Screening Students and Staff for Asymptomatic Coronavirus Disease 2019 in Chicago Schools

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Objectives To assess rates of asymptomatic severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) positivity in K-8 schools with risk mitigation procedures in place, and to evaluate SARS-CoV-2 transmission in school and household contacts of these positive individuals.

Study design In this prospective observational study, screening testing for SARS-CoV-2 was performed by oropharyngeal swabbing and polymerase chain reaction (PCR) analysis in students and staff at K-8 private schools in high-risk Chicago ZIP codes. New coronavirus disease 2019 (COVID-19) diagnoses or symptoms among participants, household contacts, and nonparticipants in each school were queried.

Results Among 11 K-8 private schools across 8 Chicago ZIP codes, 468 participants (346 students, 122 staff members) underwent screening testing. At the first school, 17 participants (36%) tested positive, but epidemiologic investigation suggested against in-school transmission. Only 5 participants in the subsequent 10 schools tested positive for an overall 4.7% positivity rate (1.2% excluding school 1). All but 1 positive test among in-person students had high PCR cycle threshold values, suggesting very low SARS-CoV-2 viral loads. In all schools, no additional students, staff, or household contacts reported new diagnoses or symptoms of COVID-19 during the 2 weeks following screening testing.

Conclusions We identified infrequent asymptomatic COVID-19 in schools in high-risk Chicago communities and did not identify transmission among school staff, students, or their household contacts. These data suggest that COVID-19 mitigation procedures, including masking and physical distancing, are effective in preventing transmission of COVID-19 in schools. These results may inform future strategies for screening testing in K-8 schools. *(J Pediatr 2021;239:74-80)*.

In response to the coronavirus disease 2019 (COVID-19) pandemic, most schools in the US transitioned to remote learning in March 2020, and many had not returned to an in-person educational setting before the end of 2020-2021 school year. Although children with COVID-19 often have relatively mild or asymptomatic illness,[1,2] there is concern that children could be vectors for severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) transmission to others in the school setting, even in the presence of risk mitigation strategies such as masking, physical distancing, testing and isolation, and quarantine of those exposed.

Observational studies have indicated several instances of suspected transmission in school settings when students who are SARS-CoV-2 positive have been identified. These cases are often linked to breaches in established COVID-19 risk mitigation practices or linked to activities outside of the school setting.[3,4] Owing to differences in COVID-19 prevalence across communities, risk mitigation practices in schools, and the design of previous studies (eg, efforts to identify both symptomatic and asymptomatic COVID-19 in students), generalizing previous research findings has been challenging. Thus, there is an unmet need to understand the risk of SARS-CoV-2 transmission in schools, particularly among asymptomatic children and in communities highly impacted by COVID-19.

As schools across the US evaluate plans for safe in-person learning, there is a need to identify the necessary measures to mitigate SARS-CoV-2 school transmission in a cost-effective and evidence-based manner. The objectives of this prospective observational study were to understand the prevalence of asymptomatic COVID-19 among students and staff in K-8 schools in high-risk Chicago

CLIA	Clinical Laboratory Improvement Amendments
COVID-19	Coronavirus disease 2019
Ct	Cycle threshold
qRT-PCR	Quantitative reverse-transcription polymerase chain reaction
SARS-CoV-2	Severe acute respiratory syndrome coronavirus-2

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communities and to assess possible cases of SARS-CoV-2 transmission within the classroom or student households.

Methods

This prospective observational study was approved by the Ann & Robert H. Lurie Children's Hospital Institutional Review Board (study ID: 2020-3963). Sample collection for COVID-19 screening testing was performed at 11 K-8 schools between January and March 2021 (ie, between winter and spring breaks). High-risk ZIP codes were defined by longitudinally sustained higher-than-average case counts per resident and used to inform the choice of schools for screening, as described below. COVID-19 incidence rates in these ZIP codes were higher than citywide rates throughout most of the pandemic, although during the time of school visits, case rates in these high-risk ZIP codes reached a nadir and were equivalent to the COVID-19 incidence observed citywide.[5] During the study period, weekly COVID-19 cases in the ZIP codes of the schools and citywide all exceeded 50 per 100 000 population and were classified as substantial or high levels of community transmission[6] (**Figure 1**; available at www.jpeds.com). Descriptive statistics were used to analyze data; proportions and medians were measured, and figures and tables were created using Microsoft Excel version 16.49 (Microsoft) and R version 4.0.2 (R Foundation for Statistical Computing).

All schools were part of the Archdiocese of Chicago, a large private school system of 160 K-8 schools in Chicago and surrounding suburbs that offered parents the choice of in-person or remote learning starting in the fall of 2020. Among the 84 schools within the Chicago city limits, 36 are in areas with a low or very low child opportunity index.[7] All schools visited during this study were within 8 high-risk Chicago ZIP codes based on relative COVID-19 incidence and/or low or very low child opportunity index[7] (**Figure 2**). Eligible schools in these high-risk communities were also chosen for participation based on school size, percentage of in-person enrollment, and agreement to participate by school administrators at each eligible school. Although the target study population to whom screening testing was offered comprised only in-person students and staff at each school, remote students were also offered testing. Each school was visited once during the study period to conduct testing; this was the sole study test for participants.

Testing was performed only for those providing informed consent. In addition to the research-related screening testing, the Lurie Children's Mobile Health Unit was made available to visit any Archdiocese school for clinical COVID-19 testing at the discretion of the school system and/or Chicago Department of Health if there was concern for extensive COVID-19 exposure events or suspected COVID-19 outbreak.

All schools abided by the same COVID-19 mitigation measures that were implemented throughout the school system. These included grouping students and teachers in self-contained cohorts to minimize cross-cohort exposure, symptom screening of students and household contacts before

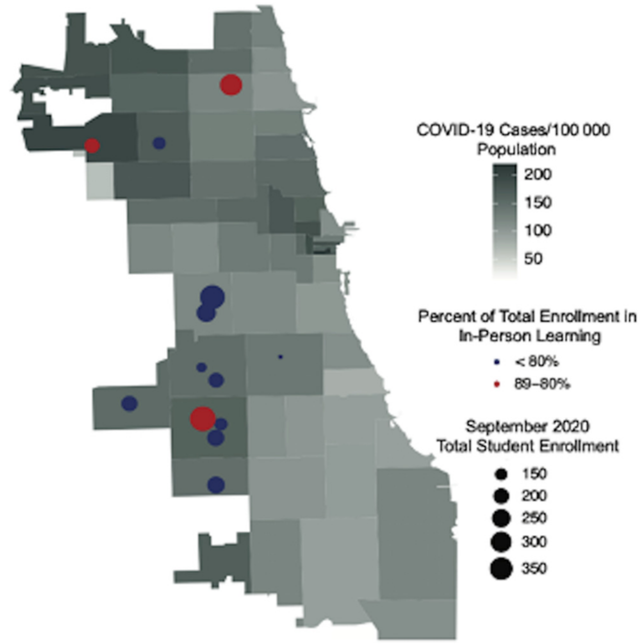

Figure 2. Incidence of COVID-19 among Chicago ZIP codes and location of schools visited. Shading of ZIP codes corresponds to the average of weekly COVID-19 cases per 100 000 population in each ZIP code during the study period January 2021 to March 2021. Circles represent location of schools visited for testing. Circle size represents total student enrollment in September 2020, and circle color indicates approximate in-person school enrollment.

arrival at school, student temperature screening on arrival to school, universal masking for all students and staff, and physical distancing of 6 feet between students and between students and staff. Principals at each school reported that COVID-19 risk mitigation measures were strictly followed, and this was confirmed by study team observations on testing days. If a student or their household member tested positive for COVID-19 or developed symptoms of COVID-19 before testing, families were required to report this to the school and quarantine according to Centers for Disease Control and Prevention guidelines or until verification of a negative COVID-19 test result.[8] If a member of a cohort tested positive for COVID-19, all members of that cohort were considered exposed, and the cohort was transitioned to remote learning while cohort students and staff were under quarantine.[9]

SARS-CoV-2 Polymerase Chain Reaction Testing

For screening testing, oropharyngeal swabs were collected at each school from study participants and stored in universal transport medium. Specimens were heat-inactivated, and viral RNA was extracted using the QIAGEN QIAamp 96 Virus QIAcube HT Kit. An initial laboratory test for SARS-CoV-2 was performed in a virology research laboratory by quantitative reverse-transcription polymerase chain reaction (qRT-PCR) with the Food and Drug Administration Emergency Use Authorization Centers for Disease Control and

Prevention 2019-nCoV qRT-PCR assay using N1 and RNase P probes. Samples that amplified with a cycle threshold (Ct) ≤40 were sent for retesting at a Clinical Laboratory Improvement Amendments (CLIA)-certified clinical microbiology laboratory using a Food and Drug Administration Emergency Use Authorization qRT-PCR assay (Abbott RealTime SARS-CoV-2; Abbott Laboratories). Notably, to improve the sensitivity of this initial assay, a high Ct cutoff for confirmatory testing was used. Qualitatively, this assay was previously validated in comparison with a clinical assay using a positivity threshold (Ct value of 35) averaged across 2 technical replicates, which equates to 1478 genomes/mL of viral transport media. We determined the limit of detection of this assay as a Ct value of 37, which equates to 370 genome equivalents/mL of viral transport media. Thus, follow-up confirmatory testing of all samples with a Ct value <40 on at least 1 of 2 technical replicates of this initial assay ensured exceeding a low likelihood of false-negative results. Positive samples from the CLIA-certified laboratory assay were reported to participants, schools, and the Chicago Department of Public Health. For clinical testing related to extensive COVID-19 exposure events or a suspected COVID-19 outbreak, nasopharyngeal swabs were collected and processed using the Abbott RealTime SARS-CoV-2 qRT-PCR assay.

Epidemiologic Investigation

Before testing, a personal or household history of COVID-19 test results, symptoms, and exposures were collected by phone and/or electronic survey. Questions regarding personal COVID-19 vaccination history were added for adult participants in February 2021. Study data were collected and managed using REDCap electronic data capture tools hosted at Northwestern University.[10,11] Following diagnosis of COVID-19 by CLIA-certified laboratory testing and/or the development of symptoms consistent with COVID-19 by study participants, symptoms and COVID-19 diagnoses within household members were monitored by phone survey within 2 weeks after the positive test date. Students and staff in the cohort of participants who were SARS-CoV-2 positive transitioned to remote learning and were recommended to remain quarantined at home in accordance with school protocols. Students and staff within the affected cohort and household contacts of participants who were SARS-CoV-2 positive were referred for COVID-19 testing. Principals were contacted 2 weeks after positive test collection to ascertain reported confirmed or suspected COVID-19 illness in students, staff, and families of those in both the quarantined and unaffected cohorts.

Results

SARS-CoV-2 Screening Testing

Eleven K-8 schools were visited for SARS-CoV-2 screening testing over a 9-week period between January and March 2021. A total of 468 participants were tested: 346 students and 122 staff members. The overall and median proportion of in-person students tested among all schools was 20%, ranging from 7% to 52% by school. Remote students represented 4.6% of the student study participants. Note that although all schools were located in high-risk ZIP codes for COVID-19, some participants resided in a neighboring ZIP code, although these generally had a similar COVID-19 incidence (**Figure 3**). Some participants also resided in neighboring non-Chicago ZIP codes, for which community COVID-19 incidence data were unavailable (**Figure 4**; available at www.jpeds.com). Community incidence rates of COVID-19 in Chicago ZIP codes in which participants lived generally decreased over the study period from January 2021 to March 2021 (**Figure 3**), consistent with citywide trends (**Figure 1**).

In the first school visited at the end of January (school 1), 11 of 25 students (44%) and 6 of 22 staff members (27%) tested positive for SARS-CoV-2. Four of the 11 positive students (36%) were remote learners who had positive or presumed positive household members within 10 days before the test date. The 7 in-person student cases were distributed among 7 different self-contained cohorts. All students who were SARS-CoV-2 positive were residents of ZIP codes with the highest community incidence of COVID-19 (**Figure 3**). Details of the epidemiologic investigation are listed below. In the remaining schools visited for screening testing (schools 2-11), 321 students and 100 staff were tested. Among these participants, 5 students (1.2%) from 4 schools but no staff members tested positive. Six participating schools registered no positive cases (**Table I**).

Among the 17 positive SARS-CoV-2 tests at the first school, Ct values on the Abbott M2000 ranged from 12.17 to 30.08 (median, 26.44; IQR, 23.9-27.9). Ct values from the 5 positive tests at the remaining schools ranged from 16.98 to 31.19 (median, 23.27; IQR, 22.7-28.7). Only 3 samples in this study, 2 from school 1 and 1 from school 2, had a Ct value below the internal control of the assay (which represents 1000 amplicon copies/mL), suggesting generally low upper airway viral loads in the majority of the positive participants (**Table II**).

Epidemiologic Investigation

Study participants were contacted to evaluate for signs of household transmission within 2 weeks of screening testing, and school administrators were contacted to identify new COVID-19 cases reported among nonparticipants. In each of the schools visited, cohorts of participating students with a positive test were quarantined and transitioned to remote learning for the recommended duration of the quarantine. One student from school 2 reported 1 day of mild headache and abdominal pain at 6 days after the positive test. All other students who tested positive remained asymptomatic. In the households of these positive individuals, 1 household member of a student who tested positive at school 6 became symptomatic and tested positive for COVID-19 on the day after the student's test (**Table II**). At all schools, including school 1, no COVID-19 infections were reported

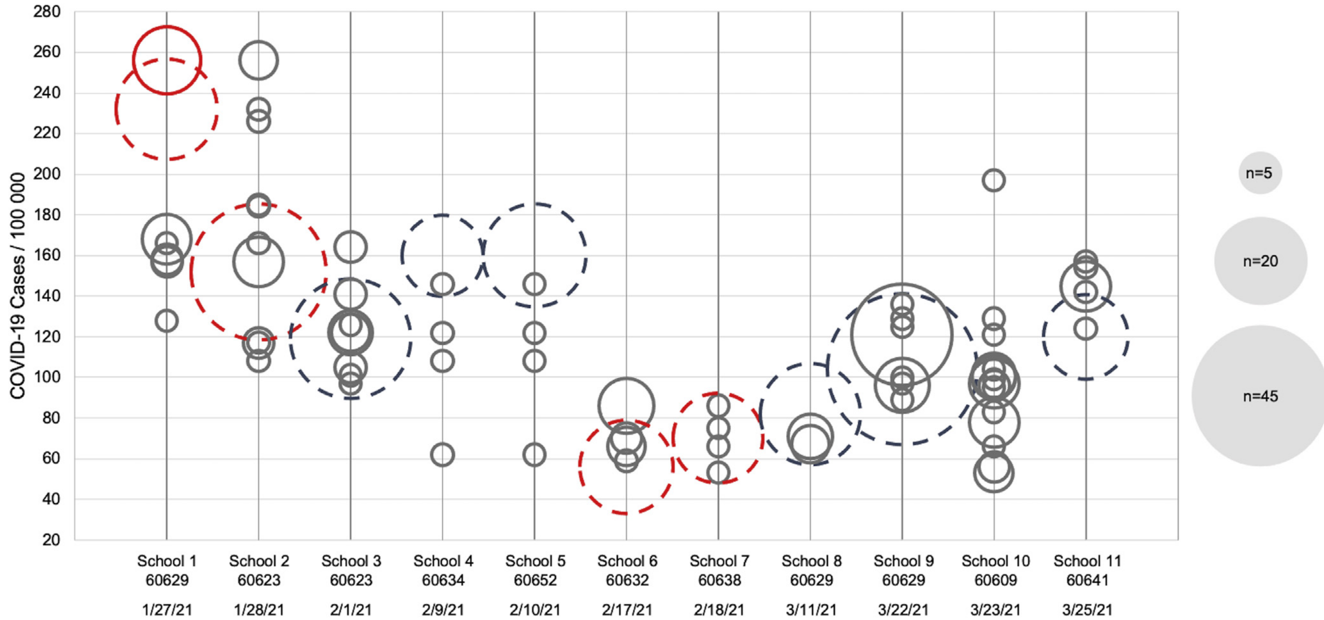

Figure 3. ZIP codes of participants and community COVID-19 incidence at the time of school visits. The *x*-axis represents school visited in chronological order. Community incidence is shown on the *y*-axis. Circle size indicates the relative number of participants per school living in each ZIP code. Dashed circles indicate the ZIP code in which the schools are located; red circles indicate the ZIP codes in which positive participants resided. Of note, there were positive participants from schools 1 and 3 who did not live within the city of Chicago and are not represented in this figure. Because no participants from school 10 lived in the same ZIP code of the school, there is no dashed circle for this school.

over the 2 weeks after the study visit date in either the affected cohort or the nonaffected cohort.

Study participants were also contacted regarding personal and household history of COVID-19 testing and symptoms present before screening testing. In school 1, of the 17 participants who tested positive, 7 (41.1%) reported a personal or household history of a positive COVID-19 diagnosis or symptoms in the previous 4 months. Of the 18 participants who tested negative at school 1 and could be contacted, 9 (50%) reported prior symptoms or positive tests in themselves or household members within the previous 4 months. In schools 2-11, few participants or household members (2.5%) had any personal or household contacts with symptoms of COVID-19 within 30 days of the testing date. There were reported prior positive tests in 14.6% of participants and 25% of household members; however, most (90%) of these tests were done >3 months before the testing date of our study.

SARS-CoV-2 Postexposure and Outbreak Testing

Two additional schools were visited for COVID-19 testing for specific outbreak investigations in February 2021, separate from screening testing initiatives. In the first of these schools, 73 of 88 in-person students and staff were tested

Table I. COVID-19 surveillance testing results

Schools	Total students tested	In-person students tested	% of in-person students tested	Total students positive	% in-person students positive	Staff tested	Staff positive	% staff positive	Total tested	Total positive	Total % positive
School 1; 1/27	25	21	7	11	44	22	6	27	47	17	36
School 2; 1/28	41	40	21	1	2	26	0	0	67	1	1
School 3; 2/1	53	50	30	2	4	15	0	0	68	2	3
School 4; 2/9	15	15	11	0	0	8	0	0	23	0	0
School 5; 2/10	28	27	22	0	0	9	0	0	37	0	0
School 6; 2/17	24	24	20	1	4	9	0	0	33	1	3
School 7; 2/18	13	13	10	1	8	9	0	0	22	1	5
School 8; 3/11	26	26	27	0	0	4	0	0	30	0	0
School 9; 3/22	75	70	52	0	0	8	0	0	83	0	0
School 10; 3/23	28	27	42	0	0	6	0	0	34	0	0
School 11; 3/25	18	17	12	0	0	6	0	0	24	0	0
Total	346	330	20	16	4.6	122	6	4.9	468	22	4.7
Total (excluding school 1)	321	306	24	5	1.6	100	0	0	421	5	1.2

Table II. Testing details of positive participants

Participants	Ct value on the Abbott M2000	Grade level	Prior testing and symptoms of participant	School, household, or community contacts with diagnosed Covid-19 or compatible illness
School 1 student	30.08	K/in-person, cohort 1	None	None
School 1 student	29.48	1/in-person	Prior positive 3 months before the test	Multiple household members positive 3 months prior to test
School 1 student	25.75	2/remote	None	Household member with fevers, chills, loss of taste and smell
School 1 student	27.11	2/in-person, cohort 1	None	None
School 1 student	28.89	2/in-person, cohort 2	None	None
School 1 student	12.17*	5/remote	None	Household member with fevers, chills, loss of taste and smell
School 1 student	26.99	5/in-person	None	None
School 1 student	24.84	6/in-person, cohort 1	None	None
School 1 student	25.11	6/in-person, cohort 1	None	None
School 1 student	22.31	6/remote	Loss of taste and smell starting 1 week before the test	Multiple household members positive at home the week before the test
School 1 student	20.19*	7/remote	Loss of taste and smell starting 1 week before the test	Multiple household members positive at home the week before the test
School 1 staff	26.44	7	Congestion and cough 3 weeks before the test	None
School 1 staff	22.86	K/in-person, cohort 1	None	None
School 1 staff	27.86	N/A	None	None
School 1 staff	23.97	N/A	Prior positive 2 months before the test	Household member positive 2 months before the test
School 1 staff	27.27	N/A	None	None
School 1 staff	28.19	N/A	None	None
School 2 student	16.98*	7/in-person	1 day of headache, abdominal pain 6 days after the test	None
School 3 student	23.27	5/in-person	None	None
School 3 student	31.19	3/in-person	None	None
School 6 student	22.68	K/in-person	None	Household member tested positive the next day; was symptomatic with viral upper respiratory symptoms
School 7 student	28.69	5/in-person	None	None

N/A, not applicable.
*Samples with a Ct value less than the internal control of the assay. These are the only samples with an approximate upper airway viral load >1000 amplicon copies/mL.

approximately 1 week following an exposure event in which 40 students and staff members were exposed to a positive staff member in a large-group in-school activity in which all attendants were in the same room while masked, although with incomplete compliance with physical distancing, for approximately 1 hour. The positive staff member became symptomatic within 24 hours after the event. All 73 exposed individuals tested negative. At the second school, 18 individuals in the school across 6 cohorts had tested positive over a 2-week period. These cohorts were quarantined, and 193 individuals from these cohorts were offered testing. Of the 81 who were tested, there were 80 negative results and 1 indeterminant result owing to amplification failure.

Discussion

This prospective observational study used COVID-19 screening testing in private K-8 schools in high-risk Chicago ZIP codes during the second COVID-19 surge in Chicago, initially while community transmission was at high levels although during the latter period of the surge when COVID-19 incidence had declined to substantial levels. We identified infrequent asymptomatic positivity in all schools except the first school visited shortly after the winter break. Among the other 10 schools visited, only 5 participants tested positive (1.2%). Among all schools, positive qRT-PCR tests generally had very high Ct values (indicating a very low SARS-CoV-2 viral load), and we did not identify subsequent transmission to school or household contacts. In the 2 additional schools visited for investigations following a large exposure event in one and increased number of positive cases in the other, we did not identify additional individuals with COVID-19 after contact tracing and testing was performed. Thus, our data are consistent with very limited transmission in schools in which infection mitigation measures were in use, including masking, distancing, and testing of symptomatic cases along with contact tracing and quarantine of those exposed.

We identified a higher-than-expected positivity rate in the first school visited. Although this may represent an enrichment of false-positive tests, the lack of a similar positivity rate across the other schools and the consistent positivity of the samples across 2 platforms in 2 independent laboratories suggest that this is unlikely barring an unknown technical issue. Under the assumption that these are true positives, we speculate that they represent residual infections acquired outside of school—and beyond the period of transmissibility—rather than being related to in-school transmission. Evidence to support this conclusion includes the following: (1) the timing of the school 1 visit shortly after a 4-week hiatus from in-person learning (ie, the 2-week winter break and the subsequent transitional 2-week remote learning period); (2) the coincident timing of the school 1 visit and the highest reported community rate of COVID-19 during the study period (January 2021-March 2021); (3) the fact that all students who were SARS-CoV-2 positive resided in the 2 ZIP codes with the highest community incidence (**Figure 3**); (4) the proximity of the school 1 visit to the holiday season, in which there was an increased likelihood of large family gatherings; (5) the lack of school contact among positive cases (ie, the cases distributed among remote students, in-person students in different cohorts, and staff members without direct contact with children); (6) increased reports of possible household exposure in these individuals over the previous few months; and (7) high Ct values correlating with very low viral loads (generally <1000 copies/mL based on extrapolation of Ct values from internal controls), associated with reduced potential for transmission. Our previous work using the same assay in symptomatic children with mild to moderate COVID-19 demonstrated a median Ct value of 11 in that population, representing an approximate 4-log difference in upper respiratory SARS-CoV-2 viral load between that population and the children in the present study.[12] Also supporting the conclusion of unlikely school transmission is the lack of new infections in staff, students, and their family members reported to the school in the 2-week period after the school visit.

Getting children back to in-person classes safely is an important goal. The closure of in-person learning not only has had drastic impacts on education, but also has highlighted the importance of in-person learning for psychosocial and interpersonal development in school-age children. Children's access to mental health and counseling services, school food programs, and other resources previously available to students in school has been limited during the pandemic.[13-16] These negative effects are most likely to be acutely felt in communities with known socioeconomic disparities, which also have been disproportionately impacted by COVID-19.[17]

Widespread screening testing for detection of asymptomatic positives with the aim of preventing subsequent secondary infections is a potential risk mitigation strategy when planning a safe return to the classroom. However, our data add to the growing evidence that risk mitigation strategies that include masking, physical distancing, and staying home when ill can be sufficient to prevent secondary transmission of SARS-CoV-2 in a school setting.[18,19] In addition, with recent declines in COVID-19 in all age groups across the US with vaccination of adults and adolescents, the public health and economic value of screening testing also may decline further and continue to decline when vaccination is expanded to young children. The potential harm of widespread school screening testing programs also should be considered and include the possibility of identifying false-positive tests and/or positive results without clinical or public health significance, leading to unnecessary school absence, quarantining of household members, and anxiety among families and schools. The cost of screening testing in schools and the need for school personnel to perform tests and report results are also important considerations. Cost estimates for once-weekly testing of all K-12 students and twice-weekly testing of school staff in the US total up to $8.5 billion per month.[20] Without providing a clear benefit in the context of comprehensive school risk mitigation strategies, directing these funds to other pediatric pandemic–related resources, such as mental health services and academic enrichment, may benefit children more than school COVID-19 testing programs.

Our study does have several limitations. The proportion of students participating at each school averaged 20%. Although this makes it possible that transmission events were missed, we would have anticipated that some new clinical infections in other students would have been reported in that case. Reasons for school leadership's hesitation regarding testing reported to the study team included concerns about missing school or work during the required quarantine period given a positive result, concern over discomfort of the swab test itself, and mandatory sharing of positive test results with the local health department. In addition, as school staff became eligible for the COVID-19 vaccine during the study period, we received feedback from vaccinated staff members indicating that they did not perceive COVID-19 testing to be beneficial. Although all exposed contacts from both school cohorts and households of the positive participants were referred for COVID-19 testing, few followed up for testing at our hospital.

As part of this study, we had intended to perform whole-genome sequencing on positive samples to more rigorously evaluate potential school transmission by assessing genetic relatedness of viral samples. However, all but 3 positive samples had insufficiently low Ct values to permit whole-genome sequencing, mandating a reliance on more traditional epidemiologic methods, such as contact tracing. Furthermore, although we intended to perform testing during periods of higher COVID-19 community activity, the incidence of COVID-19 decreased significantly during the study planning period. In addition, potentially more transmissible COVID-19 variants of concern were not identified through our hospital surveillance activities until after the study was completed. Alpha and gamma variants were first identified to be increasing in Chicago children in March 2021, and the delta variant was first identified in Chicago children in June 2021 (unpublished data). It is likely that the risk of transmission in a school setting is higher when the overall community burden of disease is concordantly higher and/or there is a higher prevalence of more transmissible variants.

In summary, with several risk mitigation strategies in place, we identified limited evidence of SARS-CoV-2 transmission in K-8 schools in high-risk communities through our prospective observational study of COVID-19 school screening testing. Our findings support the safety of in-person learning and question the benefit of screening testing in schools that use proper COVID-19 risk mitigation strategies. With the limited resources of many school systems, funds could be spent on other resources rather than on random testing of asymptomatic students. Testing could be potentially useful in identifying the relative impact of individual risk mitigation strategies to guide iterative deescalation of these strategies, especially as vaccination increases. Additional research is needed to explore the impact of screening testing in high schools, the potential benefit of testing if risk mitigation strategies are relaxed, and the potential benefit in communities during periods of high community COVID-19 incidence and/or prevalence of variants of concern. ■

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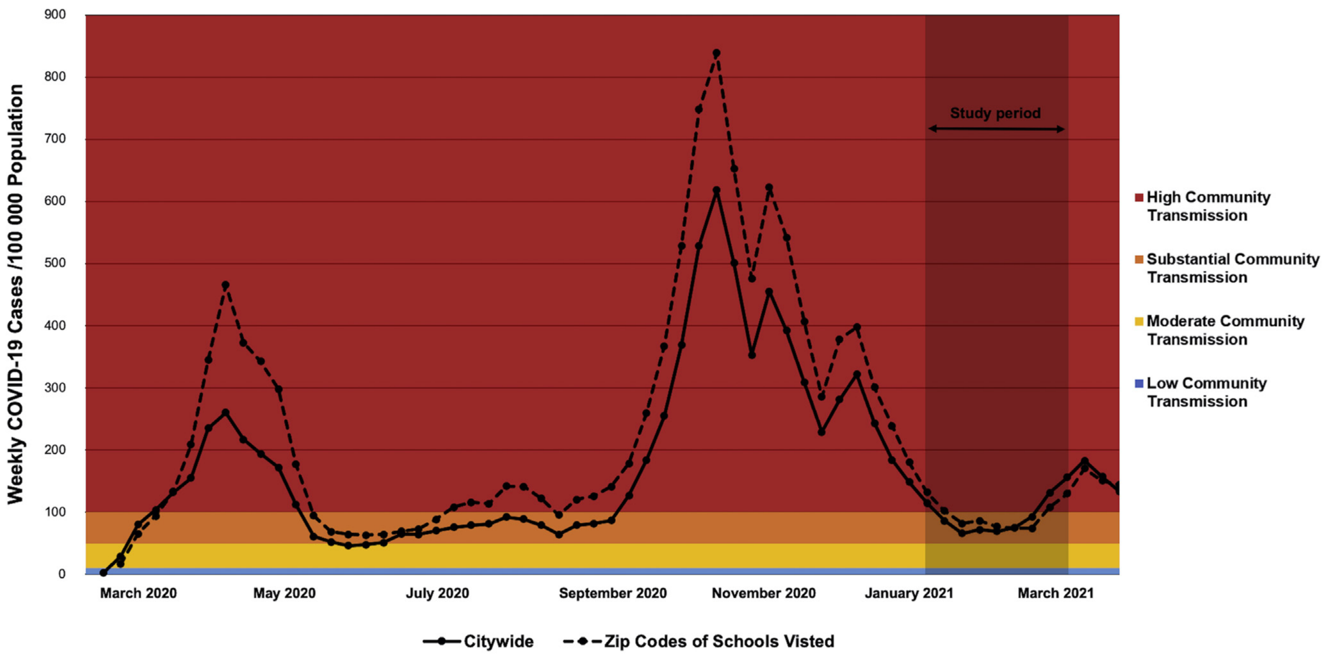

Figure 1. Weekly incidence of COVID-19 (cases per 100 000 population) in Chicago from March 2020 to April 2021. The dashed line represents COVID-19 incidence in the 8 Chicago ZIP codes in which schools were located, and the solid line represents overall citywide COVID-19 incidence. Background colors correspond to levels of community transmission according to Centers for Disease Control and Prevention stratification.[6] The shaded area represents the time period from January to March 2021, when school testing visits occurred.

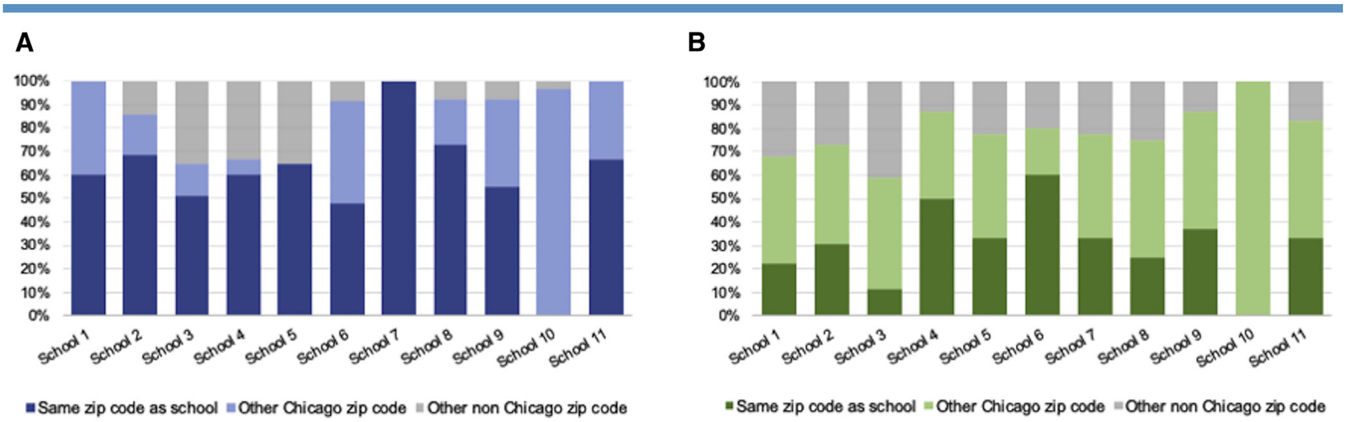

Figure 4. ZIP codes of study participants. Proportions of **A,** students and **B,** staff participants residing in the same ZIP code as the school, a different Chicago ZIP code, or a different non-Chicago ZIP code.