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Estimated Transmission Outcomes and Costs of SARS-CoV-2 Diagnostic Testing, Screening, and Surveillance Strategies Among a Simulated Population of Primary School Students

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IMPORTANCE In addition to illness, the COVID-19 pandemic has led to historic educational disruptions. In March 2021, the federal government allocated $10 billion for COVID-19 testing in US schools.

OBJECTIVE Costs and benefits of COVID-19 testing strategies were evaluated in the context of full-time, in-person kindergarten through eighth grade (K-8) education at different community incidence levels.

DESIGN, SETTING, AND PARTICIPANTS An updated version of a previously published agent-based network model was used to simulate transmission in elementary and middle school communities in the United States. Assuming dominance of the delta SARS-CoV-2 variant, the model simulated an elementary school (638 students in grades K-5, 60 staff) and middle school (460 students grades 6-8, 51 staff).

EXPOSURES Multiple strategies for testing students and faculty/staff, including expanded diagnostic testing (test to stay) designed to avoid symptom-based isolation and contact quarantine, screening (routinely testing asymptomatic individuals to identify infections and contain transmission), and surveillance (testing a random sample of students to identify undetected transmission and trigger additional investigation or interventions).

MAIN OUTCOMES AND MEASURES Projections included 30-day cumulative incidence of SARS-CoV-2 infection, proportion of cases detected, proportion of planned and unplanned days out of school, cost of testing programs, and childcare costs associated with different strategies. For screening policies, the cost per SARS-CoV-2 infection averted in students and staff was estimated, and for surveillance, the probability of correctly or falsely triggering an outbreak response was estimated at different incidence and attack rates.

RESULTS Compared with quarantine policies, test-to-stay policies are associated with similar model-projected transmission, with a mean of less than 0.25 student days per month of quarantine or isolation. Weekly universal screening is associated with approximately 50% less in-school transmission at one-seventh to one-half the societal cost of hybrid or remote schooling. The cost per infection averted in students and staff by weekly screening is lowest for schools with less vaccination, fewer other mitigation measures, and higher levels of community transmission. In settings where local student incidence is unknown or rapidly changing, surveillance testing may detect moderate to large in-school outbreaks with fewer resources compared with schoolwide screening.

CONCLUSIONS AND RELEVANCE In this modeling study of a simulated population of primary school students and simulated transmission of COVID-19, test-to-stay policies and/or screening tests facilitated consistent in-person school attendance with low transmission risk across a range of community incidence. Surveillance was a useful reduced-cost option for detecting outbreaks and identifying school environments that would benefit from increased mitigation.

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Supplemental content

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In kindergarten through 12th grade education, COVID-19 has posed risks to student, teacher, and family health; school operations; and local communities. As of May 2021, about a third of US students were not offered the option of full-time in-person attendance,[1] and virtual and hybrid models imposed substantial burdens during the 2020-2021 school year.[2-8] Districts are seeking to maintain safe in-person education for the 2021-2022 school year, despite high transmissibility of newer variants, record hospitalizations among children during the latter half of 2021,[9] and the potential for seasonal increases in transmission.[10-15]

Frequent, widespread SARS-CoV-2 testing is now a viable option,[14,15] and the federal government has allocated $10 billion for diagnostic and screening tests in US schools.[16] A key question is how to best allocate this funding to maximize in-person educational time while both controlling COVID-19 transmission and managing financial and operational costs. Centers for Disease Control and Prevention (CDC) guidelines for school reopening divide testing into 3 categories.[17] Diagnostic testing targets individuals showing symptoms of COVID-19 as well as close contacts of someone with diagnosed infection. Screening entails routine asymptomatic testing of the full school population to identify active cases and prevent onward transmission. By contrast, surveillance testing involves sampling a fraction of the population to identify potential outbreaks and trigger a public health response (eg, schoolwide screening or classroom closures). Schools require guidance on how to best allocate resources toward different testing objectives.

Previous modeling analyses have projected transmission-related outcomes associated with school attendance under a variety of mitigation measures but did not compare different testing strategies or explore their monetary or operational costs.[18-21] In this article, we address several questions regarding the role of testing in educational settings: first, to what extent can different testing strategies limit school-associated transmission of SARS-CoV-2 while sustaining in-person learning? How frequent are quarantines arising from different strategies, and to what extent can testing of contacts avert days out of school? How do testing costs compare with the financial costs associated with school absences or closures? How might these outcomes vary depending on local transmission risk? We focus on elementary and middle schools because of higher childcare costs and later vaccine rollout for these groups.[22] We use an agent-based simulation of COVID-19 transmission to compare outcomes associated with different testing strategies, with a particular focus on infections, in-person educational days, and costs.

Key Points

Question What are the costs and benefits of COVID-19 testing in primary schools (students in kindergarten through eighth grade)?

Findings In this decision analytic model of COVID-19 transmission in simulated US elementary and middle schools, test-to-stay strategies were associated with reduced quarantine time but minimal increases in transmission across all levels of community incidence. Compared with no testing, weekly screening was associated with substantial reductions to in-school transmission when community incidence was high and had lower societal cost than remote instruction, while an adaptive surveillance strategy offered a more efficient option to detect outbreaks when local incidence was lower or poorly characterized.

Meaning With federal funding available, schools should use COVID-19 testing to facilitate in-person education, adapting their testing strategy to changes in local COVID-19 risk.

Methods

This study was deemed not human subjects research by the Mass General Brigham institutional review board (2021P002876). Reporting conforms to the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) guidance.[23]

We used a previously validated agent-based simulation model (ie, a model that explicitly simulates individuals and their interactions) to estimate the effects of different testing strategies in elementary and middle schools in the United States (eMethods and eFigure 1 in the Supplement).[18] When individuals interacted with an agent (ie, person) infected with SARS-CoV-2, transmission risk was proportional to duration and intensity of exposure. In schools, individuals had sustained daily contact with a classroom cohort as well as additional interactions with other members of the school community. Outside of schools, in addition to an exogenous community infection risk, individuals interacted with household members, and each day that students did not attend school, families mixed with another randomly chosen family to reflect learning pods or social interactions.

The model drew stochastic outcomes assuming an average latent period of 3 days before the onset of infectiousness, 2 days of presymptomatic transmission if symptoms develop,[24,25] total infectious time of 5 days,[26-29] and overdispersion of infectivity in adolescents and adults[26,30] (eTable 1 in the Supplement). We assumed that adults and adolescents with fully asymptomatic disease transmit COVID-19 at half the rate of those with any symptoms.[31] In the absence of vaccination, children younger than 10 years were half as susceptible and half as infectious as symptomatic adolescents and adults.[32-36]

We modeled circulation of the delta variant, assuming twice the transmissibility of wild-type virus,[37,38] and, except in a sensitivity analysis, we assumed use of other mitigation measures (eg, masking and ventilation). We further assumed that 90% of teachers and staff and 50% of middle school students were vaccinated with an 80% efficacious vaccine.[39-41] In the eMethods in the Supplement and previous work,[18] we describe additional details of model structure, assumptions, and data sources.

Testing Strategies

Scenarios Without Testing

We first modeled 3 scenarios without school-based testing: (1) 5-day in-person attendance (the base case and the schedule assumed for all testing scenarios), (2) a hybrid model in which half of each class attends school on Monday/Tuesday and the other half on Thursday/Friday, and (3) fully remote learning. In these scenarios, we assumed that individuals with clinically identifiable symptoms isolated and underwent testing outside of school on the day symptoms appeared, that they received results within 48 hours of symptom onset, and that the classroom cohort of a diagnosed COVID-19 case quarantined for 10 days.[42]

Diagnostic Testing

The test-to-stay strategy altered both how the school managed the asymptomatic contacts of diagnosed COVID-19 cases and how students and staff with symptoms of potential COVID-19 were managed. After exposure to a confirmed case, rather than quarantining, contacts remained in school and received a rapid test each school day for 1 week, isolating only if they tested positive. (This resembles the Test and Stay program used in Massachusetts and elsewhere.[43,44]) In addition, individuals with symptoms of possible COVID-19 took a rapid test each day they had symptoms, isolating only after testing positive. We assumed 80% test sensitivity during the infectious period, and 100% specificity following a second confirmatory test.[45,46] We present both quarantine and test-to-stay versions of each of the 5-day in-person scenarios modeled.

Screening and Surveillance

Screening entailed weekly polymerase chain reaction (PCR) screening (on Mondays) of all students and teachers, with 90% coverage, 90% sensitivity during infectiousness, and a 24-hour test turnaround time. Surveillance entailed random weekly PCR testing (90% sensitivity) of 10% to 20% of the school population. Because of the small proportion of the school tested, if 1 or more cases were detected during surveillance, 90% of the school was screened the following day, including vaccinated individuals, and if further cases were found, the school continued weekly schoolwide screening (90% coverage) rather than surveillance for the remainder of the month. (We discuss considerations for threshold selection further in the eMethods in the Supplement.)

Based on recent CDC guidance,[13] we assumed that vaccinated individuals do not quarantine, but given recommendations to test vaccinated contacts,[13] we included them in test-to-stay measures and schoolwide screening. To maximize power, surveillance sampled only unvaccinated individuals.

Costs

We based screening and surveillance costs on pooled PCR testing of 8 specimens (eMethods in the Supplement). Costs of PCR testing were estimated at $40 per assay (eTable 1 in the Supplement). Rapid testing for the test-to-stay scenario cost $6 per assay. For both scenarios, we assume an $8 per-person cost of labor and supplies for nasal swab collection. In a sensitivity analysis, we also considered rapid testing with confirmatory PCR for screening and surveillance.

In comparing the costs associated with remote learning and the costs of testing, we took a modified societal perspective that focused on childcare or parent productivity costs (eMethods and eTable 1 in the Supplement); to be conservative with respect to the benefits of testing programs, we did not include educational and other student costs (which are likely to accrue but difficult to estimate) nor the health care–related costs of COVID-19. For remote and hybrid education for all students and for middle school quarantine/isolation, we estimated the cost of a day of remote instruction based on the average cost of group childcare (eTable 1 in the Supplement). For unplanned days that elementary students stayed at home for quarantine/isolation, we estimated costs based on the average childcare worker's wages over a 7-hour day to account for the higher costs of last-minute scheduling or inability to use group childcare (eTable 1 in the Supplement).[47] Although parents may choose to supervise remote learning at home, we assumed that the average productivity loss of supervising at-home learning was comparable with childcare costs.

Outcome Estimation, Reporting, and Sensitivity Analysis

For each scenario, we ran the model 1000 times for 30 days each (with no temporal discounting) and estimated the following outcomes over a 30-day period: average cumulative true incidence of SARS-CoV-2 infection among staff and students, cumulative cases detected, detection fraction (the ratio between cases detected and true infections), and proportion of weekdays spent at home (for unplanned quarantine/isolation or for planned days at home dictated by the virtual/hybrid schedule). Sensitivity analyses for multiple parameters evaluated uncertainty in the infections prevented by different strategies. Model code is publicly available as an R package (implemented in version 4.0.2) at https://github.com/abilinski/BackToSchool2.

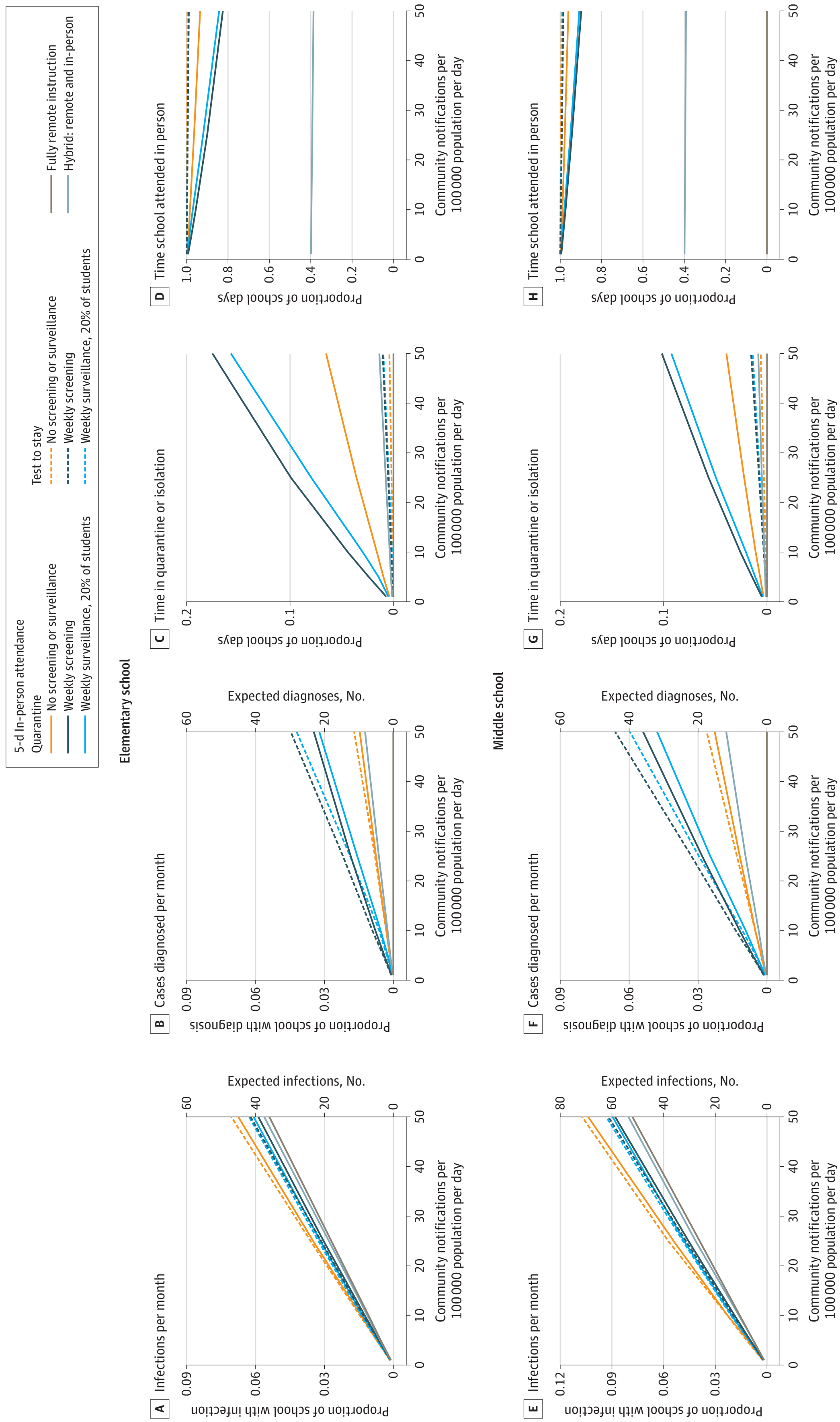
Results

Simulated Effects of In-Person School Attendance With COVID-19 Incidence

Figure 1 and eTable 2 in the Supplement show estimated 30-day incidence, case detection, and school attendance outcomes in different testing scenarios among 638 students and 60 staff in a simulated elementary school with no student vaccination or 460 students and 51 staff in a simulated middle school with 50% vaccine coverage. At the elementary school level, compared with fully remote instruction, 5-day in-person attendance with quarantine was associated with an estimated average of 2.3 additional infections per school per month at a community notification rate of 10 per 100 000 population per day (30% increase) and 9.4 additional infections at 50 community notifications per 100 000/d (25% increase) (Figure 1A). Under the test-to-stay strategy, slightly more transmission occurred; eg, an estimated mean of 11.6 infections rather than 9.4 infections over the remote instruction baseline at 50 community notifications per 100 000/d.

In the middle school with 50% vaccination, 5-day attendance with quarantine was associated with 4.9 additional infections per school per month on average (45% increase) at 10 community notifications per 100 000/d and 17.9 infections (33% increase) at 50 community notifications per 100 000/d

Figure 1. One-Month Cumulative Incidence, Case Detection, Quarantine/Isolation, and In-Person Schooling for Multiple Testing Strategies



Results are shown over a range of community COVID-19 notification rates for an elementary school of 638 students and a middle school of 460 students. For the infections and diagnoses, the outcomes do not include infections among others in the community that may result from school-associated transmission. The detection fraction as reported in the text reflects the absolute number of diagnosed cases (B and F) divided by true cumulative incidence (A and E). For easier viewing of small differences, eFigure 14 in the Supplement transforms panels A and E to show the differences between remote schooling and the other scenarios.

(Figure 1E). The test-to-stay strategy was associated with 20.4 infections, rather than 17.9 infections over remote instruction at 50 community notifications per 100 000/d.

Simulated Effects of Transmission With Weekly Screening and Surveillance

With weekly screening of all students and teachers, and with isolation of the identified cases and quarantine of their unvaccinated classroom contacts, the incremental increase in transmission associated with school attendance compared with remote learning decreased. In a community with 10 notifications per 100 000/d, when weekly screening was in place, the excess incidence associated with school attendance was an estimated 50% lower (1.1 fewer cases per school per month) in elementary school and 57% lower (2.8 fewer cases) in middle school. A slightly greater estimated proportion of school-associated transmission was prevented by screening at higher community incidence: for example, 71% (8.2 cases) in an elementary school at 50 community notifications per 100 000/d (Figure 1A and E and eTable 2 in the Supplement).

Weekly surveillance testing, at relatively low levels of community incidence (≤25 cases/100 000/d), was associated with a large projected transmission benefit relative to the number of students tested (Figure 1A and E and eTable 2 in the Supplement): for example, a 21% mean reduction in excess transmission with weekly surveillance of 20% of students in an elementary school at 10 community notifications per 100 000/d (ie, about half of the 49% reduction seen with weekly 90% screening); 36% of model runs obtained enough positive results to switch from 20% surveillance to schoolwide screening for the remainder of the month (eFigure 2 in the Supplement). At higher community incidence, surveillance was associated with nearly the same projected transmission benefit as universal screening, but this was attributable to a high probability of converting to universal screening (reaching 98.3% at 50 community notifications/100 000/d) (eFigure 2 in the Supplement).

As in the no-screening scenario, test to stay was associated with a slight reduction in the projected transmission benefits of screening or surveillance in both elementary and middle schools (Figure 1E and eTable 2 in the Supplement).

Simulated Effects of Case Detection and In-Person Learning Days Lost With Screening and Surveillance

Screening and surveillance were associated with fewer infections but with a greater number of cases detected (by more than a factor of 2 for weekly screening). Thus, without a test-to-stay policy, the days spent in quarantine or isolation also increased (Figure 1C and G). For example, weekly screening in an elementary school was associated with an estimated average of 1.0 quarantine/isolation days per student per month at 10 community notifications per 100 000/d and 3.9 at 50 community notifications per 100 000/d (Figure 1C). In middle school, quarantine of only unvaccinated students resulted in fewer days of quarantine or isolation per student despite similar incidence (Figure 1F and G).

Test to stay had the benefit of minimal quarantine and isolation, estimated at less than 0.25 days per student per month even in scenarios with high community transmission and maximal case detection through weekly screening.

Costs

The testing costs of weekly screening began at an estimated $69 per student per month at low community incidence (**Figure 2**); as incidence increased, the increased cost of deconvoluting positive pools was partially offset by quarantine-related reductions in the number of tests performed (eFigures 3 and 4 in the Supplement). Above community notification rates of 25 per 100 000/d, surveillance and screening had similar costs because positive surveillance test results regularly triggered schoolwide testing (Figure 2).

Accounting for childcare during quarantine and isolation, the estimated societal costs associated with weekly screening in an elementary school ranged from $109 per student per month at community notification rates of 5 or less per 100 000/d, to $368 per student/mo at a community notification rate of 50 per 100 000/d (eFigures 5 and 6 in the Supplement). A test-to-stay strategy was associated with greater diagnostic costs but lower combined costs of testing plus childcare at all community notification rates (Figure 2). The estimated costs of a rapid antigen screening strategy were similar to those of pooled PCR screening (eFigure 7 in the Supplement).

Cost per Infection Averted

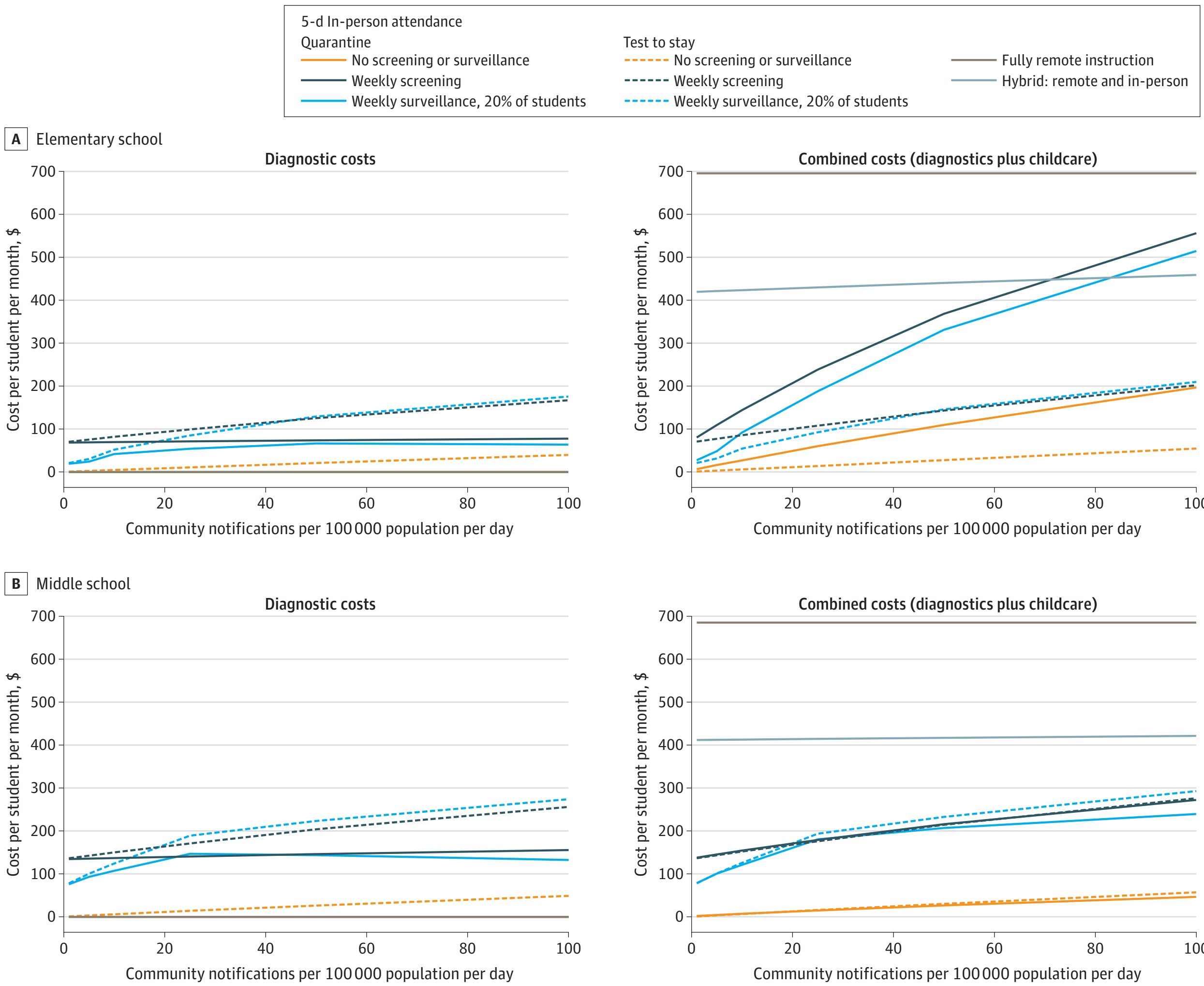
In the elementary school, the estimated costs of weekly screening per infection directly averted among students and teachers/staff were less than $16 000 at community notification rates of 25 or more cases per 100 000/d; these increased to $40 000 to $60 000 per infection averted at 10 cases per 100 000/d and more than $300 000 per infection averted at 1 case per 100 000/d. In the middle school, greater risk of transmission offset the comparative inefficiency of screening vaccinated students, resulting in similar costs per infection averted as the elementary school had (**Figure 3**). Cost per infection averted was similar for rapid antigen screening and lower in a high-transmission or unmasked school setting (eFigures 8 and 9 in the Supplement).

Sensitivity Analysis

The estimated number of infections averted by screening, with or without test to stay, was approximately 3 times higher in schools without masking than in schools where screening was added to mask use, in both elementary and middle schools (eFigures 4-5, 9, and 11-12 and eTable 3 in the Supplement). Infections averted by screening were also highly sensitive to vaccine coverage and vaccine efficacy (**Figure 4**, **Figure 5**, and eFigures 10-12 and eTable 3 in the Supplement). The estimated number of infections averted was slightly lower if screening occurred later in the week or with a less sensitive test and was less than 25% higher if screening occurred twice weekly in schools with masking or other mitigation measures (Figure 4 and Figure 5).

The transmission increases associated with the test-to-stay strategy were largest in the elementary school if the rapid test had low sensitivity for detecting infectious individuals or

Figure 2. Costs Associated With In-School COVID-19 Testing and/or Out-of-School Childcare for Different Risk-Reduction Strategies at Varying Community Notification Rates



if the community notification rate was high (Figure 4) and in the middle school if vaccination coverage was low or testing was only offered to unvaccinated individuals (Figure 5). For surveillance, reducing the weekly percentage tested to 10% (vs 20%) was associated with smaller reductions in transmission but still allowed a response to large outbreaks; surveillance was more beneficial with less in-school mitigation or more transmissible variants (eFigure 2 in the Supplement).

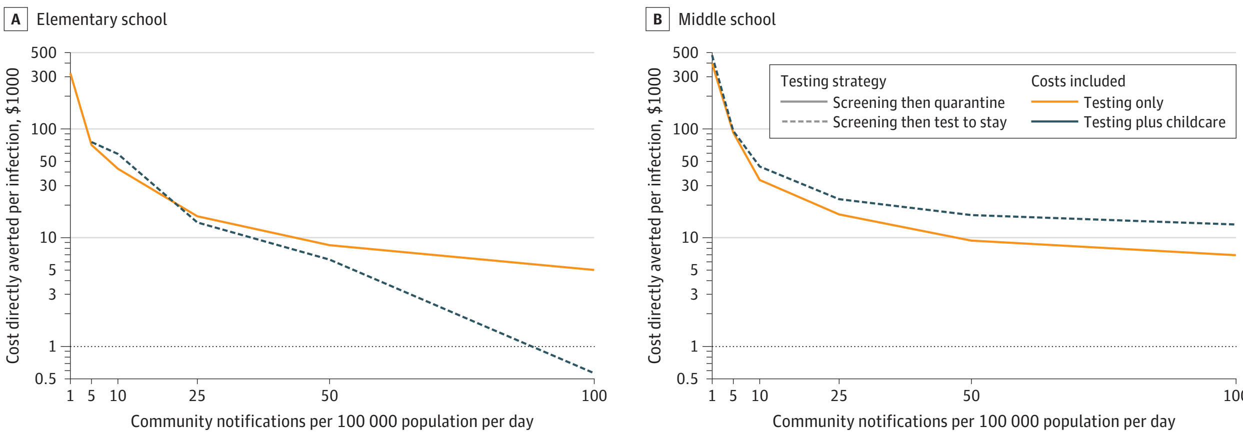
Discussion

This modeling study of a simulated population of primary school students and simulated transmission of COVID-19 highlights that well-designed COVID-19 testing can help maintain safe, 5-day in-person education despite a highly transmissible (delta) variant. In particular, we underscore the importance of considering multiple dimensions of cost in school reopening plans. While school-based testing increases expenditures, these costs may be offset societally by reducing the burden of COVID-19–related childcare costs currently borne by parents and caregivers and costs associated with lost educational time.

Gains are particularly pronounced for expanded diagnostic testing. We project that test to stay is associated with only minor increases in transmission, even at high community case rates. Such estimates are consistent with a 2021 randomized controlled trial of test-to-stay programs in the United Kingdom, which were layered on top of twice-weekly screening.[48] We further estimate that test-to-stay strategies have lower societal costs than quarantine-based strategies and could maintain student absences to less than 0.25 school days per month. Additional benefits of test to stay include situational awareness of in-school transmission that can inform mitigation policies as well as the option to adopt a broad definition of close contact without associated loss of school time.

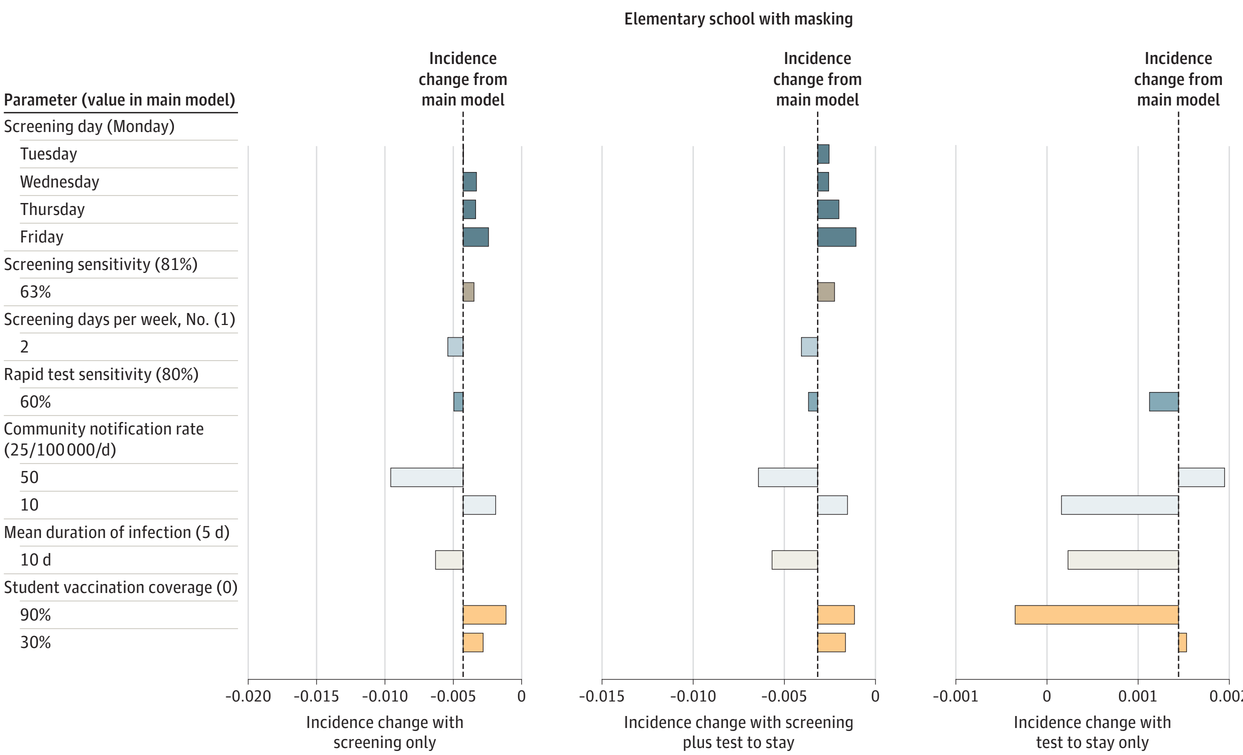
Our main test-to-stay specification allowed both close contacts and symptomatic individuals to attend school after a negative test. In practice, most schools set more conservative policies for symptomatic students, requiring them to remain home

Figure 3. Cost per Infection Directly Prevented Among Students/Staff, Compared With a 5-Day In-Person Schedule With No In-School Testing and High Mitigation



Plots show the incremental cost per infection directly averted among students and staff. For testing costs, we show the strategy of weekly screening in which exposed contacts quarantine at home, which dominates the test-to-stay strategy. By dominates, we mean that if optimizing over test costs only, it is strictly higher value to quarantine contacts rather than implement test to stay. Likewise, for combined costs of testing plus childcare, we show the strategy of weekly screening with exposed contacts undergoing daily rapid tests to stay at school, which dominates at-home quarantine. For alternative scenarios with rapid tests and/or lower in-school mitigation, see eFigures 8 and 9 in the Supplement.

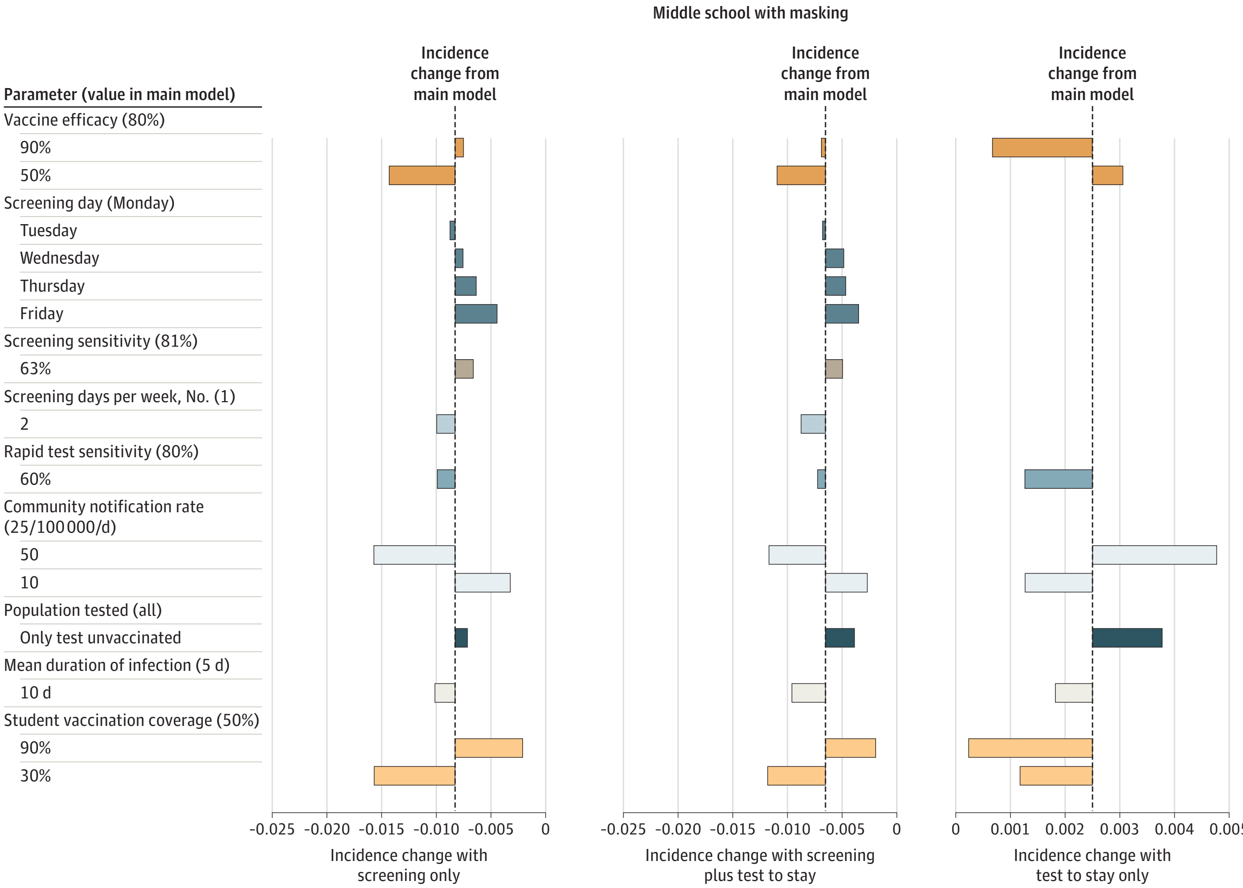
Figure 4. Sensitivity Analyses With Varying Parameter Values in an Elementary School



Incidence change is estimated as a difference in the proportion of the school's students and teachers infected with COVID-19 per month, comparing the specified testing strategy to 5-day school attendance without testing. See eFigure 11 in the Supplement for scenarios without masking.

for certain significant symptoms (eg, fever), regardless of etiology, or if they have symptoms strongly indicative of COVID-19 (eg, loss of taste or smell). This renders our analysis conservative with respect to the simulated effect of test to stay with COVID-19 transmission; in sensitivity analyses, we show that offering test to stay only to contacts maintains most benefits with respect to learning days lost (eFigure 13 in the Supplement).

Figure 5. Sensitivity Analyses With Varying Parameter Values in a Middle School



Incidence change is estimated as a difference in the proportion of the school's students and teachers infected with COVID-19 per month, comparing the specified testing strategy to 5-day school attendance without testing. See eFigure 12 in the Supplement for scenarios without masking.

We also provide information about the benefits and costs of 2 additional testing strategies: screening and surveillance. While previous analyses have documented that weekly screening can help control transmission, this analysis adds the finding that under conservative assumptions, 5-day in-person learning with screening is expected to be cost-saving from a societal perspective, compared with the hybrid or remote models often used in 2020-2021.[18,20,49] Cost savings persist across levels of community transmission up to 100 cases per 100 000 population per day, even when improved case detection from the screening program increases the time that students spend in quarantine. In addition, although limited data on implementation of various measures by state or county suggest that schools are likely to implement simpler measures such as masks before they adopt testing, our sensitivity analyses indicate that screening or surveillance could offer the greatest benefit in settings with low uptake of other mitigation measures.

In 2020-2021, screening was implemented in countries such as Germany, Austria, Norway, and the United Kingdom,[50-52] as well as some US states,[52,53] but its role remains debated. We find that the value of screening varies substantially across different levels of community transmission, between elementary and middle schools, and by school attack rate. In turn, school attack rate is influenced by factors including mitigation measures (masking, ventilation, and distancing), vaccination uptake, and the properties of emerging variants of concern. As a result, screening capacity may be useful as an "insurance policy" to maintain in-personal instructional time if cases increase during fall/winter 2021 and would be most efficiently targeted toward areas with low vaccination coverage or inconsistent adherence to other mitigation precautions.

In simulating the effect of testing with transmission, we did not include the downstream infections averted beyond students and staff, the medical costs associated with SARS-CoV-2 infection, or other dimensions of cost (eg, educational). Our estimates of cost per infection averted are therefore likely conservative, and when interpreting them, a school community's willingness to pay per averted case should consider onward transmission risk. For example, setting the value per statistical life of $8 million,[54] communities would be willing to invest $48 000 to avert a downstream infection in an unvaccinated person aged 50 to 64 years and $720 000 per infection averted in those older than 65 years.[55] Other important planning inputs might include local hospital capacity and any increased pediatric risks that may be associated with new variants. However, the widespread availability of external federal funding may render the financial costs of testing less consequential for districts than logistical and practical considerations; smaller districts with fewer resources may require additional support to implement testing programs.[15]

For districts concerned about in-school transmission but without capacity to perform regular screening, weekly surveillance of 10% to 20% of the school population may offer a middle ground. Surveillance (with conversion to weekly screening when cases are identified) can reduce the risk of large outbreaks and may allow schools to reduce testing costs when local incidence is low. However, surveillance of a small portion of the school population is likely to miss early outbreaks and requires regularly adapting school procedures. Therefore, the benefit of surveillance is largest when local testing is sparse (making it difficult to know how community case notification maps to school incidence), local incidence is rapidly changing, or there is high uncertainty in the school attack rate. Beyond transmission effects, the real-time information provided by either screening or surveillance may have value even at low incidence levels, by providing reassurance to educators and parents.

Limitations

There are a number of limitations to this analysis. Like all models, this analysis relies on assumptions about transmission dynamics, test performance, and public health responses, which are uncertain and often in flux. Public health guidance continues to evolve, particularly in terms of defining close contacts in the context of new variants and recommended precautions for vaccinated individuals, which may affect costs and benefits of testing strategies. In addition, our model does not address the operational aspects of specimen collection, laboratory transport, and reporting of results, which some schools have navigated successfully but nevertheless may pose barriers to adoption.[15] Nevertheless, this work highlights that flexible, strategic testing can help ensure stable 5-day in-person education throughout the 2021-2022 school year.

Conclusions

In this modeling study of transmission of COVID-19 in simulated US elementary and middle schools, screening tests facilitated in-person schooling with limited transmission risk across a range of community incidence, and test-to-stay policies were associated with increased school attendance but little incremental transmission. Surveillance was a useful, reduced-cost option for detecting outbreaks and identifying school environments that could benefit from increased mitigation.

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Author Contributions: Drs Bilinski and Kendall had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Bilinski, Ciaranello, Fitzpatrick, Giardina, Salomon, Kendall.
Acquisition, analysis, or interpretation of data: All authors.
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Additional Information: Model code and output are publicly available on GitHub (https://github.com/abilinski/BackToSchool2).

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Supplemental Online Content

Bilinski A, Ciaranello A, Fitzpatrick MC, et al. Estimated transmission outcomes and costs of SARS-CoV-2 diagnostic testing, screening, and surveillance strategies among a simulated population of primary school students. *JAMA Pediatr*. Published online April 20, 2022. doi:10.1001/jamapediatrics.2022.1326

This supplemental material has been provided by the authors to give readers additional information about their work.

eMethods

Model Structure

We implemented a previously published SEIR model of COVID-19 transmission.[1] For a simulated elementary school (638 students grades K-5, 60 staff) and middle school (460 students grades 6-8 , 51 staff), we generated households from synthetic population data and grouped students into fixed classroom cohorts with a primary teacher.[2] Briefly, when individuals interacted with an agent (i.e. person) infected with SARS-CoV-2, transmission risk was proportional to duration and intensity of exposure. The model drew stochastic outcomes assuming an average incubation period of three days prior to the onset of infectiousness, two days of pre-symptomatic transmission if symptoms develop,[3,4] total infectious time of five days,[5–8] and overdispersion of infectivity in adolescents and adults (Table 1).[5,9] We assumed that adults with fully asymptomatic disease transmit COVID-19 at half the rate of those with any symptoms.[10] Based on data from household contact tracing studies, we further specified that, in absence of vaccination, children under 10 were half as susceptible as symptomatic adolescents and adults.[11–15] However, they experienced exogenous infection risk similar to the overall population due to adults' relatively high vaccination coverage.

Beyond interactions with infectious agents within the simulation, students, staff, and their families had a probability of becoming infected through other community interactions equivalent to community per capita daily incidence assuming a 33% case detection rate. In vaccinated individuals, this risk was reduced by 80%; among unvaccinated adults, we upweighted community risk such that adults overall matched the community rate on average.

In scenarios without "test to stay", symptom-driven COVID diagnostic testing still occurred outside of the school environment: individuals with COVID-19 who developed clinically-recognizable symptoms were assumed to self-isolate from out-of-household contacts (including staying home from school) and to obtain testing in the community. Results became available 48 hours after the first appearance of symptoms, at which point classrooms were notified and quarantined for 10 days. Symptom-driven community-based testing, and self-isolation of symptomatic individuals who had not been tested since symptom onset outside of test-to-stay strategies, were assumed to occur regardless of in-school screening practices. We assumed that isolation and/or diagnostic testing for symptoms caused by non-COVID etiologies occurred in 1% of students and staff each week, based on survey estimates of student absenteeism and assuming that about half of reported absenteeism is due to illness.[16] Costs of non-school-based diagnostic testing were excluded in order to focus on the tests costs incurred by the school; this exclusion results in conservative estimates of the societal cost savings of the test-to-stay strategy.

For in-school testing, we assumed separate anterior nasal swab specimens were collected from each person, samples from up to 8 specimens from a single classroom were pooled and run as a single PCR, and residual individual specimens were held for testing if the corresponding pool was positive. We further assumed negligible loss of sensitivity to detect active infection from pooled testing.[17,18] Results were available 24 hours after testing. When a pooled specimen yielded a positive result, all individual specimens that had been included in the pool were immediately tested separately using PCR to identify the positive individual(s).

Of note, when testing occurs out of school, turnaround time is longer than for in-school testing (48 hours vs. 24 hours) because in the former case, we model the time from symptom onset to PCR results. This includes the time required to decide to test and to access testing, in addition to the turnaround time for the test itself. In addition, we assume that schools with screening programs will work with a lab that can handle their consistent volume of testing with rapid turnaround.

Model Parameterization and Calibration

Model parameterization is discussed at length in the Supplement of [1]. Briefly, we first identified household attack rates (including differential susceptibility and infectiousness of young children).[19–21] We adjusted these for the length of time spent in school and reduced infectiousness of asymptomatic individuals to estimate attack rates with no or minimal mitigation.[10] We then further adjusted them for a range of mitigation strategies. To partially validate our model, we compared our estimates of in-school attack rate and in-school R_t to those from empirical studies. We estimated in-school R_t with high mitigation and classroom quarantine and "bubbles" to be 0.2 for elementary schools and 0.64 in high schools, consistent with estimates from schools during 2020-2021 (e.g., [22]). Our estimates also reflect the wide range of attack rates across mitigation levels identified both in data directly from schools [23–25] and from household/population-level estimates,[26,27] as well as the association between community incidence level and transmission risk.[28]

While the initial version of the model assumed that children under 10 are half as infectious as older children in all interactions, emerging evidence suggests that they may be equally or more infectious in a household setting.[1,29] We therefore revised this assumption so that that young children were as infectious as adolescents and adults in households, but remained half as infectious in classrooms with mitigation measures, the latter reflecting age-specific classroom transmission rates in available empirical data.

We assumed that the delta variant is twice as transmissible than the wild type variant and that this multiplicative increase is constant across levels of mitigation.[30,31] The latter assumption is uncertain and requires further empirical evaluation in different contexts; for example, while it may be realistic with cloth masks, early anecdotal evidence from health care settings suggests that high filtration masks (e.g. N95, KN95) may protect nearly as well against the delta variant as they do against wild type.

Nevertheless, for our base case, we assumed high mitigation with the delta variant (R_t of approximately 0.4 in elementary schools and 1.2 in middle schools, absent vaccination) to reflect the population of schools most likely to implement testing and likely ordering of interventions (e.g., testing will likely only be implemented in schools that have already implemented masking). In a sensitivity analysis, we also present our results in a scenario with the attack rate doubled, to correspond to a scenario with reduced mitigation (e.g., no masking).[32] At the time of writing, there were limited data to update our validation for the delta variant during the 2021-22 school year. Thus far, significant heterogeneity persists, with some schools reporting minimal in-school transmission,[33] while others have identified significant outbreaks.[34] Generally more transmission has been reported in schools with fewer mitigation measures.[35]

We assumed a base case 80% vaccine efficacy against the delta variant, a decrease compared to the wild type.[36,37(p2)] However, vaccine efficacy against delta remains somewhat uncertain, with estimates in the literature from 50-90% and most around 70-80% (e.g., see studies summarized in [38]). This range reflects both mRNA vaccines and recent evidence on the J&J vaccine, with estimated 78% efficacy against infection in states with high delta prevalence during June/July 2021.[39] Our base case of 80% reflects these recent studies; we chose the higher estimate to reflect that students vaccinated more recently may be less likely to show effects of waning in the near-term, teachers have been approved for boosters expected to increase vaccine efficacy, and some evidence suggests that even if infected, vaccinated individuals have a lower probability of transmission to contacts.[40,41]

<u>Surveillance Thresholds</u>

Within a small school community, it is challenging to set an optimal threshold for triggering further investigation when conducting surveillance. We expect some COVID-19 cases to enter a school from the community *even if no transmission occurs within the school*, and ideally the threshold for triggering additional testing should take this into account. However, when testing a small fraction of the school (10-20%), the expected number of asymptomatic cases detected, assuming no in-school transmission, is generally close to 0. In the paper, we chose a 1-case trigger threshold for 3 reasons:

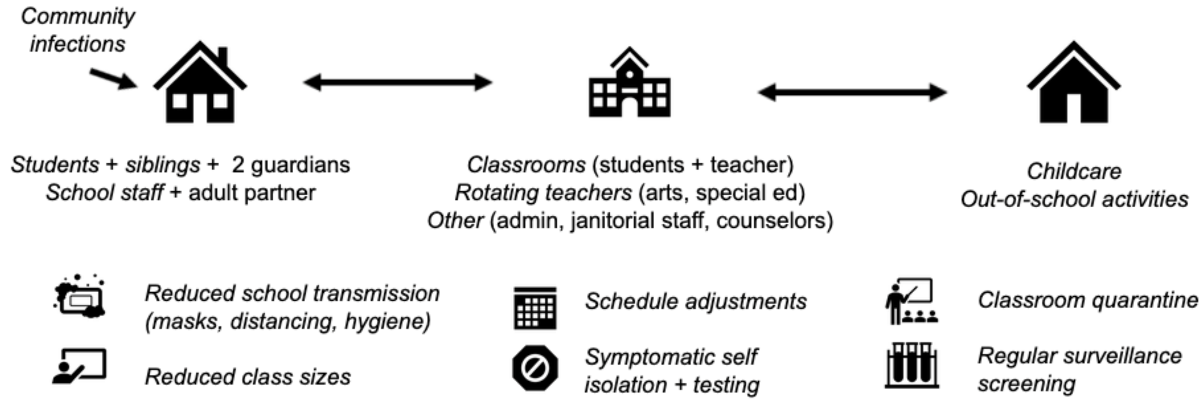
1. At low-to-moderate community notification rates (1-25 cases per 100,000/day), no surveillance scenario with a threshold above 1 could detect even large outbreaks of at least 10 in-school transmissions with any regularity: the maximum probability of detection (i.e., maximum sensitivity) was 35% for a 2-case threshold at 25 cases per 100,000/day. By contrast, a 1-case threshold had a detection probability of 30-75% across 1-25 cases per 100,000/day, while maintaining low rates of false positive triggers.
2. In our model, there was generally at least some in-school transmission at high levels of community incidence, making threshold selection less of a concern, since false positives would be rare under any threshold. (For the same reason, surveillance testing as a method of detecting outbreaks is less useful at

these levels, although a benefit remains if community case detection is low, which makes schools less likely to be aware of local incidence risks.)

3. If, in practice, a school calibrated the expected number of cases and associated threshold to the *observed* community incidence rate, this would be a significant underestimate (and for most community incidence levels we evaluated would be near 0). (However, it is not straightforward to correct for case detection, as there is no public, consistently-collected data source in the United States for estimating case detection rate, and most school leaders with whom we spoke would not be comfortable making such an estimate. Comparing percent positivity from in-school testing to population testing is inappropriate, as community testing encompasses primarily exposed symptomatic individuals with a much higher probability of infection than randomly selected individuals.)

Nevertheless, schools (or more broadly, districts) should adapt surveillance thresholds to meet their needs and level of caution. Our model is a stylized example over a single month for a single school. A longer-term strategy might also include dynamic changes back to surveillance, as well as stricter trigger thresholds when community incidence is high or when surveying large districts.

eFigure 1. Model diagram



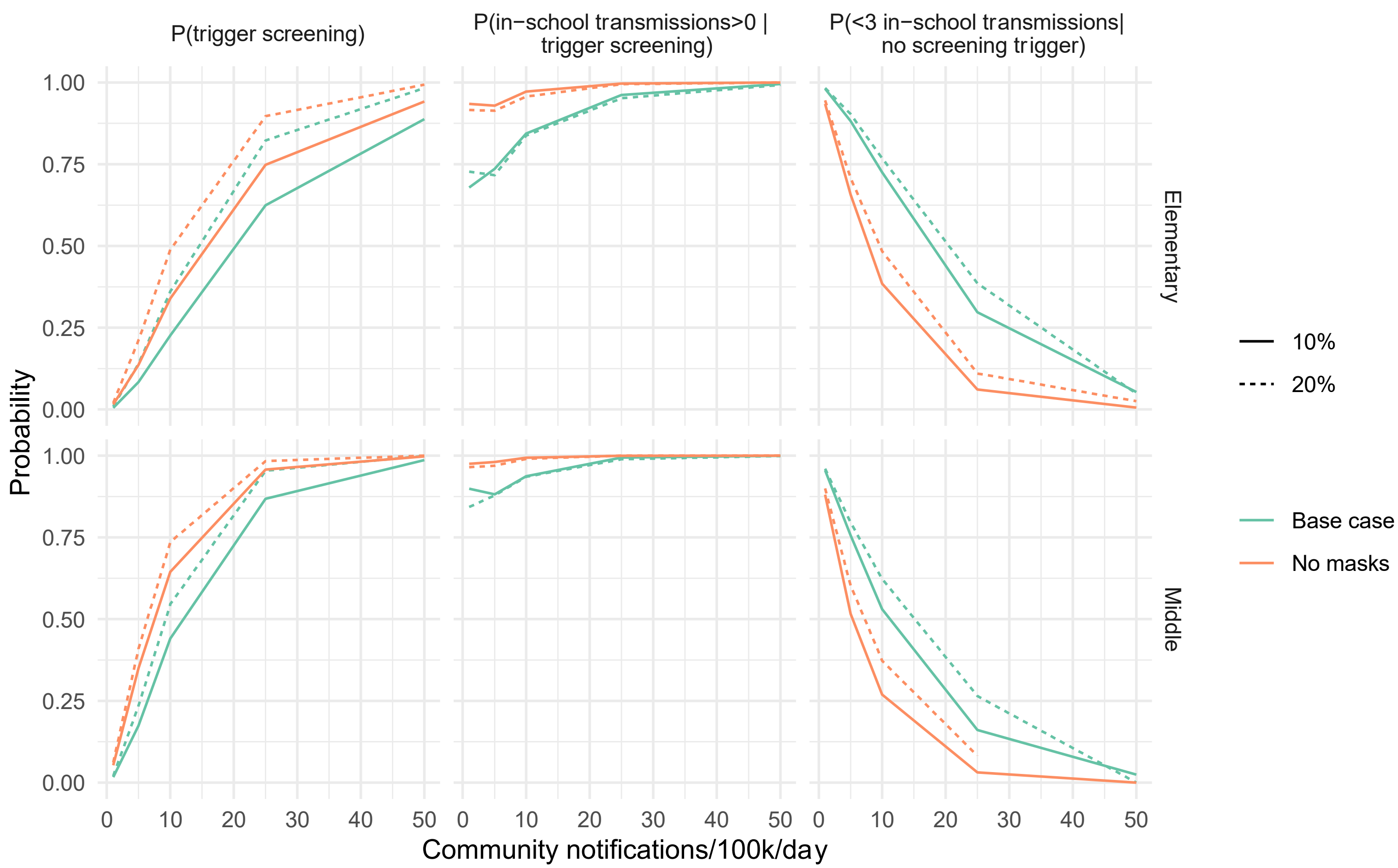
eTable 1. Model parameters

	Estimate	Sources/Notes
Key transmission model parameters (see [1] for full list and sources)		
Duration of infectiousness	Lognormal (5, 2)	Calibrated to match serial interval [42,43]. This ensures that early high transmissibility is captured, though a long tail of reduced infectiousness likely exists. (See sensitivity analyses.)
Classroom adult-adult symptomatic daily attack rate	2% (1% or 4% in sensitivity analysis)	Daily transmission rate between two unvaccinated adults during shared full-day contact The model further adjusts for reduced elementary school student susceptibility in the classroom (RR=0.5) + infectiousness (RR=0.5); and reduced infectiousness of asymptomatic middle school students + adults (RR=0.5). See eMethods for details
Relative attack rate for random school contacts (vs. classroom)	0.13	Based on 45 minutes/day of exposure
Household attack rate	50%	[22,23] (doubled for delta) and [44]
Probability of fully asymptomatic disease	20%, children (elementary + high school) 40%, adults	[10–12,15]
Probability that disease has clinically recognizable symptoms	20%, children (elementary + high school) 40%, adults	[10,45]
Presymptomatic period (days)	Normal (1.2, 0.4)	[46]
School size	Elementary: 638 students, 60 teachers/staff, 30 classes Middle: 460 students, 51 teachers/staff, 21 classes	[47]
Community COVID-19 notification rate	Varied between 1 and 100 diagnosed cases per 100,00 population per day	
Case detection ratio in community	1/3	Older US modeling estimate and current UK surveillance estimate [48,49] There is some evidence that this may be low in recent waves of infections;

		surveillance or screening can help to ascertain the true value.
Vaccine effectiveness	80%	[36,37] [36,37]
Teacher vaccination uptake	90%	[50], assuming full completion of regimens among those who received their first dose by April + 10% additional uptake
Testing parameters		
PCR		
Sensitivity of PCR testing during infectious period for screening + surveillance	0.9	[51–54]. Combined with 90% screening uptake, 81% of infectious students and staff are detected.
Frequency of testing	0, 1x, or 2x per week	Testing is assumed to occur on Monday +- Thursday
School-based screening test turnaround time	1 day	
Time from symptom onset to result of community-based diagnostic tests	2 days	
Duration of isolation after COVID-19 diagnosis	10 days	[55]
Duration of quarantine after COVID-19 exposure	10 days	[55]
Rapid testing		
Sensitivity of rapid test during infectious period for test-to-stay	0.8	While the sensitivity of rapid tests is lower than PCR tests over the full course of infection, a substantial body of evidence suggests that sensitivity is highest when individuals have sufficient viral load to transmit infection.[56] Because test-to-stay aims specifically to prevent transmission, we use sensitivity estimates focused on detection of infectious levels of virus. These include Abbott BinaxNOW culture-positive sensitivity of 93% and 79% among symptomatic and asymptomatic individuals, respectively, in Pima County[56] and sensitivity >90% among children in a school setting with Ct values in the infectious range below 25[57]. A longitudinal study on the Quidel SARS Sofia antigen FIA similarly estimated 90% sensitivity for detecting individuals while viral culture positive.[58] Last, UK surveillance data supported at least 79% sensitivity of antigen lateral

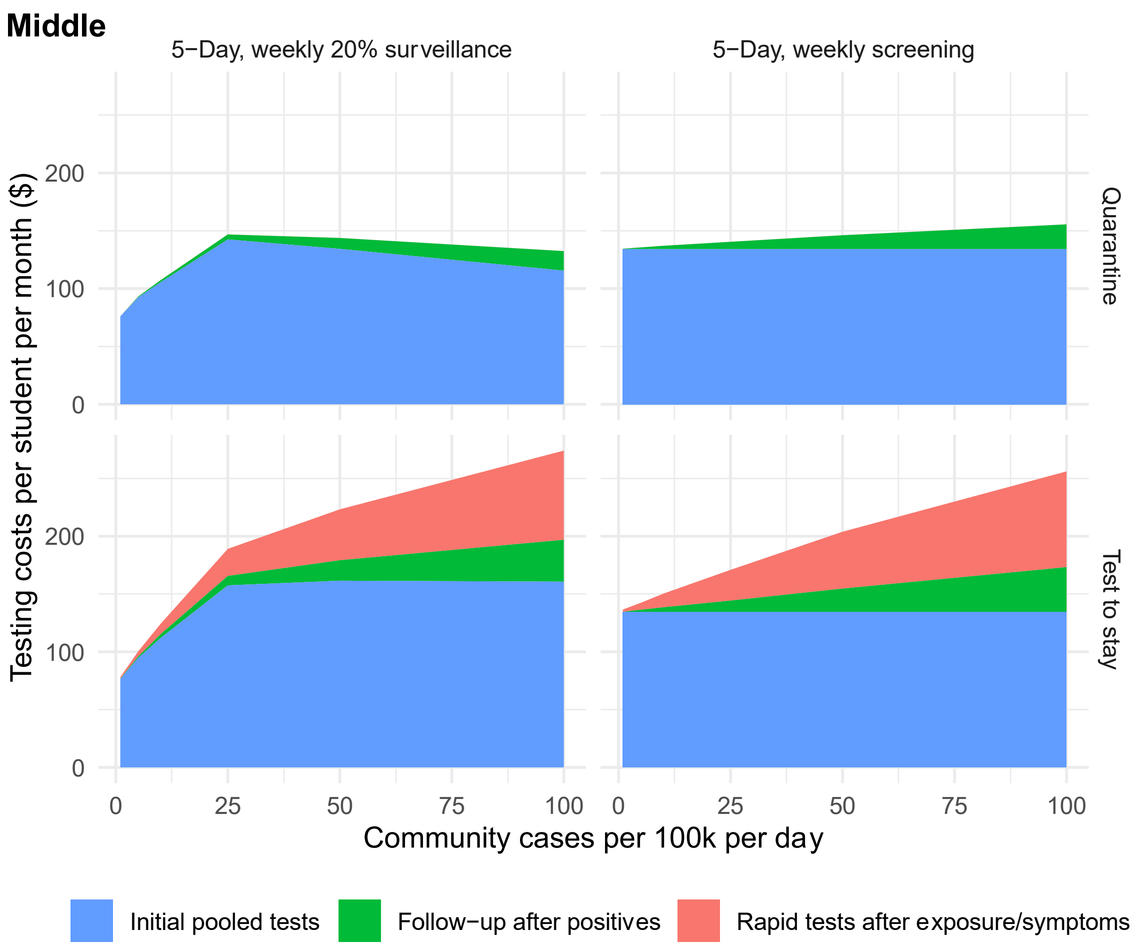
		flow devices for detection of infectious individuals.[59] In our base case, we use 80% as a conservative figure based on these estimates.
School-based test-to-stay turnaround time	15 minutes (same-day isolation of positive cases)	
Costs		
Cost per PCR run (per 8-sample pool, and per individual in pool for testing after a positive pooled result)	$40	Consistent with prices paid by early adopters [60], Massachusetts school testing, and some types of Medicare reimbursement [61]
Cost per rapid test run	$6	Assumes 50% discount from retail prices per documented bulk rates [62(p19)], consistent with other analyses [63]
Added cost per specimen collected (both PCR and rapid)	$8	[64]
Cost per planned day at home for elementary student, or any day at home for middle school student	$35.50	Based on group childcare costs for pre-kindergarten [65]; summertime childcare costs for school-aged children are similar [66]
Cost per unplanned day at home, elementary student	$85.90	Based on childcare worker wages [67]

eFigure 2. Surveillance characteristics. Color indicates the percentage of the school screened weekly (from unvaccinated individuals) under surveillance, while the line type indicates the transmission level. The left panels depict the probability of triggering screening. The middle panels depict the probability of in-school transmission, conditional on triggering screening ("true positives"). The right panels depict the probability of fewer than 3 in-school transmissions given no screening trigger ("true negatives").

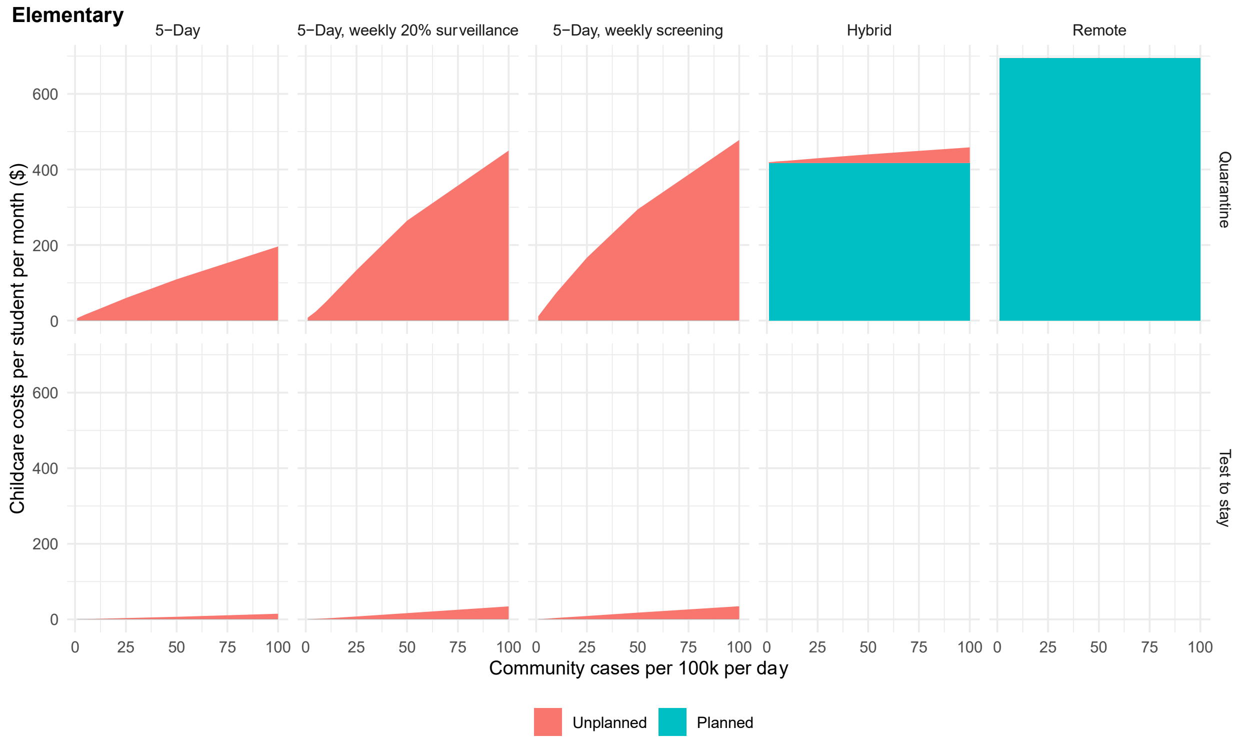


eFigure 3. Testing costs, as dollars per student per month, in an elementary school. When exposed students quarantine at home, costs plateau at higher levels of incidence as classroom quarantines cause screening days to be missed. Potential costs of community-based testing by exposed students or their contacts are not modeled. For a "test to stay" strategy that provides in-school rapid testing to symptomatic individuals and asymptomatic exposed contacts, testing costs increase as incidence rises.

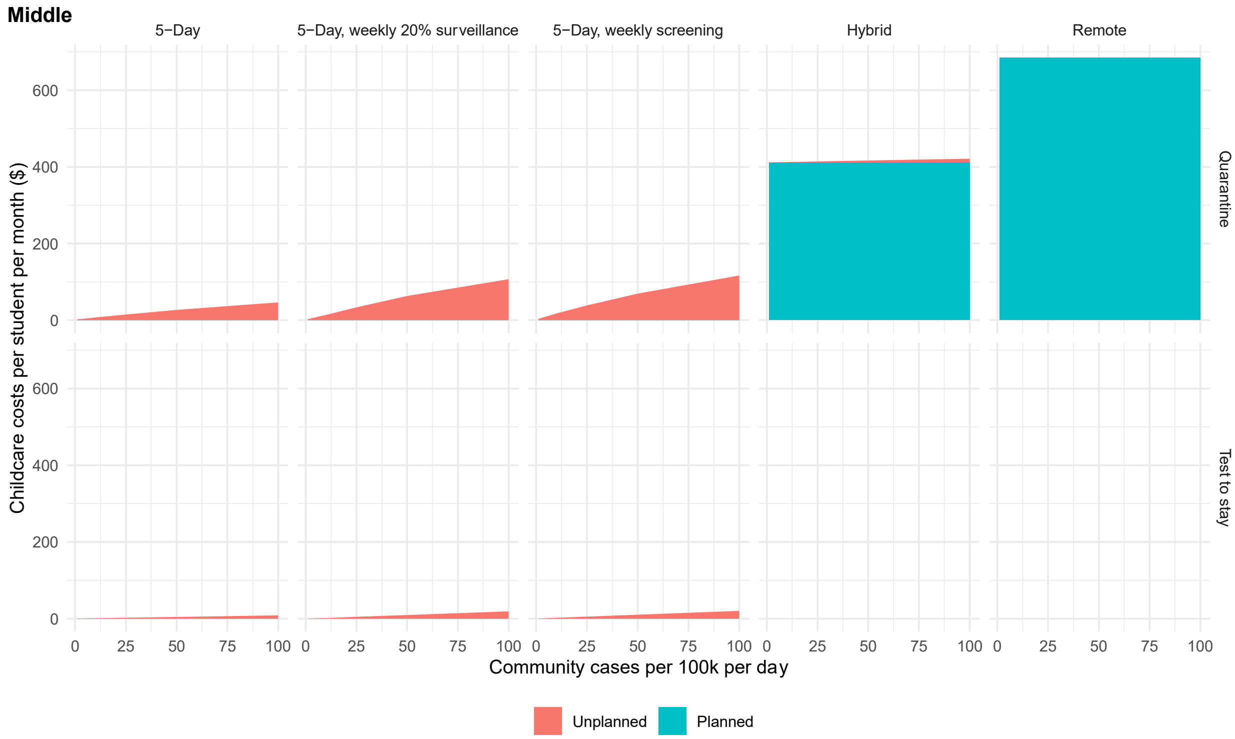
eFigure 4. Testing costs, as dollars per student per month, in a middle school.
When exposed students quarantine at home, costs plateau at higher levels of incidence, as classroom quarantines cause screening days to be missed. Potential costs of community-based testing by exposed students or their contacts are not modeled. For a "test to stay" strategy that provides in-school rapid testing to symptomatic individuals and asymptomatic exposed, testing costs increase as incidence rises.



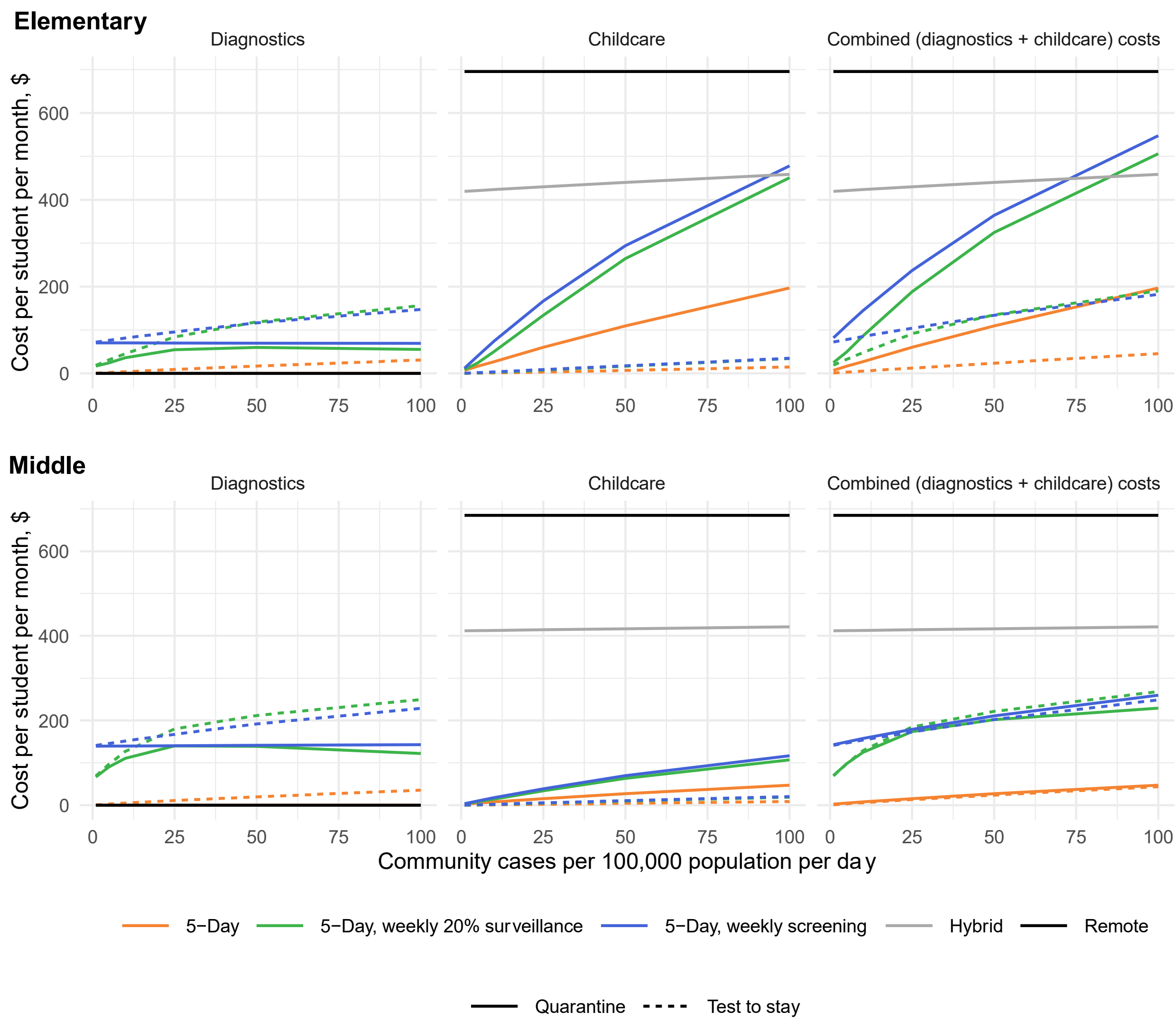
eFigure 5. Childcare or parent productivity costs (elementary school). Planned costs reflect scheduled days of remote learning, and unplanned costs reflect days spent in isolation or quarantine. Rows reflect two different approaches to managing exposed contacts (quarantine for 10 days at home, top row; or staying at school with a week of daily rapid tests, bottom row). “Test to stay” is not modeled for Hybrid and Remote schedules.



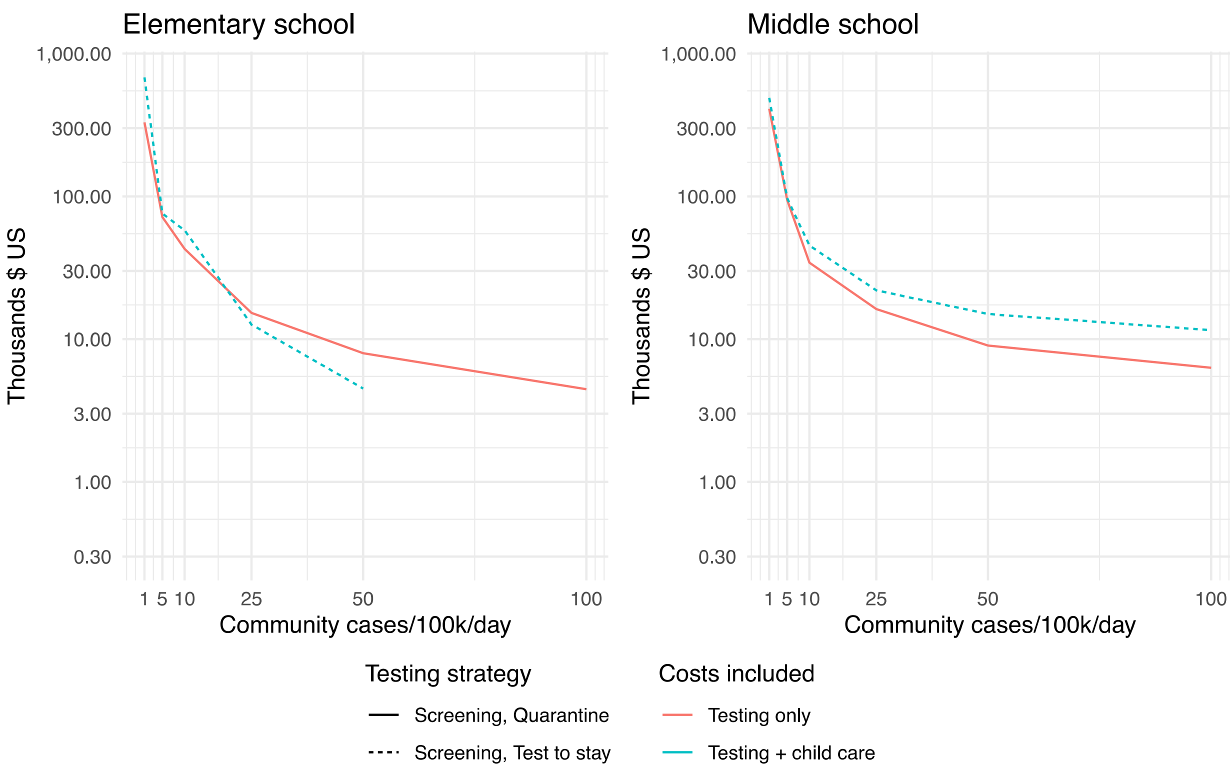
eFigure 6. Childcare or parent productivity costs (middle school). We assume that for a combination of health and logistical reasons, full classrooms quarantine after exposure. If only unvaccinated students were asked to quarantine, then costs of 5-Day + Quarantine scenarios would be reduced.



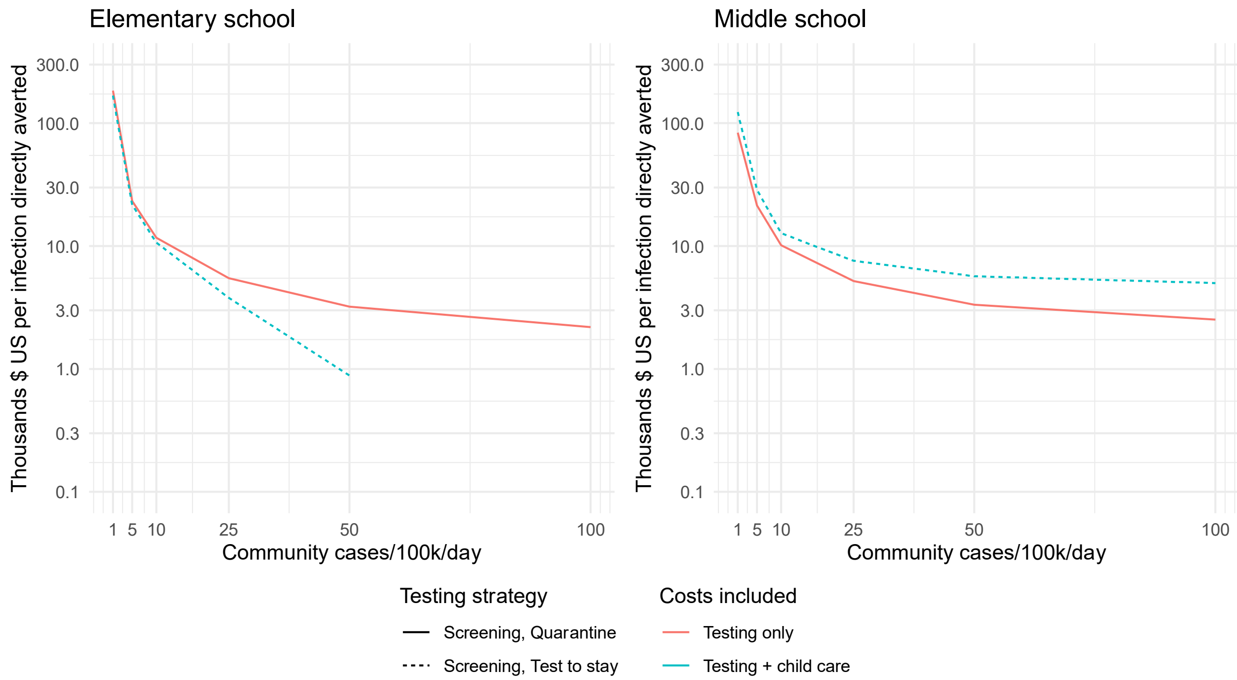
eFigure 7. Costs associated with rapid antigen screening tests. (weekly tests at $6 per test + $8 per sample collection, PCR confirmation of positive results with same one-day turnaround, 0.5% false positive rapid tests, no change in sensitivity for acute infection) compared to the costs of schedule-based mitigation and of full-time in-person attendance without asymptomatic screening.



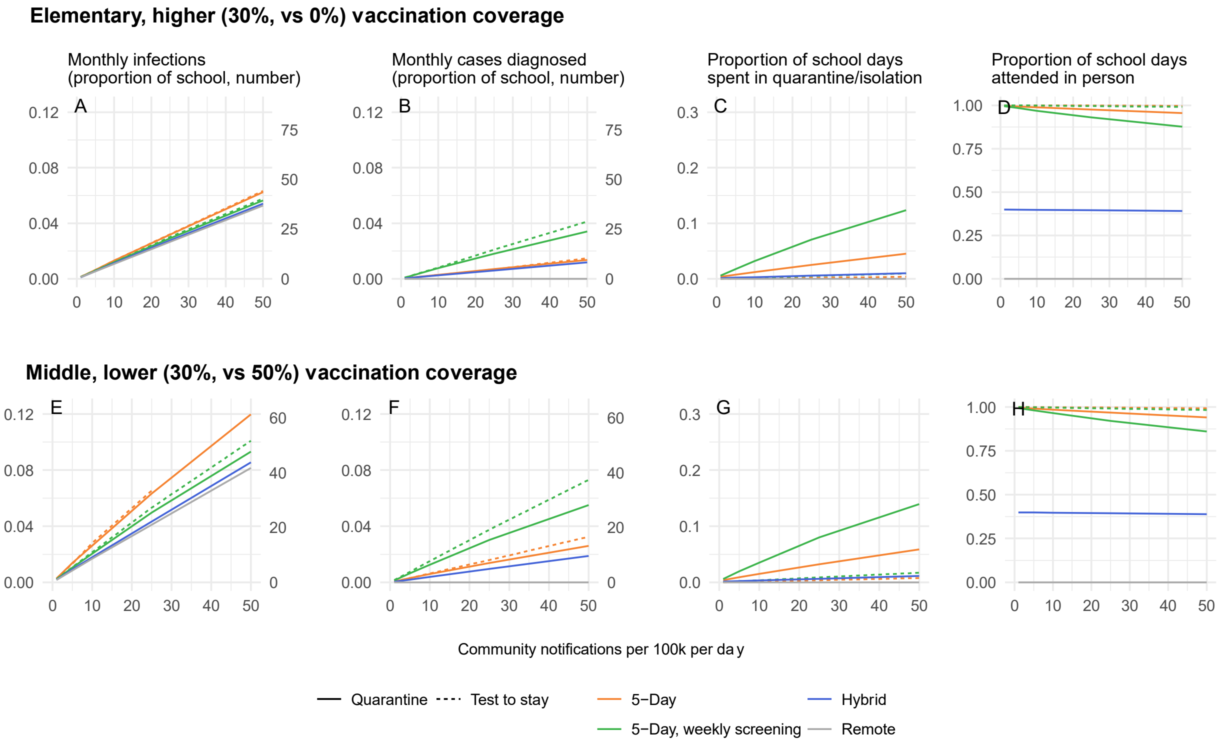
eFigure 8. Cost-effectiveness of rapid screening (cost per infection directly averted among students and staff), comparing weekly screening to full-time attendance without screening, under the same rapid screening assumptions as in eFigure 7. For testing costs (orange), we show the strategy of weekly screening in which exposed contacts quarantine at home (solid line), which dominates the “test to stay” strategy. By “dominates”, we mean that if optimizing over test costs only, it is strictly higher value to quarantine contacts, rather than implement test-to-stay. Likewise, for combined costs of testing plus childcare (blue), we show the strategy of weekly screening with exposed contacts undergoing daily rapid tests to stay at school (dashed line), which dominates at-home quarantine.



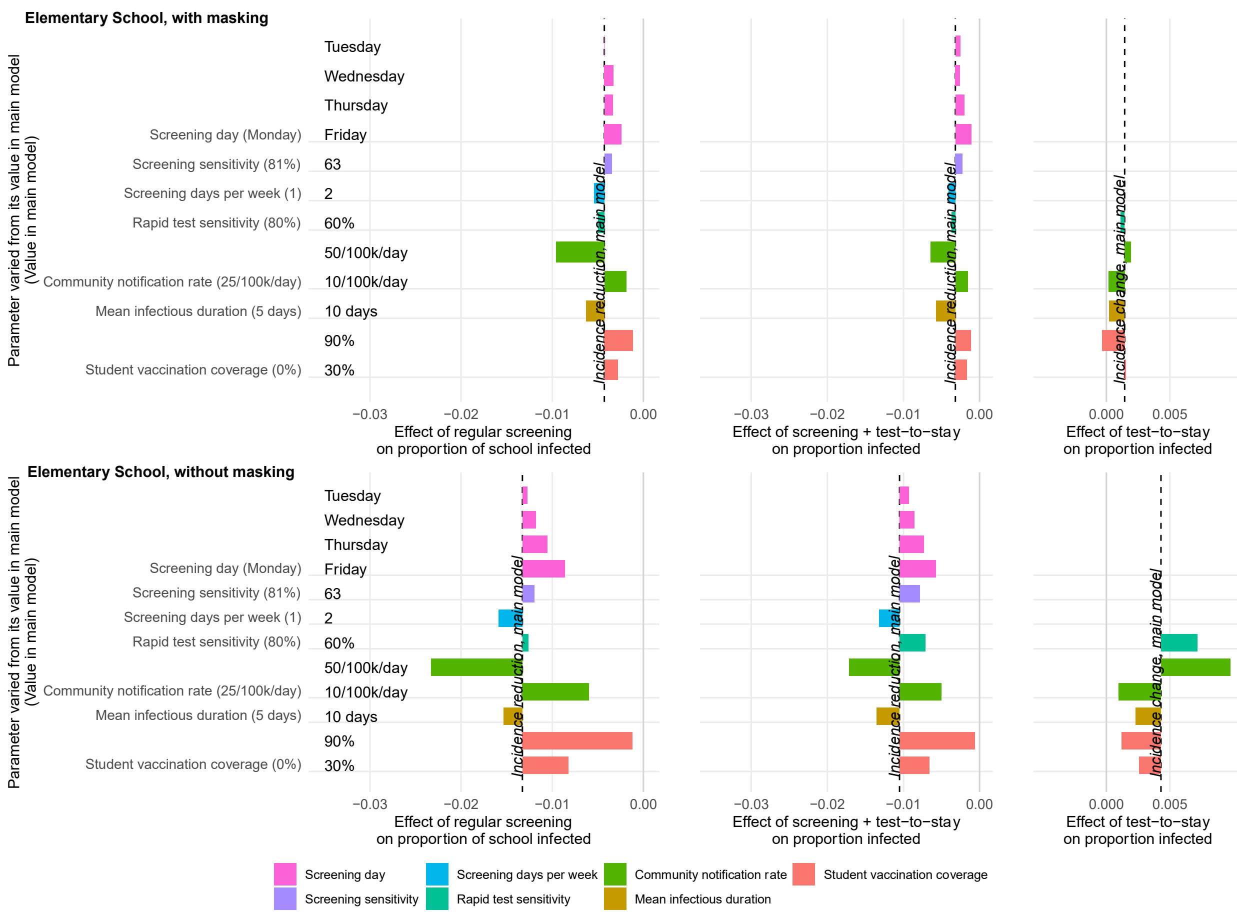
eFigure 9. Cost-effectiveness of weekly screening (cost per infection directly averted among students and staff) in a high-transmission or unmasked school setting. Screening is compared to full-time attendance without screening, assuming a two-fold increase in transmission rate over the base case (due to increased variant transmissibility or reduced in-school mitigation). For testing costs (orange), we show the strategy of weekly screening in which exposed contacts quarantine at home (solid line), which dominates the "test to stay" strategy. By "dominates", we mean that if optimizing over test costs only, it is strictly higher value to quarantine contacts, rather than implement test-to-stay. Likewise, for combined costs of testing plus childcare (blue), we show the strategy of weekly screening with exposed contacts undergoing daily rapid tests to stay at school (dashed line), which dominates at-home quarantine.



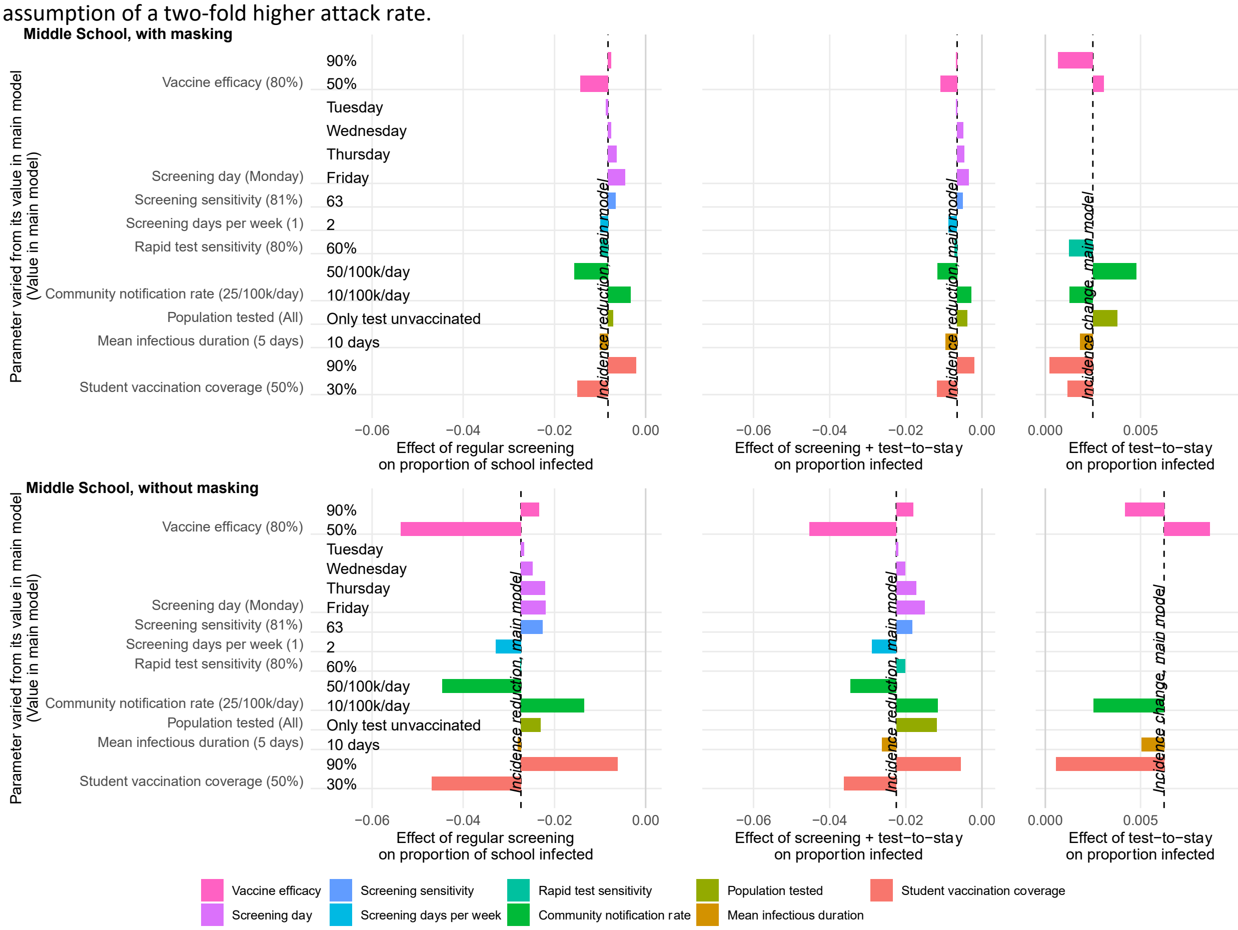
eFigure 10: Comparison of testing strategies, if vaccination coverage is higher (elementary) or lower (middle) than in the main analysis. The y axis scale has been modified compared to earlier figures, to accommodate a higher incidence in the middle school setting.



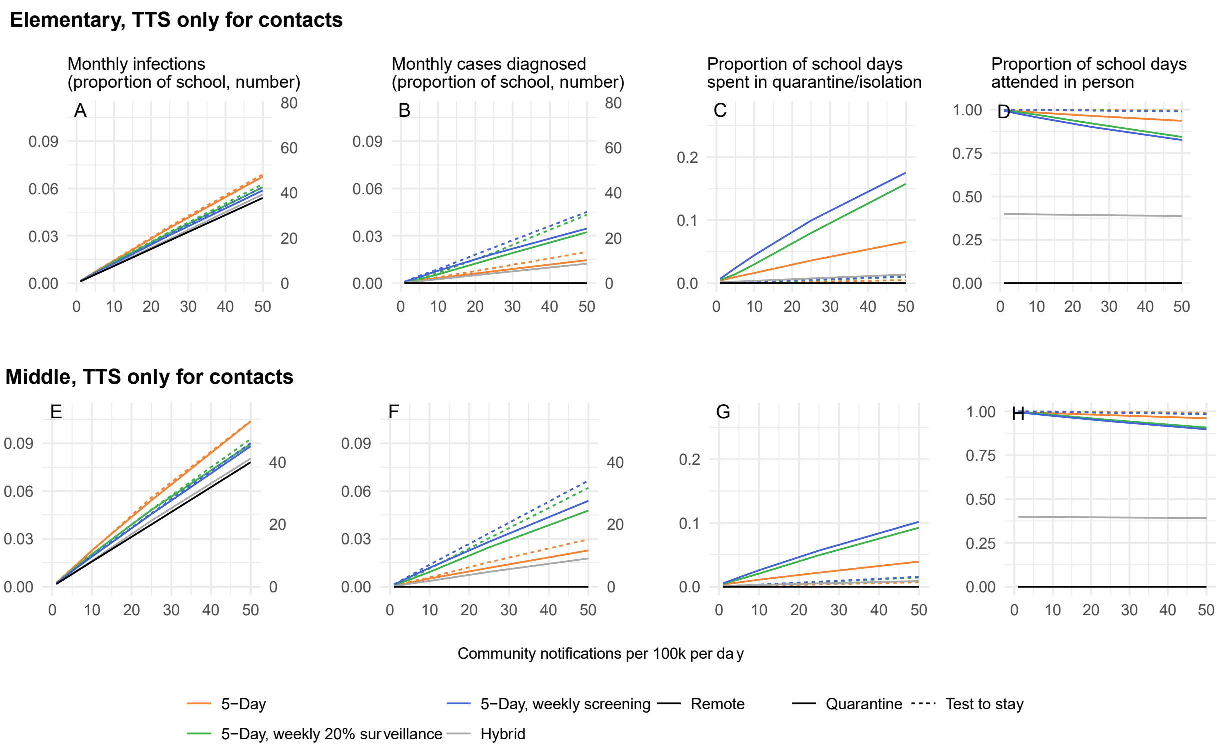
eFigure 11. Impact of testing strategies on COVID-19 incidence with and without masking and with varying parameter values, in an elementary school. Incidence impact is estimated as a difference in the proportion of the school's students and teachers infected with COVID per month, comparing the specified testing strategy to 5-day school attendance without testing. The scenario without masking corresponds to an assumption of a two-fold higher attack rate.



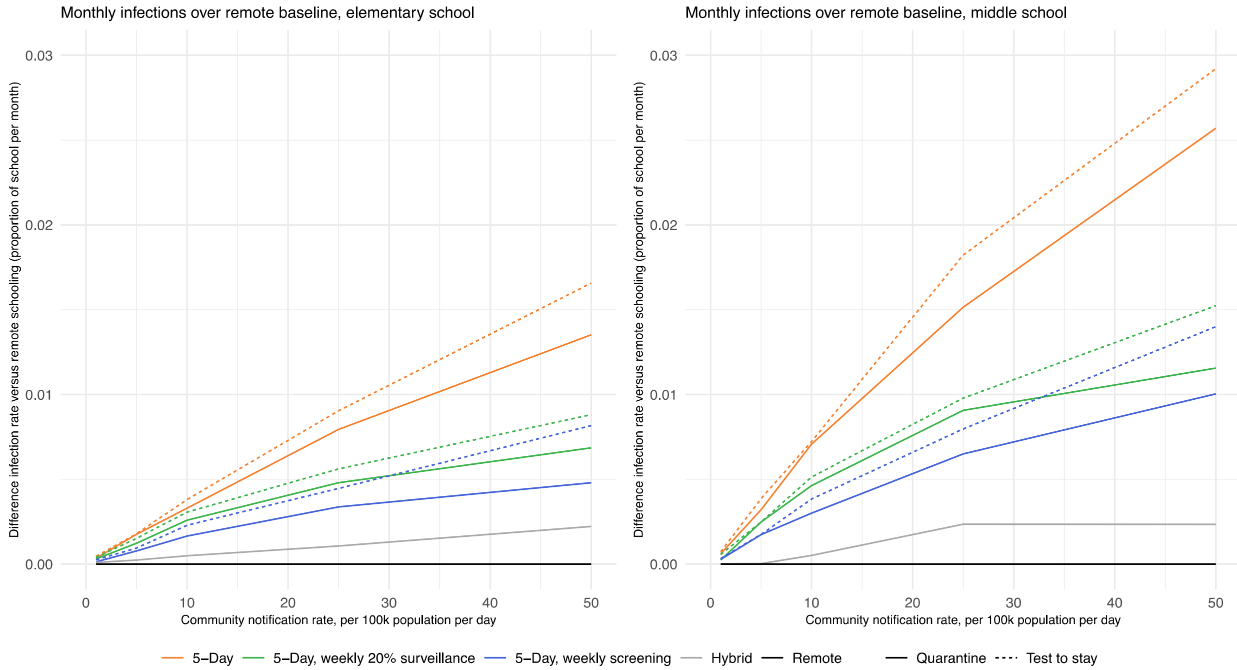
eFigure 12. Impact of testing strategies on COVID-19 incidence with and without masking and with varying parameter values, in a middle school. Incidence impact is estimated as a difference in the proportion of the school's students and teachers infected with COVID per month, comparing the specified testing strategy to 5-day school attendance without testing. The scenario without masking corresponds to an assumption of a two-fold higher attack rate.



eFigure 13: Comparison of testing strategies, if test to stay is used only for asymptomatic contacts (and symptomatic individuals are required to isolate)



eFigure 14: Expected increase in incidence with testing and hybrid models (as a proportion of school per month, in the elementary setting), compared to remote schooling.



eTable 2. Comparison of transmission, case-detection, operational, and cost outcomes between different schedules and screening frequencies

	Infection incidence (proportion of school per month)	Difference in proportion of school infected, per month vs full-time without screening	Proportion of incremental infections prevented (of difference between 5-day no screening and Remote)	Proportion of cases detected	In-person attendance (proportion of school days)	Testing costs ($ per student per month)	Testing + child care costs ($ per student per month)
Elementary school, community notification rate 10/100k/day							
5-Day, no screening, quarantine	0.014	0	0	0.22	0.984	0	27.04
5-Day, no screening, test-to-stay	0.015	0.0005	-0.16	0.21	0.999	4.83	6.05
5-Day, weekly 10% surveillance, quarantine	0.014	-0.0003	0.1	0.33	0.976	21.96	62.69
5-Day, weekly 10% surveillance, test-to-stay	0.014	-0.0001	0.04	0.35	0.999	29.61	31.55
5-Day, weekly 20% surveillance, quarantine	0.013	-0.0007	0.21	0.41	0.97	42	92.08
5-Day, weekly 20% surveillance, test-to-stay	0.014	-0.0002	0.07	0.44	0.999	52.15	54.56
5-Day, 1x/week screening, quarantine	0.012	-0.0016	0.5	0.63	0.956	69.81	144.2
5-Day, 1x/week screening, test-to-stay	0.013	-0.001	0.3	0.7	0.998	82.15	85.73
5-Day, 2x/week screening, quarantine	0.012	-0.0021	0.65	0.76	0.951	124.53	206.88
5-Day, 2x/week weekly screening, test-to-stay	0.012	-0.0016	0.49	0.87	0.997	139.74	143.99
Hybrid, quarantine	0.011	-0.0028	0.85	0.22	0.396	0	423.3
Hybrid, test-to-stay	0.012	-0.0023	0.69	0.13	0.4	1.18	418.61

Remote	0.011	-0.0033	1	0	0	0	695.32
Elementary school, community notification rate 50/100k/day							
5-Day, no screening, quarantine	0.071	0.003	-0.23	0.24	0.996	21.01	27.7
5-Day, no screening, test-to-stay	0.062	-0.0051	0.38	0.47	0.863	50.63	281.53
5-Day, weekly 10% surveillance, quarantine	0.065	-0.0027	0.2	0.59	0.991	104.92	119.87
5-Day, weekly 10% surveillance, test-to-stay	0.061	-0.0067	0.49	0.53	0.843	66.63	331.12
5-Day, weekly 20% surveillance, quarantine	0.063	-0.0047	0.35	0.67	0.99	129.39	145.92
5-Day, weekly 20% surveillance, test-to-stay	0.059	-0.0087	0.64	0.59	0.825	73.87	368.37
5-Day, 1x/week screening, quarantine	0.062	-0.0054	0.4	0.72	0.99	125.56	143.11
5-Day, 1x/week screening, test-to-stay	0.057	-0.0101	0.75	0.7	0.814	128.45	441.69
5-Day, 2x/week screening, quarantine	0.06	-0.0078	0.57	0.88	0.988	191.77	212.51
5-Day, 2x/week weekly screening, test-to-stay	0.056	-0.0113	0.84	0.22	0.386	0	440.18
Hybrid, quarantine	0.058	-0.0097	0.71	0.13	0.399	4.87	423.27
Hybrid, test-to-stay	0.054	-0.0135	1	0	0	0	695.32
Remote	0.023	0	0	0.22	0.989	0	7.54

Middle school, community notification rate 10/100k/day							
5-Day, no screening, quarantine	0.021	-0.0014	0.2	0.38	0.983	80.68	92.29
5-Day, no screening, test-to-stay	0.021	-0.0015	0.22	0.42	0.998	93.1	94.54
5-Day, weekly 10% surveillance, quarantine	0.02	-0.0024	0.35	0.45	0.98	107.41	121.4
5-Day, weekly 10% surveillance, test-to-stay	0.021	-0.0019	0.27	0.51	0.997	124.4	126.11
5-Day, weekly 20% surveillance, quarantine	0.019	-0.0041	0.57	0.63	0.974	136.95	154.63
5-Day, weekly 20% surveillance, test-to-stay	0.02	-0.0032	0.46	0.69	0.997	150.17	152.34
5-Day, 1x/week screening, quarantine	0.018	-0.0046	0.65	0.77	0.971	245.29	264.88
5-Day, 1x/week screening, test-to-stay	0.018	-0.0048	0.67	0.87	0.996	260.21	262.72
5-Day, 2x/week screening, quarantine	0.016	-0.0066	0.93	0.22	0.397	0	412.63
5-Day, 2x/week weekly screening, test-to-stay	0.017	-0.0055	0.78	0.13	0.4	1.5	412.52
Hybrid, quarantine	0.016	-0.0071	1	0	0	0	684.79
Hybrid, test-to-stay	0.104	0	0	0.22	0.961	0	26.91
Remote	0.107	0.0035	-0.14	0.24	0.994	26.33	30.52

Middle school, community notification rate 50/100k/day							
5-Day, no screening, quarantine	0.096	-0.0077	0.3	0.6	0.987	206.27	215.51
5-Day, no screening, test-to-stay	0.09	-0.0142	0.55	0.53	0.908	143.7	207.01
5-Day, weekly 10% surveillance, quarantine	0.093	-0.0105	0.41	0.64	0.986	223.31	232.83
5-Day, weekly 10% surveillance, test-to-stay	0.088	-0.0157	0.61	0.61	0.898	146.18	215.84
5-Day, weekly 20% surveillance, quarantine	0.092	-0.0117	0.46	0.72	0.985	203.89	214.44
5-Day, weekly 20% surveillance, test-to-stay	0.085	-0.0188	0.73	0.74	0.892	257.24	331.33
5-Day, 1x/week screening, quarantine	0.087	-0.0171	0.66	0.88	0.982	323.61	335.85
5-Day, 1x/week screening, test-to-stay	0.08	-0.0234	0.91	0.22	0.392	0	416.69
5-Day, 2x/week screening, quarantine	0.085	-0.0189	0.74	0.14	0.399	6.87	418.51
5-Day, 2x/week weekly screening, test-to-stay	0.078	-0.0257	1	0	0	0	684.79
Hybrid, quarantine	0.014	0	0	0.22	0.984	0	27.04
Hybrid, test-to-stay	0.015	0.0005	-0.16	0.21	0.999	4.83	6.05
Remote	0.014	-0.0003	0.1	0.33	0.976	21.96	62.69

eTable 3. Sensitivity analyses

	Variable varied	Base case value	Sensitivity analysis value	Expected incidence with no testing (proportion of school infected per month)	Change in incidence with screening	Change in incidence with screening & TTS	Change in incidence with TTS
Elementary, Masked	Student vaccination coverage	0%	30%	0.0317	-0.0028	-0.0016	0.0015
	Student vaccination coverage	0%	90%	0.0273	-0.0011	-0.0012	-0.0003
	Mean infectious duration	5 days	10 days	0.0386	-0.0063	-0.0057	0.0002
	Population tested	All	Only test unvaccinated	0.0354	-0.0053	-0.0033	0.0008
	Community notification rate	25/100k/day	10/100k/day	0.0145	-0.0019	-0.0015	0.0002
	Community notification rate	25/100k/day	50/100k/day	0.0679	-0.0096	-0.0064	0.0020
	Rapid test sensitivity	80%	60%	0.0351	-0.0049	-0.0037	0.0011
	Screening days per week	1	2	0.0346	-0.0054	-0.0041	0.0014
	Screening sensitivity	81%	63	0.0346	-0.0035	-0.0022	0.0014
	Screening day	Monday	Friday	0.0346	-0.0024	-0.0011	0.0014
	Screening day	Monday	Thursday	0.0346	-0.0034	-0.0020	0.0014
	Screening day	Monday	Wednesday	0.0346	-0.0033	-0.0026	0.0014
	Screening day	Monday	Tuesday	0.0346	-0.0042	-0.0025	0.0014
	Vaccine efficacy	80%	50%	0.0356	-0.0046	-0.0029	0.0021
	Vaccine efficacy	80%	90%	0.0344	-0.0045	-0.0036	0.0013
	Baseline			0.0346	-0.0043	-0.0032	0.0014

Elementary, Unmasked	Student vaccination coverage	0%	30%	0.0421	-0.0082	-0.0066	0.0026
	Student vaccination coverage	0%	90%	0.0288	-0.0012	-0.0006	0.0012
	Mean infectious duration	5 days	10 days	0.0516	-0.0153	-0.0135	0.0023
	Population tested	All	Only test unvaccinated	0.0504	-0.0130	-0.0090	0.0054
	Community notification rate	25/100k/day	10/100k/day	0.0217	-0.0060	-0.0050	0.0010
	Community notification rate	25/100k/day	50/100k/day	0.0927	-0.0233	-0.0171	0.0098
	Rapid test sensitivity	80%	60%	0.0494	-0.0126	-0.0071	0.0072
	Screening days per week	1	2	0.0506	-0.0159	-0.0132	0.0043
	Screening sensitivity	81%	63	0.0506	-0.0120	-0.0078	0.0043
	Screening day	Monday	Friday	0.0506	-0.0086	-0.0057	0.0043
	Screening day	Monday	Thursday	0.0506	-0.0105	-0.0073	0.0043
	Screening day	Monday	Wednesday	0.0506	-0.0118	-0.0085	0.0043
	Screening day	Monday	Tuesday	0.0506	-0.0127	-0.0093	0.0043
	Vaccine efficacy	80%	50%	0.0524	-0.0136	-0.0104	0.0054
	Vaccine efficacy	80%	90%	0.0495	-0.0131	-0.0098	0.0030
	Baseline			0.0506	-0.0133	-0.0105	0.0043
Middle, Masked	Student vaccination coverage	50%	30%	0.0645	-0.0150	-0.0118	0.0012
	Student vaccination coverage	50%	90%	0.0412	-0.0021	-0.0019	0.0002
	Mean infectious duration	5 days	10 days	0.0569	-0.0101	-0.0096	0.0018
	Population tested	All	Only test unvaccinated	0.0540	-0.0072	-0.0039	0.0038
	Community notification rate	25/100k/day	10/100k/day	0.0221	-0.0032	-0.0027	0.0013
	Community notification rate	25/100k/day	50/100k/day	0.1029	-0.0157	-0.0117	0.0048
	Rapid test sensitivity	80%	60%	0.0553	-0.0099	-0.0072	0.0013
	Screening days per week	1	2	0.0539	-0.0100	-0.0087	0.0025
	Screening sensitivity	81%	63	0.0539	-0.0066	-0.0050	0.0025
	Screening day	Monday	Friday	0.0539	-0.0044	-0.0035	0.0025

	Screening day	Monday	Thursday	0.0539	-0.0063	-0.0047	0.0025
	Screening day	Monday	Wednesday	0.0539	-0.0076	-0.0048	0.0025
	Screening day	Monday	Tuesday	0.0539	-0.0087	-0.0068	0.0025
	Vaccine efficacy	80%	50%	0.0660	-0.0143	-0.0109	0.0031
	Vaccine efficacy	80%	90%	0.0512	-0.0075	-0.0069	0.0007
	Baseline			0.0539	-0.0083	-0.0065	0.0025
Middle, Unmasked	Student vaccination coverage	50%	30%	0.1185	-0.0469	-0.0363	0.0145
	Student vaccination coverage	50%	90%	0.0507	-0.0061	-0.0055	0.0006
	Mean infectious duration	5 days	10 days	0.0831	-0.0281	-0.0262	0.0051
	Population tested	All	Only test unvaccinated	0.0876	-0.0230	-0.0119	0.0117
	Community notification rate	25/100k/day	10/100k/day	0.0391	-0.0135	-0.0116	0.0025
	Community notification rate	25/100k/day	50/100k/day	0.1556	-0.0446	-0.0346	0.0118
	Rapid test sensitivity	80%	60%	0.0877	-0.0276	-0.0202	0.0107
	Screening days per week	1	2	0.0882	-0.0329	-0.0289	0.0062
	Screening sensitivity	81%	63	0.0882	-0.0226	-0.0184	0.0062
	Screening day	Monday	Friday	0.0882	-0.0219	-0.0150	0.0062
	Screening day	Monday	Thursday	0.0882	-0.0220	-0.0173	0.0062
	Screening day	Monday	Wednesday	0.0882	-0.0248	-0.0202	0.0062
	Screening day	Monday	Tuesday	0.0882	-0.0266	-0.0219	0.0062
	Vaccine efficacy	80%	50%	0.1297	-0.0537	-0.0453	0.0086
	Vaccine efficacy	80%	90%	0.0789	-0.0234	-0.0180	0.0042
	Baseline			0.0882	-0.0274	-0.0225	0.0062

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