When do elementary students need masks in school? Model-estimated risk of in-school SARS-CoV-2 transmission and related infections among household members before and after student vaccination

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INTRODUCTION

CDC guidance for K-12 schools recommends in-person education for all students, with COVID-19 mitigation measures including distancing, ventilation, and most recently, indoor masking regardless of vaccination status.[1] Children under 12 are not currently eligible for COVID-19 vaccines. Because CDC issues guidance rather than mandates, decisions will be made at the local and state level about masking in K-12 schools. In communities with high vaccination rates and low COVID-19 incidence, and in communities where masking is less widely accepted, schools are considering removing mask requirements, including for children <12. The impact of the removal of mask restrictions on COVID-19 outcomes for elementary students, educators/staff, and their households is not well known.

METHODS

We used an agent-based dynamic transmission model of SARS-CoV-2 in K-12 schools. Model structure and data inputs are described in previous publications; the Supplemental Table describes parameterization specific to this analysis.[2] We simulated an elementary school (30 separate classes, 638 students, 60 educators/staff) across 6 different scenarios: combinations of three viral infectiousness levels (reflecting wild-type virus, alpha variant, and delta variant) and two student vaccination levels (0% and 50% coverage to reflect potential authorization in this age group). We assumed that 70% of adults (educators/staff and adult household members of both students and educators/staff) were vaccinated.

We evaluated two primary outcomes of interest over a 30-day period: 1) probability of any in-school SARS-CoV-2 transmission, and 2) increase in the number of total infections among students, educators/staff, and their household members ("immediate school community") between in-school and remote instruction. For each scenario, we varied observed community COVID-19 incidence (0 to 50 cases/100,000 people/day, 33% of cases detected) and mitigation effectiveness (0-100% reduction to in-school SAR). The full multilayer mitigation measures recommended in 2020-21 reduced wild-type SAR by

90-100%.[1,3] Without clinical data for individual mitigation measure effectiveness, we show examples based on particle and aerosol studies and expert opinion as an approximate estimate; these ranges are highly uncertain (Supplemental Table). (Additional outcomes, including hospitalizations in the immediate school community, and scenarios varying vaccine uptake among adults, are available online at https://github.com/abilinski/BackToSchool2/tree/master/5 - Drafts/Paper 3.)

RESULTS

Over 30 days in the simulated elementary school, the probability of at least one in-school SARS-CoV-2 transmission and the total number of projected infections in the immediate school community varied widely (Figures 1 and 2). Assuming that simple ventilation and handwashing are 40% effective, with the delta variant and no student vaccination, if decision-makers seek to keep the monthly probability of an in-school transmission below 50%, additional mitigation (e.g., masking) would need to be added at a community incidence of approximately 4/100,000/day (Figure 1, blue shaded areas). Using a more lenient threshold, to maintain total additional infections in the immediate school community below an average of 10 per month, masks would be needed at a community incidence of approximately 16/100,000/day (Figure 2, blue shaded areas); the community incidence cutoff is lower at more conservative thresholds (e.g., at a threshold of 5 cases per month, the cutoff is 8/100,000/day). Once students are vaccinated, thresholds shift substantially higher.

DISCUSSION

Despite high adult vaccination, the risks of both in-school SARS-CoV-2 transmission and resulting infections among students, educators/staff, and their household members remain high when the delta variant predominates and students are unvaccinated. Mitigation measures or vaccinations for students when available can substantially reduce these risks. Risks related to SARS-CoV-2 infection are only one

of many factors guiding K-12 school planning, and interpretation of model results should be limited by the uncertainty in many of the parameters, including the effectiveness of individual mitigation interventions, and the limited scope of the model beyond the school community. Additionally, the assumed case detection rate of 33% may be too high for some communities, especially in areas with decreased testing capacity, which would generally imply lower mitigation cutoffs based on the observed community incidence. These findings underscore the potential role for responsive plans, where mitigation is deployed based on local COVID-19 incidence and vaccine uptake.

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FIGURE LEGENDS

Figure 1 legend: The blue-to-yellow color scale depicts the model-predicted probability of at least one in-school SARS-CoV-2 transmission over a 30-day period. Panels reflect increasingly transmissible variants from left to right, and increasing student vaccination coverage from top to bottom. All panels reflect 70% vaccine uptake among adults (educators/staff and adult members of student and educator/staff households). The horizontal axis shows observed community COVID-19 incidence in cases/100,000 people per day. The vertical axis shows mitigation effectiveness, applied as a relative risk reduction to the fully unmitigated attack rate for each variant. Bands of mitigation effectiveness reflect approximate assumptions for three types of interventions: A includes simple ventilation and handwashing only; B adds universal masking of students and educators/staff to A; C reflects the full package of interventions widely used in the 2020-21 school year (adding distancing, daily surface cleaning, cohorting, and restrictions on shared items). The contour lines represent thresholds for different probability levels; probabilities are lower than the threshold above the contour line and higher below it. The arrows indicate the community COVID-19 incidence rate at which a school might opt to move to the next more intensive mitigation strategy (i.e., 40% to 70% and 80% to 90% effectiveness), if the goal is to maintain the probability of the one in-school transmission per month below 50%.

Figure 2 legend: The blue-to-yellow color scale depicts the average additional number of model-predicted infections over 30 days among members of the immediate school community (defined as students, educators/staff, and their household members) with in-person learning compared to a counterfactual scenario of remote-only learning. These are shown because decision-makers may tolerate some risk of in-school transmissions (Figure 1), but may wish to avoid a large increase in total infections among members of the immediate school community. Panels reflect increasingly transmissible variants from left to right, and increasing student vaccination coverage from top to

bottom. All panels reflect 70% vaccine uptake among adults (educators/staff and adult members of student and educator/staff households). The horizontal axis shows observed community COVID-19 incidence in cases/100,000 people per day. The vertical axis shows mitigation effectiveness, applied as a relative risk reduction to the fully unmitigated attack rate for each variant. Bands of mitigation effectiveness reflect approximate assumptions for three types of interventions: A includes simple ventilation and handwashing only; B adds universal masking of students and educators/staff to A; C reflects the full package of interventions widely used in the 2020-21 school year (adding distancing, daily surface cleaning, cohorting, and restrictions on shared items). The contour lines represent thresholds for different numbers of average predicted cases; numbers are lower than the threshold above the contour line and higher below it. The arrows indicate the community COVID-19 incidence rate at which a school might opt to move to the next more intensive mitigation strategy (i.e., 40% to 70% and 80% to 90% effectiveness), if the goal is to maintain the total number of additional infections in the immediate school community below 10 in a 30-day period.

Figure 1: Model-predicted probability of at least one in-school SARS-CoV-2 transmission over 30 days in a simulated elementary school setting.

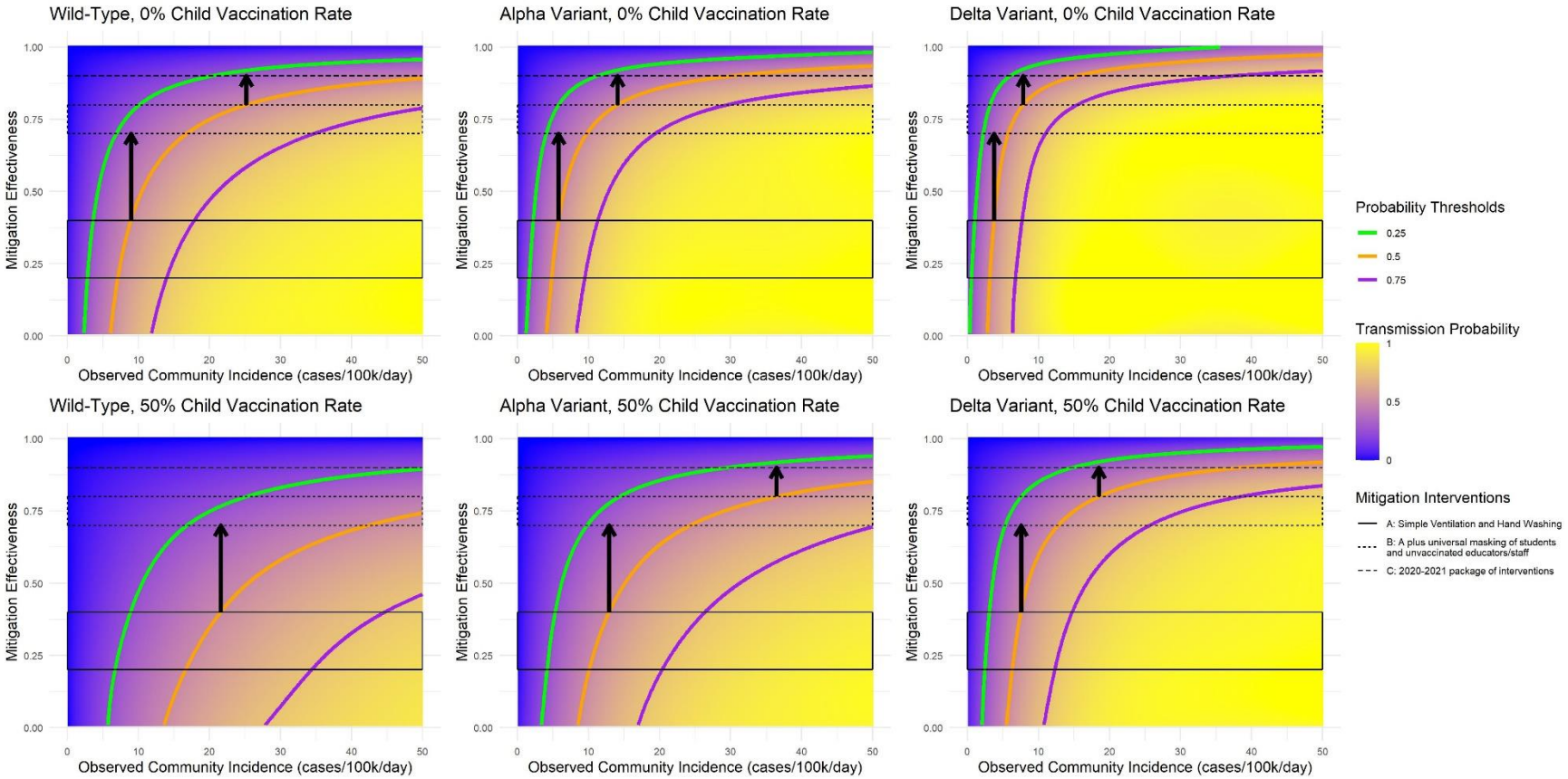
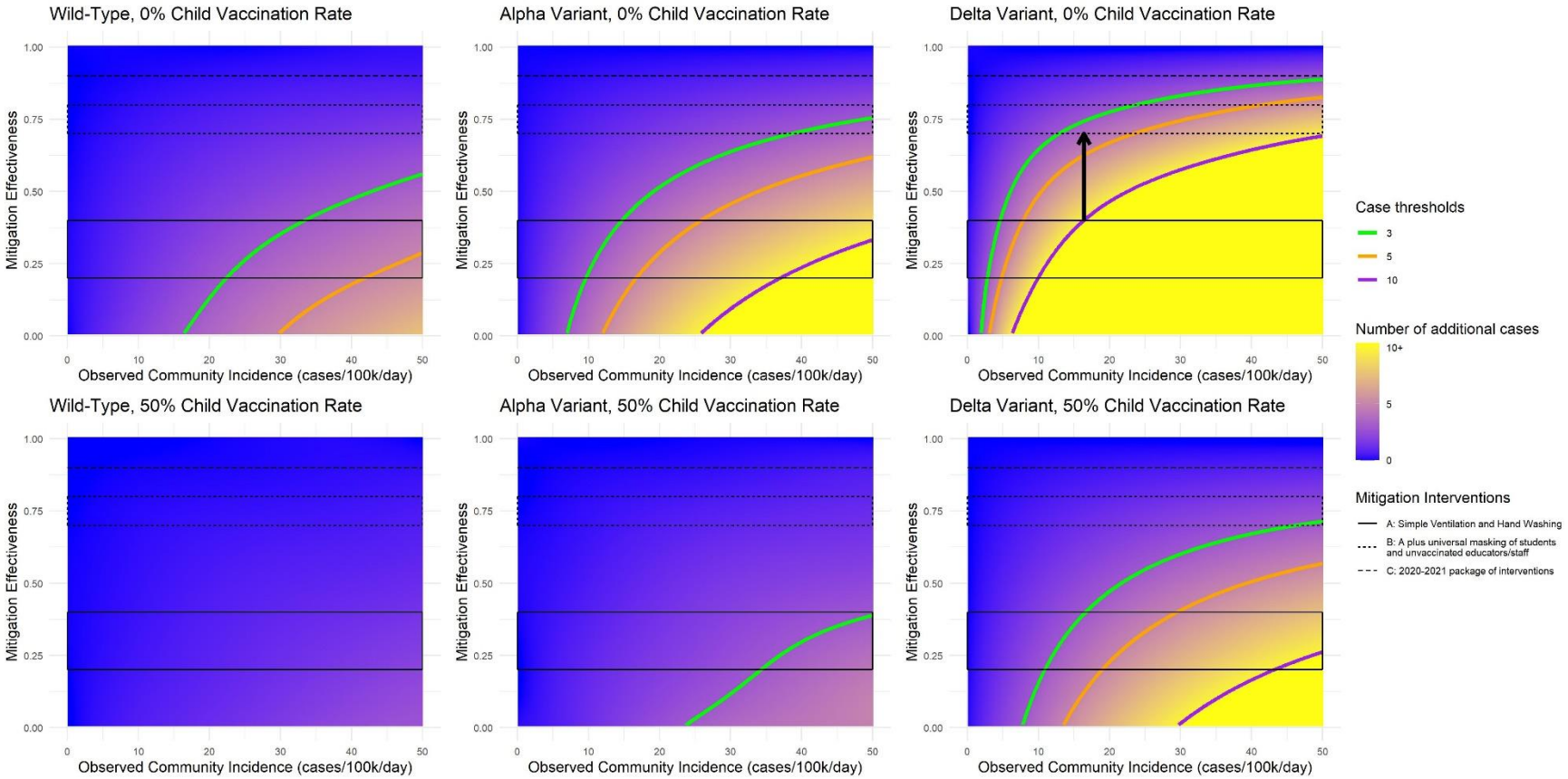


Figure 2: Model-predicted average number of additional cases over 30 days in the immediate school community (students, educators/staff, and their household members) during in-person instruction compared to remote instruction in the simulated elementary school setting.



REFERENCES

1. Centers for Disease Control and Prevention. Guidance for COVID-19 Prevention in K-12 Schools. Published July 9, 2021. Accessed July 16, 2021. https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/k-12-guidance.html
2. Bilinski A, Salomon JA, Giardina J, Ciaranello A, Fitzpatrick MC. Passing the Test: A Model-Based Analysis of Safe School-Reopening Strategies. *Ann Intern Med*. Published online June 8, 2021:M21-0600. doi:10.7326/M21-0600
3. Centers for Disease Control and Prevention. Science Brief: Transmission of SARS-CoV-2 in K-12 Schools and Early Care and Education Programs. Centers for Disease Control and Prevention. Published July 9, 2021. Accessed July 28, 2021. https://www.cdc.gov/coronavirus/2019-ncov/science/science-briefs/transmission_k_12_schools.html