RESEARCH ARTICLE

Different School Reopening Plans on Coronavirus Disease 2019 Case Growth Rates in the School Setting in the United States

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ABSTRACT

BACKGROUND: In fall 2020, all public K-12 schools reopened in broadly 3 learning models. The hybrid model was considered a mid-risk option compared with remote and in-person learning models. The current study assesses school-based coronavirus disease 2019 (COVID-19) spread in the early fall using a national data set.

METHODS: We assess COVID-19 case growth rates from August 10 to October 14, 2020 based on a crowdsourcing data set from the National Education Association. The study follows a retrospective cohort design with the baseline exposures being 3 teaching models: remote learning only, hybrid, and in-person learning. To assess the consistency of our findings, we estimated the overall, as well as region-specific (Northeast, Midwest, South, and West) and poverty-specific (low, mid, and high) COVID-19 case-growth rates. In addition, we validated our study sample using another national sample survey data.

RESULTS: The baseline was from 617 school districts in 48 states, where 47% of school districts were in hybrid, 13% were in remote, and 40% were in-person. Controlling for state-level risk and rural-urban difference, the case growth rates for remote and in-person were lower than the hybrid (odds ratio [OR]: 0.963, 95% confidence interval [CI]: 0.960-0.965 and OR: 0.986, 95% CI: 0.984-0.988, respectively). A consistent result was found among school districts in all 4 regions and each poverty level.

CONCLUSIONS: Hybrid may not necessarily be the next logical option when transitioning from the remote to in-person learning models due to its consistent higher case growth rates than the other 2 learning models.

Keywords: crowdsourced data; COVID-19; school reopening; case growth rate; hybrid education; school reopening plan.

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After the White House recommended shelter-in-place due to the coronavirus disease 2019 (COVID-19) pandemic in mid-March 2020, all K-12 public schools closed nationwide. In the summer of 2020, the US Centers for Disease Control and Prevention\textsuperscript{1} and the American Academy of Pediatrics (AAP)\textsuperscript{2} both recommended the reopening of K-12 schools, and AAP strongly recommended students be “physically present in school” as much as possible. In fall 2020, all K-12 public schools in the United States reopened in broadly 3 teaching delivery models—virtual-only (remote), hybrid (alternate of virtual learning and in-person learning), and fully in-person learning—presumably from the lowest to highest risks.\textsuperscript{1} Many states issued school reopening guidelines based on community background risks. For instance, New York State would not recommend in-person learning if background risk exceeded a 7-day average infection rate of 9%. If the average daily infection rate is less than 5% in a 2-week-period, schools could start in-person instruction.\textsuperscript{3-5} In rural states, background rates were not a key factor, as

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many of them recommended in-person learning or had no guidance at all.6

Although children are less likely to be infected, increased interactions among school children and school staff likely will lead to COVID-19 outbreaks in K-12 settings.7,8 Indeed, new pediatric cases in the United States increased rapidly about a month after school reopening,9-11 even with the implementations of non-pharmaceutical measures, such as social distancing, wearing masks, and physical barriers. This is concerning because children can transmit COVID-19 in schools to family members, and vice versa.12-14 With 35.2% of US adults having direct or within-household connections to elementary or secondary schools the downstream effects are evident.15 Children had a lower COVID-19 hospitalization rate than adults, but those with underlying conditions often end up in intensive care units upon hospitalization.16,17

Undoubtedly, the remote model can prevent school transmission, but it is disadvantageous for mental health and behavior developments, let alone the learning outcomes.1,18 The hybrid option, which often separates a class into 2 groups A and B, in 2 days of a week with the hygiene day in the middle, can alleviate some disadvantages in remote learning while facilitating non-pharmaceutical measures. Given the limitations of the remote model and perceived risk of the in-person model, the next logical model for face-to-face learning is the hybrid. However, it is not clear empirically if the hybrid is advantageous in terms of lowered school-based COVID-19 cases over the in-person model. In the current study, we used hundreds of reopened K-12 public schools in the United States to assess the spread of COVID-19 cases among the 3 reopening models at the school district level.

METHODS

We linked school-based COVID-19 outbreak data from August 10 to October 14, 2020 to school reopening policy information from different sources. We compiled the school-based COVID-19 outbreak data from the national education association (NEA) School and Campus COVID-19 Reporting Site.19 The NEA hosts a hub for educators to report the number of COVID-19 cases by student, staff, and other categories within a school, which were then verified by NEA. Based on school name, school district, city, and state, we deterministically linked this data set with the fall 2020 K-12 school district reopening plans from the Education Week website,20 which lists 901 school districts with their reopening plans, start date, and last verified date. If a reporting school cannot be linked, we used the Education Week criteria to manually classify each school reopening plan, verified through school websites and local news.

The Education Week classified schools into 3 reopening models: remote, hybrid, and in-person. Remote refers to 100% remote or distance learning, the hybrid is the majority of students received alternate in-person and remote learning (also called blended), and the in-person is all students can choose a fully in-person learning option (5 days a week on-site). Sometimes, a school can switch among these 3 models, but we used the first school day model as the reference.

We analyzed COVID-19 spread overtime at the school district level because NEA entries could not distinguish many schools, and most reopening policies were established at the district level. We pooled all confirmed COVID-19 cases together by date and district. Since a COVID-19 entry can be either from a school district or a school, as long as a district had 2 or more dates of entries with at least one positive case, they were included. In total, we included 2659 schools in 617 school districts in 48 states. New Mexico, Vermont, and the District of Columbia had no eligible entries. The baseline of confirmed cases from the 617 school districts was 1977. On average, each school district had 3.24 entry points or dates. In addition, we validated our sample with a dashboard sample hosted by the Brown University (Appendix 1).21

Following Lin et al22 and Lyu and Wehby,23 we used Poisson regression to compare the cumulative case growth by the 3 reopening plans (Model 1). To check result consistency, we separately assessed the model according to 4 census regions: Northeast (NE), Midwest (MW), South (S), and West (W).24 In addition, since many inner-city school districts were in high poverty areas, we included school-age children’s poverty data to gauge its effects. The school district poverty ages 5 to 17 per 100,000 was from the Education Data Explorer,25 and we divided it into tertiles of low, middle, and high. The case reporting date, together with the dependent variable of case count, measures the growth rate. When comparing the growth rates among the 3 learning models, the contrast was to hybrid. The interaction of the 3 teaching models vs. case report date can capture their differences. The state was included as a fixed effect to control for state-level enrollments and statewide COVID-19 risk. Hence, Model 1 includes case reporting date, an indicator variable of the 3 teaching models, the interaction of the plan versus case report date for the contrast, 4 regions, 3 poverty levels, state-level risk, and metropolitan status (yes or no). Model 2 separately ran Model 1 for 4 regions and 3 poverty levels. SAS version 9.426 was used for all statistical analyses. A p-value <.05 was considered statistically significant.

RESULTS

Among the baseline 1977 confirmed cases, 277 were from remote learning, 748 from hybrid, and 952 from
Table 1. Baseline COVID-19 Cases by 3 School Reopening Plans

| School districts reopening plans | Total | Remote | Hybrid | In-person |
|----------------------------------|-------|--------|--------|-----------|
| Confirmed cases                  | 1977  | 3.42 (6.65) | 2.61 (5.47) | 3.82 (10.67) |
| Number of school districts       | 617   | 13%    | 47%    | 40%       |
| Number of school districts by regions |       |        |        |           |
| NE                               | 172   | 10%    | 64%    | 26%       |
| MW                               | 166   | 11%    | 45%    | 43%       |
| S                                | 215   | 13%    | 34%    | 53%       |
| W                                | 64    | 25%    | 45%    | 30%       |

This table describes the first report data of each school district that met eligibility criteria.

Table 2. The Overall Estimates of COVID-19 Case Growth by School Reopening Plan

| Case growth rate (SE) OR (95% CI) | Hybrid | Remote | In-person |
|-----------------------------------|--------|--------|-----------|
|                                   | 0.049 (0.001) | Ref | 0.986 (0.984-0.988) |
|                                   | 0.011 (0.002) | 0.963 (0.960, 0.965) | 0.986 (0.984-0.988) |
|                                   | 0.035 (0.002) |          |            |

CI, confidence interval; OR, odds ratio; SE, standard error. Metropolitan status and background risk control variables were all significant.

In-person (Table 1). In-person learning districts had the highest mean confirmed cases (3.82). The mean cases for remote and hybrid learning were 3.42 and 2.61, respectively. The dominant learning mode was hybrid in the current sample (47%), followed by in-person (40%) and remote (13%). However, regional differences are evident. Among the 617 reported districts, the South had the highest number (215), and the West had the lowest (64). The Northeast had the highest proportion in hybrid, while the West had the highest proportion in remote (25%). Both the South and Midwest had more than 43% in-person.

Table 2 presents the overall log-growth rates for the 3 plans and their odds ratios (ORs). Districts adopting the hybrid had a daily growth rate of 4.7%, higher than both in-person (3.5%) and the remote (1.1%). With the hybrid in referent, the odds ratios of remote (0.963, 95% confidence interval [CI]: 0.960-0.965) and in-person (0.986, 95% CI: 0.984-0.988) were both less than 1 suggesting their growth rates were slower than the hybrid.

The above findings are the overall effects, separately estimated by regions and poverty levels, further illustrate that the hybrid’s effects were consistent across these 2 dimensions. These effects are seen in Figure 1, which contrasts differences between the hybrid and the other 2 learning models by region or poverty. Three regions’ ORs, except Midwest, for the in-person significantly lower than the hybrid: West (0.967, 95% CI: 0.960-0.974), Northeast (0.983, 95% CI: 0.974-0.992), and South (0.989, 95% CI: 0.986-0.992). Likewise, except for the Northeast, the remote’s ORs were also significantly lower: Midwest (0.956, 95% CI: 0.947-0.966), West (0.963, 95% CI: 0.957-0.969), and South (0.977, 95% CI: 0.973-0.980). In addition, ORs for the in-person significantly lower than the hybrid in all poverty levels: low (0.994, 95% CI: 0.989-0.998), mid (0.976, 95% CI: 0.973-0.980), and high (0.995, 95% CI: 0.991-0.999). Similar results apply to the remote ORs at 3 poverty level: low (0.990, 95% CI: 0.985-0.995), mid (0.986, 95% CI: 0.980-0.993), and high (0.958, 95% CI: 0.953-0.962).

DISCUSSION

As expected, the remote’s COVID-19 growth rates were significantly lower than those in in-person and hybrid learning during the study period. Not as expected, the hybrid case growth rates were significantly higher than those in-person. The highest growth rates observed for the hybrid learning model were net of state-COVID-19 background risks and metropolitan status, and they are consistent across regions and poverty levels.

Closing schools early when the cases are low would reduce the incidence of COVID-19. This logic worked in the remote learning model with a lower in-school transmission in the current study. However, contrary to the next logical progression, the hybrid did not seem to lower in-school transmission compared to in-person. Although the higher COVID-19 case growth was unexpected at first glance, it may help uncover some unknown effects. It is highly plausible that some of the students take their off-school learnings elsewhere, thus complicating COVID-19 exposures. These expected and unexpected results hinge on the dynamics of school learning models and other nonpharmaceutical practices within schools, as well as community infection rates. Given that 47% of our study districts were in hybrid learning, in-depth and community-specific comparisons of the hybrid versus in-person should be assessed.

There were several limitations to this study. First, although there were thousands of verified entries, they were crowdsourced data that may be biased. Since teachers prefer the remote over the other 2 learning models, they might not be eager to enter COVID-19 cases to the NEA site if they were from remote learning. Even though we validated our sample, the limitations from crowdsourced data should not be ignored. Second, the remote was only in reference to the school setting, but students could still be congregated in other community-provided settings (eg, Young Men’s Christian Association), which could still result in contact-based transmissions. Third, children with learning disabilities could all be in-person learning regardless of school district reopening plans. Finally, we only used the initial plan, but a school district
can change teaching models based on background rates and COVID infection dynamics. Future studies should incorporate changes in teaching models and then assess in a longer period. Nevertheless, data from hundreds of school districts in 48 states can serve as data points for future studies. In conclusion, the current study shows that in the United States, COVID-19 case growth rates in the hybrid model may not necessarily be lower than in-person learning.

IMPLICATIONS FOR SCHOOL HEALTH

Based on the pure nonpharmaceutical intervention design, the hybrid model provides a safer classroom learning environment than the in-person model. However, this design assumes that students are “stay-at-home” on the remote learning days, and it cannot control where students would go to study. Our empirical evidence showed that hybrid learning was least effective in preventing COVID-19 transmission among students. It suggests that schools should pay careful attention to students’ alternative learning options and their behavioral responses when adopting an intervention. Do students behave social distancing when out of school? Do some parents choose to send their children to other learning facilities due to their work demands? Policymakers and educators should carefully evaluate in-school COVID-19 infection routes to inform the public about school reopening plans.

In the absence of a government COVID-19 school infection tracking data system, crowdsourced data are the only source to inform researchers, governments, and the public. School teachers and administrators should actively provide school-based COVID-19 infection information to local health agencies and crowdsourcing data hubs, such as the one by NEA. In this way, school-based learnings during the pandemic can be supported by empirical evidence with optimal learning and public health outcomes.

Human Subjects Approval Statement

Our study is not a human subjects research. All the data of this study are public and available online. There is no identifiable private information. The Institutional Review Board (IRB) of the University of Nebraska Medical Center decided that the IRB review is not required for this study.

Conflict of Interest

The authors declare no conflict of interest.

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APPENDIX 1

Oster et al. developed a COVID-19 School Response Dashboard, which covered 28 million enrollments and 4 million staff in school settings. We used this ongoing sample survey to assess the validity of our crowdsourced data by comparing COVID-19 cases per 100,000 students commonly available from both data sources for the commonly available reporting periods from August 31 to October 25, 2020. In the comparison, only 33 states commonly available from both data sources are matched (AL, AZ, CO, CT, FL, ...
There were 228 school districts and 259 school districts in the dashboard and our study, respectively (Table 3). The hybrid and in-person COVID-19 infection rates in the dashboard were 52.22 and 93.24 per 100,000, respectively. In our study, the corresponding rates were 68.74 and 83.71 per 100,000, respectively. As far as student cases per 100,000 in this matched period are concerned, both data sources showed that in-person learnings were higher than the hybrid.