Test-to-Stay After Exposure to SARS-CoV-2 in K–12 Schools

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abstract

OBJECTIVES: We evaluated the safety and efficacy of a test-to-stay program for unvaccinated students and staff who experienced an unmasked, in-school exposure to someone with confirmed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. Serial testing instead of quarantine was offered to asymptomatic contacts. We measured secondary and tertiary transmission rates within participating schools and in-school days preserved for participants.

METHODS: Participating staff or students from universally masked districts in North Carolina underwent rapid antigen testing at set intervals up to 7 days after known exposure. Collected data included location or setting of exposure, participant symptoms, and school absences up to 14 days after enrollment. Outcomes included tertiary transmission, secondary transmission, and school days saved among test-to-stay participants. A prespecified interim safety analysis occurred after 1 month of enrollment.

RESULTS: We enrolled 367 participants and completed 14-day follow-up on all participants for this analysis. Nearly all (215 of 238, 90%) exposure encounters involved an unmasked index case and an unmasked close contact, with most (353 of 366, 96%) occurring indoors, during lunch (137 of 357, 39%) or athletics (45 of 357, 13%). Secondary attack rate was 1.7% (95% confidence interval: 0.6%–4.7%) based on 883 SARS-CoV-2 serial rapid antigen tests with results from 357 participants; no tertiary cases were identified, and 1628 (92%) school days were saved through test-to-stay program implementation out of 1764 days potentially missed.

CONCLUSION: After unmasked in-school exposure to SARS-CoV-2, even in a mostly unvaccinated population, a test-to-stay strategy is a safe alternative to quarantine.

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This trial is registered at www.clinicaltrials.gov (identifier NCT05052580).

WHAT'S KNOWN ON THE SUBJECT: Coronavirus disease 2019 negatively and disproportionately impacted the kindergarten through 12th grade learning system across the United States because of disruption to in-person learning. Quarantine after close contact with positive school students or staff represents an ongoing impediment to in-person learning.

WHAT THIS STUDY ADDS: Data presented from a 6-week pilot study highlight the efficacy and safety of a test-to-stay approach in schools with universal masking, with substantial reduction in missed school days, no within-school tertiary transmissions, and secondary transmissions consistent with previous reports.

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The coronavirus disease 2019 (COVID-19) pandemic resulted in widespread kindergarten through grade 12 (K–12) school building closures during the 2020–2021 school year. With school closure and remote learning, substantial learning loss has been documented. Children of color and those from less educated households were more likely to lack access to in-person education and demonstrate up to 60% lower math and English proficiency than those who are White or from more educated households,[1] thereby further widening the gap of disparities in child education. Additionally, children have experienced increased food insecurity, loss of in-person special education services, and have reported mental health and well-being challenges resulting from the pandemic.[2] Fortunately, most K–12 school buildings have reopened their doors, but keeping children in school buildings remains challenging. Mandatory quarantine of unvaccinated, unmasked close contacts for up to 14 days after exposure has been a widely used strategy to limit spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) within K–12 school buildings. Quarantines have resulted in millions of missed school days. In the fourth quarter of the 2020–2021 school year in North Carolina (NC) alone, there were more than 400 000 missed public school days because of quarantine.[3]

Days of quarantine are lost days of instruction, as well as lost social–mental health support; such losses have long-term impacts. Importantly, recent data suggest that, with mitigation measures, including universal masking in K–12 schools, the risk of SARS-CoV-2 transmission to a close contact is low, thereby limiting the benefit of quarantine for school communities.[4] In NC during the spring semester of 2021, <1% of quarantined in-school contacts developed COVID-19 in the universally masked environment, with most close contacts resulting from brief, unmasked encounters, including organized sports, daily meals, and masking nonadherence. Strategies that limit quarantine and promote in-school instruction while limiting risk of SARS-CoV-2 transmission in school buildings are needed.

To address learning losses secondary to quarantines and limit the spread of SARS-CoV-2 in the school and surrounding community, some school districts have begun implementing "test-to-stay" strategies, whereby a close contact avoids quarantine by undergoing serial testing for COVID-19 over a specified duration of time. Test-to-stay implementation varies substantially from region to region, but has undergone minimal systematic evaluation. As a result, test-to-stay widespread use and consideration in national policies has been limited. We evaluated the feasibility, effectiveness, and safety of a test-to-stay strategy in a universal masking environment in NC, with a predominantly unvaccinated school population, where quarantine is required if either the index case or close contact is unmasked but is not required for mask-on-mask student or staff exposures, regardless of the distance between the SARS-CoV-2-infected individual and the exposed contact.

METHODS

Study Design and Population

The ABC Science Collaborative designed a prospective, cohort study in collaboration with the North Carolina Department of Health and Human Services to evaluate if test-to-stay is an effective, viable, and safe approach to reduce quarantine while minimizing spread of SARS-CoV-2 in the masked K–12 school environment. Schools and school districts were eligible for participation if they had a universal masking policy in place on October 18, 2021, and received board of education and local health department approval. The ABC Science Collaborative proactively introduced the study to eligible districts that were previous collaborators and had an established precedent of collecting and transferring quality data related to the COVID-19 pandemic.

Individuals from participating districts were eligible for inclusion if they had an unmasked exposure and did not meet specific criteria for exemption from quarantine, were asymptomatic, and consented to participate in the test-to-stay research protocol via a Research Electronic Data Capture e-consent. The majority of schools and districts elected to provide the Research Electronic Data Capture e-consent link to potential participants after the known exposure. Close contacts were identified through schools' contact tracing program[5] and were then invited to participate in the study. Individuals were also excluded if they were exposed outside of the school setting, or if they were notified of close contact status >6 days after exposure. Participants who had a second exposure during the testing period were withdrawn from the study at the time of second exposure.

Testing Program and Data Collection

After electronic informed consent and assent, participants were assigned a unique identifier. The protocol required that participants undergo SARS-CoV-2 rapid antigen testing (Quidel QuickVue SARS Antigen or BinaxNOW Professional) on the day of notification and every

other day, up to 4 times during the first 7 days after known exposure (eg, days 1, 3, 5, and 7 after exposure). Testing occurred in the school in all sites except 1 district that established a centralized testing location outside the schools. Tests scheduled for a weekend were to be performed the Friday before or Monday after. In all circumstances, the final test was required, even if occurring several days late. Although participants remained in school if they tested negative, they were not allowed to continue athletic activities because of potential risk of transmission with reduced fidelity of masking in this setting.[6]

A positive COVID-19 test or the development of symptoms on any day after exposure required isolation according to state public health guidelines.[7] Data recorded included basic demographic information, daily presence, or absence of symptoms for 14 days after exposure, whether the infected person (index case) or close contact was masked, exposure setting (eg, indoor or outdoor, and specific location), test results, school absences, and transmission to other close contacts. Data regarding school-level mitigation practices were also collected and recorded using *AirTable,* a cloud-based database, or standard *Excel* spreadsheets. Schools and districts transferred anonymized data weekly to the Duke Clinical Research Institute for analysis.

Definitions and Outcome Measures

The primary safety outcome for this study was within-school tertiary transmission of SARS-CoV-2, defined as transmission to within-school close contacts of positive test-to-stay participants. The secondary safety outcome was secondary transmission, defined as test positivity among test-to-stay participants occurring after day 1 of exposure. The primary efficacy outcome was days of in-school education saved, defined as the number of days a participant was allowed to attend in-person learning after being notified of exposure to a close, in-school contact who tested positive for SARS-CoV-2.

Statistical Analysis

We used descriptive statistics to characterize the study population and circumstances surrounding exposure to the in-school index case, including masking status of case and contact. We also described the day of notification relative to the day of exposure and initial test, and day of test positivity by index case and close contact masking status. We summarized the proportion of test-to-stay participants with a positive test (secondary transmission) and the proportion of positive in-school close contacts of a positive test-to-stay participant (tertiary transmission). We characterized proportions overall, by student or staff, by school district, and by school level (elementary, middle, high). To account for the within-school correlation of outcomes, we estimated the 95% confidence interval (CI) for the proportion using a generalized linear mixed model with districts as a random effect. To support data decision-making, we estimated a posterior distribution for the secondary transmission risk using a Bayesian β-binomial conjugate model with a noninformative β distribution. We adjusted the information in the

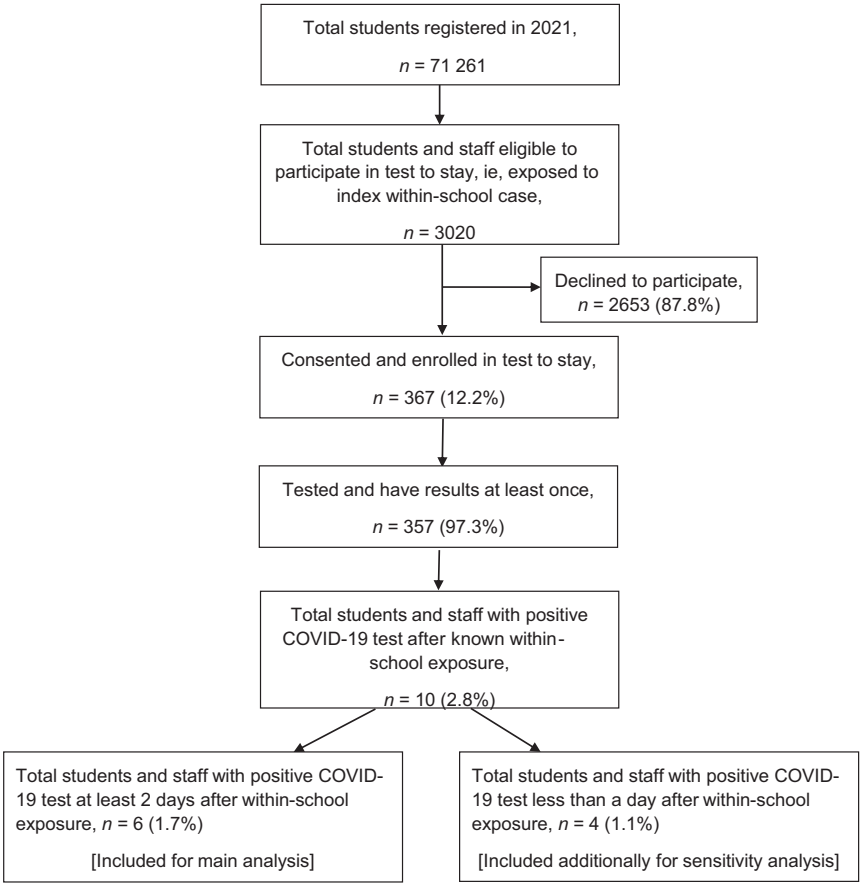

FIGURE 1
Diagram of eligible students. Diagram of eligible students in 6 universally masked NC school districts participating in test-to-stay program.

observed data using an estimated design effect to account for the information loss because of clustering. Using the estimated posterior distribution, we calculated the posterior probability of the secondary transmission rate as greater or <5%, the midpoint of the range of expected secondary transmission rates (2.5%–7.5%) on the basis of previous observational data from universally masked K–12 schools in the era of the delta variant.[4]

We analyzed school absences by symptoms, test positivity, or other unspecified reasons, and compared observed absences to those that would have occurred in the absence of the test-to-stay protocol. We calculated absences that would have occurred in the absence of the test-to-stay protocol according to the number of school days required for quarantine on the basis of each district and school's local health department guidelines. We summarized days to test positivity by median and interquartile ranges and accounted for missed days because of development of symptoms in study participants. The number of missed school days were only reported for students who tested positive or developed symptoms. For all other students and staff, we used school calendar days to determine the number of school days missed. The number of missed days varied across participants and was impacted by weekends and local health department quarantine policies.

Data from participants who had a positive test on exposure date or day 1 after exposure were excluded from primary analyses related to transmission within school because of the high likelihood that these participants were not exposed by the identified index case. A sensitivity analysis was done including data from participants

TABLE 1 Demographics of Students and Staff Exposed to Index Case

	Student Enrolled in School	Total Students and Staff Eligible to Participate in Test-to-Stay	Total Students and Staff Enrolled in Test-to-Stay, *n* (%)	Students, *n* of *N* (%)	Male, *n* of *N* (%)	White, *n* of *N* (%)	Black, *n* of *N* (%)	Hispanic, Latino, or Spanish Origin, *n* of *N* (%)	Elementary (K–5), *n* of *N* (%)	Middle (6–8), *n* of *N* (%)	High (9–12), *n* of *N* (%)
Student population from all districts	71 261	—	—	—	29 911 of 71 261 (42)	38 103 of 71 261 (53)	13 147 of 71 261 (18)	15 333 of 71 261 (22)	—	—	—
All districts		3020	367 (12.2)	365 of 367 (99.5)	175 of 367 (47.7)	285 of 365 (78.1)	56 of 365 (15.3)	55 of 367 (15.0)	—	—	—
District 1	2828	35	31 (88.6)	31 of 31 (100)	15 of 31 (48.4)	31 of 31 (100)	0 of 31 (0)	1 of 31 (3.2)	28 of 31 (90.3)	3 of 31 (9.7)	0 of 31 (0)
District 2	1642	60	60 (100)	60 of 60 (100)	25 of 60 (41.7)	46 of 58 (79.3)	6 of 58 (10.3)	15 of 60 (25.0)	41 of 60 (68.3)	15 of 60 (25.0)	4 of 60 (6.7)
District 3	226	1	1 (100)	1 of 1 (100)	1 of 1 (100)	1 of 1 (100)	0 of 1 (0)	1 of 1 (100)	1 of 1 (100)	0 of 1 (0)	0 of 1 (0)
District 4	36 112	282	135 (47.9)	135 of 135 (100)	63 of 135 (46.7)	104 of 135 (77.0)	22 of 135 (16.3)	20 of 135 (14.8)	54 of 135 (40.0)	20 of 135 (14.8)	61 of 135 (45.2)
District 5	963	118	11 (9.3)	9 of 11 (81.8)	5 of 11 (45.5)	9 of 11 (81.8)	1 of 11 (9.1)	0 of 11 (0)	11 of 11 (100)	0 of 11 (0)	0 of 11 (0)
District 6	29 490	2524	129 (5.1)	129 of 129 (100)	66 of 129 (51.2)	94 of 129 (72.9)	27 of 129 (20.9)	18 of 129 (14.0)	41 of 129 (31.8)	52 of 129 (40.3)	36 of 129 (27.9)

K–5, kindergarten through fifth grade; —, not applicable.

who had a positive test on exposure date or day 1 after exposure. We also conducted a sensitivity analysis including participants who developed symptoms during days 2 to 14 after exposure and never underwent SARS-CoV-2 testing (presumed positive) or had a positive SARS-CoV-2 test after day 7.

We used SAS software, version 9.4, to conduct all statistical analyses (SAS Institute, Inc. Cary, NC). This study was approved by the Duke University Health System institutional review board under Pro00109436 and the North Carolina Department of Health and Human Services. A committee external to day-to-day study procedures oversaw weekly review of the data.

RESULTS

During the study period, from October 18, 2021, to December 8,2021, we enrolled 367 (12.2%) participants from 5 NC school districts and 1 charter school, out of 3020 eligible students and staff exposed to index cases (Fig 1). A sixth district underwent study startup, but delayed testing because of staffing limitations. Nearly all study participants were students (99.5%) and most were White (78%) (Table 1). Most participants enrolled from the 2 largest school districts (264 of 367, 72%), with 367 of 3020 (12%) eligible participants consenting to participate, and highly variable consent rates across the districts (5%–100%) (Table 1).

Nearly all (215 of 238, 90%) exposure encounters occurred during predefined lunch and athletic activities between an unmasked index case and an unmasked close contact, with most exposures (353 of 367, 96%) occurring indoors, specifically in the context of lunch (137 of 357, 39%) or during athletics (45 of 357, 13%) (Fig 2).

The median (IQR) day of notification was 3 days (2–4) from the day of known exposure (Table 2). Nurses and administrators performed testing at each school building in 5 of 6 participating entities, with 1 district performing testing using centralized locations throughout the district.

Transmission and School Absences

A total of 883 tests were performed, with results in 357 test-to-stay participants. There was a median (IQR) of 3 (2–3) tests per participant. Six participants had a positive test after day 1, leading to a secondary attack rate (SAR) of 1.7% (95% CI, 0.6%–4.7%). The nonparametric estimate of test positivity probability for the interval-censored data, because of the testing strategy, is 2.8% (Table 3). At the time of data lock, the posterior probability of a SAR >5% was 2%. The median (IQR) day of positivity is 4.5 (4–5) days after exposure. Three participants were positive on day 1 after exposure and 1 participant tested positive on the exposure day. All 10 positive cases were found at the first administered test.

A sensitivity analysis including those identified as positive on exposure day or day 1 after exposure resulted in a SAR of 2.8% (95% CI, 1.2%–6.2%). The posterior probability of a SAR >5% was 10%. Of 11 participants who developed symptoms, 5 were presumed positives or had a positive test after day 7. A

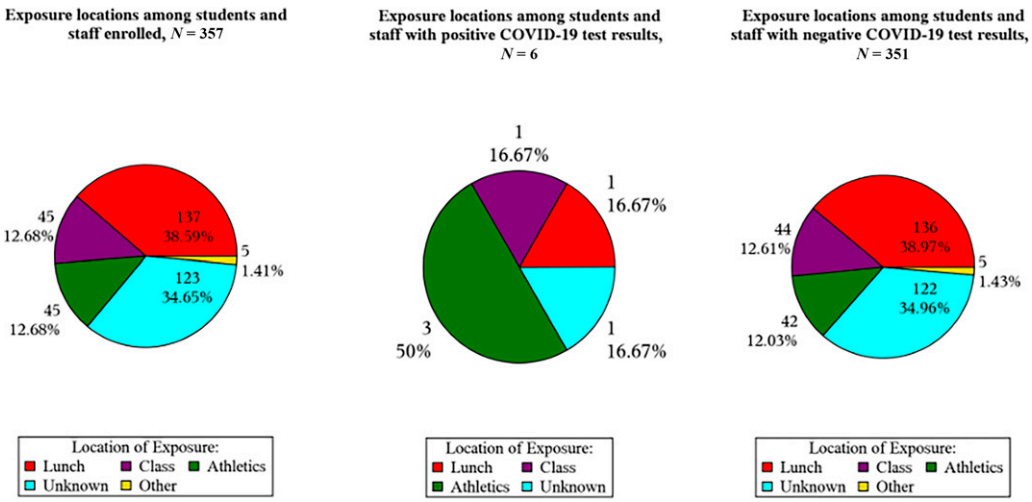

FIGURE 2
In-school exposure encounters. In-school exposure encounters by activity and/or location among test-to-stay participants.

TABLE 2 Baseline Exposure Characteristics of Students and Staff Exposed to Index Case

	Total Students and Staff Enrolled	Days to Notification of Exposure,[a] Median (IQR)	Perecent Vaccinated, *n* of *N* (%)	Percent Index Case Masked, *n* of *N* (%)	Percent Index Case Unmasked, *n* of *N* (%)	Percent Masked Participants Exposed to Index Case, *n* of *N* (%)	Percent Unmasked Participants Exposed to Index Case, *n* of *N* (%)	Percent Exposed Indoor, *n* of *N* (%)	Percent Exposed Outdoor, *n* of *N* (%)
All districts	367	3.0 (2.0–4.0)	2 of 367 (0.5)	20 of 241 (8.3)	221 of 241 (91.7)	20 of 238 (8.4)	218 of 238 (91.6)	353 of 366 (96.4)	13 of 366 (3.6)
District 1	31	3.0 (1.0–4.0)	0 of 31 (0)	0 of 31 (0)	31 of 31 (100.0)	1 of 31 (3.2)	30 of 31 (96.8)	28 of 31 (90.3)	3 of 31 (9.7)
District 2	60	3.0 (2.0–4.0)	0 of 60 (0)	1 of 60 (1.7)	59 of 60 (98.3)	0 of 60 (0)	60 of 60 (100.0)	60 of 60 (100.0)	0 of 60 (0)
District 3	1	3.0 (3.0–3.0)	0 of 1 (0)	0 of 1 (0)	1 of 1 (100.0)	0 of 1 (0)	1 of 1 (100.0)	0 of 1 (0)	1 of 1 (100.0)
District 4	135	3.0 (2.0–4.0)	0 of 135 (0)	5 of 135 (3.7)	130 of 135 (96.3)	8 of 135 (5.9)	127 of 135 (94.1)	126 of 135 (93.3)	9 of 135 (6.7)
District 5	11	0.0 (0.0–0.0)	2 of 11 (18.2)	11 of 11 (100.0)	0 of 11 (0)	11 of 11 (100.0)	0 of 11 (0)	11 of 11 (100.0)	0 of 11 (0)
District 6	129	3.0 (2.0–5.0)	0 of 129 (0)	3 of 3 (100.0)	0 of 3 (0)	—	—	128 of 128 (100.0)	0 of 128 (0)

—, not applicable.
[a] If the exposure notification date was not reported, the first test date was used to calculate days to notification of exposure

sensitivity analysis including these participants resulted in a SAR of 3.1% (95% CI, 1.4%–6.5%) and the posterior probability of SAR >5% was 13%. We identified no incidences of within-school tertiary transmission. One case of tertiary transmission was reported to have occurred in a household contact and did not result from within-school transmission. Through enrollment in the test-to-stay protocol, 1628 (92%) in-person school days were saved, with only 136 days of quarantine required compared with the expected number of 1764 days because of quarantine policy (Table 3).

DISCUSSION

In the universally masked environment, implementation of the test-to-stay protocol successfully and substantially reduced student absences after in-school exposure to COVID-19. Furthermore, implementation of test-to-stay did not result in increased transmission of SARS-CoV-2 within the school environment. This is 1 of the first systematic, individual-level research studies of a test-to-stay strategy for in-person learning. These data are consistent with reports in the lay press,[8] an investigation in Ohio, and with a cluster-randomized study in England.[9] Moreover, the SAR identified in this cohort of close contacts is consistent with a report from a larger epidemiologic study performed during the delta variant era.[10]

The results of our study are notable for several reasons. First, because NC does not require quarantine for mask-on-mask exposures, regardless of distance between the 2 parties, enrolled participants resulted entirely from conditions in which at least 1 party was unmasked. Yet, disease spread was limited, even though most NC schools are at or above enrollment capacity and do not have upgraded ventilation or further mitigation strategies in place other than universal masking. The low secondary transmission rate is likely because many of the unmasked exposures occurred at lunch, where the duration of exposure was relatively brief (<30 minutes) and students and staff were otherwise universally masked. Second, nearly half of the positive close contacts had a positive test on the day of exposure or 1 day after exposure, which suggests that using contact tracing as a way of identifying those at risk for infection can overestimate secondary infections, especially if community transmission is high. As demonstrated by whole genome sequencing in Utah[11] and multiple epidemiologic studies,[12] when universal masking is in place, students and staff are more likely to have community-acquired SARS-CoV-2 infection than to acquire infection within school buildings.[13] Third, although our study was designed with 4 tests per participant, only 50% received >2 tests, and all positive tests occurred in those receiving only 1 test as early as the day of notification. Finally, there was no tertiary transmission despite delayed notification in some cases. Although preliminary, these data suggest that the number of tests required may be able to be reduced in the universally masked environment. Reduction in the number of required tests may be an important factor for increasing the feasibility of test-to-stay, particularly when staffing and resources are at an all-time low.

Although promising, the test-to-stay method has some limitations. First, we do not know whether tertiary contacts were tested if they did not enroll in our study, only that none reported positive tests. Second, the test kits we used were rapid antigen tests, which have lower sensitivity

TABLE 3 School Absence Because of Positive COVID-19 Tests and/or Symptoms in Test-to-Stay Participants

	Total Students with Positive COVID-19 Test or Symptoms After Known Within-School Exposure	Total Students with Positive COVID-19 Test After Known Within-School Exposure, *n* of *N* (%) 95% CI	Total Number of School Days Missed Because of Positive COVID-19 Test After Exposure,[a] *n*, Median (IQR)	Total Students with Symptoms After Known Within-School Exposure, *n* of *N* (%) 95% CI	Total Number of School Days Missed Because of Symptoms After Exposure,[a] *n*, Median (IQR)	Total School Days Missed[a,b] /Total School Days Potentially Missed per Quarantine Policy[a,c], *n* of *N* (%) 95% CI
All districts[d]	20	10 of 355 (2.8) (1.3–6.2)	10, 8 (6–10)	11 of 357 (3.1) (0.4–20.2)	11, 7 (2–8)	136 of 1764 (7.7)
District 1	0	0	0	0	—	N/A
District 2	4	1 of 60 (1.7)	1, 10 (10–10)	4 of 60 (6.7)	4, 7 (2–11)	26 of 291 (8.9)
District 3	0	0	0	0	N/A	N/A
District 4	9	4 of 125 (3.2)	4, 10 (9–10)	5 of 128 (3.9)	5, 7 (2–7)	67 of 649 (10.3)
District 5	2	0 of 9 (0)		2 of 9 (22.2)	2, 7 (6–7)	13 of 72 (18.1)
District 6	5	5 of 129 (3.9)	5, 6 (5–6)	0 of 128 (0)	—	30 of 571 (5.3)

—, not applicable

[a]Summarized among participants who completed the 14-d follow-up.

[b]Total school days actually missed by students who had a positive test or symptoms.

[c]Total school days potentially missed by students without a positive test or symptoms and actually missed from students with a positive test or symptoms, per quarantine policy.

[d]Districts 1 and 3 did not report any positive tests among enrolled participants during the study period.

and specificity compared with nucleic acid amplification tests, especially in asymptomatic persons. Nevertheless, the test-to-stay method relies on rapid turnaround of results that is usually not available with nucleic acid amplification tests and serial testing increases the sensitivity of this method. Furthermore, rapid antigen tests have greater sensitivity under circumstances where the pretest probability is higher (eg, after exposure or with symptoms). Third, community rates were declining in NC during the study period (Supplemental Table 4); the point estimate for SARS-CoV-2 may be higher with a more transmissible variant such as omicron, and contact tracing to identify close contacts may become more difficult. Fourth, because of logistics and delays in notification, not every participant received 4 tests; this may have limited the ability to identify all participants who were positive. Such issues demonstrate real-world challenges with implementing a test-to-stay program. Finally, in some districts, the proportion of enrolled participants was far lower than others and enrolled participants did not represent the racial and ethnic distribution of the district. For example, District 6 had the highest number of eligible participants, yet implementation of the protocol within this district was limited by a centralized testing location, which contributed to very limited participation. Each district promoted the study within their schools, and participation varied widely. The low enrollment rate may be explained by execution under a research protocol or centralized testing within this district, which required additional transportation resources for participants. This arrangement may have limited equitable access to those who did not have access to transportation or caregivers with available time.

Based on available data, test-to-stay offers an important opportunity to limit absences and promote in-person learning during the current pandemic and could serve as a blueprint for preventing school closures and absences during the next pandemic. Considering the deleterious effects of chronic absenteeism on risk of dropout, future earnings, and related mortality,[14] such a strategy is crucial to halt learning loss acquired over the 2020 and 2021 school years.[15]

CONCLUSIONS

We found substantial evidence to safely implement a test-to-stay strategy in universally masked school environments, with no evidence of tertiary transmission and thousands of school days saved during our study period. Furthermore, we found that a test-to-stay strategy is a safe alternative to quarantine even after unmasked in-school exposure (eg, during lunch) to SARS-CoV-2 in a mostly unvaccinated population. Although this initiative represents a feasible and safe strategy to allow in-person education, it requires resources and additional support to the school districts. Supporting school districts with policy and financial resources to conduct this protocol on each school's campus would improve the program's reach and may help reduce disparities related to testing uptake, direct and indirect burden of testing, time to test, and missed school days. Future investigation should evaluate test-to-stay strategies in optionally masked settings and among those with nonhousehold exposures outside the school setting. In conjunction with already proven measures such as vaccination, rapid identification, and tracing of positive SARS-CoV-2 cases, the test-to-stay

approach should be part of a comprehensive plan for the safe return to in-person education.

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ABBREVIATIONS

CI: confidence interval
COVID-19: coronavirus disease 2019
K–12: kindergarten through 12th grade
NC: North Carolina
SAR: secondary attach rate
SARS-CoV-2: severe acute respiratory syndrome coronavirus 2

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