School Masking Policies and Secondary SARS-CoV-2 Transmission

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abstract

OBJECTIVES: Throughout the COVID-19 pandemic, masking has been a widely used mitigation practice in kindergarten through 12th grade (K–12) school districts to limit within-school transmission. Prior studies attempting to quantify the impact of masking have assessed total cases within schools; however, the metric that more optimally defines effectiveness of mitigation practices is within-school transmission, or secondary cases. We estimated the impact of various masking practices on secondary transmission in a cohort of K–12 schools.

METHODS: We performed a multistate, prospective, observational, open cohort study from July 26, 2021 to December 13, 2021. Districts reported mitigation practices and weekly infection data. Districts that were able to perform contact tracing and adjudicate primary and secondary infections were eligible for inclusion. To estimate the impact of masking on secondary transmission, we used a quasi-Poisson regression model.

RESULTS: A total of 1 112 899 students and 157 069 staff attended 61 K–12 districts across 9 states that met inclusion criteria. The districts reported 40 601 primary and 3085 secondary infections. Six districts had optional masking policies, 9 had partial masking policies, and 46 had universal masking. In unadjusted analysis, districts that optionally masked throughout the study period had 3.6 times the rate of secondary transmission as universally masked districts; and for every 100 community-acquired cases, universally masked districts had 7.3 predicted secondary infections, whereas optionally masked districts had 26.4.

CONCLUSIONS: Secondary transmission across the cohort was modest (<10% of total infections) and universal masking was associated with reduced secondary transmission compared with optional masking.

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Drs Boutzoukas and Inkelas conceptualized and designed the study, designed the data collection instruments, collected data, conducted the initial analyses, drafted the initial manuscript, and reviewed and revised the manuscript; Drs Butteris, DeMuri, and Mr Koval designed the data collection instruments, collected data, and reviewed and revised the manuscript; Drs Benjamin and Brookhart carried out the analyses and reviewed and revised the manuscript; Drs. Manuel, Smith, McGann, Weber, Falk, Kalu, Shane, Schuster, Goldman, Mr Koval, Mr Hickerson, Ms Edwards, Ms Erickson, and Ms Benjamin collected data and reviewed and revised the manuscript; Drs Zimmerman and Benjamin, Jr. designed the data collection instruments, collected data, reviewed and revised the manuscript, conceptualized and designed the study, coordinated and supervised data collection, and critically reviewed the manuscript for

WHAT IS KNOWN ON THE SUBJECT: During the coronavirus disease 2019 pandemic, masking has been a widely used mitigation strategy. Prior studies have been limited in their ability to evaluate whether masking is associated with decreased secondary transmission in schools.

WHAT THIS PAPER ADDS: Within-school (secondary) transmission was modest (<10%) in this multistate cohort of 61 K–12 districts, representing over 1 million students and staff. On unadjusted analysis, universal masking was associated with a 72% reduction in secondary transmission compared with optional masking.

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Throughout the coronavirus disease 2019 (COVID-19) pandemic, kindergarten through 12th grade (K–12) school safety has been a major focus of the Centers for Disease Control and Prevention, as well as state and local authorities. Earlier work suggested that mitigation through masking and distancing prevented school environments from being major drivers of transmission;[1–10] however, the arrival of the delta variant in the summer of 2021 intensified concerns about possible K–12 transmission, since the delta variant induced a substantial increase in community-derived cases compared with prior variants.[9] Given the evolving pandemic, coupled with changing national guidance and local policies, K–12 schools used a variety of methods to prevent transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) during the fall of 2021. These methods often differed substantially from the homogenous environments of universal masking, some physical distancing, and prolonged quarantines following exposure described in early studies of K–12 SARS-CoV-2 transmission. Moreover, prior studies assessing the impact of specific mitigation strategies also used total cases as a measure of K–12 school safety,[11,12] without attempting to distinguish between cases acquired in the community (primary infections) and those acquired at school (secondary infections). Importantly, the definitive metric of interest in determining the safety of in-person instruction is the proportion of total infections in a school community that are attributed to within-school (secondary) transmission. This metric is also critical to help districts determine the direct impact of individual mitigation strategies and policies.

Variability in K–12 school mitigation practices have made it possible to evaluate the relative contribution of each practice to reducing within-school transmission, especially when community rates are high.[13] The aim of the current study was to demonstrate the impact of various masking practices on secondary transmission in K–12 districts across the United States, using primary and secondary infection case metrics.

METHODS

We performed a national, prospective, observational, open cohort study from July 26, 2021 to December 13, 2021. Notably, these data were primarily collected during a period of the COVID-19 pandemic when the delta variant was the predominant variant. Data collection concluded at the start of the omicron variant surge in the United States. To assess whether surrounding county vaccination rates across categories of masking influenced the ratio of secondary to primary infections, we re-estimated our model, allowing for vaccination rates to have different effects across masking regimes.

School District Recruitment and Data Collection

We sought to conduct an inclusive and broad assessment of national policies and transmission within schools, so participating districts were recruited from states in which study team members were located, supplemented by districts that responded to an offer sent to every public school district in the United States (more than 13 800 districts) using an e-mail list derived from state education agency websites. Subsequent criteria for inclusion in the study can be seen in Fig 1. School districts that expressed interest in the study ($n = 143$) received initial surveys that included questions specific to a district's demographics, district-level policies on masking, requirements for quarantine, lunch procedures, definitions of close contacts, and vaccination requirements; of these, 85 districts (59%) completed the initial survey.

We invited participating school districts to provide weekly counts of SARS-CoV-2 primary cases, secondary cases, and quarantines for staff and students. These data were provided as aggregate counts at the school level and were analyzed at an aggregate district level; therefore, details on cases including student versus staff were not available. On a monthly basis, we administered brief surveys on district-level policies to assess changes in policies during the study period. Districts submitted data via AirTable (San Francisco, CA). Web-based data display enabled districts to visualize case counts and rates, as well as quarantine counts for their own data and (anonymously) for other participating districts over time.

Of the 85 participating districts, 73 (86%) districts submitted at least 1 week of infection and quarantine data; most districts that submitted at least 1 week of infection and quarantine data ultimately completed >5 weeks of data entry (64 of 73; 87.7%), while a minority of districts completed <3 weeks (8 of 73; 11%) or 3 to 5 weeks of data entry (1 of 73; 1.4%). Of the 73 districts that reported infection data, 67 districts reported case data with adjudication of primary and secondary infections. Finally, 6 districts did not consistently (100% of the reporting period) adjudicate case source as primary versus secondary infections and were excluded from analyses; ultimately 61 districts were included in quasi-Poisson regressions.

Definitions and Outcome Measures

Primary infections were those deemed to have been acquired in the community. Secondary infections were those deemed to have been acquired in the school environment

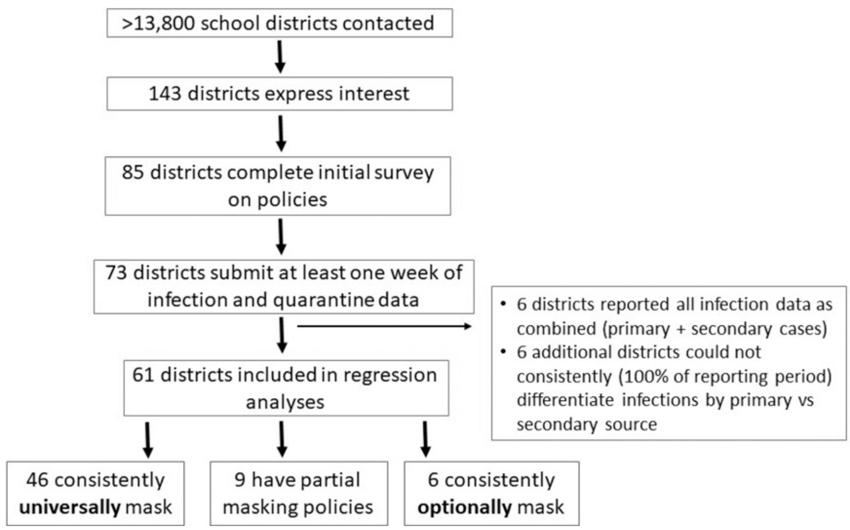

FIGURE 1
Enrollment and subsequent study inclusion. This figure displays the study population, from enrollment through exclusions, to the final study population comprised of 61 school districts: of these, 46 districts consistently universally masked, 9 partially masked, and 6 consistently optionally masked.

(ie, school-associated infections). In general, classification of primary versus secondary infection was adjudicated by school health staff in collaboration with the local public health department, according to the above definitions. There was not a category for "uncertain" source of transmission, and all local health departments followed their individual practices to determine whether the case was primarily or secondarily acquired. For analysis of secondary transmission by various masking categories, we characterized each district into 1 of the following categories: universal, optional, or partial masking. We defined a district as having either a universal or optional masking policy if they maintained this practice for the entire study period. Districts that had varying masking policies throughout the course of the study were categorized as having partial masking policies. The most common versions of partial masking policies were either: (1) starting the semester with optional masking but moving toward universal masking across the entire district; or (2) requiring masking in some grade levels, but not others; or (3) requiring masking when the community reached a specific transmission rate.

The primary outcome of interest was the number of secondary cases expected to result from additional primary cases, which we called the secondary-to-primary infection ratio, a practical measure that allows districts to measure the effectiveness of mitigation measures within schools. A higher secondary-to-primary infection ratio signifies more within-school transmission events occurring for each person who enters school with a community-acquired SARS-CoV-2 infection. Additional outcomes of interest included rates of secondary infections adjusted for district size and number of weeks reporting.

Data Monitoring and Cleaning

The research team convened monthly calls with districts to discuss data results and quality, contacting districts when potential data quality issues were identified. Each study team member was responsible for a given region of the country; when possible, team members were assigned to districts where relationships with district leadership already existed. Research team members were responsible for monitoring data from their districts and maintaining close collaboration, including multiple phone calls with district leadership to ensure that primary and secondary infections were consistently reported and that policy changes were captured. Where in-person student or staff enrollment numbers (not infection data) were missing from districts, several attempts were made to obtain these data from the districts; if these attempts were unsuccessful, then publicly available data on staff and student enrollment numbers were imputed.

Statistical Analysis

We performed descriptive analyses on aggregate data from contributing districts and characterized the demographics of participating districts, initial policies, and changes to policies. To predict secondary transmission among students and staff by masking policy, we used a quasi-Poisson regression model using the log of student and staff primary cases as an offset (denominator) and estimated predicted secondary transmission per 100 primary infections with 95% confidence intervals that accounted for overdispersion of the observed counts. We calculated the relative rate of secondary transmission from the quasi-Poisson regression model using universal masking as the reference category. To evaluate the influence of large districts' data on the results, we conducted 2 sensitivity analyses removing all districts with more than 20 000 students enrolled and more than 10 000 students enrolled and repeated the above analyses. As a secondary analysis, we evaluated secondary transmission per 1000 district population (calculated by summing students and staff in-person) per total weeks each district reported data, via repeated quasi-Poisson regression, with primary infections per 1000 district population as the denominator. To assess whether surrounding county vaccination rates across categories of masking influenced the ratio of secondary to primary infections, we re-estimated our model, allowing for vaccination rates to have different effects across masking regimes. We conducted analyses using Stata (StataCorp, Stata Statistical Software: Release 16.1. College Station, TX: StataCorp LLC) and R version 4.0.2.[14]

Institutional Review Board

No personal health information data were obtained or transmitted. This study was approved by the Duke University Hospital System Institutional Review Board (Pro00108129).

RESULTS

The 61 districts that met inclusion criteria were composed of 1 112 899 students and 157 069 staff attending in-person school across 9 states: 29 from North Carolina, 23 from Wisconsin, 3 from Missouri, 1 from California, 1 from Washington, 1 from Georgia, 1 from Tennessee, 1 from Kansas, and 1 from Texas (Table 1).[15,16] These districts reported an average of 13.5 weeks (standard deviation of 4.8) of infection data. In total, these 61 districts had 40 601 primary infections (36 032 among students, and 4569 among staff) and 3085 secondary infections (2844 among students, and 241 among staff), with an aggregate secondary-to-primary ratio of .08.

Six districts (10%) had optional masking policies, 9 had partial masking (15%), and the remaining 46 districts (75%) had required masking for the entirety of the study. Of those with partial masking policies, 4 districts switched from optional to universal masking during the study period, 2 districts transitioned between optional and required masking more than once during the reporting period, and 3 districts had optional masking with requirements for masking at either various grade levels or based on community transmission thresholds. We did not see a difference between transmission at elementary, middle, or high school levels using a univariate analysis. Districts that were fully masked had lower predicted secondary infections per primary infection than districts that

TABLE 1 Demographics, Policies Used by Districts, Vaccination Rates, and Community Transmission

	All Districts *n* = 61 (%)	Universal Masking Policy[a] *n* = 46 (%)	Partial Masking Policies *n* = 9 (%)	Optional Masking Policy *n* = 6 (%)
Students in-person	1 112 899	1 075 982	32 967	3950
Staff in-person	157 069	151 149	5294	626
District size[b]				
0–4999	34 (56)	23 (50)	5 (56)	6 (100)
5000–20 000	16 (26)	12 (26)	4 (44)	0 (0)
>20 000	11 (18)	11 (24)	0 (0)	0 (0)
Initial quarantine policy[c]				
CDC guidance	21 (34)	17 (38)	1 (11)	3 (50)
Unmasked and unvaccinated close contacts quarantine	32 (52)	24 (53)	6 (67)	2 (33)
None	1 (2)	0 (0)	0 (0)	1 (17)
Other	3 (5)	1 (2)	2 (2)	0 (0)
Not reported	4 (7)	4 (9)	0 (0)	0 (0)
Lunch policy[d]				
Distancing and/or outdoor eating	40 (66)	31 (67)	7 (78)	2 (33)
No lunch policy	21 (34)	15 (33)	2 (22)	4 (67)
Vaccine required for eligible students	1 (2)	1 (2)	0 (0)	0 (0)
Vaccine required for eligible staff	6 (10)	6 (13)	0 (0)	0 (0)
Vaccination rates in surrounding county[e]				
Initiation of study (12–18 y), %	36	41	23	20
Termination of study (5–18 y), %	38	42	25	23
County community transmission, cases per 100 000 population per 7 d[f]				
Initiation of study	97	100	107	63
Termination of study	295	266	369	417

CDC, Centers for Disease Control and Prevention; COVID-19, coronavirus disease 2019; K–5, kindergarten through fifth grade.

[a] "Partial" masking districts included: 4 districts that initially had optional masking and transitioned to masks required, 2 districts that transitioned between mask optional and required more than once during the study period, and 3 districts that had required and optional masking varying by either school grade level, or by community transmission threshold.

[b] District size determined by number of students enrolled.

[c] Initial quarantine policy was reported by the schools on the initial policy survey. "Unmasked and unvaccinated close contacts quarantine" category includes districts that required quarantine only if the exposed person was unmasked and unvaccinated. In the case that the exposed person was either masked during exposure or vaccinated, quarantine was in general not required. "Other" districts include 1 district that quarantined all K–5 classrooms if there was a positive case, but in grades 6 to 12, quarantine was only required for unmasked exposures; 1 district that required quarantine for any unvaccinated person within 3 feet or within 90 d of COVID-19 infection; and 1 district where quarantine depended on level of school.

[d] "Distancing and/or outdoor eating" category included those districts who either ate indoors and implemented distancing or staggering of lunches or ate outdoors (with or without a distancing requirement).

[e] Vaccination rates as reported by CDC vaccinations in the United States,[15] by County dataset include percent of ages 12 to 18 y in the county containing the district with at least 1 vaccine at start of study (as of July 26, 2021); as authorization of COVID-19 vaccine for ages 5 to 11 y occurred during the study period, termination of study vaccination rates include percent of ages 5 to18 y with at least 1 vaccine in the county containing the districts (as of December 13, 2021).

[f] Community transmission for each county corresponding to a district as reported by the CDC County Level of Community Transmission, including Historical Changes database,[16] as cases per 100 000 population per 7 days. "Initiation of study" date was July 26, 2021 and "termination of study" date was December 13, 2021.

TABLE 2 Quasi-Poisson Regression of Predicted Secondary Cases and Relative Rate of Secondary Transmission by Masking Policy

Masking Policy	Districts, *n* (%)	Students and Staff, *n*	Total Primary Infections, *n*	Total Secondary Infections, *n*	Predicted Secondary Cases per 100 Primary Cases	95% CI	Relative Rate of Secondary Transmission	95% CI
Universal	46	1 227 131	38 200	2776	7.3	6.3–8.4	—	—
Partial[a]	9	38 261	2106	231	11.0	6.5–18.4	1.5	0.88–2.59
Optional	6	4576	295	78	26.4	10.9–64.4	3.6	1.47–8.98

CI, confidence interval; —, reference group for regression analysis.

[a] Partial masking districts included: 4 districts that initially had optional masking and transitioned to masks required, 2 districts that transitioned between mask optional and required more than once during the study period, and 3 districts that had required and optional masking varying by either school grade level, or by community transmission threshold.

had an optional masking policy using a quasi-Poisson regression analysis (Table 2). Among the various policies, 100 additional primary cases were predicted to yield 26.4 secondary cases in districts with optional masking, 11.0 secondary cases in districts with partial masking, and 7.3 secondary cases in districts with universal masking. The relative rate of secondary transmission in optionally masked districts was 3.6 times the rate of secondary transmission in universally masked districts; equivalently, universal masking was associated with an estimated 72% reduction in secondary transmission compared with districts with optional masking (Fig 2). When we accounted for the possibility that differences in vaccination rates might have different effects across masking regimes, we found that the estimates of the effects of masking policies were substantively identical to our original estimates. A sensitivity analysis removing the 11 districts in the largest size class (more than 20 000 students) and the results were substantively unchanged (Supplemental Table 4); a sensitivity analysis removing the 15 districts with >10 000 students had similar results (Supplemental Table 5).

Upon an additional analysis that adjusted for district size and weeks reporting data, we found consistent results: districts with optional masking had 7.5 times the predicted rate of secondary transmission compared with universally masked districts (Table 3). Universal masking was associated with an 87% reduction in predicted secondary transmission rates compared with optionally masked districts.

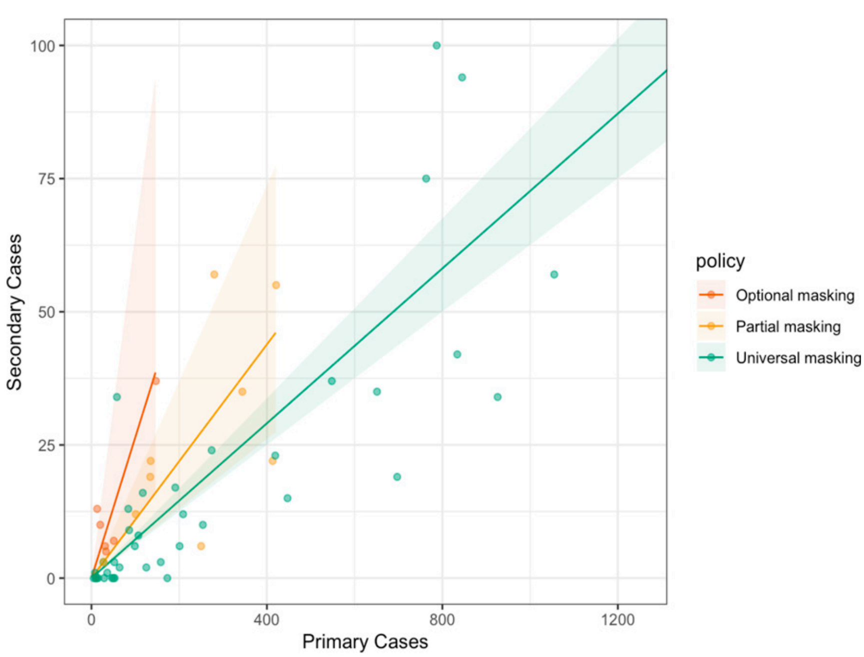

FIGURE 2
Predicted impact of masking policy on secondary transmission. Predicted impact of masking policy on secondary transmission according to optional masking, partial masking, or universal masking. Actual observations are shown by dots, predicted secondary cases are shown by solid lines, and 95% confidence intervals for the mean predictions are shown by shaded areas.

DISCUSSION

This study provides estimates of secondary transmission from a multistate, diverse network of K–12 school districts in the fall of 2021. Consistent with earlier data,[1–4,7,8] secondary transmission across the entire study cohort was low, with more than 90% of cases identified in school members originating from the community. As more students have returned to in-person instruction, schools have been more constrained in their ability to implement physical distancing. The predominant mitigation strategies have been masking and vaccinations for children 5 years of age and older. Among districts with universal masking policies, secondary transmission was reduced by 72% on unadjusted analysis, comparedwith districts having optional masking policies.

TABLE 3 Quasi-Poisson Regression of Predicted Secondary Cases and Relative Rate of Secondary Transmission by Masking Policy, Adjusted Per Capita and by Weeks Reporting to Study

Masking Policy	Districts, *n* (%)	Students and Staff, *n*	Mean Primary Infections per 1000 Students and Staff per Week, *n*	Mean Secondary Infections per 1000 Students and Staff per Week, *n*	Predicted Secondary Cases per 100 Primary Cases	95% CI	Relative Rate of Secondary Transmission	95% CI
Universal	46	1 227 131	2.7	0.16	5.8	3.62–9.27	—	—
Partial[a]	9	38 261	4.3	0.52	12.0	6.64–21.53	2.1	0.97–4.38
Optional	6	4576	5.4	2.33	43.5	30.99–61.10	7.5	4.21–13.42

CI, confidence interval; —, reference group for regression analysis.

[a] Partial masking districts included: 4 districts that initially had optional masking and transitioned to masks required, 2 districts that transitioned between mask optional and required more than once during the study period, and 3 districts that had required and optional masking varying by either school grade level, or by community transmission threshold.

At least 2 prior studies have examined the relationship between masking policies and SARS-CoV-2 infections in schools; both studies concluded that universal masking reduced infections compared with no masking,[11,12] but these studies were limited in their ability to specifically evaluate school-associated transmission. Documentation of within-school transmission is important because during periods of increased community rates, the total number of infections in a school's students and staff are expected to increase but evaluating the proportion of infections acquired within school can shed light on safety specific to the school environment. Therefore, the findings from our current study are important, particularly in times of higher community infection rates with more transmissible variants, like omicron. In such times, masking remains a critical mitigation effort to support continued in-person education. Assessment of primary and secondary infection metrics requires contact tracing to adjudicate the infection source.

Our study also highlights a framework for the current and future pandemics, allowing districts to self-monitor the success of their highly variable mitigation measures, make decisions based on their unique risk tolerances, respond to local politics, and inform on- and off-ramp decisions, particularly as vaccinations of school-aged children have become available. Though we did not notice systematic differences between transmission rates by school level, we did note some heterogeneity in transmission in a subset of schools within a district that could often be linked to mitigation practice adherence. For example, district leaders from 1 large district that had a universal masking policy noticed that the proportion of secondary infections early in the fall 2021 was higher than in previous time periods throughout the pandemic, specifically within a small subset of schools; at one point, 5% of the schools in the district were responsible for more than 30% of the secondary transmission. District leadership systematically monitored masking compliance at each school as previously described,[17] and observed a subsequent decrease to near 0 in secondary infections in high-risk schools. Through close monitoring, a second district observed a substantial increase in secondary transmission after instituting optional masking and returned to universal masking to preserve in-person learning. Notably, the measures in this study are limited by practical considerations and by the ability of school districts and their local public health authorities to test and adjudicate potential secondary cases. When testing is accessible and contact tracing is supported and performed, districts that can monitor trends in their schools will be able to make decisions to best support their local communities as the pandemic evolves.

LIMITATIONS

Our study had some limitations. First, our study was observational; policies were not randomized and, therefore, potential confounders may not be balanced among masking policy groups. Second, some districts changed policies during the study period, possibly in response to within-school transmission rates (eg, districts that started with universal masking may have switched to optional masking if transmission rates were low, and similarly, optional masking districts may have switched to universal masking if confronted with high levels of within-school transmission). Nonetheless, this dynamic should attenuate the contrast between the universal masking and optional masking districts. Third, our study relied on contact tracing, which is dependent upon local resources and testing accessibility, and may become strained at times of high community transmission. There may have been mis-adjudicated cases and missed diagnoses because testing was not required across the entire cohort following exposure; however, we do not suspect that these challenges with contact tracing are systematically different in masked versus unmasked districts. In 1 prior study, contact tracing in the K–12 environment was consistent with infection source determined by genomic sequencing;[6] however, contact tracing and testing are admittedly limited by available public health resources. In turn, this may limit the generalizability of our findings. Fourth, volunteer bias may have influenced the initial decision to participate in the study and individual districts' ongoing participation. Fifth, the participating optional masking districts originated from only smaller-sized districts, but after performing a sensitivity analysis that removed the larger districts, we found substantively identical results. Additionally, study results were robust to control for district size and weeks reported. Sixth, our study was largely completed around the time the more highly infectious omicron variant emerged, so the results may not be directly generalizable to the current context of SARS-CoV-2 mitigation. Finally, though our study is large and diverse, it is not nationally representative since it originated from 9 states.

CONCLUSIONS

Our study assessed secondary transmission, the metric of interest in evaluating the success of SARS-CoV-2 mitigation, across a multistate sample of K–12 school districts in the United States. We found that overall rates of secondary transmission were modest, and that universal masking policies were associated with markedly reduced secondary transmission compared with optional masking districts. Maintaining in-person instruction is critical for children. Providing districts with the tools to monitor transmission data in real time enables schools to respond to changing national and local policies, as well as adjust their mitigation efforts to keep in-person education as safe as possible for the remainder of the COVID-19 pandemic.

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ABBREVIATIONS

COVID-19: coronavirus disease 2019
K–12: kindergarten through 12th grade
SARS-CoV-2: severe acute respiratory syndrome coronavirus 2

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