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

Sean S M Bullis,1 Benjamin Grebber,2 Sally Cook,3 Nancy R Graham,4 Marya Carmalli,4 Dorothy Dickson,4 Sean A Diehl,4 Beth D Kirkpatrick,1,4 Benjamin Lee5

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 pre-K 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 ≥grade 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 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 prevalence adjusted = (prevalence observed + specificity −1)/(sensitivity × 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 ≥75% of the time in public.

In a low-incidence US region, we detected low SARS-CoV-2 seroprevalence among...
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. As observed elsewhere, our findings suggest significant (10-fold) under-detection of SARS-CoV-2 infections in US children. Cumulative incidence in Vermont as calculated from census and Vermont Department of Health PCR surveillance is low, 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 infectious Alpha and Delta variants. Our cohort reported few known contacts with SARS-CoV-2 infections in US children, particularly as more infectious variants circulate. During COVID-19, 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 infectious 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 interpretation of this study.

### Funding
This work was supported by Children’s Miracle Network Hospitals Fund (award number not applicable) and NIH/NIGMS [P20 GM125498-01].

### Competing interests
None declared.

### Patient consent for publication
Not applicable.

### Provenance and peer review
Not commissioned; externally peer reviewed.

### Supplemental material
This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

### Open access
This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

### ORCID iD
Benjamin Lee http://orcid.org/0000-0001-7213-5631

---

**Table 1 SARS-CoV-2 IgG seroprevalence**

<table>
<thead>
<tr>
<th>Total N</th>
<th>Age, years median (IQR)</th>
<th>Seropositive N</th>
<th>Unadjusted seroprevalence % (95% CI)</th>
<th>Adjusted seroprevalence % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers/staff</td>
<td>196</td>
<td>45.1 (36.3–53.4)</td>
<td>11</td>
<td>5.6 (2.9 to 9.8)</td>
</tr>
<tr>
<td>Students</td>
<td>336</td>
<td>12.2 (8.5–14.9)</td>
<td>18</td>
<td>5.4 (3.3 to 8.2)</td>
</tr>
<tr>
<td>PreK-5</td>
<td>149</td>
<td>8.3 (6.7–9.8)</td>
<td>4</td>
<td>2.7 (0.9 to 6.5)</td>
</tr>
<tr>
<td>Grades 6–8</td>
<td>82</td>
<td>13.1 (12.3–13.8)</td>
<td>6</td>
<td>7.3 (3.2 to 14.9)</td>
</tr>
<tr>
<td>Grades 9–12</td>
<td>105</td>
<td>16.1 (15.1–17.1)</td>
<td>8</td>
<td>7.6 (3.4 to 14.4)</td>
</tr>
<tr>
<td>Grades 6–12</td>
<td>187</td>
<td>14.6 (13.3–16.3)</td>
<td>14</td>
<td>7.5 (4.4 to 12.1)</td>
</tr>
<tr>
<td>Total</td>
<td>532</td>
<td>–</td>
<td>29</td>
<td>5.5 (3.7 to 7.7)</td>
</tr>
</tbody>
</table>

N, number; preK, pre-Kindergarten.
REFERENCES


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 okay, 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 [phone_number]. 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.

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."

((Example: Teaching a classroom of students for 1 hour would equal 1 hour))
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?

________________________
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]?

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

You may check all that apply.

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.
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
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 had any symptoms concerning for 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.
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].