


SARS CoV-2 seroprevalence in a US school district during COVID-19

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ABSTRACT

Reduced symptomatology and access to testing in children have led to underestimates of paediatric COVID-19 prevalence and raised concerns about school safety. To explore COVID-19 prevalence and risk factors in school settings, we conducted a SARS-CoV-2 serosurvey in a Vermont, USA school district in December 2020. Among 336 students (63%) and 196 teachers/staff (37%), adjusted seroprevalence was 4.7% (95% CI 2.9 to 7.2) and was lowest in preK-5 students (4–10 Years). Seroprevalence was 10-fold higher than corresponding state PCR data but was low overall with no evidence of onward transmissions. These results further support feasibility of in-person learning during COVID-19 with appropriate mitigation measures.

At the beginning of the COVID-19 pandemic, near-universal school closures were enacted to mitigate spread of SARS-CoV-2. Early studies suggested that children were less susceptible to SARS-CoV-2 and less likely to transmit.¹ However, their high frequency of asymptomatic infections² called into question the accuracy of incidence estimates using symptom-based testing and the true role of paediatric transmission, concerns that heavily influenced school reopening debates.

Therefore, we conducted a cross-sectional serosurvey to estimate COVID-19 prevalence and risk factors among students and staff attending ≥ 2 days/week of in-person learning in Colchester School District (Vermont, USA). Patients or the public were not involved in study design, conduct, reporting or dissemination. The University of Vermont Institutional Review Board approved the study. All participants/parent provided written informed consent and all children ≥ 6 provided written assent. Exclusion criteria including bleeding or clotting disorder or other condition that would preclude safe blood collection. Capillary blood collection via fingerprick was performed 2–19 December 2020 for detection of serum anti-SARS-CoV-2 IgG using the Mount Sinai two-step ELISA, which requires detection of

antibodies to both receptor binding domain and full-length spike protein.^{3,4} Participants completed a self-administered REDCap questionnaire to assess risk factors (online supplemental materials). At the time of the study, state guidelines mandated universal masking for all students and staff and physical distancing of three feet for pre-Kindergarten (pre-K)–6th-grade students and six feet for 7th–12th-grade students. Seroprevalence with 95% CIs was calculated using Blaker's method and adjusted for estimated assay sensitivity (95%) and specificity (99%) according to the formula $\text{prevalence}_{\text{adjusted}} = (\text{prevalence}_{\text{observed}} + \text{specificity} - 1) / (\text{sensitivity} + \text{specificity} - 1)$.^{4,5}

A total of 532 enrolled participants completed antibody measurement: 336 students (63%) and 196 teachers/staff (37%). The participation rate was 18% among students, equally distributed across age groups and 44% among teachers/staff. Overall adjusted seroprevalence was 4.7% (95% CI 2.9 to 7.2) and was similar among students and teachers/staff (table 1). Adjusted seroprevalence was lowest (1.8%, 95% CI 0.0 to 5.8) in pre-K-5 students. 527 participants (99%) completed the questionnaire, including all seropositive individuals. 95% identified as white race alone, similar to Vermont overall (94%). Two teachers/staff reported prior COVID-19, both were seronegative. Eighteen participants reported prior household COVID-19 contact between March and December 2020; none was seropositive. Thirty participants reported close non-household COVID-19 contact, only one student was seropositive. No associations were detected between seropositivity and out-of-state travel, sports participation, group activities or symptomatic illness without confirmatory testing. Nearly, all (99%) reported that family members wore masks $\geq 75\%$ of the time in public.

In a low-incidence US region, we detected low SARS-CoV-2 seroprevalence among

Table 1 SARS-CoV-2 IgG seroprevalence

	Total N	Age, years median (IQR)	Seropositive N	Unadjusted seroprevalence % (95% CI)	Adjusted seroprevalence % (95% CI)
Teachers/staff	196	45.1 (36.3–53.4)	11	5.6 (2.9 to 9.8)	4.9 (2.0 to 9.3)
Students	336	12.2 (8.5–14.9)	18	5.4 (3.3 to 8.2)	4.6 (2.5 to 7.7)
PreK-5	149	8.3 (6.7–9.8)	4	2.7 (0.9 to 6.5)	1.8 (0.0 to 5.8)
Grades 6–8	82	13.1 (12.3–13.8)	6	7.3 (3.2 to 14.9)	6.7 (2.4 to 14.8)
Grades 9–12	105	16.1 (15.1–17.1)	8	7.6 (3.4 to 14.4)	7.0 (2.5 to 14.3)
Grades 6–12	187	14.6 (13.3–16.3)	14	7.5 (4.4 to 12.1)	6.9 (3.6 to 11.8)
Total	532	–	29	5.5 (3.7 to 7.7)	4.7 (2.9 to 7.2)

N, number; preK, pre-Kindergarten.

students and staff attending in-person learning mid-way through the 2020–2021 academic year. Seroprevalence increased with age, consistent with patterns of COVID-19 incidence in US children.⁶ As observed elsewhere, our findings suggest significant (10-fold) under-detection of SARS-CoV-2 infections in US children.⁷ Cumulative incidence in Vermont as calculated from census and Vermont Department of Health PCR as of December 2020 was 0.46% in children ≤ 19 .^{8,9} Our cohort reported few known contacts with SARS-CoV-2-infected individuals, suggesting that missed asymptomatic infections may have occurred, even in a low-risk population in a low-incidence region. Importantly, however, our data indicate that such infections were not associated with known cases of onward transmission. Of note, our study occurred prior to vaccine rollout and significant emergence of the more infections Alpha and Delta variants. Our study had several limitations. Participation was limited to a single school district and response rate was low, limiting precision and introducing potential selection bias, meaning results may not be readily generalisable. We were unable to perform antibody measurement before the school year, preventing estimation of the timing of infections and successful vaccine rollout in 2021 precluded planned follow-up assessment. Individuals with waning antibody responses may have been missed. Finally, questionnaire data are subjected to recall bias. Our results further support the global experience demonstrating feasibility, with proper mitigation, of in-person education during COVID-19. Until younger children are eligible for vaccination and where community transmission remains high or vaccine coverage remains limited, mitigation measures remain important to ensure safe in-person learning, particularly as more infectious variants circulate.

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Contributors BL conceptualised and designed the study, managed recruitment, enrolment, specimen collection, processing and ELISA, performed data management and analyses and reviewed and revised the manuscript. SSMB performed specimen collection and ELISA, data entry, drafted the initial manuscript and reviewed and revised the manuscript. BG and SC assisted with study instrument design, managed and performed specimen collection and reviewed and revised the manuscript. SAD, NRG and MC established and/or performed ELISA, and reviewed and revised the manuscript. DD assisted with study design, performed instrument design and data management, performed analyses and reviewed and revised the manuscript. BDK reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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COVID-19 Serosurvey Questionnaire #1

Thank you again for agreeing to participate in this study. This questionnaire will provide us with important information that we will use to understand your blood antibody results. It should take no longer than 5-10 minutes to complete. Please answer to the best of your ability. The results of this questionnaire will remain confidential.

You must complete this questionnaire in order for antibody test results to be released to you.

General instructions

As you navigate, please use the "Next Page" and "Previous Page" buttons at the bottom of the page, rather than the "Back" and "Forward" buttons on your browser. If you need to change a response, you can use the "Reset" buttons to clear your answer for that question. If at any time you need to stop and would like to resume later, please use the "Save & Return Later" button at the bottom of the page. You will be asked to write down a unique code to re-access your survey. If you forget to do this, that is ok, it just means you will need to start the survey over. If you have personal or health-related questions

At any time, if you have any questions involving personal or medical information, please call either [REDACTED] information. Please do NOT send us any emails that involve private information.

The questions on this survey refer to [general_info_arm_2][participant_firstname] [general_info_arm_2][participant_lastname]. If you have more than one child or household member participating, only answer these questions as they specifically pertain to [general_info_arm_2][participant_firstname] [general_info_arm_2][participant_lastname].

Questionnaire #1 Date

Which school(s) does [general_info_arm_2][participant_firstname] work in? Please select all that apply.

- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]

Approximately how many hours of the day does [general_info_arm_2][participant_firstname] have direct contact with students, no matter the distance?

If you work at the district office or have a position where it is not routine to have direct contact with the students, please select "0 Hours."

- 0 Hours
 - 1 Hour
 - 2 Hours
 - 3 Hours
 - 4 Hours
 - 5 Hours
 - 6 Hours
 - 7 Hours
 - 8 Hours
 - 9+ Hours
- ((Example: Teaching a classroom of students for 1 hour would equal 1 hour))

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Which grades does [general_info_arm_2][participant_firstname] work with? Only include those grades where direct contact is routine. Please select all that apply.

- pre-K
- K
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12

Has [general_info_arm_2][participant_firstname] ever had a positive test for COVID-19?

- Yes
- No

If so, when? (Provide your best estimate if exact date is unknown).

How many people live in [general_info_arm_2][participant_firstname]'s home (not including [general_info_arm_2][participant_firstname]) right now?

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

How many people in [general_info_arm_2][participant_firstname]'s house are under 21 years old? (Not including [general_info_arm_2][participant_firstname])

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

Does [general_info_arm_2][participant_firstname] live with anyone at home under the age of 21 that attends school outside of the Colchester School District?

- Yes
- No

If yes, which school(s) do they attend?

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Has either of [general_info_arm_2][participant_firstname]'s parents ever had a positive test for COVID-19? If so, who?

- Yes, mother
 Yes, father
 Yes, both parents
 None
 Not applicable

Only count parents who were living in the house with [general_info_arm_2][participant_firstname] at the time they were diagnosed.

If you are a teacher or staff member, this question may not apply to you--if this is the case, please select "Not applicable."

When was the parent diagnosed? (Provide your best estimate if exact date is unknown).

If more than one parent was diagnosed, enter the MOST RECENT date.

Has any of [general_info_arm_2][participant_firstname]'s siblings ever had a positive test for COVID-19? If so, who?

- Yes, sister
 Yes, brother
 Yes, more than one sibling
 None
 Not applicable

Only count siblings who were living in the house with [general_info_arm_2][participant_firstname] at the time they were diagnosed.

If you are a teacher or staff member, this question may not apply to you--if this is the case, please select "Not applicable."

How many total siblings were diagnosed with COVID-19?

- 2
 3
 4
 5 or more

When was the sibling diagnosed? (Provide your best estimate if exact date is unknown).

If more than one sibling was diagnosed, enter the MOST RECENT date.

Has anybody else living with [general_info_arm_2][participant_firstname] ever had a positive test for COVID-19?

- Yes
 No

Who had a positive test for COVID-19 while living with [general_info_arm_2][participant_firstname]? You may check all that apply.

- Yes, grandmother
 Yes, grandfather
 Yes, child
 Yes, other housemate

Only count people who were living in the house with [general_info_arm_2][participant_firstname] at the time they were diagnosed.

For this question, the answer choice "Child" only applies to teachers and staff filling out their own survey, to indicate if they have ever had a child who had COVID-19 while living in the same house.

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When was the grandparent diagnosed? (Provide your best estimate if exact date is unknown).

If more than one grandparent was diagnosed, enter the MOST RECENT date.

How many children living in the house were diagnosed with COVID-19?

- 1
 2
 3
 4
 5 or more

When was your child diagnosed? (Provide your best estimate if exact date is unknown).

If more than one child was diagnosed, enter the MOST RECENT date.

How many other people living in the house were diagnosed with COVID-19?

- 1
 2
 3
 4
 5 or more

List their relationships to
[general_info_arm_2][participant_firstname]

When was the other housemate diagnosed? (Provide your best estimate if exact date is unknown).

If more than one other housemate was diagnosed, enter the MOST RECENT date.

Has [general_info_arm_2][participant_firstname] ever been told to quarantine by the health department because they were found to be a close contact of someone OUTSIDE THE HOUSEHOLD with COVID-19?

- Yes
 No

If so, when did the quarantine begin? (Provide your best estimate if exact date is unknown)

If this has happened more than once, please enter the MOST RECENT date.

Did [general_info_arm_2][participant_firstname] participate in any organized summer activities (such as camps or sports leagues), either as participant, coach, or teacher/counselor, or attend organized day care during the previous spring or summer?

- Yes
 No

In which organized summer activities did [general_info_arm_2][participant_firstname] participate? Check all that apply.

- Day camp (of any type)
 Sleep-away camp
 Sports league
 Daycare
 Other

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If other, please explain:

Since the beginning of school, has [general_info_arm_2][participant_firstname] been participating in any organized activities or been in group settings, either as participant, coach, or teacher/counselor?

Yes
 No

Since the beginning of school, in which organized activities or group settings has [general_info_arm_2][participant_firstname] been participating? Please check all that apply.

Sports team/league
 Other classes/lessons outside of school
 Group child care or learning groups
 Other

If other, please explain:

Since March 2020, has [general_info_arm_2][participant_firstname] traveled outside of Vermont?

Yes
 No

Do NOT include travel for essential purposes, such as for medical care or for visitation (for example, to see a parent with joint custody but who lives outside of Vermont).

If yes, where (city, state, country)?

If there has been more than one trip outside of Vermont, please enter information for the MOST RECENT trip.

If yes, when did [general_info_arm_2][participant_firstname] return from travel? (Provide your best estimate if exact date is unknown)

If there has been more than one trip outside of Vermont, please enter the MOST RECENT date.

Since March 2020, did [general_info_arm_2][participant_firstname] ever have any symptoms concerning COVID-19 but for which [general_info_arm_2][participant_firstname] could not get tested?

Yes
 No

If this has happened more than once, please answer the following questions for the MOST RECENT illness for which testing could not be performed.

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If so, which symptoms? (Please check all that apply)

- Fever or chills
- Cough
- Shortness of breath or difficulty breathing
- Fatigue
- Muscle or body aches
- Headache
- New loss of taste or smell
- Sore throat
- Congestion or runny nose
- Nausea or vomiting
- Diarrhea

If so, please indicate the approximate date when these symptoms began.

Is anyone in [general_info_arm_2][participant_firstname]'s household considered an essential worker?

- Yes
- No
- Not sure

If so, please list who (parent, grandparent, sibling, etc.) is an essential worker and their occupation.

If more than one, please list all essential workers.

On average, how frequently does everyone in the household wear masks or cloth facial coverings when in public?

- None of the time
- < 25% of the time
- 25-49% of the time
- 50-74% of the time
- 75% of the time or more

Is [general_info_arm_2][participant_firstname] Hispanic/Latino or not Hispanic/Latino?

- Hispanic/Latino
- Not Hispanic/Latino
- Prefer not to answer

What is [general_info_arm_2][participant_firstname]'s race? Select one or more.

- American Indian or Alaskan Native
- Asian
- Black or African American
- Native Hawaiian or Other Pacific Islander
- White
- Prefer not to answer

To complete the survey, please click "Submit" below. Once you click "Submit," you cannot change any of your answers. You may go back now to review any of your answers if desired by clicking the "Previous Page" buttons.

After you submit, you will receive a separate email link that will allow you to access the antibody test results for [general_info_arm_2][participant_firstname].