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Article Summary
In the first 9 weeks of in-person instruction in North Carolina schools, we found extremely limited within-school secondary transmission of SARS-CoV-2, determined by contact tracing.

What's Known on This Subject
The frequency of within-school transmission of SARS-CoV-2 with in-person instruction in communities with widespread transmission is unknown. Many school districts across the United States are currently deciding whether or not to reopen for in-person learning for the second semester.

What This Study Adds
We examined 11 school districts with nearly 100,000 students/staff open for 9 weeks of in-person instruction, tracking secondary transmission of SARS-CoV-2; within-school infections were extremely rare. Each case was independently adjudicated for community or within-school acquisition by local health departments.

CONTRIBUTORS' STATEMENT
Drs. Zimmerman and Benjamin conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript.

Drs. Zimmerman, Brookhart, Zadrozny, and Benjamin designed the data collection instruments, collected data, carried out the initial analyses, and reviewed and revised the manuscript.

Drs. Zimmerman, Akinboyo, Boutzoukas, McGann, Maradiaga Panayotti, Smith, Zadrozny, Armstrong, Weber, Brookhart, and Benjamin reviewed and revised the manuscript.

Drs. Zimmerman and Benjamin conceptualized and designed the study, coordinated and supervised data collection, and critically reviewed 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: In an effort to mitigate the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), North Carolina (NC) closed its K–12 public schools to in-person instruction on 03/14/2020. On 07/15/2020, NC's governor announced schools could open via remote learning or a "hybrid" model that combined in-person and remote instruction. In August 2020, 56 of 115 NC school districts joined the ABC Science Collaborative (ABCs) to implement public health measures to prevent SARS-CoV-2 transmission and share lessons learned. We describe secondary transmission of SARS-CoV-2 within participating NC school districts during the first 9 weeks of in-person instruction in the 2020–2021 academic school year.
METHODS: From 08/15/2020–10/23/2020, 11 of 56 school districts participating in ABCs were open for in-person instruction for all 9 weeks of the first quarter and agreed to track incidence and secondary transmission of SARS-CoV-2. Local health department staff adjudicated secondary transmission. Superintendents met weekly with ABCs faculty to share lessons learned and develop prevention methods.
RESULTS: Over 9 weeks, 11 participating school districts had more than 90,000 students and staff attend school in-person; of these, there were 773 community-acquired SARS-CoV-2 infections documented by molecular testing. Through contact tracing, NC health department staff determined an additional 32 infections were acquired within schools. No instances of child-to-adult transmission of SARS-CoV-2 were reported within schools.
CONCLUSIONS: In the first 9 weeks of in-person instruction in NC schools, we found extremely limited within-school secondary transmission of SARS-CoV-2, as determined by contact tracing.

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causes the illness coronavirus disease 2019 (COVID-19) and is responsible for the pandemic that has affected more than 12 million Americans.[1,2] In the United States (U.S.), pre-kindergarten through grade 12 (K–12) public schools are comprised of more than 50,000,000 children and 5,000,000 adults, many of whom have risk factors for severe COVID-19. In the first weeks of the pandemic, most U.S. schools preemptively closed to in-person instruction through the end of the 2019–2020 school year to prevent transmission of SARS-CoV-2. Public schools that educate K–12 serve a central role in U.S. education, public health, and the economy. Therefore, closing public schools has substantial repercussions for children and families.

On July 15, 2020, the governor of North Carolina (NC) allowed school districts to decide whether to provide all remote or some in-person instruction via a hybrid model through which all students may attend school in-person,[3] but daily operations occur at less than full capacity. Families in districts offering the hybrid model could choose between hybrid or all remote learning. For many schools, the hybrid model resulted in students attending in-person school for 2 days each week (e.g., 50% of children receive in-person instruction Monday and Tuesday; 50% Thursday and Friday; and Wednesday was used for cleaning the building during remote instruction for all students). Districts that chose the hybrid model were also required to follow pandemic mitigation strategies as directed by the NC Department of Health and Human Services (NCDHHS) Strong Schools toolkit.[4] In particular, districts were required to have universal masking for all ≥5 years of age (except the adapted curriculum, during meals, and when sufficiently distanced outside), implement 6-foot distancing, and wash hands ("3W's": wear a mask, wait 6 feet, wash hands), as well as perform daily symptom monitoring and temperature checks. Additional details on implementing mitigation strategies were left to the discretion of each school system.

Local school district leaders approached faculty from Duke University and the University of North Carolina at Chapel Hill, seeking to better understand the scientific underpinnings of SARS-CoV-2 mitigation strategies and further guide district-specific policies around reopening. In response to this request, faculty at Duke University and the University of North Carolina at Chapel Hill developed the ABC Science Collaborative (the ABCs).[5]

In this manuscript, we describe the ABCs and evaluate our hypothesis that in-person instruction, if accompanied by assiduous adherence to masking, distancing, and hand hygiene, would not result in substantial risk of SARS-CoV-2 spread within schools for children or staff.

We also report on lessons learned from efforts to provide safe, in-person, public education to students across NC during this pandemic.

METHODS

Formation and Work of the ABCs

Following initial requests and interest from local school districts, faculty and staff developed a program with three aims: 1) educate school leaders, staff, and the community; 2) have school-specific data drive decision-making; and 3) generate new science to improve health-related outcomes for children. Faculty then offered the program to the remaining school districts in NC. As the first quarter of instruction progressed, participating school districts agreed to a memorandum of understanding to share lessons learned. Districts had the option to withdraw from the collaborative at any time, and the degree of participation in activities was left to the discretion of each district. Similarly, data sharing across the ABCs was encouraged, but not compulsory.

District Education Plan and Professional Learning Community

The ABCs developed a multifaceted educational plan targeted at adult stakeholders. In the 3 weeks prior to the start of the school year and throughout the first 9 weeks of instruction, the ABCs provided 60-minute educational webinars and question/answer sessions focused on the prevention, transmission, and outcomes of SARS-CoV-2 infection to superintendents, teachers, local school leaders, staff, parents, and school boards. Additionally, ABC faculty moderated weekly small group sessions with superintendents and school leaders to share emerging science and discuss implementation plans for COVID-19 school policies.[6]

Peer-to-Peer Support for Public Health Prevention Measures

Over 9 weeks of instruction, superintendents and ABC faculty met weekly to address questions related to policy, revise district policies based on lessons learned, and draft common documents related to SARS-CoV-2 prevention in schools. Specifically, the superintendents from districts conducting in-person instruction shared information and protocols around re-opening (and staying open). ABC faculty and staff provided scientific input on mitigation strategies. Resulting documents, including a key document outlining "12 Principles" were made available to all members of the collaborative (Supplemental Figure 1). Districts participating in ABC adopted varying degrees of the 12 Principles, though midway through the 9 weeks of instruction, most had implemented at least 10 of the 12 principles as a result of lessons learned.

Evaluation of Secondary Transmission

Study Population

During the first 9 weeks of instruction in NC public schools, participating school districts provided confidential data to the ABCs about SARS-CoV-2 cases and secondary transmission in schools. We specifically requested data from districts who had implemented the hybrid model for the entire 9-week period and had tracked cases and secondary transmission by school.

Outcome Measures

The primary outcome was the number of within-school (secondary) transmissions of SARS-CoV-2 in traditional public schools conducting in-person learning. Case adjudication of within-school transmission was performed via contact tracing by the local health department. All close contacts were quarantined for 14 days; testing for contacts was encouraged by NCDHHS, but not

required. Secondary outcomes included clusters, defined by the NCDHHS as a minimum of 5 cases in the same facility within a 14-day period and plausible epidemiological linkage between cases;[7] consequently, clusters do not capture all cases of within-school transmission.

Data Sources

For districts participating in data sharing, we obtained publicly available data for the number of staff, student enrollment, and student distribution by race, ethnicity, and expenditure for the 2019–2020 academic year. We confirmed the number of children attending in-person with each superintendent. Data on timing and instructional models for each district was obtained via combinations of the following: conversations with school superintendents through the Lighting Our Way Forward[8] collaborative program to guide school reopening between NCDHHS, N.C. State Board of Education, and Department of Public Instruction, data on EDNC.org, and policy updates from district websites.[9] Data for clusters and community transmission across the state were available on the NCDHHS website.[10] After local health department adjudication, superintendents reported data on primary and secondary cases by school and week of instruction to ABC faculty. Only those 11 school districts providing in-person instruction for 9 weeks of instruction and able to report both primary and secondary infections were included in the analysis of secondary transmission.

Definitions

There are 100 counties in the state of NC, each of which has a school district (n=100, “county districts”). Additionally, some cities within these counties have their own school districts separate from the county schools (n=15, “city districts”). Widespread community transmission

was defined as molecular test positive in >1/1000 county residents over 14 days for ≥5 of the 9 instructional weeks.

Analyses

We performed descriptive analyses to aggregate data from contributing districts to characterize the number of people in school buildings, secondary transmission in schools, and transmission within surrounding communities.

Institutional Review Board Approval

No personal health information data were obtained or transmitted; this work is part of the ABC research program (Duke University Institutional Review Board Pro00107036).

RESULTS

Study Cohort

Of 115 school districts in NC, 56 participated in the ABCs (Figure 1; Table 1). Districts participating in the ABCs tended to be larger in population (7,739 vs. 4,516), had fewer non-Hispanic White students (46.8% vs. 54.9%; Table 1), and offered fewer weeks of in-person instruction (3.6/9 vs. 5.7/9 weeks).

Of participating ABC school districts, 35/56 offered in-person instruction for at least part of the 9 weeks, and 21 remained all remote. Of the 35 offering in-person instruction, 17 offered in-person for all 9 weeks, and 18 for part of the 9 weeks; of these 18, approximately half (8/18) offered in-person for 4+ weeks. None of the participating school districts had to close during the 9 weeks because of SARS-CoV-2 transmission. Eleven of the 17 school districts that offered in-

person for all 9 weeks participated in this study, 9 of which were county districts, and 2 were city. These districts provided primary infections by school and week of instruction (Table 2). These districts further provided all cases of secondary transmission by school and week, as determined by local public health contact tracing.

Across NC, the rate of SARS-CoV-2 infections was 1–2 cases per 1,000 residents per week for most of the 9 weeks examined (Figure 2). The rate of community-acquired cases was slightly higher in the 11 counties that house the 11 school districts contributing data for this report. Figure 2 displays the number of community-acquired cases within the 11 school districts per 1,000 students.

Primary Cases and Secondary Transmission

Across the 11 school districts, 773 community-acquired SARS-CoV-2 infections were documented by molecular testing; however, there were only 32 adjudicated cases of secondary transmission across the 11 districts combined in 9 weeks of instruction. Six districts had 0 secondary infections, 2 had 1 case, and 3 had multiple cases. There were 6 cases of secondary transmission in the pre-K setting; 11 in elementary schools, 6 in middle schools, 5 in high schools, and 4 in K–12 schools. There were no cases of child-to-adult within-school transmission.

Clusters of SARS-CoV-2 Infection

During the first 9 weeks of instruction across the state of NC, there were 38 reported clusters in school children; of these, 2 occurred in charter schools (10 cases) and 19 in private schools (191

cases). Of the 17 clusters in traditional public schools, 2 (10 cases) occurred in schools entirely engaged in remote learning.

There were 15 clusters that occurred in the state of NC within traditional public schools providing in-person instruction, 11/15 (89 cases) occurred in schools that did not participate in the ABCs. One cluster (5 cases of within-school transmission) occurred in an ABC district that was open for 4 weeks of instruction, and 3 clusters (15 cases of within-school transmission) occurred in the ABC-participating school districts that provided data for this manuscript. One of these ABC clusters occurred in a district that exempted masking in pre-kindergarten during the early days of the school year, a policy that was in accordance with NCDHHS guidance permitting mask exemptions for younger children. As a result of this cluster, the pre-kindergarten class was closed to in-person instruction temporarily, and masking exemption in pre-kindergarten environment was reversed. Thereafter, there were no additional cases of secondary transmission in the pre-kindergarten environment in that district.

Two clusters occurred in the special needs environment of ABC-participating school districts, 1 of which was linked to children eating together in close proximity. In both of these clusters, the district temporarily closed in-person learning at the respective schools. Masking adherence was re-emphasized; where masking was not feasible, face-shields were employed. Additionally, the ABCs and local superintendents jointly developed specialized plans for lunch and breakfast routines to prevent subsequent mealtime transmission. This included eating outdoors when possible, maintaining 6’ distance, doing all food preparation prior to taking masks off (e.g., opening milk cartons), limiting mask-off time to 15 minutes for eating, and no talking while eating and masks are off.

Other Lessons Learned

In weekly superintendent meetings, several key contributors to success were noted: daily screening of students and staff, high rates of mask adherence for children and adults, transparency in publicly reporting SARS-CoV-2-confirmed infections (e.g., via website), efficient contact tracing, close collaboration with local health departments, regular updates with staff and principals to encourage adherence and report any breaches in safety protocols or secondary transmission cases, detailed schedule for all aspects of the school day in order to adhere to the 3Ws, definitive plans for the special needs community, and opening in the hybrid model of instruction. These refinements informed the 12 Principles for Safer Schools.[11] Superintendents frequently noted operational challenges related to quarantine policies, pandemic fatigue, and family cooperation with contact tracing. The 11 districts reported quarantining more than 3,000 children and staff over 9 weeks. These reductions in staff were especially burdensome in smaller districts where employees could not be substituted. As the 9 weeks progressed, 2 districts reported reduced compliance with masking and distancing, primarily within the adult population, so these districts asked ABC faculty to meet with all of their principals to reinforce the importance of long-term adherence to safety protocols, masking, and distancing at the end of the first instructional quarter.

DISCUSSION

During an ongoing pandemic with widespread community transmission, cases of SARS-CoV-2 with subsequent morbidity and mortality will occur regardless of whether schools allow in-person instruction. A key question exists for policy makers: Is the within-school spread of SAR-CoV-2 greater, equal to, or less than that observed in the broader community? During our study,

counties housing the 11 participating school districts had 1–2 new SARS-CoV-2 infections per 1,000 residents per week; this is considerable community transmission, as reflected by the 773 community-acquired cases. On average, NC residents with SARS-CoV-2 infected slightly more than 1 other individual during these 9 weeks.[12] If secondary transmission were as common in schools as in the community, we would anticipate 800–900 secondary infections within schools; however, only 32 within-school SARS-CoV-2 transmissions occurred.

SARS-CoV-2 outbreaks and clusters have been commonly reported on residential colleges and universities,[1] as well as in overnight camps[2] and an overnight summer school retreat for high school students.[13] SARS-CoV-2 in school-aged children from March 1–September 19, 2020 peaked in July in parallel with overall community peaks.[14] Closure of K–12 schools has often been used as a mitigation strategy for the SARS-CoV-2 pandemic.[15] A recent systematic review noted that school closures alone would prevent only 2–4% of deaths, which is much less than other social distancing interventions.[16]

Internationally, efforts to minimize school closures in some countries have been implemented with success.[17] Taiwan avoided widespread closures by implementing local temporary school closures based on low thresholds for infected cases within individual schools.[18] Nevertheless, in the U.S., little data other than modeling studies are available on SARS-CoV-2 transmission in schools that practiced COVID-19 mitigation strategies, including mask wearing, physical distancing, hand hygiene, and surface disinfection. Our data support the concept that schools can stay open safely in communities with widespread community transmission.

The reasons for district success in limiting secondary transmission were not formally tested; however, common themes emerged during the teleconferences with ABC faculty and superintendents, and are outlined on the ABC website[11] and available for public use. Foremost

among these themes was consistent adherence to the 3W's. Additionally, superintendents credited the following important components of success: detailed plans for all activities within school, contact tracing with county health departments, public reporting of infections, and the ability to share lessons learned peer-to-peer.

NC traditional public schools were especially effective in preventing clusters compared to the private sector. There are approximately 1.8 million school children in NC, 80% of which attend traditional public schools. The remaining 20% attend charter schools, private schools, or are home-schooled. Approximately 150,000 children in NC attend private schools (based on attendance from 2019 data) this academic year, but there were more clusters (19), with more SARS-CoV-2 cases (191) in this subgroup than all NC traditional public schools combined.

Most of the cases of secondary transmission in ABC districts (and all 3 clusters) were related to absent face coverings. These 3 clusters occurred in very young children, during lunch, or among children with substantial special needs. In the special needs environment, masking is not always feasible; superintendents reported masking compliance of 50–100% for children outside the mainstream classroom, due to severe emotional and cognitive disabilities. Of the severely disabled children who cannot mask, approximately 50% are able to wear a face shield. Superintendents also emphasized increased distancing in the special needs environment, and several ABC districts implemented tactics related to ventilation (e.g., spending more time outside, opening windows where feasible, and improving air flow and filters).

Several policies related to quarantine were especially burdensome for superintendents, due to substantial staffing shortages with little gain in public safety. In the 2020 school environment, all individuals within 6 feet of a SARS-CoV-2 infected person for longer than 15 minutes must self-quarantine, even if all wore masks. This policy is counter-productive for 3

reasons: 1) as evidenced by these data, secondary transmission in the setting of masking is uncommon; 2) this policy discounts the benefits of masking and sends a mixed message to the public on the benefit of face coverings; and 3) in other environments (e.g., some healthcare settings), personnel are not required to quarantine if they have face coverings (even if they were wearing a medical mask rather than an N95 mask) while caring for an asymptomatic patient who has SARS-CoV-2. Moreover, regardless of test results, the 14-day length of quarantine provides little motivation for parents of potentially exposed children to obtain testing, thereby limiting our general understanding of transmission dynamics. Recent guidance from the Centers for Disease Control and Prevention recently provided options to reduce quarantine duration following exposure in the setting of negative testing[19]; using these updated guidelines to implement mandated testing, with reduced quarantine time after exposure, might address this concern.

Limitations

Our study has limitations. Participation in the ABCs is voluntary and not every school district in NC participated in the ABCs or this study. Participation in the ABCs and voluntary submission of data may select for school districts that enforce adherence to preventative measures, emphasize transparency, and cooperate with peers; these characteristics are likely associated with greater adherence to masking, reduced secondary transmission, and lower risks to students. Adjudication of secondary transmission was by local health department staff in each district, with varying resource capabilities. While health department staff requested testing of contacts, testing could not be universally enforced because it is not required to return to school in NC. Due to confidentiality concerns, we were not able to analyze incidence of child-to-child or adult-to-child transmission, nor could we determine the relative effectiveness of any specific school

policies. Finally, these data are applicable to reduced population density, both through the hybrid model and from students within the districts (approximately one-third of students) opting to remain remote.

CONCLUSIONS

Our cohort study demonstrated that enforcing SARS-CoV-2 mitigation policies such as masking, physical distancing, and hand hygiene, resulted in minimal clusters of SARS-CoV-2 infection and low rates of secondary transmission in schools, and did not cause a larger community infection burden. Our data indicate that schools can reopen safely if they develop and adhere to specific SARS-CoV-2 prevention policies.

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Table 1. Comparison of School Districts that were Within and Outside of the ABC Science Collaborative during the First 9 Weeks of the 2020–2021 Academic School Year in North Carolina

Variables	ABC Collaborative Members (N=56)	Other North Carolina Districts (N=59)	Districts Submitting Data (N=11)
Average number of staff	859	540	1,172
Average number of students	7,739	4,516	10,971
Student enrollment by race, ethnicity (%)			
Non-Hispanic White	47	55	55
Non-Hispanic Black	27	20	21
Indian	1	3	<1
Pacific Island	<1	<1	<1
Asian	2	1	2
Two or more races	6	6	6
[1]Hispanic	18	15	15
Average number of weeks open for in-person learning in Q1	3.6	5.7	9
Number of districts open by week			
Week 1	19	31	11
Week 2	18	30	11
Week 3	18	30	11
Week 4	18	33	11
Week 5	22	36	11
Week 6	23	39	11
Week 7	24	43	11
Week 8	27	46	11
Week 9	31	47	11
[1]North Carolina reports race and ethnicity in a combined format.			

Table 2. Description of the 11 Districts within the ABC Science Collaborative

District	County Population	Staff 2019	Students 2019	Hispanic[1]	African American	Asian	White	Multiple Races[2]	Students in Person	Primary Infections
1	38,755	967	4971	11	4	1	78	5	3972	60
2	28,150	626	3087	12	<1	<1	82	4	2163	43
3	43,965	1073	6354	15	7	1	72	5	5068	69
4	223,842	3847	31116	15	22	2	54	7	19434	315
5	N/A[3]	727	4359	26	19	5	40	10	2835	24
6	184,023	3399	21829	14	14	3	63	6	16523	91
7	10,194	254	1109	11	35	<1	47	7	628	6
8	102,950	1733	12461	14	14	1	63	7	8815	69
9	N/A[3]	330	1727	21	8	1	64	6	1024	7
10	181,005	4228	25043	12	44	1	35	6	12700	83
11	38,236	1000	5361	26	3	<1	66	4	4284	6

[1]North Carolina reports ethnicity as a separate category within race.
[2]Races with <1% for all districts listed include Native American and Pacific Islander.
[3]Sites 5 and 9 are city districts and, therefore, county population cannot be estimated.

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