reported COVID-19 cases among all school staff and students of the Vancouver School District, compared to all Vancouver residents. Seven-day average of new SARS-CoV-2 cases among Vancouver residents and dates of serology collection. Median date of completion of questionnaire was March 4th. Dotted line shows total weekly Vancouver resident COVID-19 cases. Plain line shows total weekly cases among all students and staff from the Vancouver School District. Dashed line shows cumulative weekly serology tests performed among school staff sample. Gray background denotes when public school was in session.

288x192mm (150 x 150 DPI)

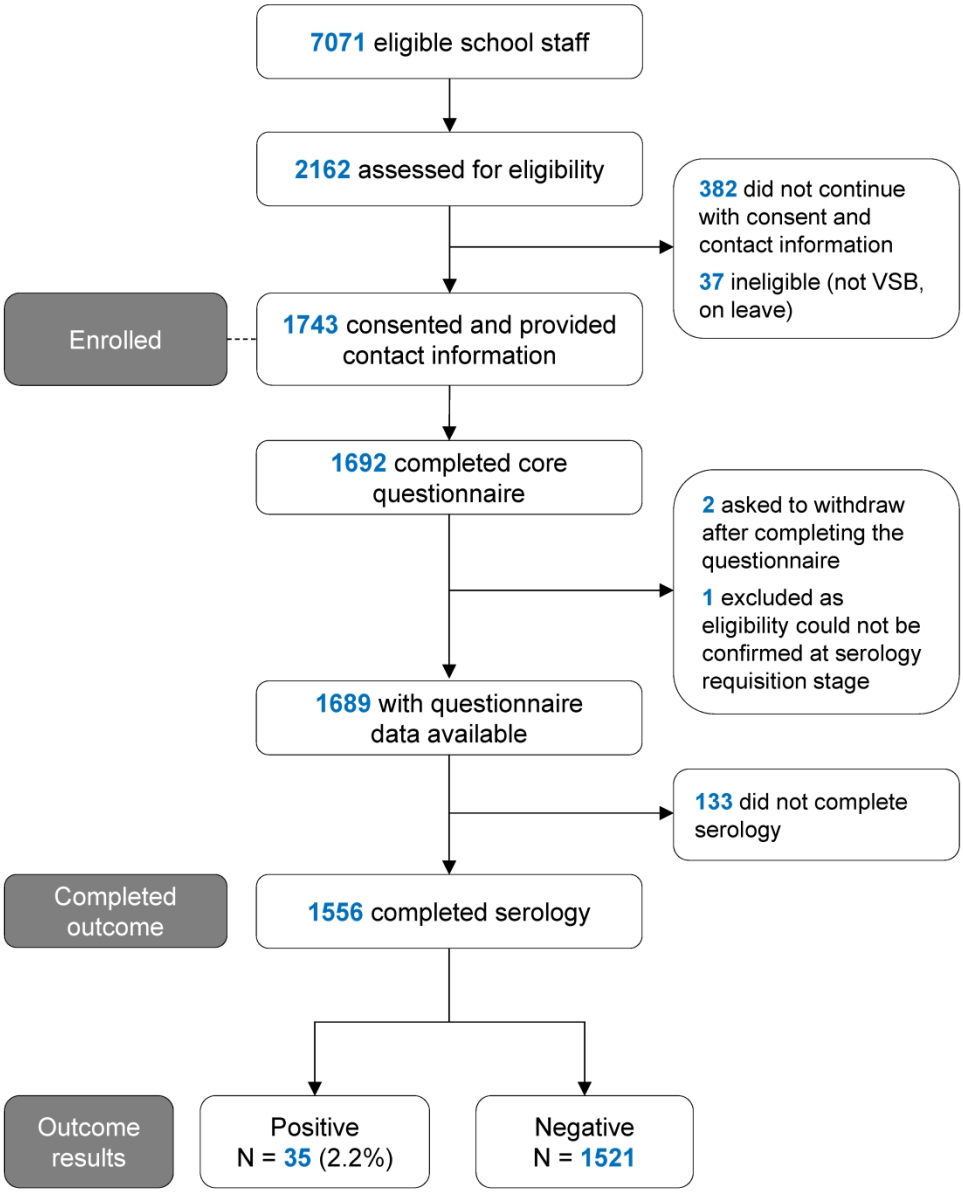
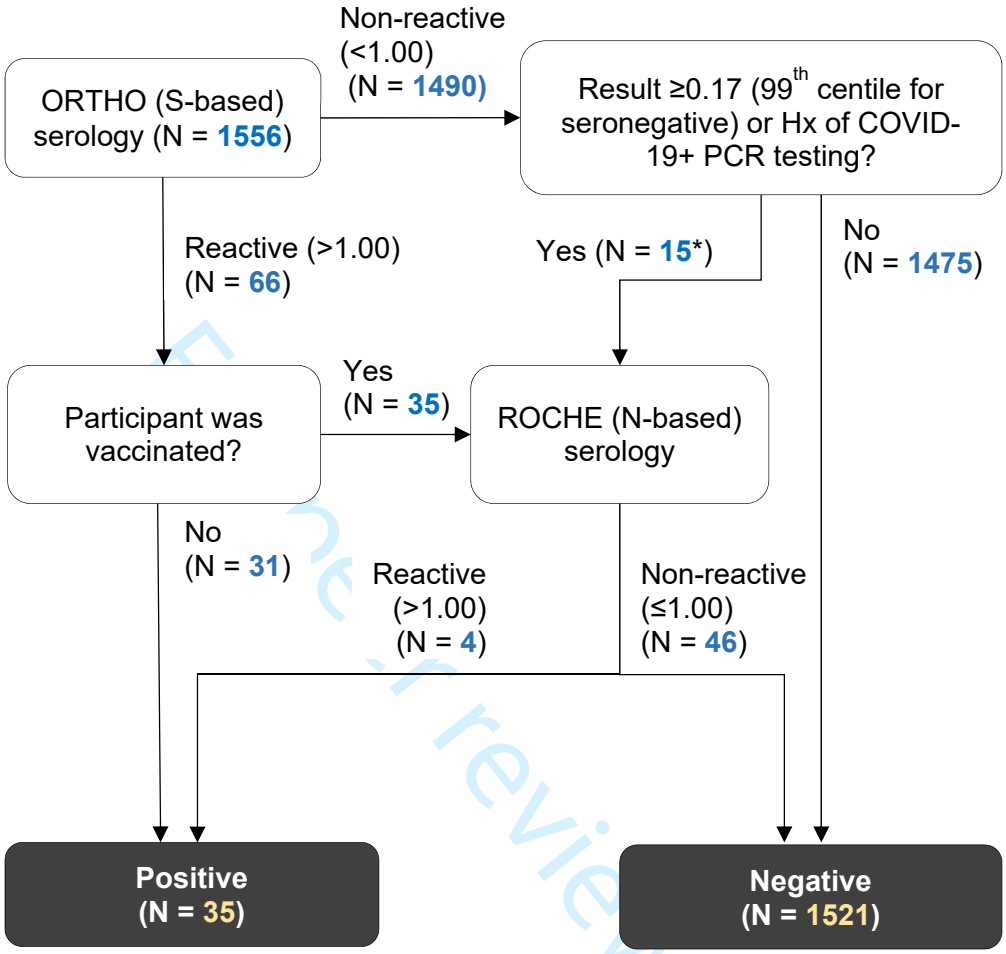


Figure 2: Flow diagram for enrollment of school staff study sample.

163x201mm (600 x 600 DPI)

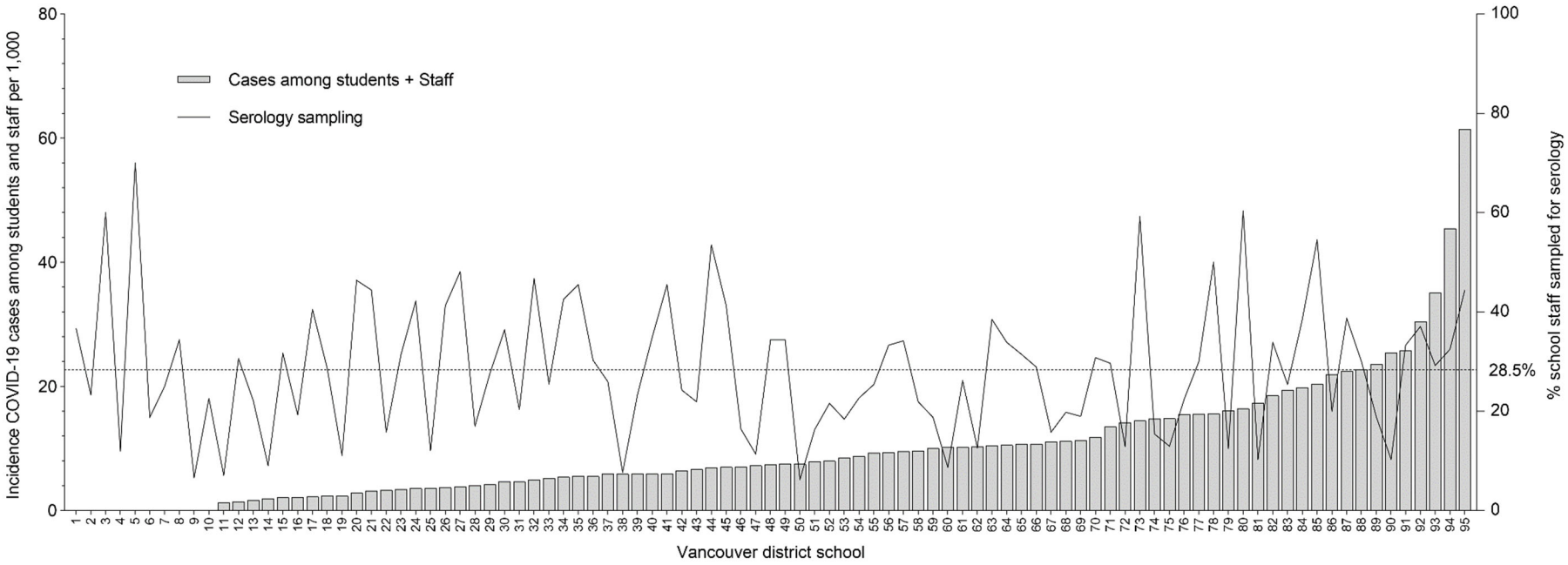
Supplemental Figure 1: Seroprevalence case assignment strategy



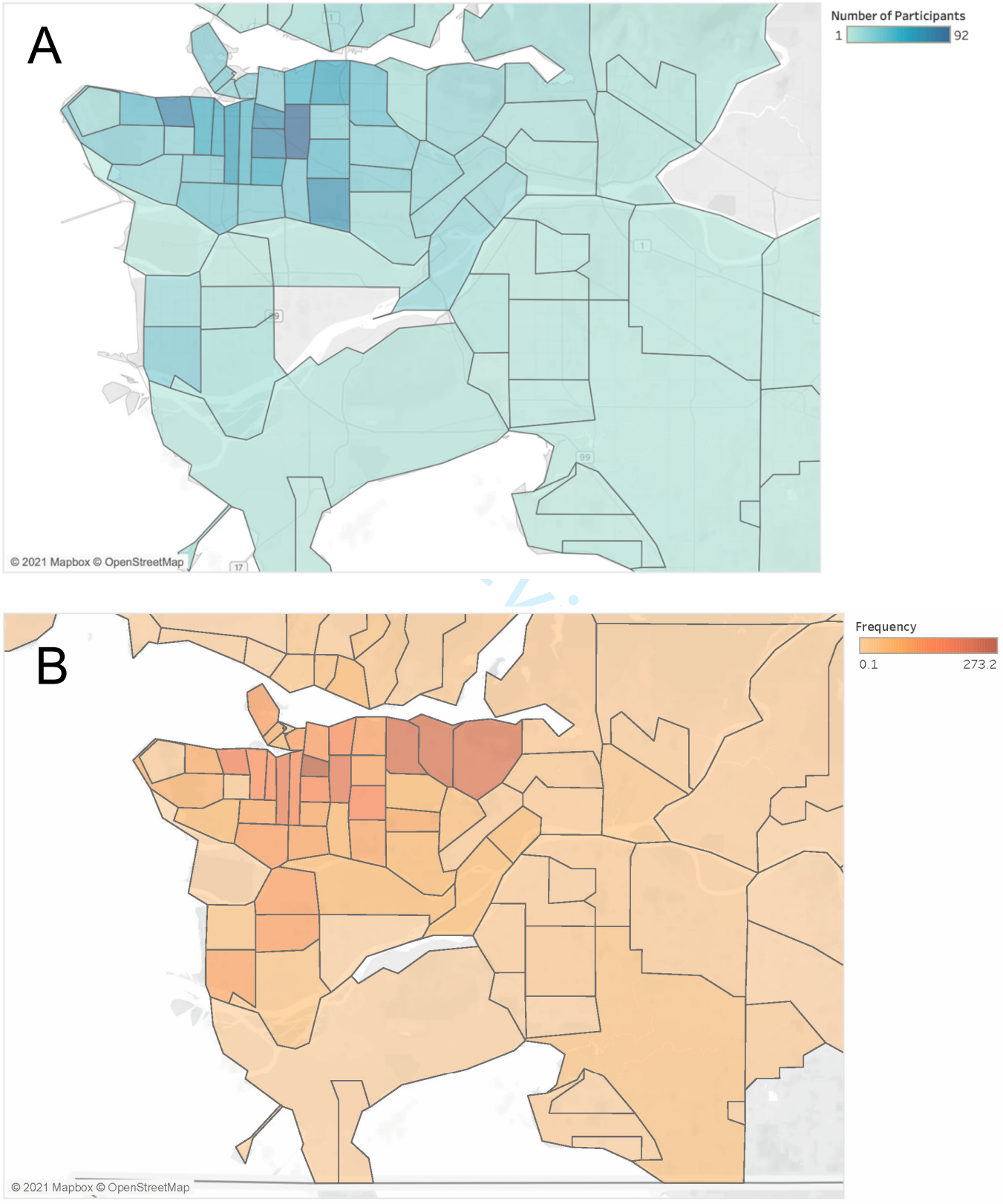
To distinguish between antibodies due to COVID-19 versus antibody responses to vaccination, a dual, stepwise serology testing strategy was employed, where more sensitive S-based testing (using ORTHO assay) was used in unvaccinated school staff who composed the majority of our study sample, and virus-specific N-based antibody testing (using Roche assay) was used in vaccinated school staff.

*One case reported PCR positive testing had subthreshold S-based serology reactivity of 0.39.

Supplemental Figure 2: Cumulative incidence of reported COVID-19 cases (based on Public Health data from Vancouver Coastal Health) in students (n = 47280 students) and staff (n = 7071) from September 8, 2020 to March 4, 2021, and the percentage of school staff sampled for serology, for each school of The District. Data exclude Vancouver Alternate Secondary Schools. Dotted line shows average percentage staff sampled for serology testing across all 95 schools in the District (28.5%).



Supplemental Figure 3: Geographical distribution of (A) the school staff sample with serology data (N = 1556) versus (B) the reference blood donor group (N = 5417) by areas of residency (based on first 3 postal code digits).



Supplemental Table 1: Reported positive viral testing among entire Vancouver School District staff

Reporting period	Classroom staff* N = 5091	Non-classroom staff** N = 1408	Other school staff*** N = 572	Overall N = 7071
Up to and including September 9th, 2020	7	1	1	9
Between September 10th 2020 and March 4th 2021 inclusive (median date of completion of study questionnaires)	58	18	8	84
Between March 5th 2020 and April 23rd 2021	34	8	4	46

*Teachers, Teacher Librarians, Resource Teachers, Student Support Workers, Family and Youth Workers, and Counsellors, including staff who are on call for these positions.

**Principals/VPs, Office Administrative Assistants, Facilities Staff, Building Engineers, and Custodians, including staff who are on call for these positions.

***Food services, Supervision Aides, and District staff, including staff who are on call for these positions.

Supplemental Table 2: Distribution of school staff by occupation type and elementary/secondary schools, in study sample versus the entire District

Occupation, %	**% Study sample (n=1689)**	**% District (n=7071)**
Teacher (classroom teacher, teacher librarian, resource teacher)	61.0	53.4
Student Support Worker or Youth and Family Worker	17.1	20.0
Administration (Principal, Vice-principal, Administrative Assistant)	10.1	8.1
Other (maintenance staff, school district office staff, or other)	11.7	14.6
School type, %		
Elementary School	63.7	54.0
Secondary School	28.1	29.3
Other (e.g., mixed schools, district office)	8.3	16.7

Supplemental Table 3: Results of ORTHO (Spike-based) or ROCHE (N-based) serology testing, and according to self-reported viral PCR, for Spike-POSITIVE, VACCINATED cases (n=35)

Antibody detection				Self-reported COVID-19 PCR result?	Days between vaccine and serology	Final case assignment
Spike reactivity	Spike (index)	N reactivity	N (index)			
R	4.8	NR	0.082	Not tested	16	Negative
R	73.6	NR	0.089	No	14	Negative
R	252	R	150.7	Yes	1	Positive
R	142	NR	0.088	No	24	Negative
R	69.9	R	99.09	Yes	20	Positive
R	31.1	NR	0.084	Not tested	20	Negative
R	279	NR	0.144	Not tested	15	Negative
R	27.8	NR	0.09	Not tested	15	Negative
R	13.7	NR	0.088	Not tested	56	Negative
R	47.3	NR	0.087	No	32	Negative
R	163	NR	0.089	Not reported	11	Negative
R	10.5	NR	0.091	No	2	Negative
R	2.64	NR	0.09	Not tested	17	Negative
R	15.3	NR	0.092	Not tested	16	Negative
R	285	NR	0.082	Not tested	16	Negative
R	7.95	NR	0.085	No	?	Negative
R	16.8	NR	0.086	Not tested	31	Negative
R	114	NR	0.087	Not tested	17	Negative
R	90	NR	0.082	Not tested	16	Negative
R	15.9	NR	0.096	Not tested	18	Negative
R	486	R	44.52	Yes	88	Positive
R	63.5	NR	0.09	Not tested	?	Negative
R	1.07	NR	0.093	No	14	Negative
R	3.78	NR	0.095	Not tested	20	Negative
R	20.5	NR	0.212	No	21	Negative
R	132	NR	0.088	No	57	Negative
R	20.7	NR	0.095	Not tested	20	Negative
R	147	NR	0.085	No	21	Negative
R	61.5	NR	0.093	Not tested	24	Negative
R	106	NR	0.096	Not tested	23	Negative
R	73.6	NR	0.091	Not tested	?	Negative
R	79.9	NR	0.094	No	35	Negative
R	2.47	NR	0.095	Not tested	16	Negative
R	9.71	NR	0.098	No	15	Negative
R	8.56	NR	0.094	Not tested	28	Negative

R: reactive; NR: non-reactive; the only 3 vaccinated staff that tested positive by both S- and N-based assays also reported a history of COVID-19 by positive PCR viral test (in red), and none of the vaccinated school staff who tested negative by the N-based serology assay reported a positive PCR viral test. All spike (S)- reactive cases were contacted by phone or email to confirm the date they received a COVID-19 vaccine between the date of survey completion and blood sampling. Three participants indicated that they had received a COVID-19 vaccine, but omitted to indicate the date in the questionnaire or email response.

Supplemental Table 4: Results of ORTHO (Spike-based) or ROCHE (N-based) serology testing, and according to self-reported viral PCR, for seropositive, INFECTED cases (n=35)

Antibody detection				Self-reported COVID-19 PCR result?	Time between PCR test and serology	Vaccinated? [days between vaccine and serology]
Spike reactivity	Spike (index)	N reactivity	N (index)			
R	6.2	R	1.44	Yes	2 months	No
R	224	R	57.99	Not tested	-	No
R	129	R	5.99	Not tested	-	No
R	112	R	127	Yes	1.9 month	No
R	226	R	125.3	Yes	3.2 months	No
R	433	R	64.64	Not tested	-	No
R	270	R	166.7	Yes	2.5 months	No
R	8.73	NR	0.483	Yes	3 weeks	No
R	272	R	6.41	Yes	3 months	No
R	3.22	NR	0.074	Not tested	-	No
NR	0.39	R	8.61	Yes	11.25 months	No
R	445	R	2.84	No	-	No
R	242	R	1.99	Not tested	-	No
R	52.4	R	4.58	Yes	5.5 months	No
R	138	NR	0.564	Not tested	-	No
R	318	R	42.54	Not tested	-	No
R	2.27	R	117.6	Yes	2.75 months	No
R	562	R	28.92	Yes	~7 months	No
R	216	R	119.3	Yes	2.3 months	No
R	381	R	193.3	Not tested	-	No
R	142	R	11.03	Yes	1.5 month	No
R	331	R	3.54	Not tested	-	No
R	69.7	R	16.88	Not tested	-	No
R	252	R	150.7	Yes	2 months + 6 days	Yes [1]
R	69.9	R	99.09	Yes	4.25 months	Yes [20]
R	4.44	R	4.26	Not tested	-	No
R	45.1	R	4.22	Not tested	-	No
R	581	R	44.07	Yes	1 year + 2 weeks	No
R	503	R	45.95	Yes	6.75 months	No
R	10.3	R	1.01	Yes	2.75 months	No
R	211	R	130.5	Yes	1.84 month	No
R	310	R	80.05	Yes	4.5 months	No
R	224	R	15.64	Not tested	-	No
R	327	R	57.04	Yes	4 months + 2 days	No
R	486	R	44.52	Yes	3.75 months	Yes [8]

R: reactive; NR: non-reactive; One school staff who tested positive for COVID-19 by PCR viral test tested negative by serology ~5 months later both by S- and N-based assays. Another who reported a positive PCR test did not complete the serology testing.

SUPPLEMENTAL DATA: Weighted seroprevalence analysis in Canadian blood donors

Create weight according to month*fsa2*sex*agegroup distribution in study sample.

By removing samples without complete information, 1527 left in study sample, which made 104 groups. Samples from February were treated as January samples. There are data from 16407 samples from British Columbia blood donors, which made 410 groups.

The weighted analysis involved: 1526 school staff and 5417 blood donors.

School staff data				Entire school district		Blood donor data	
		N	%	N	%	Weighted N	Weighted %
Total		1526	100	6751*	99.73#	5417	100.0
Month	**1**	267	17.5			947.8	17.50
	3	873	57.21			3099.0	57.21
	4	347	22.74			1231.8	22.74
	5	39	2.56			138.4	2.56
FSA2	**V0**	5	0.33	35	0.52	17.7	0.33
	V1	1	0.07	15	0.22	3.5	0.07
	V2	4	0.26	67	0.99	14.2	0.26
	V3	108	7.08	796	11.79	383.4	7.08
	V4	28	1.83	232	3.44	99.4	1.83
	V5	788	51.64	3301	48.90	2797.2	51.64
	V6	463	30.34	1686	24.97	1643.6	30.34
	V7	128	8.39	561	8.31	454.4	8.39
	V8			24	0.36		
	V9	1	0.07	16	0.24	3.5	0.07
Sex	**F**	1238	81.13			4394.7	81.13
	M	288	18.87			1022.3	18.87
Age	**17-24**	11	0.72			39.0	0.72
	25-	431	28.24			1530.0	28.24
	40-	967	63.37			3432.7	63.37
	60-	117	7.67			415.3	7.67
Roche N		Negative				5276.7	97.41
		Positive				140.3	2.59 (95%CI: 2.17- 3.11)

* with data available; # 18 staff had a residency location outside the "V" postal code.

APPENDIX 1: COVID-19 mitigations measures in Vancouver schools (2020/21 school year)

Prior to reopening, the District implemented COVID-19 safety plans consistent with the British Columbia Centre for Disease Control (BCCDC) COVID-19 Public Health Guidance for K-12 School Settings: http://www.bccdc.ca/Health-Info-Site/Documents/COVID_public_guidance/Guidance-k-12-schools.pdf. and Provincial COVID-19 Health & Safety Guidelines for K-12 Settings: https://www2.gov.bc.ca/assets/gov/education/administration/kindergarten-to-grade-12/safe-caring-orderly/k-12-covid-19-health-safety-guidlines.pdf with support from Public Health.

COVID-19 safety plans included public health measures (e.g., protocols for testing and contact tracing), environmental measures (e.g., maximization of distance in classrooms, enhanced cleaning and disinfection, improved fresh air intake), administrative measures (e.g., staggered scheduling, assigning students and staff cohorts), personal measures (e.g., daily symptom checks, physical distancing, hand hygiene, respiratory etiquette), and personal protective equipment.

At the beginning of the school year (late August/September), parents were given the option of: 1) full time in-person schooling, 2) home schooling, 3) online learning and 4) a temporary online learning with return to full time schooling with re-entry dates offered later in fall and in January 2021.

During the entire school year, daily health assessments were required by all staff and students (via parents) prior to arriving at school and again upon arrival. Anyone with even minor symptoms of cold or flu-like illness was to stay home or go home if these symptoms developed mid-day. Classrooms and other spaces were arranged to maximize distance between students and staff. Class sizes were set by grades: 20 students / class for kindergarten; 22 for grades 1 to 3; 30 for grades 4 to 12. School staff and their students were assigned specific classrooms which were between 75 m^2 – 83 m^2 for elementary students (K to grade 7) and 75 m^2 – 80 m^2 for secondary students (grades 8 to 12) with larger spaces available for elective courses (e.g., physical education, food studies, metal, woodworking, automotive). In addition, secondary classrooms were divided into two separate groupings (AM and PM) of 15 students.

The plan also included revising school schedules and learning groups where students also had staggered recess and lunch breaks, and were assigned specific outside areas. Elementary students (K-7) received full day in-class instruction in their assigned learning groups/cohorts. Secondary students (grades 8 to 12) had both in-class instruction and remote learning and their schedules shifted to a quarter system with maximum two in-person classes a day with further instruction given remotely.

Ventilation measures included opening windows to promote fresh air flow to classrooms as well as indoor air ventilation improved with the HVAC systems running longer during the day, recirculating less air and the filters changed to higher efficiency (MERV13) filters.

Other measures included, the addition of hand sanitizer to classrooms and common areas, directional traffic flow within the school, provision of plexiglass as needed for certain staff roles, and the training of all staff on the safety plan and protocols. In addition to the regular daily cleaning by custodial staff, twice daily disinfection of all high touch frequency items was conducted. Shared items in classrooms were limited and the teachers, or if in secondary school, the students disinfected those used. Initially, masking was encouraged, but not required. Non-medical mask use was encouraged but not required early in the school year, and then in February 2021 masks were required for all staff and students in grades 6-12 in common spaces, and ultimately from April onward for students grades 4-12 at all times while indoors at school. This guidance did not apply if staff or students did not tolerate a mask for health or behavioural reasons. Masks remained recommended for K-3 students and were not required until October 4, 2021. Two reusable cloth masks were distributed to all staff and students in September 2020, and again in

January 2021. The vast majority of enrolled staff did not wear face shields. Face shields were made available to student support staff who work in close proximity to students with diverse needs and to first aid attendants.

SARS-CoV-2 nucleic acid amplification (PCR) was available for anyone with symptoms through the provincial health system, and advised for students or staff with fever or new symptoms which persisted for over 24 hours. Tests were generally processed within 24 hours, and positive tests were automatically reported to Public Health which investigated cases within 24 hours, and initiated contact tracing. Symptomatic close contacts were asked to seek testing; asymptomatic testing was not used to release contacts from isolation on an earlier timeline. All close contacts, including close contacts at school, were isolated for at least 14 full days. Entire classes were not isolated unless all members were identified as close contacts. School closures to control transmission were not required during the study period. Also, at the time, vaccination programs had not substantially reached working-age people until April 14, and the majority of school staff vaccinations occurred in May. Last day of classes was June 29th, 2021 and June 30th was the last day for staff (administrative day).

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any pre-specified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3,4 + Appendix 1
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	3
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	3, and Supplementary file, Page 7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*3*
Bias	9	Describe any efforts to address potential sources of bias	3, 5, 7 (limitation section of discussion)
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA (descriptive

			analysis)
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	3
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5 + flow chart (Fig. 2)
		(b) Give reasons for non-participation at each stage	Fig 2
		(c) Consider use of a flow diagram	Fig 2
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA (cross-sectional)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	6 and Supp Fig 1, Supp Table 2 & 3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6, Supp Fig 1
		(*b*) Report category boundaries when continuous variables were categorized	Tables
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7, Supplemental Data
Discussion			
Key results	18	Summarise key results with reference to study objectives	7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	7,8
Generalisability	21	Discuss the generalisability (external validity) of the study results	7,8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.