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COVID-19 Infections among Students and Staff in New York City Public Schools

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Summary: This study analyzes COVID-19 incidence, prevalence, and secondary transmission among students and staff in New York City public schools.

What's Known: In-person learning in schools may increase the risk of acquiring COVID-19 infection for students and staff. No studies have been published from large urban school districts in the United States to measure incidence, prevalence, and secondary transmission of COVID-19 infection.

What This Study Adds: When strict protocols were implemented for preventing, diagnosing, and managing school-associated cases, in-person learning in public schools was not associated with increased prevalence and incidence overall compared with the general community, and secondary transmission was infrequent.

CONTRIBUTORS STATEMENT

Dr Varma conceptualized and designed the study, analyzed and interpreted the data, drafted the initial manuscript, and critically revised the manuscript for important intellectual content.

Mr Thamkittikasem, Ms Arslanian, Ms Bray, Dr Stephens, and Dr Long conceived the study, acquired data, interpreted data, and critically revised the manuscript for important intellectual content.

Ms Whittemore and Ms Alexander analyzed the data, interpreted the data, and critically revised the manuscript for important intellectual content.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

ABSTRACT

Background

The 2019 novel coronavirus disease (COVID-19) pandemic led many jurisdictions to close in-person school instruction.

Methods

We collected data about COVID-19 cases associated with New York City public schools from polymerase chain reaction (PCR) testing performed in each school on a sample of asymptomatic students and staff and from routine reporting . We compared prevalence from testing done in schools to community prevalence estimates from statistical models. We compared cumulative incidence for school-associated cases to all cases reported to the city. School-based contacts were monitored to estimate the secondary attack rate and possible direction of transmission.

Results

To assess prevalence, we analyzed data from 234,132 persons tested for SARS-CoV-2 infection in 1,594 New York City public schools during October 9–December 18, 2020; 986 (0.4%) tested positive. COVID-19 prevalence in schools was similar to or less than estimates of prevalence in the community for all weeks. To assess cumulative incidence, we analyzed data for 2,231 COVID-19 cases that occurred in students and staff compared with the 86,576 persons in New York City diagnosed during the same period; the overall incidence was lower for persons in public schools compared with the general community. Of 36,423 school-based close contacts, 191 (0.5%) subsequently tested positive for COVID-19; the likely index case was an adult for 78.0% of secondary cases.

Conclusions

We found that in-person learning in New York City public schools was not associated with increased prevalence or incidence overall of COVID-19 infection compared with the general community.

BACKGROUND

Schools provide large health, social, and economic benefits to children, families, and societies. The American Academy of Pediatrics recommends that jurisdictions strive to ensure that "students [be] physically present in school."[1] However, schools might also serve as a setting in which respiratory infections transmit readily, amplifying community incidence. The 2019 novel

coronavirus disease (COVID-19) pandemic led many jurisdictions to close in-person school instruction for several months or the entire 2020–2021 academic year.[2] Closures might reduce community transmission; in part because they are often instituted along with other restrictions on businesses and gatherings, any added value has been difficult to measure.[3,4] Evidence has recently emerged that in-person schooling can be conducted in a way that minimizes COVID-19 transmission among students and staff and that the harms of school closure might outweigh a potential benefit in reducing community transmission.[5,6]

In response to rapidly accelerating transmission of COVID-19, New York City (NYC) closed public schools on March 16, 2020 and transitioned all students to remote (online) learning. NYC's first epidemic wave was among the most lethal in the world, resulting in over 23,195 confirmed and probable COVID-19 deaths during February 29–June 1, 2020.[7] During subsequent months, NYC reduced, but did not eliminate, COVID-19 transmission and opened its public schools to in-person instruction on September 21, 2020 with the implementation of substantial preventive measures.

To continuously assess the safety of its public schools, the City instituted a program to monitor the prevalence of COVID-19 infection by testing a sample of asymptomatic students and staff physically present in school each day. We analyzed data from this monitoring program and from cases occurring among students and staff diagnosed through community-based testing during October 9–December 18, 2020.

METHODS

Setting

The NYC Department of Education (DOE) directly oversees 1,607 schools, located in 1,400 buildings. These schools enroll approximately 1.1 million students annually. For the 2020–21 academic year, all families were given the option of either fully remote or "hybrid" learning, which was defined as 1–3 days of in-person school per week combined with remote learning on the other days. No students received full-time, in-person learning. During October 12–November 20, 288,199 students attended hybrid learning, and 80,876 adults were employed and physically present in schools as teachers, staff, or administrators. Schools were closed from November 19–December 6, and only elementary and special education schools were reopened in December. More details are available in the **Online-Only Supplement**. During December 7–18, these numbers were 164,673 students and 44,634 adults **(eTable 1).**

For in-person learning, DOE made comprehensive changes to school policy, practices, and facilities. Details are in the **Online-Only Supplement**. Multiple city agencies involved in school health established a joint coordination center, hereafter referred to as the Situation Room, to receive, investigate, and act on reports of COVID-19 infection in students, teachers, or staff associated with the public school system.

Case Detection

Reports of COVID-19 cases associated with schools were received in the Situation Room through three sources. First, as mandated by law, clinical laboratories are required to report to the New York City Department of Health and Mental Hygiene (DOHMH) information about any city resident who has a SARS-CoV-2 viral diagnostic test performed. New, laboratory-confirmed cases (or their parent/guardian) are interviewed and asked about any association with a school, and school-associated cases are notified to the Situation Room. Second, all school-affiliated persons were required and actively encouraged to notify their school if they are diagnosed with COVID-19, and schools notified the Situation Room about these cases; such reports are necessary if the person is not a NYC resident. Third, polymerase chain reaction (PCR) testing was performed in each school at least monthly, with results reported directly from clinical laboratories to the Situation Room.

Testing in Schools

Each public school was assigned a random day when testing would be performed among asymptomatic persons in a school. Testing was performed at least once per month in each school; the frequency changed to once per week for some schools in October-November, then for all schools in December. Further information about the change in testing frequency, consent, and sampling proportions is in **Online-Only Supplement.** In each school, a single swab of the right and left anterior nares was collected and underwent PCR using standard, FDA-authorized methods at one of two commercial laboratories (Bioreference; Fulgent/Color Genomics).

Actions in Response to a Case

Each case prompted an investigation to determine if there were additional cases, and contact tracing was initiated using established protocols in collaboration with school administrators. For public schools, a close contact was defined as any person physically present in a classroom for any duration with the case or any person that spent at least 10 minutes cumulatively within 6 feet during the infectious period (from two days before through 10 days after symptom onset date or, if asymptomatic, specimen collection date).[8] Classrooms and buildings were closed and cleaned following Department of Education (DOE) protocols.

Definitions

A COVID-19 case was defined as a person who tested positive for SARS-CoV-2 on an FDA-authorized PCR or antigen test who had not previously tested positive within the past 90 days. We excluded persons that were neither positive on a PCR or antigen test, including probable deaths and symptomatic persons with known COVID-19 exposure. Testing performed in schools only involved PCR. Testing in the community included PCR and antigen testing.

A COVID event was defined as ≥2 cases occurring within the same school during a 7-day period regardless of whether the cases were known or presumed to be epidemiologically linked. We inferred index cases and possible direction of transmission using dates of diagnosis, symptom onset, interaction, and the absence of other explanations for infection, such as household contact.

The type of school was classified using terminology of the NYC DOE to describe the range of grades included in a school, because schools can have a wide range of different grade levels: early childhood (preschool-2), elementary (preschool-5), junior high-intermediate-middle (6-8), high school (9-12), K-8, and K-12.

Statistical Analysis

School period prevalence was calculated by dividing the number of persons who tested positive for SARS-CoV-2 by the number of persons tested for a given school week (Monday–Friday) when testing was performed. For comparison, we calculated the period prevalence for the community by using estimates of the number of persons with COVID-19 infection in NYC, then dividing by the City's population to obtain an estimate of period prevalence.[9,10] The model by the Shaman group permitted analysis by age group for a given week.

We defined incidence as all cases reported during the evaluation period divided by the corresponding population. School incidence was calculated using the results of any testing done on a student or staff person associated with in-person learning (i.e., in-school testing, community testing, and verified self-report), then dividing all cases associated with the schools by the number of persons estimated by DOE to have been physically present in school during the evaluation period. We compared school incidence per week to community incidence using data for COVID-19 cases (PCR-positive or antigen-positive) from DOHMH. Incidence was stratified by age group and borough and calculated by school type. Because of the change in policy

regarding schools and testing detailed in the **Online-Only Supplement**, we divided the incidence analysis into two periods (October 12–November 19 and December 7–18).

All statistical analysis was conducted in R (version 4.0.3).[11]

RESULTS

Prevalence of COVID-19 Infection from Testing in Schools

Of 234,132 asymptomatic persons tested for SARS-CoV-2 infection in 1,594 NYC public schools during October 9–December 18, 2020, 986 (0.4%) tested positive. Except for the first and last weeks of testing, test positivity increased each week from 0.19% during October 12–16 to 0.67% during December 14–18, consistent with rising test positivity citywide during the same period **(Table 1)**. The median age of all cases was 31 years with 25%–75% interquartile range (IQR) of 10–47 years; for staff, it was 43 years (IQR 34–53), and for, students, 9 years (IQR 7–11).

Among staff who tested positive for COVID-19, test positivity was highest among K-8 schools, followed by elementary and early childhood schools **(Table 2)**. Among students who tested positive, test positivity was highest among students at elementary schools, followed by early childhood schools and K-8 schools.

Period prevalence in the schools never exceeded both model estimates for community prevalence; school prevalence was lower than community prevalence in four of the eight weeks for both models and between the two model estimates for the other four weeks **(Table 3)**. Stratified by age, the school period prevalence was similar or lower for all groups compared with estimated community period prevalence except for persons aged 65-74 years old **(eTable 2)**.

Incidence of COVID-19 Infection from Testing in Schools and Community

During October 9–November 19, 2020, 44,091 persons in the city were diagnosed with COVID-19; for the same period, there were 1,259 COVID-19 cases in persons associated with the schools (including 458 diagnosed from in-school testing) **(Table 4)**. During this period, 3-6% of persons aged 18 years or older had a PCR performed each week across the community[12]; in contrast, 11-27% of staff in schools had a PCR performed in school each week. Incidence among the school population was 341.1 cases per 100,000 population compared with incidence among the general community of 528.9 cases per 100,000 population. For persons 5-17 years old, incidence was 168.6 per 100,000 for the school population vs. 383.7 per 100,00 for the community; for persons 18 years and above, it was 955.8 for the school population and 581.5 for the community. Stratified by age groups, incidence was lower in the school community for all persons except in those aged 65–-74 years. Of all school cases identified during this period, 37.3% were missing age data.

During December 7–18, 2020, 42,485 persons in the city were diagnosed with COVID-19; for the same period, there were 972 COVID-19 cases in persons associated with the schools (including 529 diagnosed from in-school testing). During this period in December, 4-6% of

persons aged 18 years and older had a PCR performed each week across the community[13]; in contrast, 41–51% of staff in schools had a PCR performed in school each week. Incidence among the school population was 464.4 cases per 100,000 population compared with incidence among the general community of 509.6 cases per 100,000 population. For persons 5-17 years old, incidence was 244.7 per 100,000 for the school population vs. 367.3 for the community; for persons 18 and above, incidence was 1274.8 for the school population and 560.1 for the community. Stratified by age groups, incidence was lower in the school community for persons less than 18 years old and higher for persons aged 18–44, 45–64, and 65–74 years. Of all school cases identified during this period, 38.4% were missing age data.

Outcomes of Close Contacts

A total of 36,423 persons were classified as school-based close contacts of a case with an exposure date during October 9–December 18, 2020. Of those 36,423 close contacts, 191 (0.5%) tested positive for COVID-19 during the 14 days of quarantine **(Table 5)**. For the 191 cases, 132 (69%) had sufficient information about illness onset date, exposure period, and exposure locations for both cases and contacts to infer the likely direction of transmission. For these 132 cases, 67 (51%) likely involved transmission from staff-to-staff, 36 (27%) from staff-to-student, 18 (14%) student-to-staff, and 11 (8%) from student-to-student.

DISCUSSION

During eight weeks of in-person school, we found that persons associated with public schools had an overall burden of COVID-19 infections that was no higher than the burden in the general community and that transmission within schools was not common. Although our observation period was short, it involved a large, demographically diverse population that underwent extensive testing and case investigations.

We assessed burden by analyzing both prevalence and incidence of COVID-19. In both analyses, we found that the overall population of persons participating in in-person learning in public schools had lower or similar measures of COVID-19 infection than the NYC community, using statistical models or official case notifications for comparison. We found that staff may have an elevated risk of COVID-19 infection relative to the community, but that this risk is not clearly attributable to transmission in schools. Overall incidence was higher for staff than the general community and markedly higher for persons aged 45–64 years and 65–74 years during December. The fact that prevalence remained similar to or less than model estimates for persons 18-64 years old, however, suggests that increased incidence was attributable to increased ascertainment of infection—staff were tested at far higher rates, including 10 times the rate in December, than adults in the community—or acquisition of infection outside of school settings because of rising community incidence. Both prevalence and incidence were higher among persons aged 65–74 years, although the small number of cases makes it difficult to draw definitive conclusions.

Our evaluation cannot explain why we observed that in-person school was not associated with an overall increased COVID-19 burden, particularly among students. It is possible that the population that chose in-person learning adhered more rigorously to individual protective measures—such as mask wearing, physical distancing, and hand hygiene—or has other unmeasured characteristics, such as prior infection, that could explain lower levels of COVID-19 infection. It is also possible that the hours spent during school, however limited, help reduce the overall risk of infection by reducing the opportunity for high-risk activities in the community. Longer-term analysis of school COVID-19 monitoring data and further evaluations, such as testing a representative population of students attending remote learning, could help elucidate factors that explain these findings.

Studies have shown that the strongest predictor of COVID-19 outbreaks in schools is the incidence of COVID-19 infection in the surrounding community.[14] In our evaluation, we observed that the prevalence of infection in the school community rose with increases in community incidence. Our policies to prevent COVID-19 transmission required us to close a classroom for 14 days in response to an individual case and, in situations with more than one case within a seven-day period, to close the entire building for 14 days if we could not link transmission to an exposure outside the school. Given that COVID-19 has a maximum 14-day incubation period and many persons could not recall a specific exposure that led to infection, the number of building closures grew as community transmission increased. However, the overall proportion of buildings closed for 14 days remained a small proportion of all buildings (9% for October–November; 13% for December).

We estimated the secondary attack rate associated with school exposures was 0.5%, and, notably, that a staff person was the likely index case for 78% of these secondary cases. Our findings align with experiences from other jurisdictions that adults are more likely to transmit infection in school settings than children, even in situations, such as in NYC, where the prevalence of undiagnosed infection was highest in younger children.[15] Schools should strengthen prevention and diagnosis of COVID-19 among staff, including strict adherence to masks and physical distancing in school and out of school and promotion of and priority access for routine periodic testing. Our estimate of the secondary attack rate is prone to error. It could be an overestimate because we do not have definitive proof that all cases arising during quarantine were acquired from the school-based index case that triggered quarantine, rather than from other sources of exposure either inside or outside the school. The secondary attack rate could also be an underestimate because close contacts do not universally undergo testing, even though the city's contact management program includes daily monitoring calls during quarantine that encourage contacts to get tested.

Our evaluation was subject to important limitations. First, investigations depend on interviews with patients (or their guardians) and their contacts, and such interviews rarely provide definitive information about the duration and source of infection. Second, in situations with more than one case within a school, we can only infer and cannot verify whether infections were linked and, if so, the direction of transmission. Third, during the October–November period, only 41% of parents provided consent to have their children tested. Our results could under-estimate prevalence—but, importantly, not incidence for that period—if those students were systematically more likely to have undiagnosed COVID-19 infection. Fourth, more than one-

third of school-associated cases had missing data about age, making it necessary to interpret analysis of school incidence by age strata with caution. Fifth, our analysis did not include seroprevalence data, which could provide additional information to assess prevalence and incidence in the school population. Sixth, while the two models of community prevalence provide plausible lower and upper bound estimates to compare with school testing data, the models were not developed to estimate the proportion of persons that might test positive by PCR in a predominantly asymptomatic population. Finally, our analysis only covered a brief period of the school year and was not designed to assess the contribution of schools to community transmission. Multiple events that could increase community COVID-19 transmission occurred in NYC contemporaneous with the opening of public schools, including the opening of in-person learning at non-public schools and universities, the opening of higher-risk indoor activities such as dining and fitness gyms (albeit with restricted capacity), the onset of cooler, lower humidity weather, and large increases in incidence in neighboring jurisdictions.

CONCLUSION

We found that in-person learning in NYC public schools was not associated with increased prevalence and incidence overall compared with the general community. Strict protocols for preventing, diagnosing, and managing school-associated cases might have contributed, but further studies are needed to understand which measures are most important to reducing transmission among students and staff. Longer follow-up and evaluation are also needed to understand how much increased incidence among staff is attributable to increased ascertainment through testing or increased exposures either in school or outside of school. Other jurisdictions seeking to open schools might wish to consider similar policies and practices for reducing

transmission, periodic testing to monitor the effectiveness of COVID-19 safety measures, and use of multi-agency operations centers, such as ours, to manage the complex process of receiving, investigating, and acting upon COVID-19 cases continuously.

DISCLAIMER

The conclusions, findings, and opinions expressed by authors contributing to this journal do not necessarily reflect the official position of the U.S. Department of Health and Human Services, the Public Health Service, the Centers for Disease Control and Prevention, or the authors' affiliated institutions.

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TABLE 1. Results of period prevalence testing for COVID-19 in public schools over time — New York City, October–December 2020

5-day testing week	No. of persons tested*	No. of persons tested positive for COVID-19 (%)	No. of students tested	No. of students tested positive for COVID-19 (%)	No. of staff tested	No. of staff tested positive for COVID-19 (%)
October 12–16	14,509	27 (0.19%)	5,300	8 (0.15%)	9,209	19 (0.21%)
October 19–23	25,795	30 (0.12%)	9,308	16 (0.17%)	16,487	14 (0.09%)
October 26–30	32,934	51 (0.15%)	11,536	21 (0.18%)	21,398	30 (0.14%)
November 2–6	29,796	65 (0.22%)	11,001	26 (0.24%)	18,795	39 (0.21%)
November 9–13	32,436	138 (0.43%)	12,755	56 (0.44%)	19,681	82 (0.42%)
November 16–20	23,920	146 (0.61%)	8,212	36 (0.39%)	15,708	110 (0.70%)

5-day testing week	No. of persons tested*	No. of persons tested positive for COVID-19 (%)	No. of students tested	No. of students tested positive for COVID-19 (%)	No. of staff tested	No. of staff tested positive for COVID-19 (%)
December 7–11	41,998	309 (0.74%)	19,409	162 (0.83%)	22,586	147 (0.65%)
December 14–18	32,744	220 (0.67%)	14,224	96 (0.68%)	18,520	124 (0.67%)

*For all persons, a single swab of the right and left anterior nares was collected and underwent nucleic acid amplification testing using standard, FDA-authorized methods. For the period during November 20–December 7, all public schools were closed. For December 7-18, only elementary and special education schools were open.

TABLE 2. Overall COVID-19 positivity by school type, stratified by staff and students — New York City, October–December 2020

School type*	No. of staff tested positive for COVID-19 (percent positive)**	No. of students tested positive for COVID-19 (percent positive)*
Secondary school (6-12)	13 (0.31%)	5 (0.23%)
High school (9-12)	52 (0.27%)	11 (0.16%)
Elementary (3K-5)	351 (0.44%)	335 (0.54%)
Early childhood (3K-2)	5 (0.36%)	4 (0.45%)
Junior High-Intermediate-Middle (6-8)	48 (0.32%)	39 (0.34%)
K–8	76 (0.46%)	51 (0.43%)
K–12	1 (0.15%)	0 (0.00%)

*School type refers to the classification used by the New York City public school system to describe the range of grades included in a school; as indicated, schools can have a wide range of different grade levels. 3K refers to pre-school starting at age 3 years.

**For all persons, a single swab of the right and left anterior nares was collected and underwent nucleic acid amplification testing using standard, FDA-authorized methods. The frequency of testing in schools varied during the period due to changes in State and City policy. During October-November, all schools had at least monthly testing, and some schools had weekly testing during October-November. During December, only elementary and special education schools were open, and all schools had weekly testing.

TABLE 3. Comparison between COVID-19 school period prevalence and model estimates of overall NYC community period prevalence — October –December 2020.*

	No. of persons estimated to have active COVID-19 infection in NYC for Model 1	Estimated NYC period prevalence for Model 1 (95% CI)	No. of persons estimated to have active COVID-19 infection in NYC for Model 2	Estimated NYC period prevalence for Model 2 (95% CI)	No. of persons tested positive for COVID-19 in schools	No. of persons tested for COVID-19 in schools	School period prevalence
October 12–18	9189	0.110 (0.108–0.113)	21,451	0.257 (0.254–0.261)	27	14,509	0.19 (0.13–0.27)
October 19–25	13312	0.160 (0.157–0.162)	24,329	0.292 (0.288–0.296)	30	25,795	0.12 (0.08–0.17)
October 26–November 1	15166	0.182 (0.179–0.185)	29,417	0.353 (0.349–0.357)	51	32,934	0.15 (0.12–0.21)

	No. of persons estimated to have active COVID-19 infection in NYC for Model 1	Estimated NYC period prevalence for Model 1 (95% CI)	No. of persons estimated to have active COVID-19 infection in NYC for Model 2	Estimated NYC period prevalence for Model 2 (95% CI)	No. of persons tested positive for COVID-19 in schools	No. of persons tested for COVID-19 in schools	School period prevalence
November 2–8	25231	0.303 (0.299–0.306)	41,420	0.497 (0.492–0.502)	65	29,796	0.22 (0.17–0.28)
November 9–13	30616	0.367 (0.363–0.371)	58,224	0.698 (0.693–0.704)	138	32,436	0.43 (0.36–0.50)
November 16–20	35908	0.431 (0.426–0.435)	71,272	0.855 (0.849–0.861)	146	23,920	0.61 (0.52–0.72)
December 7–11	58533	0.702 (0.696–0.708)	128,381	1.540 (1.532–1.548)	309	41,998	0.74 (0.66–0.82)

	No. of persons estimated to have active COVID-19 infection in NYC for Model 1	Estimated NYC period prevalence for Model 1 (95% CI)	No. of persons estimated to have active COVID-19 infection in NYC for Model 2	Estimated NYC period prevalence for Model 2 (95% CI)	No. of persons tested positive for COVID-19 in schools	No. of persons tested for COVID-19 in schools	School period prevalence
December 14–18	58822	0.706 (0.700–0.711)	133,741	1.604 (1.596–1.613)	220	32,744	0.67 (0.59–0.77)

*Model 1 estimates of the number of persons with COVID-19 infection in New York City from the Shaman Group at Columbia University Mailman School of Public Health. The model used available case, mortality, and mobility data to estimate the number of persons with COVID-19 infection who are potentially infectious to others; as a result, it is likely to be an under-estimate of all persons who test positive using a nucleic acid amplification test of a respiratory specimen. Model 2 estimates the number of persons with COVID-19 infection in New York City from covid19-projections.com, an open source project by Youyang Gu. The number of persons actively infectious includes those who were recently infected and no longer infectious; as a result, its estimates of prevalent infections are substantially higher than model 1 and, therefore, represent an upper-bound estimate of prevalent infections. To calculate period prevalence, we divided the number of persons estimated to have active COVID-19 infections by the population of New York City. See Appendix for further details.

TABLE 4. Overall COVID-19 cases associated with in-person public school and comparison with population incidence — New York City, October–December 2020.*

	No. of COVID-19 cases associated with in-person school (%)	Incidence per 100,000 population among persons associated with in-person school	No. of COVID-19 cases in NYC population (%)	Incidence per 100,000 population in NYC
Total during October 9–November 19	1,259	341.1	44,091	528.9
Students	486 (38.6%)	168.6		
Staff	773 (61.4%)	955.8		
Age group (years)				
0–4	20 (1.6%)	122.4	1,085 (2.5%)	207.2

	No. of COVID-19 cases associated with in-person school (%)	Incidence per 100,000 population among persons associated with in-person school	No. of COVID-19 cases in NYC population (%)	Incidence per 100,000 population in NYC
5–9	149 (11.8%)	132.8	1,440 (3.3%)	297.3
10–14	137 (10.9%)	128.3	1,805 (4.1%)	406.7
15–17	32 (2.5%)	72.3	1,277 (2.9%)	506.1
18–44	281 (22.3%)	484.1	23,233 (52.7%)	698.7
45–64	162 (12.9%)	534.2	10,943 (24.8%)	539.9
65–74	8 (0.6%)	759.0	2,795 (6.3%)	388.8
≥75	0 (0.0%)	0.0	1,497 (3.4%)	266.6

	No. of COVID-19 cases associated with in-person school (%)	Incidence per 100,000 population among persons associated with in-person school	No. of COVID-19 cases in NYC population (%)	Incidence per 100,000 population in NYC
Unknown**	470 (37.3%)		0 (0.0%)	
Total during December 7–18	972	464.4	42,485	509.6
Students	403 (41.5%)	244.7		
Staff	569 (58.5%)	1274.8		
Age group (years)				
0–4	18 (1.9%)	132.1	1,141 (2.7%)	217.9

	No. of COVID-19 cases associated with in-person school (%)	Incidence per 100,000 population among persons associated with in-person school	No. of COVID-19 cases in NYC population (%)	Incidence per 100,000 population in NYC
5–9	202 (20.8%)	168.4	1,536 (3.6%)	317.2
10–14	54 (5.6%)	189.0	1,685 (4.0%)	379.7
15–17	0 (0.0%)	0.0	1,104 (2.6%)	437.6
18–44	179 (18.4%)	633.0	20,296 (47.8%)	610.4
45–64	134 (13.8%)	790.3	11,623 (27.4%)	573.4
65–74	12 (1.2%)	1973.7	3,200 (7.5%)	445.2
≥75	0 (0.0%)	0.0	1,866 (4.4%)	335.8

	No. of COVID-19 cases associated with in-person school (%)	Incidence per 100,000 population among persons associated with in-person school	No. of COVID-19 cases in NYC population (%)	Incidence per 100,000 population in NYC
Unknown	373 (38.4%)		0 (0.0%)	

*We defined incidence as all cases reported during the evaluation period divided by the corresponding population. School incidence was calculated using the results of any testing done on a student or staff person associated with in-person learning (i.e., in-school testing, community testing, and verified self-report), then dividing all cases associated with the schools by the number of persons estimated by DOE to have been physically present in school during the evaluation period. We compared school incidence per week to community incidence using data for COVID-19 cases (PCR positive or antigen positive) from the New York City Health Department. Because of the change in policy regarding schools and testing, we divided the incidence analysis into two periods (October 12–November 19 and December 7–18).

**Because more than one-third of the school-associated cases had missing data about age, incidence data by age group should be interpreted with caution.

TABLE 5. Outcomes of close contacts of school cases — October 9–December 18, 2020

	No. of persons (%)
Total number of close contacts identified with exposure date during October 9–December 18, 2020	36,423
Close contacts who tested positive for COVID-19 within 14 days of exposure date	191 (0.5%)
Close contacts for whom direction of infection was known	132 (69.1%)
Staff to staff	67 (50.8%)
Staff to student	36 (27.3%)
Student to staff	18 (13.6%)
Student to student	11 (8.3%)

Appendix

TABLE OF CONTENTS

METHODS

Setting

For in-person learning, DOE made comprehensive changes to school policy, practices, and facilities, including: Anyone physically present at a school completed a symptom screening form and temperature checks; face coverings were worn by all persons and at all times while on school property (with medical-grade masks and face shields available for use by staff); physical distance of 6 feet was required at all times; class sizes were reduced with cohorts of students and student-teacher pairs maintained as much as possible during the entire day; parents and other visitors were excluded from school; and improvements were made in natural ventilation and centralized ventilation systems.[1] Lunch was provided in classrooms to minimize interaction between groups of students. If a case occurred in a classroom, the classroom was closed and all persons quarantined for 14 days; if 2 or more cases occurred in a school in different classrooms, an investigation was initiated into the source of infection, and, if no source external to school-based interactions found, the entire building was closed for 14 days. New York City additionally adopted a threshold for closure of the entire public school system if the percent positivity of all viral diagnostic tests performed in New York City was 3.0% or higher.

Agencies included in the Situation Room included: Department of Education; Department of Health and Mental Hygiene (DOHMH); Department of Buildings; and Health and Hospitals Test & Trace Corps.

Testing in Schools

Persons eligible for testing included any student or staff member who was physically present in the school on the day of in-school testing and provided consent for testing. Students were required to have written consent signed by a parent or guardian, and verbal assent was obtained at the time of testing; 41% of eligible students had written signed consent during the period during October 8–November 19, and 61% of eligible students had written signed consent during December 7-18. (Consent form available at: https://www.schools.nyc.gov/docs/default-source/default-document-library/student-covid-19-testing-consent-form---september-27-2020). Staff provided verbal consent on-site for testing, and labor union policy for teachers mandated penalties for failure to consent. Personnel in the Situation Room used a random number generator to identify persons for testing from the eligible population with the sample size determined by the size of the school: 20% for schools with <500 students, 15% for schools with 500–999 students, and 10% for schools with >999 students. The sampling proportion was based on the assumption that a larger base population requires a smaller sampling proportion to estimate prevalence and logistic constraints regarding the number of specimens that could be efficiently collected each day in different size schools.

Two major changes occurred in testing and schooling during the period of evaluation. First, during the week of October 11, 2020, New York State (NYS) designated several areas of NYC as “clusters,” mandating closure of in-person schooling in areas of highest COVID-19 transmission and weekly testing of a sample of students in schools adjacent to these areas. Second, NYC closed all public schools during November 19–December 6 due to crossing its

pre-defined threshold of 3% citywide test positivity. During December 7–18, only elementary and special education schools were re-opened, all schools were mandated to undergo testing weekly, rather than monthly, and children who did not have a signed consent form for testing were required to switch to remote learning.

New York State mandated that aggregate results of all testing be published online (https://schoolcovidreportcard.health.ny.gov/).

Statistical Analysis

To standardize laboratory data, we created new demographic variables for age group and the composite of race and ethnicity. We then merged laboratory data with a complete list of public schools using a unique school identifier. We calculated the proportion of tests that were positive and performed multivariable logistic regression using age group, gender, race/ethnicity, and location of school by borough as predictors. Boroughs included Brooklyn, Bronx, Manhattan, Queens, and Staten Island. Age groups included persons aged 0–3, 4–10, 11–18, 19–24, 25–44, 45–64, 65–74, and ≥75 years as well as an unknown group. Race/ethnicity groups included non-Hispanic American Indian, non-Hispanic Asian/Pacific Islander, non-Hispanic Black, non-Hispanic Multiracial, non-Hispanic White, and Hispanic/Latino as well as an unknown group. Confidence intervals were calculated using the profile likelihood method in R.[2]

We matched the Situation Room data portal to the city's case and contact investigations and monitoring database to obtain additional information about each school-affiliated case. To identify individuals who might have contracted COVID-19 in a school setting, a list of school-based close contacts identified through Situation Room investigations was matched against subsequent confirmed positive cases also handled by the Situation Room. Close contacts who were last exposed to a COVID-19 case during October 9–December 18, 2020, were then included in the analysis.

We created a list of all responses to school events during the evaluation period to include the date of the most recent case, response action (no closure; classroom closure; building closure), number of cases, number of students that were cases, number of staff that were cases, number of persons quarantined, whether at least one case was identified through testing performed in school as part of the prevalence survey, and whether the epidemiologic investigation concluded whether transmission likely occurred outside of school for at least one case in the event.

Data Management

The Situation Room data portal contained all COVID-19 cases associated with in-person learning at a public school, including those from testing performed in schools (prevalence survey) and those reported through public health surveillance and self-report as described above. Data from the Situation Room was managed in Microsoft Dynamics. The Test & Trace Corps at NYC Health + Hospitals managed a Salesforce database of all COVID-19 cases investigated and their close contacts. The number of students in attendance and staff employed were provided by the DOE. Modeling estimates for NYC prevalent infections were drawn from two sources described below.

Model 1

Estimates of the number of active COVID-19 infections in New York City (NYC) were provided by the Shaman Group at Columbia University Mailman School of Public Health.[3] The model used available case, mortality, and mobility data to estimate the number of persons with COVID-19 infection who are potentially infectious to others; as a result, it is likely to be an under-estimate of all persons who test positive using a nucleic acid amplification test of a respiratory specimen. Estimates were stratified by week, age group, and borough. To calculate period prevalence, we divided the number of persons estimated to have active COVID-19 infections by the relevant population. Denominators were drawn from the 2014–2018 American Community Survey (ACS) 5-year estimates.

We calculated 95% confidence intervals for each estimate of period prevalence. Estimates were available by age and borough.

Model 2

Alternate estimates of the number of active COVID-19 infections in NYC were drawn from covid19-projections.com, an open source project by an independent data scientist.[4] This model used machine learning techniques on top of a classic infection disease model and is described in detail here. To calculate period prevalence, we divided the number of persons estimated to have active COVID-19 infections by the population of NYC. The number of persons actively infected includes those who were recently infected and no longer infectious; as a result, its estimates of prevalent infections are substantially higher than model 1 and, therefore, represent an upper-bound estimate of prevalent infections. The denominator was drawn from the 2014–2018 ACS 5-year estimates. We calculated 95% confidence intervals for each estimate of period prevalence. Estimates for this model were not available by age or borough.

Ethics

Data from this program was collected as part of a program to monitor and prevent COVID-19 transmission in public schools, and analyses were conducted by city government personnel to evaluate the effectiveness of this program. As such, it was considered a public health program to control an acute health emergency. This activity was reviewed by the Centers for Disease Control and Prevention (CDC) and conducted consistent with applicable federal law (45 CFR 46.102(l)(2)) and CDC policy.[§]

RESULTS

Prevalence of COVID-19 Infection from Testing in Schools

In multivariable logistic regression, borough, age, and ethnicity were significantly associated with a positive test. Compared with persons aged 45–64 years, the odds of a positive test were higher for persons aged 4–10 years (adjusted odds ratio [aOR] 1.44, 95% confidence interval [CI] 1.22–1.70) and persons aged 65–74 years (aOR 1.76, CI 1.19–2.51). Compared with persons who identified as Non-Hispanic White, the odds of a positive test were higher for persons who identified as Hispanic or Latino (aOR 1.31, CI 1.05–1.63). Compared with persons attending school in Manhattan, the odds of a positive test were higher for persons attending school in Brooklyn (aOR 1.58, CI 1.26–1.98), Bronx (aOR 1.81, CI 1.46–2.26), Queens (aOR 1.32, CI 1.06-1.67), and Staten Island (aOR 1.95, CI 1.44–2.64).

Classroom and Building Closures

Of 457 COVID-events (≥2 cases diagnosed in a school within a 7-day period), 389 (85.1%) involved at least one staff person, and 317 (69.4%) involved at least one student **(eTable 3).** The number of persons quarantined per event ranged from 2–170. Most events resulted in a building closure (n = 374; 81.8%) rather than only a classroom closure. At least one case was identified by prevalence (in-school) testing for 277 (60.6%) school events, and transmission likely occurred outside of school for at least one case in 46 (10.1%) school events.

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TABLES

eTable 1. Estimated number of persons present for in-person schooling — New York City, October–December 2020*

	No. of students present in-person at least once during October 2020	No. of students present in-person at least once during December
Students	288,199	164,673
Staff	80,876	44,634
Age group (years)		
0–4	16,336	13,629
5–9	112,212	119,976
10–14	106,766	28,571
15–17	44,261	1,261
18–44	58,044	28,277
45–64	30,328	16,956
65–74	1,054	608
≥75	74	29
Borough		

Brooklyn	102,875	60,889
Bronx	73,393	39,505
Manhattan	53,422	29,478
Queens	109,467	60,380
Staten Island	30,798	19,075

*Because some students were enrolled at schools in more than one borough, totaling in-person counts by borough will not result in the citywide count of students present in-person for the period of interest.

eTable 2. Prevalence of COVID-19 infection in school community compared with estimated community prevalence by age groups.

Age group, years*	No. of persons tested positive / No. of persons tested for COVID-19 in schools	School Positivity	Estimated Community Positivity, range**
October 12-November 20, 2020			
0–4	1/223	0.45%	0.07%–0.41%
5–14	148/52,050	0.28%	0.13%–0.72%
15–24	24/8,600	0.28%	0.12%–0.86%
25–44	150/52,189	0.29%	0.14%–0.95%
45–64	120/43,038	0.28%	0.12%–0.65%
65-74	11/2,754	0.40%	0.06%–0.35%
≥75	0/205	0%	0.04%–0.20%

Age group, years*	No. of persons tested positive / No. of persons tested for COVID-19 in schools	School Positivity	Estimated Community Positivity, range**
December 7-18, 2020			
0–4	1/62	1.61%	0.58%–0.80%
5–14	257/33,330	0.77%	0.68%–0.84%
15–24	8/1,164	0.69%	0.96%–1.03%
25–44	136/19,863	0.68%	0.87%–0.97%
45–64	109/18,917	0.58%	0.56%–0.63%
65-74	13/1,248	1.04%	0.31%–0.42%
≥75	0/89	0%	0.26%–0.35%

*Age groups were calculated using strata in the Shaman group model.

**Estimated community positivity is based on models from Shaman group described in Results. Given that estimates are provided for each week, we present the range from low to high for the mid-point estimate for each weekly period.

eTable 3. Common features of COVID-19 school building events — New York City, October–December 2020

	No. of events (%)
Total no. of school events with ≥2 cases	457
≥1 student involved	317 (69.4%)
≥1 staff involved	389 (85.1%)
Building closed	374 (81.8%)
Classroom closed	83 (18.2%)
At least one case identified through survey	277 (60.6%)
Transmission likely occurred outside of school for ≥1 case(s)	46 (10.1%)

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