Association of Elementary School Reopening Status and County COVID-19 Incidence

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ABSTRACT

OBJECTIVE: To examine the association between elementary school opening status (ESOS) and changes in pediatric COVID-19 incidence.
METHODS: We conducted a cross-sectional study of US counties with school districts with ≥500 elementary school students. The main exposure was ESOS in September, 2020. The outcome was county incidence of COVID-19. Age-stratified negative binomial regression models were constructed using county adult COVID-19 incidence.
RESULTS: Among 3220 US counties, 618 (19.2%) were remote, 391 (12.1%) were hybrid, 2022 (62.8%) were in-person. In unadjusted models, COVID-19 incidence after school started was higher among children in hybrid or in-person counties compared with remote counties. After adjustment for local adult incidence, among children aged 0 to 9, the incidence rate ratio of COVID-19 (IRR) compared with remote counties was 1.01 (95% confidence interval [CI] 0.93−1.08) in hybrid counties and 0.79 (95% CI 0.75−0.84) in in-person counties.
CONCLUSIONS: Counties with in-person learning did not have higher rates of COVID-19 after adjustment for local adult rates.

KEYWORDS: COVID-19; in-person learning; school reopening; school safety

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WHAT'S NEW

In-person learning is unlikely to be associated with increased COVID-19 transmission in children under 10, after adjustment for local adult COVID-19 rates.

OPTIMAL STRATEGIES FOR school reopening related to COVID-19 remain uncertain.[1] Virtual or hybrid instruction has been associated with increased rates of mental health risk and stress for parents,[2] but significant concerns remain regarding COVID-19 transmission from in-person instruction, with mixed reports on household transmission from in-person and hybrid schooling.[1,3] British data suggest that that reopening high schools may be associated with higher community COVID-19 transmission than reopening elementary schools.[4] To help resolve these conflicting findings, the goal of this study was to examine the association between school district opening status and changes in pediatric COVID-19 incidence.

METHODS

We conducted a retrospective, cross-sectional study of US and Puerto Rico counties. COVID-19 case data were obtained from the Centers for Disease Control (CDC) Case Surveillance Restricted Access Detailed Data.[5] Elementary school opening status (ESOS) was obtained from the ESOS dataset, which reflects school opening status from all districts with ≥500 elementary students as of September 20−30, 2020.[6] County populations by age were obtained from the US Census 2019 five-year American Community Survey.[7]

The primary outcome was the county-level incidence of COVID-19 measured as cases per 100 susceptible person-years. Daily susceptible persons by age were calculated as the county population minus all prior COVID-19 cases in the age group. The main exposure variable was county-level ESOS, defined as remote, hybrid, or in-person. Counties with multiple school districts were defined using the modal ESOS by district land area within the county, so that counties could have only one ESOS assignment.

Additional covariates were age group, defined as '0−9 years, 10−19 years, 20−59 years, and 60+ years; county socioeconomic status (SES), defined as counties' quintile of US Census Small Area Income and Poverty Estimates, incorporating data from the Internal Revenue Service, state/county Supplemental Nutrition Assistance Program benefits; and state/county poverty data files.

ANALYSIS

We first determined the daily incidence of COVID-19 by age group and ESOS. We plotted daily COVID-19 rates before and after school opening in each age group by ESOS, using July 1, 2020 to August 16, 2020 as the before period, August 17, 2020 to September 7, 2020 as a middle wash-in period (a period in which schools started at varying times), and September 8, 2020 to November 30, 2020 as the after period. The wash-in period was selected based on the weeks in which 82% of districts start.[8] To compare rates by time, we created age-stratified negative binomial regression models including time period (excluding the wash-in period), ESOS, and a time-ESOS interaction term. The interaction term evaluated the extent to which ESOS was associated with the degree of progression of COVID-19 rates over time.

To assess the association between ESOS and pediatric COVID-19 rates, we constructed negative binomial regression models using COVID-19 incidence as the outcome. These models were designed to address confounding by transmission to children from adults and the effects of SES (which is independently associated with COVID-19 rates) on transmission.[9] Models included: 1) an unadjusted model including only ESOS; 2) an adult-adjusted model including ESOS and the $\log_2$ incidence of COVID-19 in adults aged 20 to 59 (to account for every doubling of local adult incidence); and 3) a full model adding SES to the adult-adjusted model. The adult-adjusted and full models did not include counties with no adult cases of COVID-19 as modeling the effect of adult COVID-19 transmission does not make sense when there is no transmission. As a sensitivity analysis, we recreated the models reassigning ESOS 3 ways: 1) by the most permissive ESOS in the county (ie, the county was treated as in-person if any district was in-person), 2) as the most restrictive in the county (ie, the county was treated as remote if any district was remote), and 3) restricting to counties with only one ESOS.

RESULTS

Among 3220 US counties, 618 (19.2%) were remote, 391 (12.1%) were hybrid, 2022 (62.8%) were in-person, and 189 (5.9%) did not have an ESOS because no school districts with more than ≥500 elementary students were present (Supplemental Figure 1). Among children 0 to 9 years, COVID-19 incidence in counties with remote learning increased after school started (56%, 95% CI 32−85). Compared with remote learning, increases were 48% (95% CI 12−94) steeper in hybrid counties and 60% (95% CI 32−95) steeper in in-person counties. Among children 10 to 19 years, the incidence in counties with remote learning increased 71% (95% CI 46−101). Increases were steeper by 41% (95% CI 9−83) in hybrid counties, and 75% (95% CI 45−110) steeper in in-person counties (Supplemental Figure 2). Similar results occurred in adults 20 to 59 years and ≥60 years.

In unadjusted models, counties with hybrid or in-person ESOS, COVID-19 incidences in persons aged 0 to 9 years or 10 to 19 years were higher after school started compared with counties with remote learning (Table 1). After adjustment for counties' adult COVID-19 rates, hybrid

Table 1. County-Level Incidence Rate Ratios (IRRs) of COVID-19 in Hybrid and In-Person Learning Elementary School Opening Statuses (ESOS) Compared With Remote Learning Settings

	IRR Compared With Remote Learning (95% CI)					
	Most Common ESOS in County		Most Permissive ESOS in County		Most Restrictive ESOS in County	
	Hybrid	In-person	Hybrid	In-person	Hybrid	In-person
Age 0–9						
Unadjusted model	1.35 (1.12, 1.62)	1.26 (1.10, 1.43)	1.28 (1.03, 1.58)	1.43 (1.24, 1.65)	1.30 (1.11, 1.52)	1.03 (0.92, 1.16)
Adult-adjusted model	1.01 (0.93, 1.08)	0.79 (0.75, 0.84)	1.02 (0.93, 1.11)	0.82 (0.78, 0.88)	0.93 (0.87, 0.99)	0.83 (0.79, 0.87)
Full model	0.99 (0.92, 1.07)	0.79 (0.75, 0.83)	0.99 (0.91, 1.09)	0.82 (0.77, 0.87)	0.92 (0.86, 0.98)	0.81 (0.77, 0.85)
Age 10–19						
Unadjusted model	1.45 (1.21, 1.75)	1.67 (1.46, 1.90)	1.33 (1.08, 1.64)	1.88 (1.63, 2.16)	1.46 (1.25, 1.70)	1.29 (1.14, 1.45)
Adult-adjusted model	1.11 (1.05, 1.17)	1.11 (1.07, 1.16)	1.11 (1.04, 1.19)	1.15 (1.10, 1.20)	1.09 (1.04, 1.14)	1.09 (1.05, 1.14)
Full model	1.05 (1.00, 1.11)	1.06 (1.02, 1.11)	1.04 (0.97, 1.11)	1.08 (1.03, 1.13)	1.06 (1.01, 1.11)	1.07 (1.03, 1.11)

CI indicates confidence interval.

ESOS represented the type of school setting present when schools reopened in Autumn 2020. IRRs are shown when ESOS is determined by the most common setting in a county, based on the most permissive ESOS in a county, or the most restrictive ESOS in the county. IRRs are reported in an unadjusted model, in a model adjusting for counties' adult COVID-19 rates, and in a full model adjusting for adult rates and county-level socioeconomic status.

learning was not associated with differing rates of COVID-19 in children aged 0 to 9 but remained associated with modestly higher rates in persons aged 10 to 19 years. In-person learning was associated with decreased COVID-19 rates in children ages 0 to 9 but increased rates in persons age 10 to 19, after adjustment for counties' rates of COVID-19 in adults. The addition of SES to the model did not change the interpretation from the adult-adjusted model. Sensitivity analyses reinterpreting counties' ESOS as the most locally permissive did not alter the association. When restricting to the 2250 (69.9%) counties with only one ESOS, results were similar to the main analysis (Supplemental Table).

DISCUSSION

Our data demonstrated considerable variation in school opening status, similar to prior reports.[2] Hybrid and in-person ESOS were associated with higher COVID-19 incidence in unadjusted models, showing that areas with more permissive ESOS have more cases of COVID-19. Even with adjustment for local adult COVID-19 incidence and SES, hybrid and in-person learning were associated with higher rates of COVID-19 among individuals aged 10 to 19. However, the opposite was true in children aged 0 to 9, in whom in-person learning was associated with lower COVID-19 rates after adjustment for local adult rates and SES.

There are several potential reasons for the differences observed between younger and older children. Studies have shown age-related differences in transmission risk within households,[9] and an increased risk of COVID-19 transmission from secondary schools versus primary schools.[4] We speculate that younger children may be more likely than older children to contract COVID-19 at home than school. Children attending in-person school settings may be exposed to fewer adults than those in remote settings due to ad-hoc childcare coverage. In contrast, older children may be more likely to transmit to peers and adults[10] thus making in-person schooling higher risk in the older age group. Locations outside of the home and school, including celebrations, are likely an important location of transmission for children, and could vary by age.[11] Children of different ages may also have variable adherence to mitigation measures such as social distancing and masking. These age-related differences could explain why unadjusted models of COVID-19 incidence, which reflect overall transmission within counties, differ from adjusted models, which reflect transmission independent of adults.

This study had several limitations. First, some counties may have changed ESOS during the study period. Second, there are several hybrid models; we treated all hybrid models as the same because no single model was prevalent enough to analyze separately. Third, applying these findings to high school reopening decisions should be undertaken with caution, since we did not evaluate high school reopening status, nor were vaccines available to children during the study period. However, opening status was nearly always a district-wide policy and thus this was unlikely to affect our study results.[12] Fourth, we did not take specific mitigation measures into account, although adjusting for adult rates would be expected to partially account for this since adult rates are tied to local mitigation strategies. Fifth, counties can be heterogeneous in terms of characteristics and COVID-19 approaches, so our findings should be regarded as county-averaged associations. Sixth, due to data limitations we could not separate elementary students from preschool children by age, include small school districts, or include nonpublic schools. Finally, as a cross-sectional study, we were limited in our ability to evaluate causality of ESOS and COVID-19 rates.

In conclusion, hybrid and in-person ESOS were associated with higher COVID-19 incidence in unadjusted models. Adjustment for local adult transmission negated the association for children 0 to 9 but not for those 10 to 19. This finding suggests that additional investigation into the effects of school reopening should evaluate outcomes by age.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.acap.2021.09.006.

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