

Community SARS-CoV-2 Surge and Within-School Transmission

Kanecia O. Zimmerman, MD, MPH,^{a,b,d} M. Alan Brookhart, PhD,^c Ibukunoluwa C. Kalu, MD,^d Angelique E. Boutzoukas, MD,^d Kathleen A. McGann, MD,^d Michael J. Smith, MD, MSCE,^d Gabriela M. Maradiaga Panayotti, MD,^d Sarah C. Armstrong, MD,^b David J. Weber, MD, MPH,^e Ganga S. Moorthy, MD,^d Daniel K. Benjamin, Jr, MD, PhD,^{a,b,d} for The ABC Science Collaborative

abstract

OBJECTIVES: When the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic began, experts raised concerns about in-person instruction in the setting of high levels of community transmission. We describe secondary transmission of SARS-CoV-2 within North Carolina kindergarten through 12th-grade school districts during a winter surge to determine if mitigation strategies can hinder within-school transmission.

METHODS: From October 26, 2020, to February 28, 2021, 13 North Carolina school districts participating in The ABC Science Collaborative were open for in-person instruction, adhered to basic mitigation strategies, and tracked community- and school-acquired SARS-CoV-2 cases. Public health officials adjudicated each case. We combined these data with that from August 2020 to evaluate the effect of the SARS-CoV-2 winter surge on infection rates as well as weekly community- and school-acquired cases. We evaluated the number of secondary cases generated by each primary case as well as the role of athletic activities in school-acquired cases.

RESULTS: More than 100 000 students and staff from 13 school districts attended school in person; of these, 4969 community-acquired SARS-CoV-2 infections were documented by molecular testing. Through contact tracing, North Carolina local health department staff identified an additional 209 infections among >26 000 school close contacts (secondary attack rate <1%). Most within-school transmissions in high schools (75%) were linked to school-sponsored sports. School-acquired cases slightly increased during the surge; however, within-school transmission rates remained constant, from presurge to surge, with ~1 school-acquired case for every 20 primary cases.

CONCLUSIONS: With adherence to basic mitigation strategies, within-school transmission of SARS-CoV-2 can be interrupted, even during a surge of community infections.



^bThe ABC Science Collaborative, ^aDuke Clinical Research Institute and ^cDepartments of Population Health Sciences and ^dPediatrics, School of Medicine, Duke University, Durham, North Carolina; and ^eDepartment of Epidemiology, University of North Carolina at Chapel Hill School of Medicine, Chapel Hill, North Carolina

Drs Zimmerman and Benjamin conceptualized and designed the study, coordinated and supervised data collection, designed the data collection instruments, collected data, conducted the initial analyses, drafted the initial manuscript, reviewed and revised the manuscript, and critically reviewed the manuscript for important intellectual content; Dr Brookhart designed the data collection instruments, collected data, conducted the initial analyses, and reviewed and revised the manuscript; Drs Akinboyo, Boutzoukas, McGann, Maradiaga Panayotti, Smith, Armstrong, Weber, and Moorthy reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Address for correspondence: Daniel K. Benjamin, Jr, MD, PhD, Duke Clinical Research Institute, 300 W. Morgan St, Suite 800, Durham, NC 27701. E-mail: danny.benjamin@duke.edu

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WHAT'S KNOWN ON THIS SUBJECT: In spring 2020, concerns about high levels of community transmission continued to impede in-person education for many school districts across the United States. The impact of high community transmission of severe acute respiratory syndrome coronavirus 2 community transmission on within-school transmission remains unknown.

WHAT THIS STUDY ADDS: Among >100 000 students and staff in 13 school districts implementing mitigation strategies, community-acquired infections among school-aged children increased during a surge of infections in North Carolina, but school-acquired infections remained stable and uncommon, with a <1% secondary attack rate.

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In March 2020, the World Health Organization declared that coronavirus disease 2019 (COVID-19), which is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), had officially become an international pandemic. Kindergarten through 12th grade (K–12) schools across the world preemptively closed their doors to in-person education in hopes of preventing disease spread. Early data from Europe,¹ North Carolina,² and Wisconsin³ demonstrated that within-school transmission was uncommon with a few key mitigation strategies in place (eg, masking, hand hygiene, physical distancing). Furthermore, early data also suggested that within-school transmission was independent of community transmission. Nonetheless, as community cases of SARS-CoV-2 soared in late fall 2020, major policy organizations, including the US Centers for Disease Control and Prevention (CDC), recommended that community rates be used to make decisions related to in-person K–12 education.⁴

A year after initial school closures, many public K–12 schools remain closed or only partially open, with proponents of school closures often citing concerns about high levels of community spread, within-school crowding, and inability to improve classroom ventilation. The severe and negative impact of prolonged school closures on children's physical, emotional, developmental, and academic health has been extensively documented, with increasing evidence of worsening behavioral health,⁵ suicidality, physical abuse,^{6,7} obesity and disordered eating,^{8–11} and racial and ethnic disparities in digital access, food insecurity, school absenteeism, and failing grades.^{12–14} To further investigate the impact of community transmission on the risk of in-person K–12 education, The ABC

Science Collaborative (ABCs) evaluated within-school transmission of SARS-CoV-2 during a community SARS-CoV-2 surge in North Carolina.

METHODS

Study Population

During the SARS-CoV-2 pandemic, ABCs partnered with >50 K–12 public school districts in North Carolina, including 13 districts that provided in-person instruction from October 26, 2020, to February 28, 2021. ABCs developed in summer 2020, when local North Carolina school districts requested scientific input to help guide return-to-school policies during the COVID-19 pandemic. ABCs paired scientists with school communities to ensure leaders had the most relevant and up-to-date information on COVID-19 to guide decisions on school policies. The 13 districts also participated in biweekly educational and quality improvement sessions with ABCs faculty and agreed to prospectively track community- and school-acquired SARS-CoV-2 cases by school and week; these data were provided to ABCs for analysis. The start of the study period was determined on the basis of the start of the second quarter of K–12 instruction for most of the study districts. After this start date, communities across North Carolina (and much of the United States) identified substantial increase in COVID-19 cases (ie, “the surge”). The districts in this study had >100 cases per 100 000 population per 7 days, meeting the CDCs “red zone” in their school guidance from 2020 and first quarter 2021.⁴

During the study period, North Carolina law required districts to adhere to a hybrid model of education, with 6-foot distancing for middle and high school, and to follow the North Carolina

Department of Health and Human Services StrongSchoolsNC Public Health Toolkit as their guide for mitigation strategies.¹⁵ North Carolina law permitted minimal physical distancing (<6 feet) and hybrid education for prekindergarten through fifth-grade (PreK–5) students. The central tenants of the tool kit are universal masking, hand-washing, and distancing in classrooms. Only one student was allowed per bus seat, and traffic flow was directed in school hallways. Additionally, the tool kit initially required health screening questions and temperature checks before entering school buildings, but because of a lack of efficacy, this screening requirement was no longer required toward the end of the study period. In most hybrid models, up to 50% of enrolled students could attend school on a single day; to facilitate equal access to in-person education for all enrolled students, students alternated days of in-person education. On in-person days, PreK–5 students mostly stayed with their classrooms, and many districts had grade-based cohorts for sixth through eighth grades to minimize student contact and facilitate contact tracing. Additional caution (eg, increased distancing, outdoor seating, musical instrument covers) was taken in circumstances in which masking was not possible (eg, meals, band class or practice). Masking during and outside of play for school sports was also required, and in most cases, teams were not permitted to use the locker rooms before, during, or after games. North Carolina did not have specific requirements for children with special educational needs to attend in-person classes.

Outcome Measures

The primary outcome was the number of school-acquired SARS-CoV-2 cases confirmed by molecular

diagnostic tests in participating public schools during the study period. Contact tracers from the participating school districts and the local health departments adjudicated each case as community or school acquired according to standard criteria¹⁵ and as part of standard contact tracing to determine epidemiological linkage and source of SARS-CoV-2 infection. Schools also noted whether school-acquired cases were associated with involvement in school-sponsored sports. In most cases, districts and the public health department were conservative in denoting within-school transmission versus community-acquired cases. For example, if cases were identified within classmates who were also known to be friends and gathered outside of school, infection was most often attributed to within-school transmission, although transmission more likely occurred in the unsupervised environment. The determination of epidemiological linkage due to sports was made in the same manner as all other secondary infections, with timing of secondary infection (eg, practice) and close contact (eg, teammate) considered as part of standard contact tracing. Testing of close contacts was encouraged but not required.

Data Sources

Superintendents or other leaders from participating school districts provided data on the number of students and staff participating in in-person instruction and the number of community- and school-acquired cases for each week during the study period. For analyses comparing the pre- and postsurge periods, we used SARS-CoV-2 data from August 2020 for 11 of the participating school districts, as previously described.² We obtained publicly available data from the North Carolina Department of Public Instruction on district enrollment, as well as racial and ethnic distribution, for the 2020–2021 school year. We used

data from the Johns Hopkins COVID-19 data repository¹⁶ for community SARS-CoV-2 rates in terms of new cases per 1000 persons per 7 days for the county where the school district was located.

Analyses

We used descriptive statistics to characterize the study population as well as community- and school-acquired cases of SARS-CoV-2 in participating school districts. We combined data from this study period (October 2020 to February 2021) and the previous reporting period (August 2020 to October 2020)² to evaluate the effect of the surge in weekly community SARS-CoV-2 rates on weekly community- and school-acquired cases in the study cohort. We also estimated the effect of the surge on the expected number of secondary cases generated within the school system for each primary case. This number was computed by dividing the total number of school-acquired cases each week by the total number of community-acquired cases. To understand the role of athletic activities on school-acquired cases, we also considered secondary transmission metrics after subtracting the school-acquired cases that were due to high school sports. To estimate the effect of the surge on school-acquired cases (with and without cases resulting from sports), we conducted an interrupted time-series analysis using an overdispersed Poisson regression model for the transmission rates in the different periods. Post hoc, we also conducted exploratory analyses to characterize the expected number of secondary cases for each primary case in elementary, middle, and high school. For these exploratory analyses, we excluded schools that were combined high and middle schools or combined elementary and middle schools. We also excluded the

largest district because of its size relative to the other districts and its primary focus on elementary schools in the face-to-face environment, which greatly skewed the available data, making it inappropriate for the analysis methods. We used R version 4.0.2 to conduct all statistical analyses.

Data collection and analyses were performed as part of the ABCs research program under a waiver of written consent (Duke University Institutional Review Board Pro00107036).

RESULTS

Study Cohort

The 13 districts participating in this study were diverse in terms of district sizes, racial and ethnic background of students, and rural or urban locations (Table 1). In total, the districts had >100 000 students and staff participating in in-person education during the study period. Overall, 12 of 13 (92%) participating districts systematically implemented minimal physical distancing (<6 feet) in PreK–5 for at least part of the study period, and all districts offered in-person education for at least some middle and high school students in addition to their elementary school students. All districts permitted activities such as band, chorus, and high school sports (ie, basketball and indoor track during the study period).

Each participating district had specific procedures in place (eg, daily walk-throughs) to evaluate and encourage the fidelity and adherence to masking of >90% of staff and students >90% of the time in the mainstream curriculum. Within the special needs curriculum, masking adherence for students was ~50%, with efforts made to ensure that students remained in small cohorts and practiced additional distancing when able and that teachers and staff used

TABLE 1 District Characteristics

| Unique Identifier | Enrolled Students ^a | County Designation ^b | White, % ^a | Black, % ^a | Hispanic, % ^a | Economically Disadvantaged, % ^c |
|-------------------|--------------------------------|---------------------------------|-----------------------|-----------------------|--------------------------|--|
| 1 | 963 | Small metropolitan | 47 | 34 | 12 | ≥90 |
| 2 | 1642 | Micropolitan | 45 | 8 | 22 | 54 |
| 3 | 2828 | Noncore ^d | 84 | 1 | 13 | 57 |
| 4 | 3830 | Medium metropolitan | 38 | 20 | 26 | 62 |
| 5 | 4963 | Medium metropolitan | 66 | 3 | 27 | 57 |
| 6 | 4499 | Medium metropolitan | 79 | 4 | 11 | 44 |
| 7 | 5766 | Medium metropolitan | 72 | 7 | 16 | 44 |
| 8 | 7133 | Micropolitan | 70 | 2 | 25 | 60 |
| 9 | 12376 | Micropolitan | 62 | 15 | 15 | 39 |
| 10 | 20 038 | Large fringe metropolitan | 63 | 14 | 15 | 40 |
| 11 | 22 971 | Small metropolitan | 35 | 46 | 12 | 67 |
| 12 | 29 490 | Large fringe metropolitan | 54 | 23 | 16 | 62 |
| 13 | 68 978 | Medium metropolitan | 29 | 42 | 17 | 66 |

^a Public Schools of North Carolina. Pupils in membership by race and sex, school year 2020-21. Public Schools of North Carolina Web site. Available at: <http://apps.schools.nc.gov/ords/f?p=145:15::N0>. Accessed August 19, 2021.

^b Centers for Disease Control and Prevention (CDC). COVID-19 integrated county view. CDCW Web site. Available at: <https://covid.cdc.gov/covid-data-tracker/#county-view>. Accessed August 19, 2021.

^c North Carolina (NC) Department of Public Instruction (DPI). School Nutrition. NC DPWI Web site. Available at: <https://www.dpi.nc.gov/districts-schools/district-operations/school-nutrition>. Accessed August 19, 2021.

^d Denotes nonmetropolitan counties that do not meet the micropolitan definition; they are counties without a city, town, or urban cluster of ≥10 000 residents and fall under the most rural designation in the National Center for Health Statistics urban-rural classification scheme for counties.

supplemental personal protective equipment (ie, face shields). None of the districts implemented large-scale overhauls of their ventilation systems; districts had no choice but to continue to operate in classrooms and old buildings (and often times in schools where the windows did not open); no districts installed high efficiency particulate air filters; and only 1 district upgraded filters, where possible, but found that in most cases, recommended filters did not fit on heating, ventilation and air conditioning (HVAC) systems that were 2 to 3 times past their life cycles (approximate HVAC age of 50 years). Each district made efforts to have students eat outside or ≥6 feet apart in their classrooms during breakfast and lunch. Students remained in classroom cohorts (11–25 students per cohort) in elementary school, grade A/B cohorts during middle school (eg, 100 students per cohort), and A/B cohorts during high school (eg, ~300–500 students per cohort). None of the districts implemented surveillance or screening testing of students or staff members. SARS-CoV-2 diagnostic testing was widely available free of charge in North Carolina. All students and staff from each district were given explicit

directions for how and when to get tested after exposure.

Community Rates and Community-Acquired Infections in School Buildings

During the presurge period, the average weekly incidence of community-acquired infection was 1.17 cases per 1000 people, increasing to 3.6 during the surge. Across the 13 school districts, 4969 students and staff with documented community-acquired SARS-CoV-2 infections were present on school campuses. The rate of primary infections reported in the schools during the presurge and surge periods tracked closely with community rates (Fig 1).

School-Acquired Cases and Their Relationship to Community Rates

Community-acquired infections within school buildings resulted in only 209 school-acquired infections in students and staff, including 93 in elementary school, 26 in middle school, 87 in high school, and 3 in central office staff (Table 2). These 209 infections occurred among >26 000 close contacts, resulting in a secondary attack rate of <1%. School-sponsored athletics was the setting of transmission for 75% of

school-acquired infections among high school students and staff, with indoor basketball accounting for the majority of cases.

In the interrupted time-series analysis, we observed an increase in the rate of school-acquired cases during the surge period relative to presurge (relative rate = 2.3; 95% confidence interval [CI] 1.2–4.7), but the rate remained low through the time period studied, averaging slightly <0.08 school-acquired cases per 1000 people. After we subtracted the cases due to sports, the relative increase in the rate of school-acquired cases decreased to 1.5 (95% CI 0.7–3.4). The within-school reproductive rate remained relatively constant from the presurge to surge period, with ~1 school-acquired case for every 24 primary cases during the surge. The within-school reproductive rate decreased slightly during the surge period after we subtracted the cases due to sports, with ~1 school-acquired case for every 35 primary cases.

Exploratory analyses for evaluating the expected number of secondary cases for each primary case by elementary, middle, or high school

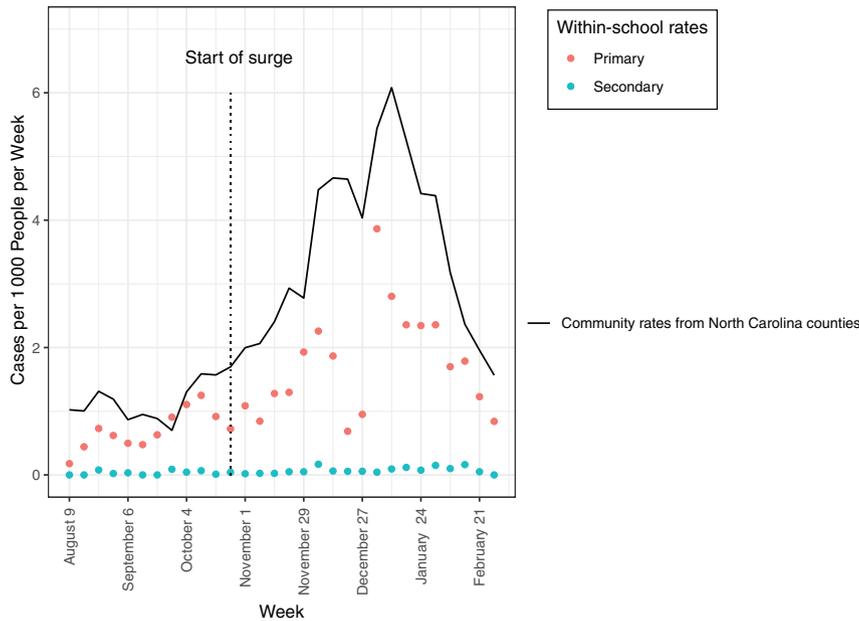


FIGURE 1 Community rates of infection versus community-acquired (primary) and school-acquired (secondary) infections in school buildings.

were underpowered to resolve differences between grade levels between the surge and presurge periods (Table 3).

DISCUSSION

In a racially and ethnically diverse real-world setting, with participants strictly adhering to masking and

variable distancing, school-acquired SARS-CoV-2 infection was uncommon. As demonstrated by the low number of school-acquired cases compared with the number of community-acquired cases entering school buildings, along with the transmission observed when masking is more difficult (eg, sports), we found that within-

school transmission of SARS-CoV-2 can be prevented by simple mitigation strategies. These data also underscore how within-school transmission should be the key metric for evaluating whether schools and districts can and should be open to in-person instruction, rather than relying on community-acquired rates.

Our findings are notable, particularly because substantial credence has been given to the importance of community transmission in the debate to reopen schools, perhaps with the intent of encouraging communities to control transmission and help end the pandemic. Nevertheless, children were clearly not the priority in this public health recommendation; bars and sporting events were allowed to open even as schools remained closed. Moreover, on the basis of the February 2021 CDC guidance for school reopening,⁴ 94% of schools in the United States would not have qualified for reopening.¹⁷ Local control of school reopening resulted in differential application of community transmission standards and other guidelines largely based

TABLE 2 Community- and School-Acquired SARS-CoV-2 Infections

| Unique Identifier | Students Face to Face | Staff | Community Acquired | School Acquired | School Acquired, by School Level | | | | |
|-------------------|-----------------------|--------|--------------------|-----------------|----------------------------------|--------|------|---------------------------------|---------------------|
| | | | | | Elementary | Middle | High | High School Sports ^a | Quarantine |
| 1 | 760 | 169 | 44 | 4 | 1 | 0 | 3 | 1 | 21 |
| 2 | 1024 | 230 | 101 | 0 | 0 | 0 | 0 | 0 | 119 |
| 3 | 2320 | 404 | 116 | 6 | 3 | 1 | 2 | 2 | 626 |
| 4 | 3055 | 457 | 229 | 1 | 0 | 0 | 1 | 1 | 1243 |
| 5 | 4284 | 658 | 131 | 37 | 11 | 4 | 22 | 22 | 1652 |
| 6 | 4338 | 648 | 315 | 11 | 3 | 2 | 6 | 3 | 2243 |
| 7 | 5068 | 665 | 293 | 11 | 5 | 3 | 3 | 0 | 1995 |
| 8 | 5467 | 928 | 479 | 12 | 0 | 0 | 12 | 10 | 5000 |
| 9 | 10 249 | 1536 | 405 | 27 | 17 | 4 | 6 | 2 | 2762 |
| 10 | 16 523 | 2316 | 427 | 53 | 32 | 10 | 11 | 11 | 2182 |
| 11 | 17 000 | 2712 | 306 | 26 | 12 | 2 | 12 | 9 | 2277 |
| 12 | 19 434 | 3231 | 1149 | 2 ^b | 0 | 0 | 0 | 0 | 5202 |
| 13 | 48 549 | 9180 | 974 | 19 | 9 | 0 | 9 | 5 | 1297 |
| Total | 138 071 | 23 134 | 4969 | 209 | 93 | 26 | 87 | 66 | 26 619 ^c |

^a Also included in the "High" category.

^b Occurred in the central office.

^c Approximately 17% of the face-to-face population.

TABLE 3 Rate of Expected Secondary Infections per 100 Primary Cases (95% CI), by Grade Level

| Grade Level | Presurge Secondary Infections per 100 Primary Cases (95% CI) | Post Surge | Post Surge Without Sports |
|-------------|--|------------------|---------------------------|
| Elementary | 6.51 (3.70–11.5) | 4.43 (2.82–6.96) | 4.43 (2.91–6.75) |
| Middle | 4.48 (1.73–11.6) | 2.68 (1.25–5.75) | 2.68 (1.31–5.47) |
| High | 1.57 (0.49–5.06) | 3.92 (2.36–6.51) | 1.05 (0.42–2.63) |

on wealth, race, and ethnicity; private schools quickly opened in fall 2020, as did public schools in more rural locations. Meanwhile, public schools in urban locations, particularly those with substantial proportions of Black and Hispanic populations, remained shuttered.^{18,19} Uncoupling of community transmission and school reopening not only is supported by science but also promotes equity.

Although these data come from a large and diverse sample size, the results are not particularly surprising. Few public schools across the country that opened early in fall 2020 implemented overhauls of ventilation systems or had large-scale screening or surveillance testing. Yet where masking mandates were present and adhered to, there were no reports of substantial spread within the school environment or of increased community spread; this is in contrast to the outbreaks observed in Tel Aviv, where schools opened without masking mandates in place.²⁰ Data from North Carolina in the first quarter of the school year demonstrated only 32 cases of school-acquired infection from 773 community-acquired cases within school buildings at a time when community transmission was >4 times the high level of community transmission in CDC guidelines.² Among 11 schools in Wisconsin, within-school transmission was limited despite diagnostic test result positivity up to 40% in the surrounding communities.³ Similar findings were reported in schools in Utah and St Louis, Missouri.^{21,22} Masking is known to be effective; there is no reason to believe that

this central tenet of public health mitigation strategies would not also reduce transmission within school buildings, where adherence to policies and procedures is typically routine. Importantly, data collection required to monitor within-school transmission, the most important metric for identifying the safety of schools, is not dependent on collaboration with an entity, such as ABCs. Rather, data collection relies on collaboration between schools and public health officials. Data should be widely replicable, particularly as mitigation strategies (eg, mask mandates) change over the coming year.

We also did not observe substantial differences in school-acquired cases between elementary, middle, and high school, despite minimal physical distancing implemented in elementary school or concerns that older students may be more likely to spread disease. Moreover, transmission in high schools largely resulted from participation in sports. Although preliminary, these data are supportive of reduced distancing between children at schools, consistent with recent data from Massachusetts, which identified no significant differences in infections in schools with 3- vs 6-foot distancing, and from other states (eg, Utah) that never implemented a 6-foot distancing rule. Reduced distancing will also allow more children in school buildings at one time, effectively increasing their participation in in-person education. The findings of transmission through participation in athletics are also consistent with previous findings.^{23,24} Although North Carolina has a mask mandate

for athletics, these rules are inconsistently followed and enforced on athletic fields and courts. These data highlight the need for alternative strategies to prevent transmission (eg, vaccination) and provide early detection and mitigation of infection (eg, testing) and the need for added vigilance in enforcing masking in athletics and during sports team activities, similar to how these strategies are enforced in the classroom.

Our study has some limitations. First, submission of data to ABCs was voluntary, and we may have selected school districts that were particularly adherent to preventive measures and valued transparency. Second, these data relied on existing contact tracing practices, including adjudication of cases by the local health department, which can be imperfect and hampered by limitations in resources and personnel; however, contact tracing is the existing standard to identify infections and the sources of infections within the community, where community spread was consistently greater than that in schools. Moreover, in school buildings, attendance records are kept and shared with the public health department, increasing the likelihood that all contacts within a school are identified, compared with those within the community, where refusal to reveal contacts is not infrequent. When compared with genotyping of SARS-CoV-2 specimens, the gold standard in identifying source of infection, contact tracing is an accurate method to identify the source of SARS-CoV-2 transmission.²¹ Third, no surveillance or screening testing

was implemented in these districts, potentially underestimating the number of community-acquired infections entering school building; however, this analysis focuses on secondary infections arising from known primary cases. Fourth, testing of all students and staff after exposure to a community-acquired case could not be enforced given current policies in North Carolina; however, testing was widely available at no cost within the state. Many of the included counties allowed testing out of quarantine according to CDC guidance, and uptake of testing among exposed teachers is known to be near universal. Fifth, to protect privacy of students and staff, most school districts did not track or report primary cases by staff compared with students, nor were data collected specific to extracurricular activities other than sports. Finally, it is unknown whether transmission among athletic teams (including players and coaches) occurred during play or other team events, such as travel to and from games.

CONCLUSIONS

With strict adherence to masking and some distancing, school-acquired SARS-CoV-2 infection is uncommon, even in the setting of

high community infection rates. Consistent with previous data, schools can and should reopen safely.

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ABBREVIATIONS

ABCs: The ABC Science Collaborative
CDC: Centers for Disease Control and Prevention
CI: confidence interval
COVID-19: coronavirus disease 2019
K-12: kindergarten through 12th grade
PreK-5: prekindergarten through 5th grade
SARS-CoV-2: severe acute respiratory syndrome coronavirus 2

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