Test-to-Stay After SARS-CoV-2 Exposure: A Mitigation Strategy for Optionally Masked K-12 Schools

Melissa M. Campbell, MD,[a,b] Daniel K. Benjamin, Jr., MD, PhD,[a,b,c] Tara K. Mann, PhD, RN,[a] Alex Fist, MPH,[a] Ashley Blakemore, MA,[a] Kylee S. Diaz, BS, CCRP,[a] Hwasoon Kim, PhD,[a] Laura J. Edwards, BSPH,[a] Zsolt Rak, PhD,[a] M. Alan Brookhart, PhD,[d] Zack Moore, MD, MPH,[e] Elizabeth Cuervo Tilson, MD, MPH,[e] Ibukun Kalu, MD,[a,b] Angelique E. Boutzoukas, MD,[a,b] Ganga S. Moorthy, MD,[a,b] Diya Uthappa, BS,[f] Zeni Scott, MD,[b] David J. Weber, MD, MPH,[g] Andi L. Shane, MD, MPH, MSc,[h] Kristina A. Bryant, MD,[i] Kanecia O. Zimmerman, MD, PhD, MPH[a,b,c]; on behalf of the ABC Science Collaborative

abstract

OBJECTIVES: We evaluated the impact of a test-to-stay (TTS) program on within-school transmission and missed school days in optionally masked kindergarten through 12th grade schools during a period of high community severe acute respiratory syndrome coronavirus 2 transmission.

METHODS: Close contacts of those with confirmed severe acute respiratory syndrome coronavirus 2 infection were eligible for enrollment in the TTS program if exposure to a nonhousehold contact occurred between November 11, 2021 and January 28, 2022. Consented participants avoided school exclusion if they remained asymptomatic and rapid antigen testing at prespecified intervals remained negative. Primary outcomes included within-school tertiary attack rate (test positivity among close contacts of positive TTS participants) and school days saved among TTS participants. We estimated the number of additional school-acquired cases resulting from TTS and eliminating school exclusion.

RESULTS: A total of 1675 participants tested positive or received at least 1 negative test between days 5 and 7 and completed follow-up; 92% were students and 91% were exposed to an unmasked primary case. We identified 201 positive cases. We observed a tertiary attack rate of 10% (95% confidence interval: 6%–19%), and 7272 (89%) of potentially missed days were saved through TTS implementation. We estimated 1 additional school-acquired case for every 21 TTS participants remaining in school buildings during the entire study period.

CONCLUSIONS: Even in the setting of high community transmission, a TTS strategy resulted in substantial reduction in missed school days in optionally masked schools.

[a]Duke Clinical Research Institute, [b]Department of Pediatrics, [c]Co-Chair, The ABC Science Collaborative, Durham, North Carolina; [d]Department of Population Health Sciences, [f]Doctor of Medicine Program, Duke University School of Medicine, Durham, North Carolina; [e]North Carolina Department of Health and Human Services, Raleigh, North Carolina; [g]School of Medicine, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina; [h]Children's Healthcare of Atlanta, Atlanta, Georgia; and [i]University of Louisville and Norton Children's Hospital, Louisville, Kentucky

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WHAT IS KNOWN ON THIS SUBJECT: Coronavirus disease 2019 caused substantial disruption to in-person K–12 US education. Even after in-person education resumed, students and school staff faced frequent disruptions, especially in optionally masked districts in which they often did not qualify for quarantine exemptions after severe acute respiratory syndrome coronavirus 2 exposure.

WHAT THIS STUDY ADDS: In optionally masked districts, a test-to-stay approach resulted in substantial reduction in missed school days compared to optionally masked districts not employing a test-to-stay approach.

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During the coronavirus disease 2019 (COVID-19) pandemic, school exclusion after exposure to a COVID-19 case has been a central strategy in limiting the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in kindergarten through 12th grade (K–12) school settings. Nevertheless, school exclusion has been detrimental to learning and a disruption for schools, children, and families.[1–3] Data have consistently demonstrated that those excluded rarely became infected when mitigation strategies were used. In universally masked schools during periods of high community transmission (eg, ancestral, Alpha, Delta, variants), <3% of close contacts excluded from schools for within-school exposures subsequently developed COVID-19.[4,5]

We recently demonstrated that elimination of school exclusion and serial SARS-CoV-2 testing after brief, unmasked exposures to a COVID-19 case (eg, during lunch) did not result in within-school tertiary transmission (ie, spread from a positive close contact to another individual) and preserved >90% of predicted exposure-related missed school days in universally masked settings.[6] However, the effect of a test-to-stay (TTS) strategy within optionally masked settings remains unknown. Based on previous data, optionally masked districts have increased numbers of close contacts and school exclusions as well as 8 times the incidence of within-school transmissions compared to universally masked districts.[7] We sought to evaluate the impact of a TTS approach on within-school transmission and missed in-person education in optionally masked settings during the emergence of the highly transmissible Omicron variant.

METHODS

Study Design and Population

As previously described, the ABC Science Collaborative (ABCs) designed a prospective cohort study to evaluate whether TTS is an effective approach to reducing school exclusion while minimizing SARS-CoV-2 spread in K–12 schools.[6] The study protocol was amended in November 2021 to include optionally masked schools and districts in North Carolina, as detailed below.

Students and staff were eligible for enrollment into the study if they met the following criteria: (1) had a nonhousehold, within or outside-of-school exposure to SARS-CoV-2 between November 29, 2021 and January 28, 2022 as identified through the school contact tracing program; (2) were asymptomatic at the time of enrollment; and (3) were subject to school exclusion on the basis of control measures recommend by the US Centers for Disease Control and Prevention (CDC) and North Carolina Department of Health and Human Services (NCDHHS) for close contact status because of unmasked exposure within 6 feet of a SARS-CoV-2 case.[8] Individuals were excluded if they were notified of close contact status >5 days after exposure because of shorter incubation periods for Delta and Omicron variants compared to previous strains.[9,10] Close contacts who chose not to participate in the study were excluded from school for 7 to 14 days in accordance with local health department policy.

Testing Program and Data Collection

After electronic informed consent and assent, participants were assigned a unique identifier. The protocol required that participants undergo serial SARS-CoV-2 rapid antigen testing by using the Quidel QuickVue SARS Antigen test (Quidel Corporation, San Diego, CA)[11] or the BinaxNOW Ag Card (Abbott Diagnostics Scarborough, Inc., Scarborough, ME)[12] at 3 times: (1) on the day of exposure notification; (2) day 3; and (3) day 5 postexposure. Tests scheduled for a weekend were performed on the nearest school day (eg, Friday or Monday); in all cases, a final test on or after day 5 was required. Testing occurred onsite by a trained collector at the local school, and self-collections were not permitted.

During the initial part of the study period (November 29, 2021 to January 12, 2022), students and staff were followed for symptoms, additional exposures, and transmission for a total of 14 days. The Omicron variant became the dominant variant in January 2022,[13,14] and its shortened incubation period resulted in modified CDC and NCDHHS quarantine guidance. In turn, during the latter part of study period (January 3, 2022 to January 28, 2022), follow-up for study participants was reduced to 10 days. All participants were required to wear a face covering in school for the follow-up period and were strongly encouraged to wear a mask in the community. A positive COVID-19 test or the development of symptoms on any day after exposure required isolation according to CDC and NCDHHS control measures. During the Omicron surge, participants with subsequent SARS-CoV-2 exposures during the testing period were eligible to continue the study protocol by restarting their 5- to 7-day testing period; they were followed for 10 days after the most recent exposure. Students were allowed to participate in athletic activities after the 5-day testing period if they remained asymptomatic, tested negative on serial testing, and continued to wear a mask during athletic activities.

Data recorded for each participant included basic demographic information, daily presence or absence of symptoms, whether the infected person (primary case) or enrolled participant (close contact) was masked, exposure setting (eg, indoors or outdoors, during athletics, and specific location), test results, school absences, and transmission to other school close contacts. Each week, schools and districts used *AirTable* to securely transfer anonymized data to the Duke Clinical Research Institute (Durham, NC) for analysis.

Definitions

We characterized TTS participants' SARS-CoV-2 status as test positive, negative, or unknown. Test-positive participants had a positive SARS-CoV-2 test result within 14 days after known exposure to a within-school primary case from November 29, 2021 to December 21, 2021 or 10 days after a known exposure to a nonhousehold within-school or outside-of-school primary case from January 3, 2022 to January 28, 2022. Negative participants did not have a positive test and had a negative test on or after day 5 after known exposure. The 5 day test criteria to determine a negative participant was based on the reduced sensitivity of rapid-antigen tests to detect the variant within the first 2 days after exposure.[15,16] Unknown participants did not test positive during the study period, did not have a documented negative test on or after day 5 postexposure, or were lost to follow-up; therefore, unknown participants were excluded from analysis. The analysis-eligible population was defined as the cohort of participants with a positive test during the study period or at least 1 negative test on or after day 5 of exposure, and completed study follow-up. For repeated exposures, participants were categorized as unique participants enrolled more than once if their subsequent exposure occurred after completion of the testing period from the previous exposure.Omicron

Primary Outcomes

The primary outcomes were within-school tertiary attack rate (TAR) among tertiary TTS participants, and days of school saved. We defined the within-school TAR as transmission from a positive TTS participant to a within-school close contact who enrolled in the TTS study once notified of close-contact status. Per NCDHHS guidance, a close contact was defined as "[an individual] who was within 6 feet of an infected person for a cumulative total of 15 minutes or more over a 24-hour period starting from 2 days before symptoms began (or, for asymptomatic individuals, 2 days before test specimen collection date) until the time the individual is isolated."[8] At the time of this study and per NCDHHS guidance, a mask-on-mask encounter with a positive SARS-CoV-2 individual was not considered an exposure. For a case to contribute to the calculated TAR, the positive case had to meet the NCDHHS close contact definition (eg, "being within 6 feet of another person for 15 minutes cumulatively or longer, within a 24-hour period [eg, 5 minutes at arrival, 5 minutes at lunch, and 5 minutes at dismissal]")[17] and be attributed to a school-based exposure. TAR is a primary outcome for this study because TTS could have a direct impact on this measure in 2 ways. First, TTS could result in increased transmission by eliminating school exclusion for a potentially infected student or staff member (eg, a positive participant who received a false negative rapid antigen test result, specifically during Omicron).[18] Alternatively, TTS could result in decreased transmission through more rapid identification and isolation of cases with serial testing and required masking of participants in an otherwise optionally masked setting. We defined days of school saved as the number of days a participant was allowed to attend in-person work or education after being designated as a close contact instead of being required to undergo school exclusion in the absence of TTS. We calculated missed school days that would have occurred according to the number of required days of school exclusion after exposure to a primary case within each participating district. Notably, the required 10 to 14 calendar days of exclusion for most within-school close contacts was lowered to 5 days after December 30, 2021 across all districts on the basis of changes in CDC and state guidance. For participants with a positive test or reported symptoms who had missing data on number of missed school days, we imputed this value by assuming that missed testing days after the occurrence of symptoms were school absences because of illness and presumed infection required 10 calendar days of isolation. We accounted for school holidays during the December 2021 to January 2022 winter break when calculating saved days of in-person learning.

Secondary Outcomes

The secondary outcomes for this study are: (1) the proportion of test-positive participants, including both secondary and tertiary close contacts; and (2) the number of additional school-acquired cases because of TTS. To estimate these additional cases, we first used the proportion of tertiary contacts who enrolled in TTS to estimate the total number of positive tertiary contacts, including tertiary contacts not enrolled in TTS. We then estimated the number of positive tertiary cases for each TTS participant by dividing the estimated positive tertiary cases by the analysis-eligible secondary contacts enrolled in TTS.

Statistical Analysis

We used descriptive statistics to characterize the analysis-eligible study population. For each participant, we characterized the circumstances surrounding exposure to the primary case, including masking status of both the primary case and the close contact, as well as whether the exposure occurred within or outside-of-school. We also described the time to notification after exposure among all analysis-eligible participants, number of tests completed during the study protocol, and time to test positivity among positive participants.

We summarized the TAR, days saved, test positivity among TTS participants, and the estimated number of additional school-acquired cases because of allowing close contacts to remain in school through TTS. We also summarized the proportion of analysis-eligible study participants who had symptoms, missed school days, and were not tested after symptom onset. We characterized proportions of positive results overall, by status as student or staff, and by school district. To account for possible correlated outcomes (eg, scenarios in which participants may be more likely to test positive) at the district level, we estimated the 95% confidence interval (CI) for the proportion using a generalized linear mixed model with district as a random effect.

Considering the changing dynamics of the pandemic and, subsequently, the study protocol, we conducted a primary analysis over the entire study period (November 29, 2021 and January 28, 2022 excluding winter break) and a second analysis during the period when the Omicron variant comprised most COVID-19 cases (January 3, 2022 to January 28, 2022). Among the analysis-eligible population, we also performed 3 sensitivity analyses to better characterize the data. First, we repeated all analyses among study participants who had a positive test on or after the day of exposure because of the possibility that an early positive test result represented a primary case instead of a secondary case. Second, we conducted analyses excluding athletic exposures and exposures acquired outside-of-school because of the higher risk of transmission previously documented in these settings.[19] Third, we presumed that participants with symptoms and absence of a negative follow-up test were COVID-19–positive.

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 NCDHHS. A committee external to day-to-day study procedures oversaw weekly review of the data.

RESULTS

Primary Analysis (November 29, 2021–January 28, 2022)

Study Population

From November 29, 2021 to January 28, 2022, we enrolled 2463 (16%) participants out of 15 066 students and staff eligible for the study protocol from 9 optionally masked school districts. Of the enrolled participants, 92% were students and the majority were white (79%). Among those enrolled, 1675 (68%) met criteria for the analysis-eligible population, including 23 reexposed cases. Of these, 92% were students and the majority were white (78%). The demographics of the analysis-eligible population was representative of the enrolled population. (Table 1). Ninety-one percent of exposure encounters included an unmasked primary case, 89% included an unmasked close contact in which a close contact was defined as an individual who was within 6 feet of the primary case for >15 minutes within a 24 hour period,[17] and the median (25th, 75th percentile) time to notification of close contact status was 2 days (1, 3) from known exposure. Seventy-six (3%) of analysis-eligible participants had an outside-of-school exposure, and 85 (3%) had an exposure during an athletic event.

TAR and School Absences

We identified 20 of 192 enrolled tertiary contacts as test-positive, resulting in a TAR of 10% (95% CI 6%–19%); Table 2. A total of 934 school days were missed out of the anticipated 8206 days without TTS, resulting in 89% of in-person instruction days saved among the analysis-eligible population (Table 3). When comparing the TAR by school level, elementary and high schools reported a TAR of 13% (12 of 91 and 5 of 38, respectively), middle schools reported a TAR of 5% (3 of 63), and administrative offices had zero cases of known tertiary transmission. Overall, 201 of 1675 (12%) TTS participants were test-positive, including both secondary and tertiary close contacts. Secondary attack rates across school levels were similar, ranging from 11% to 15%, with zero cases of transmission in administrative buildings. We estimated 1 additional within-school case for every 21 individuals avoiding school exclusion through TTS (Table 4).

The median (minimum, maximum) time to positivity was 3 (1, 5) days after exposure, and 82% (165 of 201) of positive cases were identified by day 5 after known exposure (Supplemental Table 6). Table 2 summarizes 2 sensitivity analyses. In the first sensitivity analysis, exclusion of those with positive tests on exposure day or day 1 after exposure resulted in a TAR of 13% (95% CI 8% to 21%). In the second sensitivity analysis excluding close contacts who had an athletic exposure or an outside-of-school exposure, there was no meaningful change in the proportions of overall positives or tertiary cases, and TAR remained similar at 11%. Of the analysis-eligible population, 506 participants (30%) received 2 rapid antigen tests, 695 (41%) received 3 tests, and 168 (10%) received 4 tests during the study period. The mean number of tests received was 2.4 tests (SD: 0.9, interquartile range: 2–3); Table 5.

Secondary Analysis (January 3, 2022–January 28, 2022)

During the period when the Omicron variant comprised most SARS-CoV-2 cases, 932 participants met criteria for the analysis-eligible population, including 8 reexposed cases during the January 2022 study period. Among 1564 enrolled, 89% were students and 80% were white (Table 1). Ninety-two percent of exposure encounters occurred with an unmasked primary case and 92% with an unmasked close contact. Of the 1564 participants enrolled, 1187 (76%) had a within-school exposure, 66 (4%) were close contacts of an out-of-school, nonhousehold primary case, and 311 participants (20%) had an unknown or missing exposure location. Of the within-school exposures, 67 participants (6%) enrolled after an athletic exposure. The median (25th, 75th percentile) time to notification was 1 (0, 3) day from known exposure.

TAR and School Absences

We identified 7 of 109 tertiary contacts as test positive, resulting in a TAR of 6% (95% CI: 3%–13%) (Table 2). Among the 940 participants meeting the analysis-eligible criteria, 530 days were missed, compared to an anticipated

TABLE 1 Total Participant Demographics Compared with Analysis-eligible Participant Demographics by District and by Study Period

		Study Population		Students		Male		White		Black		Hispanic or Spanish Origin[f]	
Study Periods and Districts	Total Individuals[b] Eligible for TTS	Enrolled[c] (%)	Analysis Eligible[d] (%)	Enrolled[d] (%)	Analysis Eligible[e] (%)	Enrolled[c] (%)	Analysis Eligible[e] (%)	Enrolled[d] (%)	Analysis Eligible[e] (%)	Enrolled[c] (%)	Analysis Eligible[d] (%)	Enrolled[d] (%)	Analysis Eligible[e] (%)
11/29/21–1/28/22													
All districts	15066[e]	2463 (16)	1675 (68)	2265 (92)	1543 (92)	1159 (47)	783 (47)	1937 (79)	1305 (78)	359 (15)	240 (14)	240 (10)	149 (9)
District A	495	314 (63)	221 (70)	308 (98)	215 (97)	140 (45)	101 (46)	309 (98)	218 (99)	2 (1)	2 (1)	18 (6)	12 (5)
District B	—[g]	196	92 (47)	178 (91)	84 (91)	93 (47)	47 (51)	113 (58)	45 (49)	76 (39)	42 (46)	24 (12)	6 (7)
District C	10967	470 (4)	279 (59)	410 (87)	241 (86)	245 (52)	143 (51)	329 (70)	193 (69)	120 (26)	73 (26)	42 (9)	26 (9)
District D	—	189	152 (80)	187 (99)	150 (99)	97 (51)	79 (52)	175 (93)	139 (91)	3 (2)	2 (1)	29 (15)	26 (17)
District E[a]	—	321	274 (85)	314 (98)	268 (98)	143 (45)	122 (45)	210 (65)	178 (65)	74 (23)	63 (23)	39 (12)	30 (11)
District F	451	197 (44)	92 (47)	172 (87)	76 (83)	86 (44)	30 (33)	152 (77)	69 (75)	23 (12)	9 (10)	36 (18)	13 (14)
District G	2658	667 (25)	457 (69)	596 (89)	410 (90)	304 (46)	210 (46)	575 (86)	390 (85)	35 (5)	23 (5)	45 (7)	29 (6)
District H[a]	60	25 (42)	25 (100)	25 (100)	25 (100)	13 (52)	13 (52)	18 (72)	18 (72)	3 (12)	3 (12)	4 (16)	4 (16)
District I	435	84 (19)	83 (99)	75 (89)	74 (89)	38 (45)	38 (46)	56 (67)	55 (66)	23 (27)	23 (28)	3 (4)	3 (4)
1/3/22–1/28/22													
All districts	11017[e]	1564 (14)	940 (60)	1392 (89)	829 (88)	738 (47)	437 (46)	1246 (80)	741 (79)	225 (14)	134 (14)	147 (9)	73 (8)
District A	265	155 (58)	91 (59)	149 (96)	85 (93)	71 (46)	41 (45)	152 (98)	90 (99)	0 (0)	0 (0)	11 (7)	5 (5)
District B	—	196	92 (47)	178 (91)	84 (91)	93 (47)	47 (51)	113 (58)	45 (49)	76 (39)	42 (46)	24 (12)	6 (7)
District C	7338	282 (4)	152 (54)	235 (83)	124 (82)	151 (54)	82 (54)	201 (71)	108 (71)	72 (26)	40 (26)	23 (8)	14 (9)
District D	—	65	40 (62)	65 (100)	40 (100)	30 (46)	19 (48)	63 (97)	38 (95)	2 (3)	2 (5)	10 (15)	7 (18)
District F	451	197 (44)	92 (47)	172 (87)	76 (83)	86 (44)	30 (33)	152 (77)	69 (75)	23 (12)	9 (10)	36 (18)	13 (14)
District G	2528	585 (23)	390 (67)	518 (89)	346 (89)	269 (46)	180 (46)	509 (87)	336 (86)	29 (5)	18 (5)	40 (7)	25 (6)
District I	435	84 (19)	83 (99)	75 (89)	74 (89)	38 (45)	38 (46)	56 (67)	55 (66)	23 (27)	23 (28)	3 (4)	3 (4)

[a] Districts E and H returned to universal masking in January because of o.
[b] Reexposure cases are reported and counted as unique cases.
[c] Percentages are calculated on the basis of the number of participants eligible to participate in test-to-stay; only districts that reported the number of total participants eligible to participate in test-to-stay are included in the overall total.
[d] Percentages are calculated on the basis of the number of participants enrolled.
[e] Percentages are calculated on the basis of the number of analysis-eligible participants.
[f] The North Carolina Department of Public Instruction database does not capture race and ethnicity as 2 separate categorical variables.
[g] The em dash (—) represents unknown eligible participant numbers because the number of exposures were not reported by the district.

TABLE 2 Test Positivity and TAR Among Analysis-Eligible Population and in Sensitivity Analyses: Limited to Tests After 1-Day Postexposure and Excluding Outside-of-School and Athletic Exposures

	11/29/2021–1/28/2022 (Delta and Omicron) (%)	1/3/2022–1/28/2022 (Omicron) (%)
Primary and secondary analyses		
Test-positive cases among analysis-eligible population[a]		
Number of analysis eligible	1675	940
Total positive tests (secondary and tertiary)	201 (12)	132 (14)
Positive tests among tertiary contacts in TTS (TAR)	20 of 192 (10)	7 of 109 (6)
Sensitivity analyses		
Test positivity limited to tests after 1 d postexposure		
Number of analysis eligible	1619	903
Total positive tests (secondary and tertiary)	145 (9)	95 (11)
Positive tests among tertiary contacts in TTS (TAR)	16 of 124 (13)	7 of 76 (9)
Test positivity excluding outside-of-school exposures and athletic exposures		
Number of analysis eligible	1550	841
Total positive tests (secondary and tertiary)	188 (12)	121 (14)
Positive tests among tertiary contacts in TTS (TAR)	19 of 185 (11)	7 of 103 (7)

[a] Analysis-eligible population based on unique exposure events rather than unique participants.

3660 days in the absence of TTS, resulting in 86% school days saved (Table 3). Overall, 132 of 940 (14%) participants were test-positive, including secondary and tertiary close contacts. We estimated one additional within-school case for every 29 individuals avoiding school exclusion through TTS (Table 4).

The median (25th, 75th percentile) days to positivity was 3 (1, 4) days after exposure and 86% (113 of 132) of positive cases were identified by day 5 after known exposure, demonstrating a slightly shorter incubation during circulation of Omicron in comparison with the Delta variant wave (Supplemental Table 6). Exclusion of those with positive tests on exposure day or day 1 after exposure resulted in a TAR of 9%. Similar to data from the entire study period, when excluding close contacts who had an athletic exposure or an outside-of-school exposure, there was no meaningful change in the proportions of overall positives or tertiary cases, and TAR remained at 7%. Of the analysis-eligible population, 309 participants (33%) received 2 rapid antigen tests, 456 (49%) received 3 tests, and 2 (0%) received 4 tests during the study period. Similar to during the entire study period, the mean number of tests administered during the Omicron variant wave was 2.3 tests (SD: 0.8, interquartile range: 2–3); Table 5.

TABLE 3 Missed Versus Predicted Missed Days of School for Students and Staff throughout Entire Study Period among Enrolled Participants[a] in Optionally Masked Districts: Data from November 29, 2021 to January 28, 2022

Study Period and Participants	Observed Missed Days	Predicted Missed Days Without TTS	Proportion of Saved Days (%)
11/29/2021–1/28/2022 (Delta and Omicron)			
Elementary school	410	3344	88
Middle school	295	2601	89
High school	229	2233	90
Administration[b]	0	15	100
Unknown/multiple levels	0	13	100
Total	934	8206	89
1/3/2022–1/28/2022 (Omicron)			
Elementary school	257	1658	85
Middle school	178	1124	84
High school	95	850	89
Administration[b]	0	15	100
Unknown or multiple levels	0	13	100
Total	530	3660	86

[a] Staff were categorized based on the school-level associated with their work.
[b] Administration refers to physical work in an administrative office rather than within a school level.

DISCUSSION

This study prospectively evaluated the impact of a TTS program on within-school transmission and missed school days in optionally masked districts in North Carolina during circulation of the highly transmissible Delta and Omicron variants. Although we observed relatively high overall test positivity and tertiary transmission in this setting, many enrolled participants did not exhibit symptoms nor test positive, leading to substantial reduction in missed school days. The rate of test positivity observed in this study is substantially higher than the attack rate previously described within universally masked school districts during circulation of Alpha and Delta variants. However, part of this observed difference is likely related to the highly transmissible nature of the Omicron variant, echoing early reports describing Omicron infection rates

TABLE 4 Estimate of Additional COVID-19 Cases Resulting from Students and Staff Remaining in School via TTS

Variable	11/29/2021–1/28/2022 (Delta and Omicron)	1/3/2022–1/28/2022 (Omicron)
Analysis-eligible population (A)	1675	940
Total tertiary contacts reported (B)	667	435
Total tertiary contacts enrolled in TTS (C)	192	109
Positive tertiary contacts enrolled in TTS (D)	20	7
Risk calculation		
Proportion of tertiary contacts who enroll in TTS (E = C/B)	0.29	0.25
Estimate of total positive tertiary contacts (F = D×(1/E))	68.97	28
Estimate of positivity rate (transmission)[a] (G = [F/(A-C)] ×100), %	4.7 (CI: 1.7–13.1)	3.4 (CI: 0.7–15.2)
Number of additional cases per 100 TTS participants	∼5	∼4
Close contacts remaining in school to generate 1 additional case	21	29

[a] To calculate rate, tertiary contacts enrolled in TTS were subtracted from analysis-eligible population in the denominator.

being 4 times higher than the wild-type variant and twice as high as the Delta variant.[13]

The test positivity, including positives among secondary and tertiary contacts, in this study is lower than what we have previously reported in school districts that used neither universal masking nor test to stay. This finding also underscores what we have previously observed, which is that without mitigation strategies in place, particularly universal masking, transmission within schools mirrors that of surrounding communities.[20]

Our estimate of 1 additional within-school case for every 21 close contacts participating in TTS and remaining in school is also notable and permits quantification of risks compared to benefits of mitigation strategies, which has been a staple for decision-making within many school systems in the United States. At least 3 arguments support acceptance of this risk-benefit ratio in favor of in-person learning with TTS even under conditions of high community transmission and optional masking. First, many students who have been ineligible to attend in-person education because of COVID-19–related exposures have missed out on access to education, health care, and other social resources, which may have long-term negative effects on their development.[21] For example, available data suggest that learning loss during the pandemic has been substantial, not to mention pervasive, across races, ethnicities, and socioeconomic classes. The individual and societal consequences of learning loss are great. Recent estimates suggest that worldwide, this generation of students could lose 17 trillion in lifetime earnings as a result of inadequate access to education.[22] Second, the large majority of children experience mild COVID-19, and among those vaccinated, the risk of severe disease in children and adults is even lower.[23] Third, as demonstrated in this study, source control is possible via masking of close contacts[24]; therefore, we can minimize the risk to household contacts and the community at large. On the other hand, >1200 COVID-19–related pediatric deaths have occurred, disproportionately affecting historically minoritized children. Furthermore, postacute sequelae of COVID-19 (ie, “long COVID-19”) can occur despite mild acute disease. Long COVID-19 has resulted in such disability that >3 million adults in the United States have had to stop working or reduce work hours.[25]

Our work presented here and across previous studies[6,7,26] provides schools with 4 approaches to manage respiratory infections:

TABLE 5 Proportion of Enrolled versus Analysis-Eligible Participants Receiving Rapid Antigen Tests by Quantity and Study Period and Proportion of Positivity by Time Period

	11/29/2021–1/28/2022 (Delta and Omicron)		1/3/2022–1/28/2022 (Omicron)	
Number of tests administered	Enrolled (%)	Analysis Eligible (%)	Number of tests administered	Enrolled (%)
1	766 (31)	306 (18)	554 (35)	173 (18)
2	823 (33)	506 (30)	541 (35)	309 (33)
3	706 (29)	695 (41)	467 (30)	456 (49)
4	168 (7)	168 (10)	2 (0)	2 (0)
Total participants	2463	1675	1564	940
Total tests administered	5202	4075	3045	2167
(mean, SD, median, min, Q1, Q3, max)	(2.1, 0.9, 2, 1, 1, 3, 4)	(2.4, 0.9, 3, 1, 2, 3, 4)	(2.0, 0.8, 2, 1, 1, 3, 4)	(2.3, 0.8, 2, 1, 2, 3, 4)

Q1, quarter 1; Q3, quarter 3.

(1) universal masking without systematic testing of exposed students (low rates of estimated subsequent infection, <5%); (2) universal masking with systematic testing of those exposed during brief periods of unmasking (low rates of estimated subsequent infection); (3) voluntary masking with systematic testing of exposed students (moderate rates of subsequent infection, 5% to 10%); and (4) voluntary masking without systematic testing of exposed students (high rates of subsequent infection, >20%).

This study has several limitations. First, the robustness and accuracy of contact tracing programs may have varied across districts and over time, because of availability of resources and information about potential contacts, as well as the changing dynamics of the pandemic, such as the short incubation period of the Omicron variant. This limitation could have led to missed or misclassification of cases, which was likely compounded by limited sensitivity of rapid antigen results early in the course of Omicron infection[18]; however, sensitivity analyses designed to address misclassification demonstrated similar results. Second, we only have information on close contacts for positive individuals participating in TTS, potentially leading to an underestimation or overestimation of TAR, and in our risk calculation, we assumed the same rate of transmission to tertiary contacts who did and did not enroll in TTS. Third, the analysis-eligible population constituted only 68% of the enrolled population, creating the potential for selection bias and limited generalizability of results. Nonetheless, the demographics of the analysis-eligible population was similar to those enrolled, so there is no reason to suspect systematic differences in test positivity in those within or outside of the analysis-eligible population. Fourth, on the basis of known district demographics, non-white participants enrolled less frequently than expected in some districts, which may be because of the requirement to consent to a research study or other unknown barriers; however, we do not expect this inadequate representation to limit the generalizability of study results. Finally, we were unable to assess the fidelity of masking or masks used on close contacts within each of the districts.

Strengths of this study include the number of participants within the study, the distribution and diversity of enrolling districts (eg, rural and urban settings) across the state of North Carolina, the ability to study and quantify risk within optionally masked districts, and the capture of transmission within school buildings during circulation of 2 highly transmissible SARS-CoV-2 variants. Finally, with minimal exclusion criteria from the protocol, the study results are more generalizable to the real, everyday challenges faced by school districts as they make decisions about mitigation strategies.

CONCLUSIONS

The burden of SARS-CoV-2 testing programs on schools and the need to support schools with funding, personnel, and infrastructure to implement a TTS program is substantial; yet, a TTS program has the potential for great benefit. As the pandemic evolves, our approaches to mitigation strategies, testing, and risk tolerance should evolve, with an emphasis on preserving in-person learning. Many school district are tasked with assessing risk and making informed decisions regarding mitigation strategies. On the basis of our data, a TTS approach allows more students and staff to remain in the classroom, with a modest increase in subsequent infections in optionally masked settings, even during the circulation of a highly transmissible variant. A TTS strategy should be considered to preserve in-person learning, now and in future pandemics.

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ABBREVIATIONS

ABCs: ABC Science Collaborative
CDC: Centers for Disease Control and Prevention
CI: confidence interval
COVID-19: coronavirus disease 2019
K–12: kindergarten through 12th grade
NCDHHS: North Carolina Department of Health and Human Services
REDCap: research electronic data capture
SARS-CoV-2: severe acute respiratory syndrome coronavirus 2
TAR: tertiary attack rate
TTS: test-to-stay

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Address correspondence to Kanecia Zimmerman, MD, MPH, Associate Professor of Pediatrics, Duke Clinical Research Institute, Duke University School of Medicine, 300 Morris St, Durham, NC 27701. E-mail: kanecia.zimmerman@duke.edu

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