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Low In-School COVID-19 Transmission and Asymptomatic Infection Despite High Community Prevalence

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There is concern that in-person schooling during the coronavirus disease 2019 (COVID-19) pandemic will facilitate disease transmission. Through asymptomatic surveillance and contact tracing for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), we found low rates of asymptomatic SARS-CoV-2 infection and little in-school transmission of COVID-19 when physical distancing and masking strategies were enforced despite a high community prevalence of COVID-19. (*J Pediatr* 2021;237:302-6).

Opening schools and keeping them open for in-person instruction during the coronavirus disease 2019 (COVID-19) pandemic has been controversial.¹ Some studies have demonstrated a minimal impact of in-person learning or school reopening on community transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), whereas others have shown that transmission may be more common among children in school environments than in community settings.²⁻⁶ The role of asymptomatic children and faculty/staff in the transmission of SARS-CoV-2 in the school setting is unclear.

The objective of the present study was to determine the epidemiology of SARS-CoV-2 symptomatic disease, asymptomatic infection, and transmission in the school setting with strict mitigation strategies in place. Our study was conducted during periods of high community disease activity, including weeks when Tennessee had the highest per capita COVID-19 rates in the US.⁷ The 7-day average of daily new COVID-19 cases per 100 000 population in Davidson County, Tennessee ranged from 2 to 148, and county-wide test percent positivity ranged from 2% to 24% during the study period. Daily case rates peaked at 159 per 100 000 adults and 82 per 100 000 children on December 13, 2020. We hypothesized that asymptomatic cases would occur in schools owing to community transmission, but with strict mitigation strategies there would be little in-school spread of SARS-CoV-2 from asymptomatic attendees.

Methods

We performed surveillance for asymptomatic SARS-CoV-2 infection and conducted systematic contact tracing of asymptomatic and symptomatic infections among students (aged 3 to <15 years) and faculty/staff attending in-person school in an independent prekindergarten through 8th grade school with 393 students and 77 faculty/staff in Nashville, Tennessee between September 2020 and January 2021. Strict mitigation strategies were in place. The school conducted in-person instruction starting in August 2020 with the exception of 3 weeks of virtual instruction. Two of these virtual weeks were due to an outbreak that occurred in the school as outlined below, and 1 week was planned after winter break to allow for social distancing after families traveled for the holidays.

Study investigators were members of the school's COVID-19 advisory council and provided advice regarding mitigation strategies. Example mitigation strategies included physical distancing of desks spaced at least 3 feet apart, universal masking for all age groups at all times except during indoor lunch, outdoor lunch, and recess. In the event of inclement weather, students ate in their classrooms with

COVID-19	Coronavirus disease 2019
PCR	Polymerase chain reaction
RT-qPCR	Reverse-transcription quantitative PCR
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
VUMC	Vanderbilt University Medical Center

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lights dimmed and were not allowed to talk while eating. Further mitigation strategies are outlined in **Table I** (available at www.jpeds.com).

Asymptomatic SARS-CoV-2 Infection Surveillance and Testing

Students and faculty/staff provided consent/assent for collection of saliva specimens for SARS-CoV-2 polymerase chain reaction (PCR) testing every 2 weeks and to be contacted by study personnel if a child or faculty/staff member had symptomatic COVID-19 for a standardized telephone survey to determine acquisition in school or in the community. Testing of asymptomatic specimens was not performed in real time, and results were not reported to participants. All asymptomatic surveillance samples were from saliva, and no nasopharyngeal swabs were taken.

Reverse-transcription quantitative PCR (RT-qPCR) testing for SARS-CoV-2 RNA in participant saliva specimens was performed using purified total nucleic acid extracts or saliva processed and following an extraction-free protocol (Additional methods are available in the **Appendix** [available at www.jpeds.com]). Saliva samples have been shown to be sensitive specimens for detection of asymptomatic SARS-CoV-2 shedding, with a sensitivity rate of approximately 93%.⁸

To capture potential asymptomatic SARS-CoV-2 cases, serum for COVID-19 antibody testing was collected from consenting faculty/staff at the beginning and middle of the school year, on September 8, 2020 and January 27, 2021, with testing performed in the Vanderbilt University Medical Center (VUMC) Diagnostic Laboratories via the Abbot Architect (Abbott Labs) chemiluminescent assay (**Appendix**).

SARS-CoV-2 Cases

Cases were defined as children with PCR-confirmed SARS-CoV-2 detection. Symptomatic SARS-CoV-2 infection was defined as the presence of at least 1 high-risk symptom or 2 low-risk symptoms (**Appendix**).

Community vs in-school transmission of SARS-CoV-2 was determined through systematic contact tracing conducted by the school nurse (**Table II**; available at www.jpeds.com). Community acquisition was defined as exposure to a household contact or community member with a positive SARS-CoV-2 test before the detection of SARS-CoV-2 in the student or faculty/staff. In-school acquisition was defined as exposure to a student or faculty/staff with a positive SARS-CoV-2 test within 14 days before symptom onset, without any known preceding community exposures. Cases, grade level, and location of transmission were tracked prospectively.

For comparison, the 7-day average of the pediatric asymptomatic community SARS-CoV-2 infection rate on the date of the asymptomatic saliva collection was estimated by testing patients presenting to VUMC and affiliated outpatient clinics at the time of non-COVID-19 hospital

admission or previous initiation of chemotherapy, stem cell or solid organ transplantation, or procedures requiring anesthesia by the VUMC Diagnostic Laboratories (**Appendix**).

Institutional Review Board Approval

The study was approved by the Vanderbilt University Institutional Review Board. Participants enrolled in the asymptomatic SARS-CoV-2 infection surveillance study provided informed consent/assent. The Vanderbilt University Institutional Review Board allowed reporting of deidentified symptomatic cases for the entire school, including students and faculty, without the need for informed consent/assent. As such, the denominator for asymptomatic PCR results was 194 students and 36 faculty/staff, and that for antibody results was 36 faculty/staff, but the denominator for symptomatic disease cases was the entire school (393 students and 77 faculty/staff).

Results

Asymptomatic Screening Results

Between September 8, 2020, and January 27, 2021, 194 of 393 students (49.4%) and 36 of 77 faculty/staff (46.8%) enrolled in the asymptomatic screening study. During each screening session, between 166 and 205 participants were tested, and 1 to 3 were SARS-CoV-2 PCR-positive. Only 14 of the 1451 total screens were positive. One participant screened positive on 2 separate test dates (**Table III**). The positive asymptomatic rate among school attendees was lower than or equivalent to the VUMC pediatric positive asymptomatic rate (range, 0.5%-1.1% vs 0.4%-4.3%; **Figure 1**). The majority (12 of 14) of positive asymptomatic school participants had low viral loads with cycle thresholds >30. Symptomatic infection following positive asymptomatic SARS-CoV-2 detection in school attendees developed in 3 of 14 instances. Eleven of 14 participants who tested positive for asymptomatic SARS-CoV-2 had a known community exposure, and only 3 had an unknown exposure source (**Table III**). There was no in-school transmission from the asymptomatic infected participants.

COVID-19 IgG Antibody Test Results

At 1 month after school started, only 1 of 33 tested faculty/staff members (3%) had a positive antibody test, and this individual had a documented SARS-CoV-2 infection before the start of school. By 6 months, there were 4 additional positives among 34 tested faculty/staff (11.8%). Of 5 total faculty who tested positive for antibody, 4 had symptomatic COVID-19 and 1 had a history of COVID-19 exposure. None had in-school acquisition.

SARS-CoV-2 Cases in the School

Thirty-one of 393 (7.9%) students and 10/77 (13%) faculty/staff had symptomatic SARS-CoV-2 (**Figure 2**). Only 4

Table III. Clinical data on participants who were asymptomatic when SARS-CoV-2 was detected by screening

Participant number	Date of positive asymptomatic screen	Student or faculty/staff	Clinical data	Exposure
1	9/8/20	Student	Remained asymptomatic after positive study screen	Unknown*
2	10/15/20	Student	Developed congestion after screen, non-study PCR-confirmed 5 days after positive study screen	Community
3	10/29/20	Student	Symptomatic, non-study PCR-confirmed SARS-CoV-2 14 days prior to positive study screen	Community
4	11/12/20	Student	Asymptomatic, non-study PCR-confirmed SARS-CoV-2 29 days prior to positive study screen	Community
5 [†]	11/12/20	Student	Developed headache 1-day after positive study screen, non-study PCR-confirmed SARS-CoV-2 5 days after positive study screen	Community
6 ^{†,‡}	11/12/20 12/3/20	Student	Developed cough, headache, rhinorrhea 2-days after first positive study screen, non-study PCR-confirmed SARS-CoV-2 5 days after first positive study screen	Community
7	12/3/20	Student	Remained asymptomatic after positive study screen	Unknown*
8	12/3/20	Faculty/staff	Asymptomatic, negative non-study PCR test	Community
9	12/16/20	Student	Remained asymptomatic after positive study screen	Unknown*
10	1/13/21	Student	Symptomatic, non-study PCR-confirmed SARS-CoV-2 15 days prior to positive study screen	Community
11	1/13/21	Faculty/staff	Symptomatic, non-study PCR-confirmed SARS-CoV-2 16 days prior to positive study screen	Community
12	1/27/21	Student	Symptomatic, non-study PCR-confirmed SARS-CoV-2 19 days prior to positive study screen	Community
13	1/27/21	Student	Asymptomatic, negative non-study PCR test	Community

*Only 3 participants who tested positive for asymptomatic SARS-CoV-2 had an unknown exposure source. All other participants with positive asymptomatic screens had previous known SARS-CoV-2 exposure or symptomatic SARS-CoV-2.
[†]Participant with SARS-CoV-2 RT-qPCR cycle threshold <30 on an asymptomatic screen. Siblings developed mild symptoms (cough, headache, rhinorrhea) 1-2 days after the participant's positive screen when asymptomatic.
[‡]Participant had a positive study screen on 2 separate occasions.

student cases and 1 staff case resulted from in-school transmission. The index case was known to be at school during the infectious window before the onset of

symptoms. All in-school transmission was attributed to a single cluster among prekindergarten students early in the year and determined to be due to improper masking. The

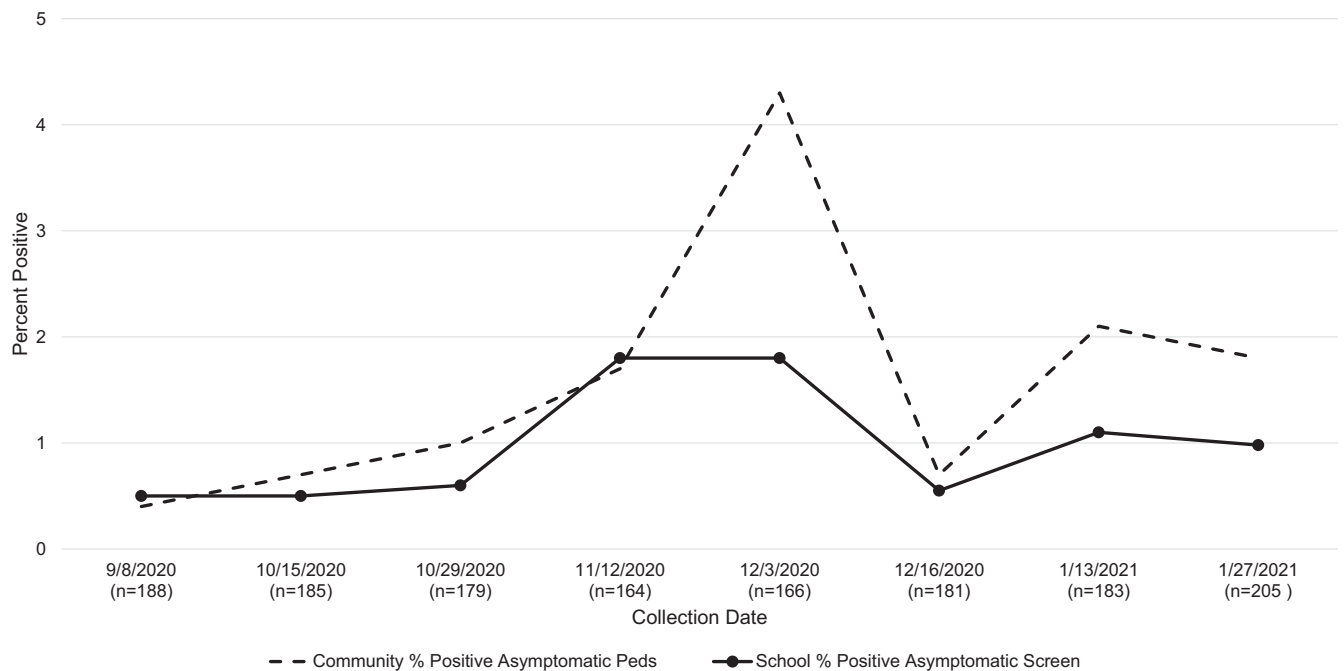


Figure 1. SARS-COV-2 detection in saliva specimens collected from asymptomatic school attendees between September 2020 and January 2021. Results from asymptomatic saliva screening of students and faculty/staff. The percent positive for each specimen collection is shown as a *black solid line*, with *dots* indicating day of testing. VUMC asymptomatic screening results (representing community percent positive) are shown as *dashed black lines*. Sample sizes noted in the graph represent total number of students and faculty/staff screened on that date.

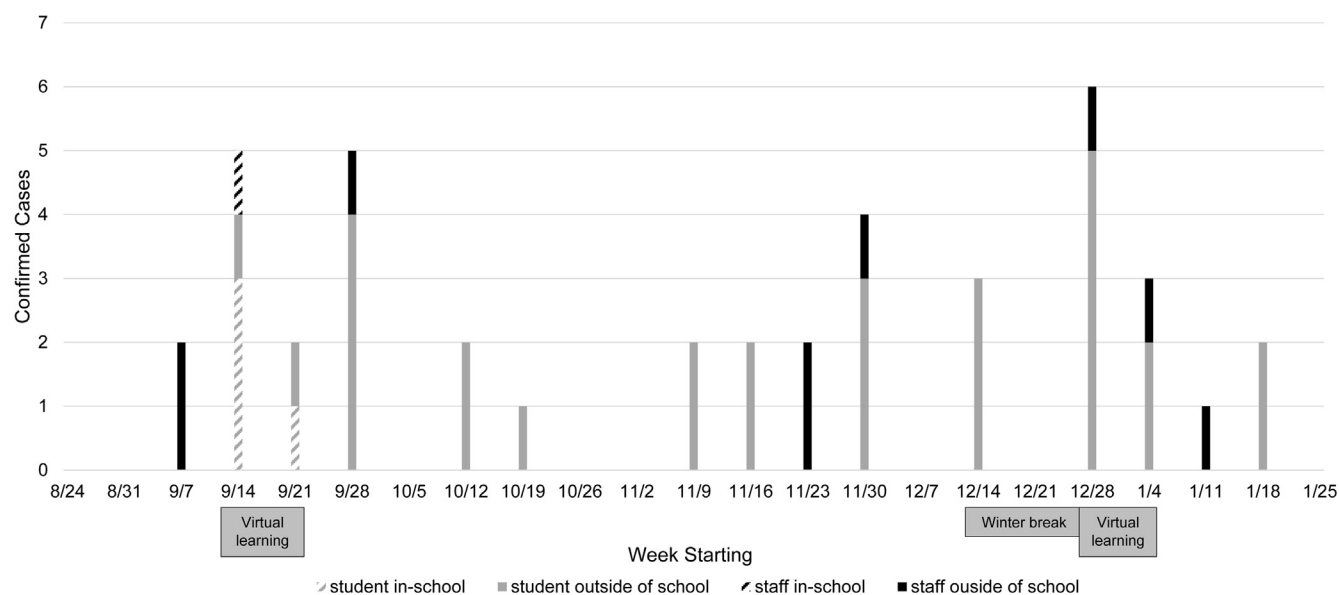


Figure 2. Weekly PCR-confirmed symptomatic COVID-19 cases and community vs school transmission and cases among symptomatic students and faculty/staff in the school. Student in-school transmission is represented by *gray dashed bars*, student community transmission by *solid gray bars*, faculty/staff in-school transmission by *black dashed bars*, and faculty/staff community transmission by *solid black bars*.

school converted to virtual learning for a 2-week period after this cluster and resumed in-person instruction with strict adherence to masking.

Discussion

Despite high community rates of COVID-19, including a period when Tennessee had the highest disease activity in the US,⁷ SARS-CoV-2 transmission was uncommon in a school in which strict physical distancing and masking strategies were enforced. The only in-school infection cluster occurred early in the school year, when the masking procedures were suboptimal. The remainder of positive cases among school attendees were acquired outside of the school setting. In addition, the frequency of asymptomatic infection in the school was similar to or less than rates gleaned from asymptomatic screening at VUMC, and none of the asymptomatic individuals transmitted to others in school.

Saliva specimens were used for screening of asymptomatic individuals because these specimens were easy to obtain and the collection was more tolerable for children. Studies have confirmed the presence of human ACE-2, the entry receptor for SARS-CoV-2, in salivary glands, making saliva specimens attractive for asymptomatic surveillance.⁹ Saliva specimens perform similar to or better than oropharyngeal, nasal, or nasopharyngeal swabs for detecting SARS-CoV-2.^{8,10}

Opening schools for in-person instruction can be done safely when appropriate mitigation strategies are in place and strictly enforced.^{2,3,11-16} Although our study took place before vaccination was available for faculty/staff and during times of high community prevalence, we found little

in-school SARS-CoV-2 transmission and low rates of COVID-19 IgG seroconversion among faculty/staff.

Universal masking was required for all ages of students and faculty/staff and is a key component in the mitigation of COVID-19 spread.^{11,17} The only in-school transmission in our study was among a cluster in prekindergarten, which was traced to poor adherence with masking. In response to this early cluster of cases, the school converted to virtual learning for 2 weeks and enforced strict masking on return. No further in-school transmission was detected, including among the youngest children. School outbreaks in Israel and North Carolina similarly have been attributed to an absence of face coverings.^{11,17} Other mitigation strategies in our study included maintaining small class sizes (12 students); spacing desks at least 3 feet apart; keeping cohorts of students together; having outdoor lunch and recess, with indoor lunch only during inclement weather, when students were not allowed to talk while eating; and providing repeated communication to parents about restricting social gatherings.

Our study has some limitations, including performance at a single school, a 6-month study duration, and an approximately 50% enrollment rate for students and faculty/staff for asymptomatic screening. In addition, saliva testing of asymptomatic persons performed in 2-week intervals for study feasibility could have missed cases. These results might not be generalizable to schools of different characteristics or less intensive mitigation strategies. The school implemented multiple mitigation strategies throughout the school year, so our study is unable to ascribe efficacy to any or all, but rather we describe low transmission with

measures used. Despite these limitations, our study strongly supports emerging data indicating that schools with enforced mitigation strategies have little in-person transmission even when community COVID-19 rates are high. Active surveillance for asymptotically infected students might be unnecessary if mitigation strategies are rigorously enforced. Larger studies with more frequently collected saliva specimens during periods of high community transmission are needed. ■

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Table I. School mitigation strategies**Mitigation strategies**

- Physical distancing (desks spaced at least 3 feet apart).
- Strict hand hygiene. Use of hand sanitizers was required before lunch and after recess and were available throughout the day as needed.
- Universal masking for all ages at all times except lunch.
- Class cohorts of 12 and minimal mixing of cohorts. Teachers (not students) change classrooms.
- Ability to convert from in-person to remote learning.
- Restricted visitor access and screen for COVID-19.
- Symptom screening and temperature checks for all students and family members in the car during drop off.
- Students who had sibling contacts of COVID-19 cases at any local school were quarantined.
- Students with household members with pending COVID-19 tests were excluded.
- No school team sports, choir, or band.
- Outdoor lunch and recess. If inclement weather, children ate in their classrooms with lights dimmed and were not allowed to talk while eating.
- Quarantine for close contacts of a symptomatic COVID-19 case (>15 minutes within 6 feet of an index case).^{*} For younger students, quarantine of entire cohort if unable to reliably distinguish close contacts. Quarantine was required for both unmasked and masked exposures.

^{*}On December 5, 2020, the quarantine period changed from 14 days to 10 days with the option to reduce it to 7 days with negative a SARS-CoV-2 PCR test.

Table II. Questions used to ascertain school vs community transmission of COVID-19 infection

1. Has anyone in your family been exposed to someone who tested positive for COVID-19 or who later found out they had COVID-19?
2. Does anyone else in the home have symptoms of COVID-19? If yes, when did their symptoms start in relation to your child's?
3. Are both parents working from home? If they are not, has anyone at their work tested positive for COVID-19?
4. Did your child participate in any playdates in the past 2 weeks? If yes, have any of their playmates been diagnosed with COVID-19?
5. Does your child participate in any sports or other afterschool activities? If yes, have there been any COVID-19 exposures?
6. Did anyone in your family eat in a restaurant in the 1-2 weeks before their COVID-19 diagnosis?
7. Have you had any visitors (relatives or friends) in the past 1-2 weeks? If yes, were they diagnosed with COVID-19?