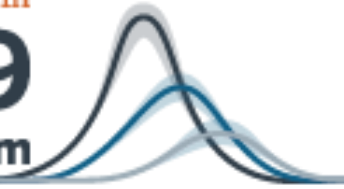


The University of Texas at Austin

COVID-19

Modeling Consortium



COVID-19 projections for the reopening of the University of Texas at Austin in fall of 2021

Contributors: Kaitlyn E. Johnson, Remy Pasco, Spencer Woody, Michael Lachmann, Darlene Bhavnani, Jessica Klima, Spencer J. Fox, Lauren Ancel Meyers

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Summary

There are more than 50,000 students enrolled at the University of Texas at Austin (UT), with an estimated 80% from Texas and 93% from the United States. During the 2020-21 academic year, UT offered hybrid and online courses to mitigate the risks of COVID-19 transmission on campus. The 2021-22 academic year is scheduled to begin on August 25, 2021. Given the wide availability of COVID-19 vaccines in the US, UT is planning to resume in-person classes and on-campus activities. UT will urge vaccination for all unvaccinated students, make COVID-19 testing readily available to all students, staff and faculty, strongly encourage masking and conduct contact tracing when viral cases are detected.

In order to assist UT in safely reopening, this report estimates the SARS-CoV-2 vaccination coverage and infection prevalence among students at the start of the academic year and then provides projections under a variety of vaccination and testing levels. For each scenario, we project infections, costs associated with testing, and required isolation facilities from August 25 through December 16, 2021. We also derive the level of proactive testing needed to keep COVID-19 levels below the *very high transmission threshold* of 140 cases per 100,000 people over seven days.

Assuming that SARS-CoV-2 will spread at levels estimated prior to interventions such as widespread masking and increased vaccinations, we project that COVID-19 risks will depend on vaccination rates among UT students and that proactive testing can be scaled to mitigate those risks. Specifically, we estimate the following:

- We estimate that between 46% and 64% (median: 57%) of UT students will have been fully vaccinated by August 25, 2021.

- There will be between 187 and 236 (median: 209) infected UT students in Austin during the first week of the semester, corresponding to an expected prevalence of COVID-19 between 0.38% and 0.47% (median: 0.42%).
- If 60% of students are vaccinated by August 25, then proactive testing of unvaccinated students two times per week is recommended to prevent the epidemic from exceeding the highest risk threshold. At this level of testing, UT can expect to spend roughly \$4.5 million on the COVID response, including \$2 million on rapid tests.
- If 80% of students are vaccinated, then symptomatic testing alone should be sufficient to prevent the epidemic from exceeding the highest risk threshold. At this level of vaccination, UT can expect to spend \$520,000 on the COVID response.
- If 60% of students living in UT residence halls are vaccinated and UT does not require proactive testing, then we project a peak occupancy of 13 to 45 (median: 25) students requiring an isolation room in a single day. If 80% are vaccinated, then the estimated peak demand decreases to between 2 and 11 (median: 6) students simultaneously requiring isolation. These estimates do not account for additional cases identified through contact tracing or proactive testing, which may increase the number of students requiring isolation.
- These findings highlight the need for continued mitigation measures such as testing prior to returning to campus, wearing of face masks, social distancing, frequent testing throughout the semester, self-isolation when symptomatic and other risk-reduction measures as UT reopens during a time of high levels of community spread.

The projections below assume that vaccine coverage, vaccine efficacy, and transmission rates are constant through December 16, 2021, and thus do not capture future policy, behavioral, or viral changes that may alter these quantities.

Scenarios

To project the health and economic costs associated with the reopening of UT, we built a mathematical model of COVID-19 transmission that incorporates vaccination and proactive testing. We analyzed 35 distinct scenarios with vaccination coverage ranging from 40% to 80% of the student body and proactive testing ranging from never to daily.

The projections assume the following:

- Population: 50,000 UT students
- Time period: August 25 - December 16, 2021 • Initial conditions on August 25:

- Initial disease prevalence: 420 [380-470] infections per 100,000 students based on importation estimates
- Immunity from infection: 40% (32-48%) of students previously infected, including infections during the summer 2021 surge
- Vaccine efficacy: 70% effective at preventing symptomatic disease, 64% effective at preventing infection [1–3], and 50% reduction in infectiousness if infected [4]
- Symptomatic testing: PCR testing of all symptomatic detected individuals two days after symptom onset, with 90-95% compliance of isolation following a positive test
- Proactive testing: Antigen testing of unvaccinated individuals, with a participation rate of 50% and immediate isolation following a positive test.

All other model parameters are provided in the Appendix.

We compare our projections to the following threat thresholds:

- High risk: 100 symptomatic detected cases per 100,000 people in a seven-day period, corresponding to the CDC red (high) alert level [5].
- Very high risk: 140 symptomatic detected cases per 100,000 people in a seven-day period, corresponding to the situation in January of 2021, when the university delayed the start of hybrid courses.

Our cost analyses consider the following:

- Cost of proactive testing: Procuring and processing antigen tests, maintaining testing sites, and salaries for testing personnel
- Costs of case detection: Confirmatory/symptomatic (PCR) testing, sequencing, contact-tracing, isolation facility usage
- Cost of exceeding high risk threshold: Daily cost of reverting to online instruction

The Appendix provides specific values that were chosen in consultation with the UT administration. We do not account for other indirect costs, including planning efforts, facility cleaning following case detection, or illness-associated costs for symptomatic cases.

Estimates and projections

COVID-19 introductions and vaccine coverage in late August

We estimated the prevalence of the virus among UT students during the first week of the semester, assuming that 50,000 students will be on campus by August 25, 2021 (Appendix A.1). The estimates are based on the prevalence of COVID-19 in Austin and in the home counties of students as of July 25, 2021. We do not account for changes in prevalence after July 25 or for transmission among students that return to Austin prior to August 25.

Assuming case detection rates between 1 in 3.5 and 1 in 4.4 [6], **we estimate that the prevalence of SARS-CoV-2 among UT students in Austin on August 25 will be between 0.38% and 0.47%, corresponding to 187 - 236 infections.**

We also estimated the vaccination coverage among UT students on August 25 based on the county-level vaccination rates reported for 16-49 year olds in Texas [7] and for individuals over 18 in the home counties of students from other US states [8] using data as of July 25, 2021. Using recent vaccination rates, we projected coverage on August 25, 2021 (Appendix A.2). Our upper bound accounts for 12% higher vaccination rates among college educated adults [9] and our lower bound accounts for 20% lower rates among 18-24 year olds relative to older adults [10].

We estimate that between 46% and 64% (median: 57%) of the UT student body will be fully vaccinated.

Projected COVID-19 prevalence throughout the fall semester

The projections suggest that spread of COVID-19 among UT students will depend primarily on the vaccination rate and secondarily on the level of proactive testing for unvaccinated individuals.

Figure 1 and Table 1 compare the projections assuming a low (left graph) or high (right graph) level of vaccine coverage as of August 25:

- If vaccination rates remain near 60% and proactive testing is not implemented, then the prevalence of symptomatic infections is expected to peak between 90 and 320 cases (median: 180) and the total infected during the fall semester to be in the range of 5,000 to 16,300 (median: 11,200).

- At a 60% vaccination rate, if unvaccinated students are tested two times per week, the expected peak reduces to 28 - 53 (median: 35) and the total infected to 900 - 3,900 (median: 1,700).
- If vaccination rates reach 80% by the end of August, then symptomatic cases would be expected to peak between 19 and 40 (median: 25) and total cases would be expected to reach 790 - 3,300 (median: 1,500), even without proactive testing.

Projections for other vaccination rates are provided in Table 1 and Figure A2.

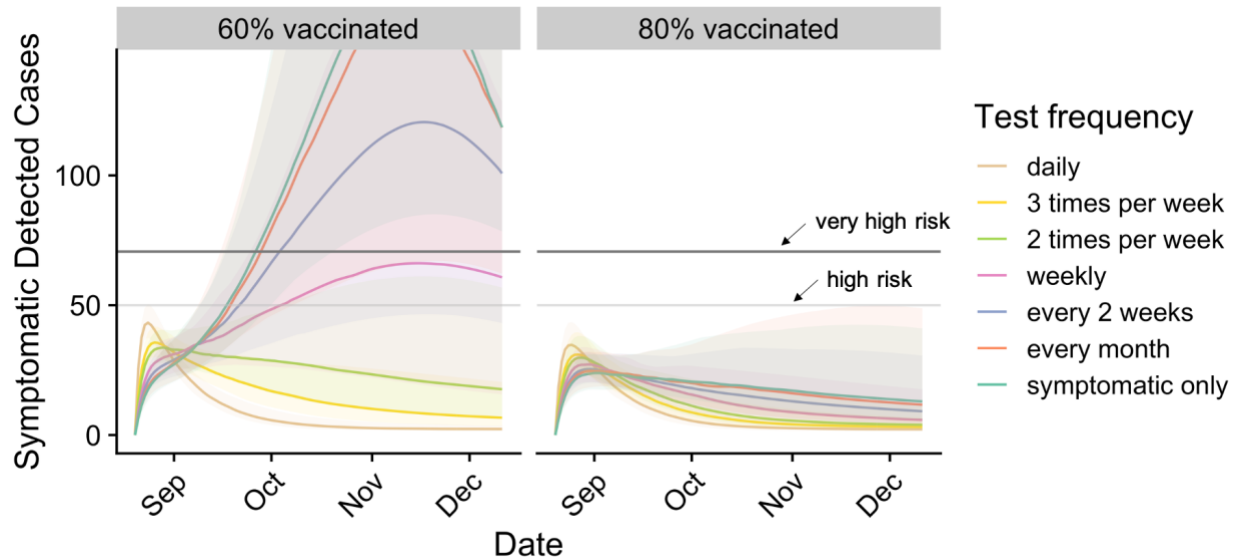


Figure 1. Projected COVID-19 cases among UT students through December 16, 2021 under different levels of proactive testing, assuming 60% (left graph) or 80% (right graph) of students are fully vaccinated by August 25, 2021. Graphs project the daily prevalence of symptomatic infections detected through December 16, 2021 through a combination of symptomatic and proactive testing. Colors indicate the testing frequency for the unvaccinated population, assuming 50% compliance. Shading indicates the 90% prediction intervals. Horizontal lines represent the risk thresholds.

Table 1. Projected total infections among UT students through December 16, 2021, under various scenarios for vaccination coverage and proactive testing frequency. Numbers are medians (90% prediction intervals) across 500 simulations.

		Percent of UT students fully vaccinated by August 25				
		40%	50%	60%	70%	80%
Proactive testing frequency	none	19,100 (15,500 - 23,200)	15,400 (11,700 - 19,800)	11,200 (5,500 - 16,300)	5,000 (2,200 - 10,400)	1,500 (790 - 3,300)

monthly	18,100 (13,300 - 22,000)	13,700 (10,100 - 18,800)	9,600 (4,900 - 14,900)	3,700 (1,900 - 8,800)	1,300 (660 - 3,300)
every 2 weeks	16,100 (11,600 - 20,300)	12,400 (8,500 - 17,100)	7,600 (3,500 - 13,100)	2,900 (1,300 - 6,200)	1,100 (630 - 2,200)
weekly	13,500 (8,500 - 18,500)	8,200 (4,400 - 15,100)	4,500 (1,700 - 8,900)	1,900 (1,000 - 4,000)	740 (460 - 1,600)
2 times per week	7,400 (2,800 - 12,000)	3,300 (1,800 - 6,400)	1,700 (900 - 3,900)	910 (540 - 2,000)	540 (310 - 1,100)
3 times per week	2,600 (1,100 - 6,100)	1,500 (800 - 3,100)	940 (580 - 1,900)	630 (380 - 1,400)	440 (270 - 880)
daily	470 (320 - 730)	400 (280 - 580)	360 (250 - 540)	340 (220 - 580)	300 (180 - 500)

Frequency of proactive testing required to manage spread

We estimate the frequency of testing needed to prevent the number of symptomatic cases from exceeding the *very high risk threshold*, which corresponds to the level of infection that triggered UT's delay of in-person instruction in January 2021. Our estimates assume that 50% of unvaccinated students comply with proactive testing.

Figure 2 and Table 2 provide the minimum frequency of testing (left graph) and resulting volume of tests administered per week (right graph) across a range of vaccination scenarios:

- If vaccination rates remain near 60%, then proactive testing should be offered at least two times per week (totalling 20,000 tests per week) to provide a 95% guarantee that symptomatic infections will not exceed the *very high risk threshold* during the fall semester.
- If 80% of students are vaccinated, then symptomatic testing only should suffice.

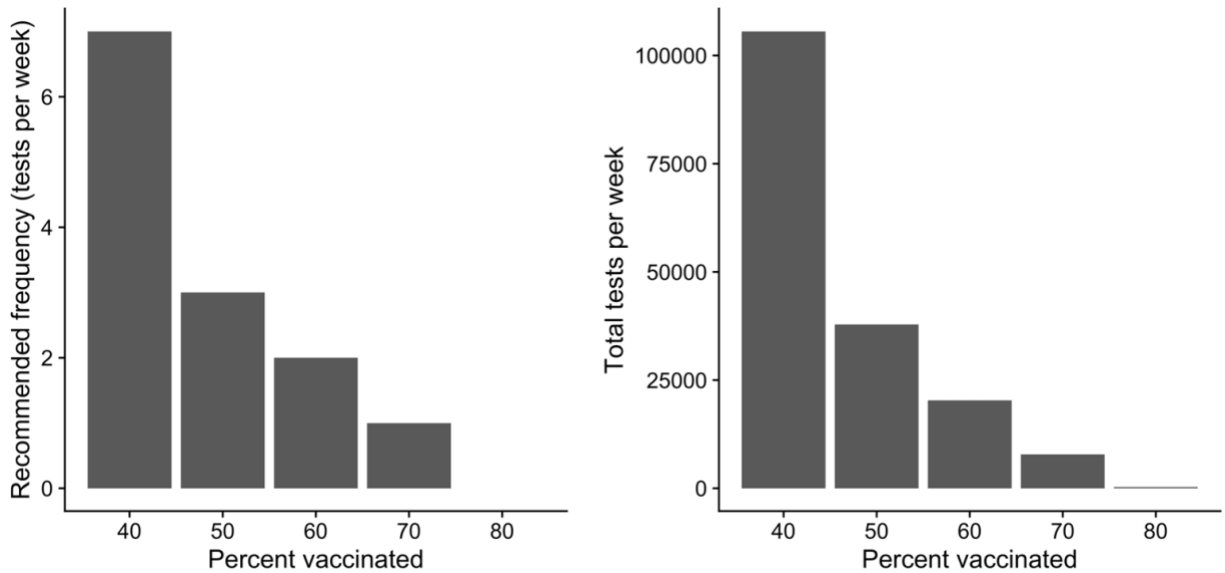


Figure 2. Minimum level of proactive testing to provide 95% guarantee that symptomatic infections will not exceed the *very high risk threshold* across a range of vaccination scenarios. The left graph indicates the minimum frequency of tests per unvaccinated student, assuming 50% compliance. The right graph shows the corresponding total numbers of tests administered per week. The x-axes indicate the percent of UT students fully vaccinated by August 25, 2021.

Table 2. Estimated level of proactive testing to provide 95% guarantee that symptomatic cases will remain below the *very high risk threshold*.

	Percent of UT students fully vaccinated by August 25				
	40%	50%	60%	70%	80%
Minimum frequency	daily	3 times per week	2 times per week	weekly	none
Total proactive tests per week	105,000	37,500	20,000	7,500	0

Economic costs

We project the cost to the university in each vaccination and testing scenario. Regardless of testing frequency, the costs are expected to be significantly higher under the currently estimated (~60%) vaccination scenario than the high (80%) vaccination scenario (Figure 3, Table 3, Figure A3). For any vaccination rate, we project that ramping up proactive testing to prevent a surge beyond the *very high risk threshold* would be cost saving, assuming that crossing the threshold would trigger a move to

online instruction. While proactive testing entails up-front infrastructure, supply and personnel costs, it can avert the higher costs of providing isolation facilities, sequencing, contact tracing, and PCR testing as well as avoiding the high cost of moving all courses online.

Figure 3 and Table 3 provide the breakdown of expected costs for all vaccination and proactive testing scenarios:

- Under the currently estimated vaccination scenario (~60%), the projections indicate that proactive testing of unvaccinated students two times per week would be required to keep cases under the *very high risk threshold*. We estimate that the costs to the university would total \$4.5 million with this level of proactive testing compared to \$10.7 million without proactive testing.
- Under the high vaccination (80%) scenario, the projections indicate that proactive testing is not needed to control spread, and the estimated costs to the university would be \$520,000.

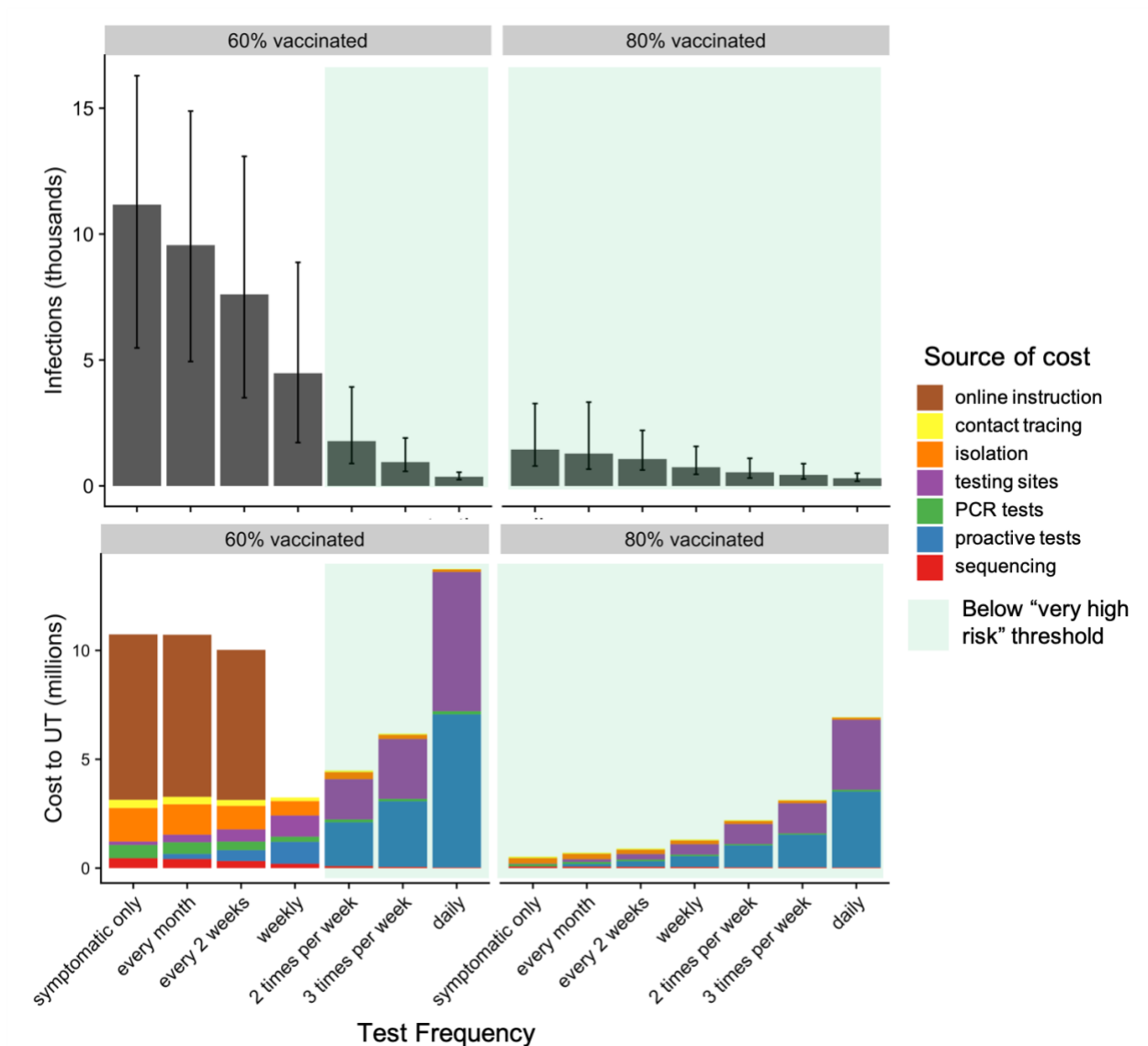


Figure 3. Projected health and economic costs through December 16, 2021 under different levels of proactive testing, assuming 60% (left graph) or 80% (right graph) of students are fully vaccinated by August 25, 2021. The top graphs indicate the median and 90% predictive interval of projected cumulative infections. The bottom graphs indicate the projected costs, broken down by the source (colors). The green shading indicates testing frequencies that are expected to keep symptomatic prevalence below the *very high risk threshold*.

Table 3. Projected costs (in million USD) to UT through December 16, 2021, under various scenarios for vaccination coverage and proactive testing frequency. Numbers are medians (90% prediction intervals) across 500 simulations.

	Percent of UT students fully vaccinated by August 25
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		40%	50%	60%	70%	80%
Proactive testing frequency	none	14.1 (12.8 - 16.0)	13.1 (10.9 - 15.1)	10.7 (7.4 - 13.3)	1.4 (0.7 - 10.3)	0.52 (0.35 - 0.93)
	monthly	14.4 (12.5 - 16.6)	13.1 (10.3 - 15.2)	10.7 (6.6 - 13.5)	1.5 (1.0 - 9.7)	0.71 (0.54 - 1.18)
	every 2 weeks	15.0 (13.3 - 16.6)	13.3 (10.7 - 15.8)	10.0 (2.0 - 13.3)	1.6 (1.2 - 8.5)	0.90 (0.78 - 1.20)
	weekly	15.4 (12.9 - 17.9)	12.3 (6.3 - 15.6)	3.2 (2.6 - 11.8)	2.1 (1.8 - 2.6)	1.3 (1.2 - 1.5)
	2 times per week	15.6 (6.7 - 18.0)	5.9 (5.4 - 13.9)	4.5 (4.3 - 5.0)	3.3 (3.2 - 3.6)	2.2 (2.1 - 2.5)
	3 times per week	9.6 (9.2 - 17.0)	7.8 (7.6 - 8.2)	6.2 (6.0 - 6.4)	4.6 (4.5 - 4.8)	3.1 (3.1 - 3.2)
	daily	20.6 (20.5 - 20.6)	17.2 (17.1 - 17.2)	13.8 (13.7 - 13.8)	10.3 (10.2- 10.4)	6.9 (6.8 - 7.0)

Projected isolation facility needs for residence hall students

There are an estimated 7,400 students who live in on-campus housing at UT Austin. Assuming 80% of residential students who test positive require an isolation facility room for an average of seven days, we project the peak occupancy for each vaccination scenario (Figure 4, Table 4) under symptomatic testing only. If 60% of students are vaccinated and only symptomatic testing is performed, then we project a peak demand of between 13 and 45 (median: 25) students requiring simultaneous isolation. In contrast, at an 80% vaccination rate, the peak occupancy is expected to be between 2 and 11 (median: 6) students. Of note, these projections likely represent underestimates of isolation facility usage, as they do not account for positives that may be identified through contact tracing or proactive testing.

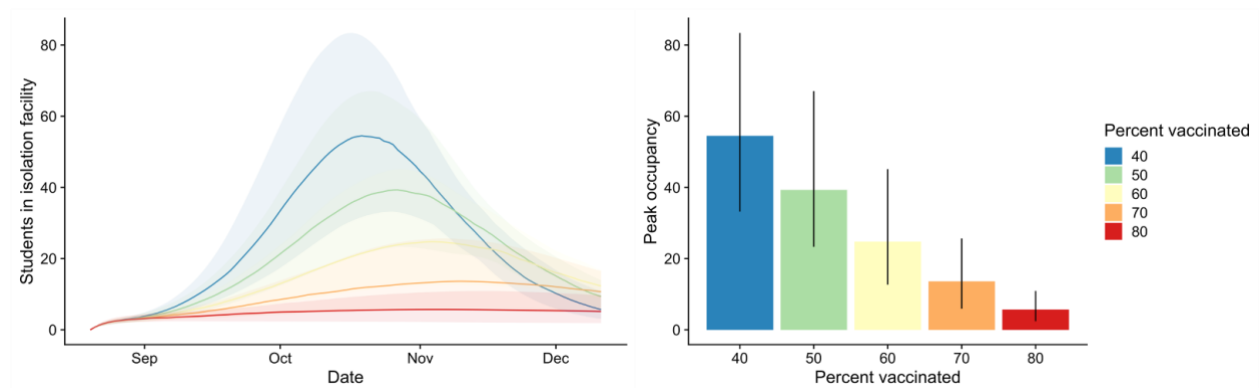


Figure 4. Projected number of students living in UT residence halls requiring an isolation room across a range of vaccination scenarios. The left graph shows the median and 90% prediction intervals of isolation facility occupancy and the right graph provides the medians and 90% prediction intervals in peak occupancy.

Table 4. Projected demand for isolation facilities across vaccination scenarios. Values are medians (90% prediction intervals).

	Vaccination rate				
	40%	50%	60%	70%	80%
Total students requiring isolation	1,700 (1,200 - 2,100)	1,400 (1,000 - 1,900)	1,000 (700 - 1,500)	650 (350 - 1,000)	330 (190 - 510)
Peak demand	55 (33-83)	39 (23-67)	25 (13 - 45)	14 (6-26)	6 (2-11)

Final Considerations

Our projections suggest that proactive testing of unvaccinated students can help to suppress transmission and be cost saving overall, particularly if vaccination levels remain relatively low. However, increasing vaccination coverage among students is likely the most effective means of reducing the burden of COVID-19 and keeping costs low.

These projections are based on numerous assumptions and should be interpreted merely as rough guideposts to inform decision making at UT. The spread and associated costs of COVID-19 will depend not only on vaccination coverage and proactive testing efforts, but also on UT policies, student behavior, vaccine uptake throughout the semester, and the potential emergence of new variants with different transmission rates or severity. If vaccine efficacy against the Delta variant or newly

emerging variants is found to be significantly lower than assumed in these projections, then proactive testing of vaccinated students may also be advisable during surges in infections. Our projections assume a high and constant transmission rate from August 15 through December 16, 2021 and thus do not account for measures such as face mask usage, physical distancing, and contact tracing that might significantly mitigate spread. Finally, we assume that 50% of unvaccinated students would be willing to participate in proactive testing, which may not be attainable.

Appendix

A.1 Estimating introduction risks

To estimate the number of UT students who will return to Austin infected, we consider the prevalence of the virus in the county of residence for each student. For each home county, c , we define the following:

n_c : the number of UT students originating from county c $p_{i,c}$: the probability that a student from county c is infected with COVID-19

The expected number of students that will arrive infected from that county is then the product of these two quantities:

$$i_c = n_c \cdot p_{i,c}$$

While n_c is known, p_c must be approximated. We assume that p_c is equal to the background prevalence of COVID-19 in the county. For example, if there are 100 students from a given county with a COVID-19 prevalence of 5%, we assume that 5 students are currently infected. In order to calculate the expected total number of infected UT students i , we simply add up the expected number of infected students from each county that UT students come from:

$$i = \sum_c i_c$$

To determine the number of students originating from various US counties, the UT registrar provided the county-level residence for all students enrolled at the University of Texas at Austin as of July 25, 2021. For students whose permanent residence is outside of the US, we assume they already reside in Austin and therefore have a disease prevalence equal to that of Travis county. These data were used to estimate both the initial prevalence of SARS-CoV-2 infections and vaccination rates among UT students.

For a given home county c of a returning student, the prevalence of SARS-CoV-2 p_c is the fraction of the population that are currently infected and capable of infecting others. To approximate prevalence, we consider the following four quantities:

1. **Incidence in reported cases in county c , through t days ago ($C_{c,t}$).** We obtained confirmed case count data from the New York Times [11,12].
2. **Reporting rate in county c (k_c).** Many infections are never reported because they are asymptomatic, mild or not tested for other reasons [6,13]. Based on recent estimates of detection rates from the spring of 2021, we assume a median of a 1 in 3.9 reporting rate and present scenario bounds of 1 in 3.5 to 1 in 4.4 [6].
3. **Duration of the infectious period (τ).** We make the simplifying assumption that newly detected infections are infectious for 7 days after detection [14].
4. **The population size of the region (N_r).**

First, we estimate the number of current infections in a county as

$$I_c = \frac{1}{k_c} \sum_{t=1}^{\tau} C_{c,t}$$

We then estimate the prevalence in county c as

$$p_c = \frac{I_c}{N_c}$$

A.2 Estimating vaccination rates

To estimate the number of UT students who will return to Austin infected, we consider the vaccination rate in the county of residence for each student. For each student's home county, c , we define the following:

n_c : the number of UT students originating from county c

$p_{v,c,t'}$: the projected probability that a student from county c is fully vaccinated for COVID-19 at time t'

While n_c is known, $p_{v,c,t'}$ must be approximated. We assume that $p_{v,c,t}$ is equal to the current vaccination rate in the county and $p_{v,c,t'}$ is the projected vaccination rate in the region on August 25, 2021. To estimate $p_{v,c,t'}$ at some time $t' > t$, we assume that in the short term, the number of newly vaccinated people in a county each day will remain constant (i.e. linear increase in overall vaccination rate). To estimate the linear growth rate in vaccination rate in each county, $\beta_{v,c}$, we fit the previous month's vaccination rates to a linear model in each county:

$$p_{v,c,t} = \beta_0 + \beta_{c,r}t$$

Where β_0 is the y-intercept, or the vaccination rate on June 25, 2021. We then project the vaccination rate for the future:

$$p_{c,t'} = \beta_0 + \beta_{c,r}t'$$

Where t' corresponds to the future time (August 25, 2021) we are projecting. For this analysis, we used the reported rates of fully vaccinated individuals from June 25, 2021 to July 25, 2021, and we use the fitted vaccination rate (proportion newly fully vaccinated per day) to extrapolate the vaccination rate on August 25, 2021. For students coming from Texas, we use data on vaccination rates in the county for 16-49 year olds [7]. For students from the US outside of Texas, we use data on vaccination rates in the region for the 18 and older population [8]. For students from outside of the US, we assume they will have a vaccination rate equal to that of Travis county.

The expected number of students that will arrive fully vaccinated from that county is then the product of these two quantities:

$$v_{c,t'} = n_r \cdot p_{v,c,t'}$$

In order to calculate the expected total number of vaccinated UT students v , we simply add up the expected number of vaccinated students from each county that UT students come from:

$$v = \sum_c v_{c,t'}$$

For a given home county c of a returning student, the COVID-19 vaccination rate p_v is the fraction of the population that are fully vaccinated. To account for the course nature of this data in terms of its age distribution and demographic information, we reason it was possible that true vaccination rates in students could be k_v times higher. We consider the scenario bounds of:

1. Lower bound scenario: 18-24 year olds have been shown to be 80% as likely to be vaccinated compared to the general population $k_v=0.8$ [10]
2. Upper bound scenario: college educated individuals have been shown to be 1.12 times more likely to be vaccinated than the general population: $k_v= 1.12$ [9] We then estimate the student vaccination rate in the population of N students as

$$p_v = k_v \frac{v}{N}$$

A.3 COVID-19 Transmission model with vaccination and testing

The model structure is diagrammed in Figure A1 and described in the equations below.

In short, the population is divided into four groups based on vaccination status (subscripts u and v) and quarantine status (subscript q). Within these groups, individuals can transition between disease states: susceptible (S), exposed (E), infectious pre/asymptomatic (I_a), infectious symptomatic (I_s), and recovered (R). The symbols S , E , I_a , and R denote the number of people in that state in the given vaccination/quarantine group. Individuals can transition from the active (in contact with others) state to the quarantine state and back based on receiving a positive test result and being released from quarantine, respectively. The total size of the active population (anyone not in quarantine) at any time is given by:

$$X(t) = S_u + E_u + I_{au} + I_{su} + R_u + S_v + E_v + I_{av} + I_{sv} + R_v.$$

The force of infection at time t , denoted as $\beta^*(t)$ is given by:

$$\beta^*(t) = \beta_A(I_{au} + e_v I_{av}) + \beta_S(I_{su} + e_v I_{sv})$$

Where β_A and β_S are the transmission rate of asymptomatic and symptomatic individuals respectively, and e_v is the reduction in transmissibility of vaccinated infected individuals.

The model equations governing transition from one state to the next are given by:

$$\frac{dS_u}{dt} = -\beta^*(t)\frac{S_u}{X(t)} - S_u w_u(1 - Sp)if_u + S_{qu}k - in$$

$$\frac{dE_u}{dt} = \beta^*(t)\frac{S_u}{X(t)} - \gamma E_u - E_u w_u(1 - Sp)if_u$$

$$\frac{dI_{au}}{dt} = \gamma E_u - \delta_{au}I_{au} - I_{au}w_uSeif_u + E_{qu}k + in$$

$$\frac{dI_{su}}{dt} = p_{sym}\delta_{au}I_{au} - \delta_s I_{su} - i_{sym}I_{su} - I_{su}w_uSeif_u$$

$$\frac{dR_u}{dt} = \delta_s I_{su} + (1 - p_{sym})\delta_{au}I_{au} - R_u w_u(1 - Sp)if_u + R_{qu}k + \delta_q I_{squ} + \delta_q I_{aqu}$$

$$\frac{dS_{qu}}{dt} = S_u w_u(1 - Sp)if_u - S_{qu}k$$

$$\frac{dE_{qu}}{dt} = E_u w_u(1 - Sp)if_u - E_{qu}k$$

$$\frac{dI_{aqu}}{dt} = I_{au}w_uSeif_u - \delta_q I_{aqu}$$

$$\frac{dI_{squ}}{dt} = I_{su}w_uSeif_u + i_{sym}I_{su} - \delta_q I_{squ}$$

$$\frac{dR_{qu}}{dt} = R_uw_u(1 - Sp)if_u - R_{qu}k$$

$$\frac{dS_v}{dt} = -\sigma_v\beta^*(t)\frac{S_v}{X(t)} - S_vw_v(1 - Sp)if_v + S_{qv}k$$

$$\frac{dE_v}{dt} = \beta^*(t)\frac{S_v}{X(t)} - \gamma E_v - E_vw_v(1 - Sp)if_v$$

$$\frac{dI_{av}}{dt} = \gamma E_v - \delta_{av}I_{av} - I_{av}w_vSeif_v + E_{qv}k$$

$$\frac{dI_{sv}}{dt} = p_{sym,v}\delta_{av}I_{av} - \delta_s I_{sv} - i_{sym}I_{sv} - I_{sv}w_vSeif_v$$

$$\frac{dR_v}{dt} = \delta_s I_{sv} + (1 - p_{sym,v})\delta_{av}I_{av} - R_vw_v(1 - Sp)if_v + R_{qv}k + \delta_q I_{sqv} + \delta_q * I_{aqv}$$

$$\frac{dS_{qv}}{dt} = S_vw_v(1 - Sp)if_v - S_{qv}k$$

$$\frac{dE_{qv}}{dt} = E_vw_v(1 - Sp)if_v - E_{qv}k$$

$$\frac{dI_{aqv}}{dt} = I_{av}w_vSeif_v - \delta_q I_{aqv}$$

$$\frac{dI_{sqv}}{dt} = I_{sv}w_vSeif_v + i_{sym}I_{sv} - \delta_q I_{sqv}$$

$$\frac{dR_{qv}}{dt} = R_vw_v(1 - Sp)if_v - R_{qv}k$$

Where σ_v is the relative susceptibility to infection if vaccinated, Se and Sp are the sensitivity and specificity of surveillance tests, w and u are the willingness to test amongst the vaccinated and unvaccinated individuals respectively, f_u and f_v are the surveillance testing frequencies among vaccinated and unvaccinated individuals respectively, i is the probability that an individual isolates after receiving a positive test result, i_{sym} is the probability that an individual isolates and seeks testing after developing symptoms, k is the rate of confirmatory testing, γ is the transition rate from exposed to infectious calculated from the latent period duration, and δ_{av} and δ_{sv} are the proportion of infected individuals who eventually show symptoms in the unvaccinated and vaccinated groups respectively, δ_{av} and δ_{sv} are the transition rates out of the asymptomatic compartment for the vaccinated and unvaccinated individuals, respectively, and δ_q and δ_{sq}

$$\delta_s \quad \delta_{sq}$$

are the transition rates out of the symptomatic compartments for the active and quarantined individuals respectively. The values of the transition rates are estimated from the average time spent in each compartment. See Table A2 for all parameter values. The model is implemented as a system of differential equations that are solved in R using the deSolve package [cite]. It is assumed that the entire population of active individuals, including vaccinated and unvaccinated individuals are well mixed. The initial conditions are given in Table A1, and the values for the parameters in the transmission model are given in Table A2.

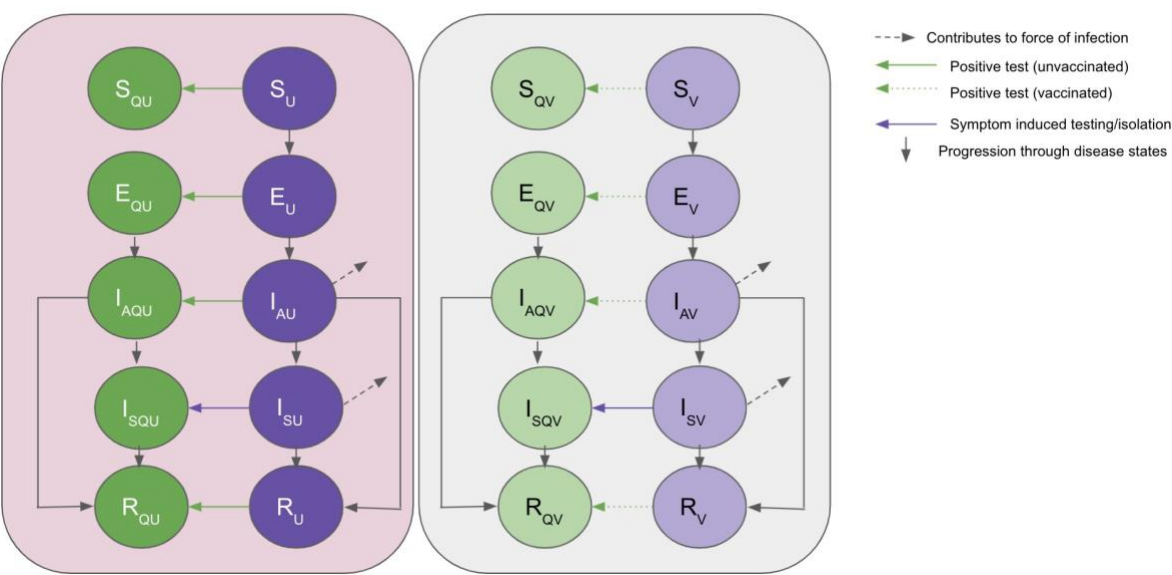


Figure A1. Compartmental model of COVID-19 transmission incorporating testing and vaccination. Each group (defined by vaccination (v) and quarantine states (q)) is modeled with a set of compartments. Upon infection, susceptible individuals (S) progress to the exposed compartment (E) and then to asymptomatic infectious compartment (I_A). Some of those progress to symptomatic infections (I_S) and some go directly to recovered (R). Testing frequencies dictate the rate at which individuals move into their corresponding disease states in the quarantine group.

Table A1. Initial conditions

Variable	Settings
Initial day of simulation	8/25/2021

Initial infection prevalence among UT students	420 [380-470] per 100,000 based on introduction estimates described in Appendix A.1
Initial fraction immune among UT students	Triangular (32%, 40%, 48%) based on CDC seroprevalence estimates for TX [5] + hospitalizations from June 15-Aug 03, 2021
Number of UT students	50,000
Number of students living in on-campus housing	7,400

Table A2. Transmission model parameters

Parameter	Value	Source
e_v : Reduced transmissibility of infected individuals that have been vaccinated	0.5	[4]
σ_v : relative susceptibility to infection if vaccinated	Triangular(0.27, 0.36, 0.5) corresponding to (73%, 64%, 50%) efficacy at preventing infection	Contact tracing data from Israel [2] + Pfizer study in HCWs/ Vaccine efficacy against delta [1,15–18]
$sym_{red,v}$: overall reduction in chance of symptomatic disease if vaccinated	Triangular (27%, 30%, 35%) corresponding to (73%, 70%, 65%) effective at preventing symptomatic disease	Contact tracing data from Israel [2] Pfizer/Moderna[1,19]

S_p : specificity of antigen test	99.5%	test specificity [20–22]
S_e : sensitivity of antigen test	90% for antigen	test sensitivity [20–22]
w_v : test acceptance rate in vaccinated individuals	50%	Assumed [23]

w_u : test acceptance rate in unvaccinated individuals	50%	Assumed [23]
f_v : daily frequency of test offer to vaccinated individuals	0	Assumed that vaccinated individuals would be exempt from proactive surveillance testing
f_u : daily frequency of test offer to unvaccinated individuals	Varied from once every month to dailly	Assumed
i : isolation probability for individuals who receive a positive test result or who develop symptoms	Triangular(90%, 92.5%, 95%)	Assumed
i_{sym} : isolation probability for individuals who develop symptoms	Triangular(20%, 25%, 33%)	Assumed

k : rate of confirmation testing	1/2	Assumed based on time to seek test after rapid result + UT PCT test-turnaround time
t_{exposed} : duration of latent period	3 days	[14]
t_{presym} : duration of presymptomatic period	2.3 days	[14]
$t_{\text{infectious}}$: total duration of infectiousness (same for both asymptomatic and presymptomatic)	7 days	[14,24]
$t_{\text{symptomatic}}$: duration of symptomatic infectiousness	4.7 days	$t_{\text{infectious}} - t_{\text{presym}}$
$t_{\text{quarantine}}$: duration of quarantine for positive individuals	7 days	[25]

p_{sym} : proportion of infectious individuals that eventually show symptoms	Triangular(0.5, 0.6, 0.7)	[26]
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$p_{sym,v}$: proportion of vaccinated infectious individuals that eventually show symptoms	Triangular(0.1, 0.15, 0.29)	<p>Calculated based on reduction in susceptibility (σ_v) and reduction in overall symptomatic probability of those vaccinated</p> $p_{sym,v} = \frac{(1 - sym_{red})}{\sigma_v}$
δ_s : recovery rate from symptomatic infection	1/4.7 = 0.21	Calculated from the average time in the symptomatic infectious state
δ_{au} : transition rate out of asymptomatic unvaccinated compartment	$\frac{1}{t_{asym,u}}$ $t_{asym,u} = \text{Triangular}(0.12, 0.14, 0.17)$	<p>Calculated based on the average time in asymptomatic compartment and the proportion symptomatic</p> $t_{asym,u} = p_{sym}t_{presym} + (1 - p_{sym})t_{infectious}$ <p>which implies</p> $\delta_{au} = (t_{asym,u})^{-1}$
δ_{av} : transition rate out of asymptomatic vaccinated compartment	$\frac{1}{t_{asym,v}}$ $t_{asym,v} = \text{Triangular}(0.03, 0.04, 0.06)$	<p>Calculated based on the average time in asymptomatic compartment and the proportion symptomatic</p> $t_{asym,v} = p_{sym,v}t_{presym} + (1 - p_{sym,v})t_{infectious}$ <p>which implies</p> $\delta_{av} = (t_{asym,v})^{-1}$
δ_q : rate of release from quarantine if true positive	1/7 = 0.14	Calculated from time in the symptomatic quarantined state

R_0 : basic reproductive number	Triangular(4.5, 5, 5.5)	Wildtype $R_0 \sim 2.7$ [27] Alpha 60% more transmissible than wildtype [28], Delta 60% more
		transmissible than Alpha [29]
β : daily transmission rate of infectious individuals	Triangular(0.64, 0.71, 0.79)	Calculated from R_0 , $\beta = \frac{R_0}{t_{infectious}}$
p_{sym} : proportion of infectious individuals that eventually show symptoms	Triangular(0.5, 0.6, 0.7)	[26]
$p_{sym,v}$: proportion of vaccinated infectious individuals that eventually show symptoms	Triangular(0.56, 0.6, 0.63)	$\frac{sym_{red}}{\sigma_v}$ Calculated as:
in : number of introductions per week	UT population: Triangular(4, 5, 6) Residence halls: Triangular (2, 5, 8)	Assumed
p_{isofac} : probability of using isolation facility if living in oncampus housing and testing positive	UT population: 68%	Estimated from 2020-2021 isolation facility data and case data
	Residence halls: 80%	Assumed from conversations with Aaron Voyles using data from the 2020-2021 academic year

Table A3. Cost parameters

Variable	Setting	Source
Confirmatory PCR test	\$23 per test	Jessica Klima (they have 20k tests to deplete)
Sequencing of positive sample	\$60 per sample	Jessica Klima (assuming a full plate)
Contact-tracing	\$50 per positive	Darlene Bhavnani (tracers only, no admin staff)
Isolation facility usage	\$300 per student per day	Johnathan Robb (cost ATX charges UT for usage)
	68% of students testing positive use isofac	2,229 total new students in isofac of 3,271 positives during the 2020-2021 academic year
	7 day isolation period	Assumed from duration of infectiousness
Rapid surveillance tests	Free for physical test from the state, \$6.25 per test for staff	Jessica Klima
Testing sites	\$12,500 per testing site	Jessica Klima

	1,375 tests per site per week	Jessica Klima
Cost per day of moving classes	\$100,000 per day	Discussions with Art Markman and John Salsman (cost of computers to UT students, cost for units that wanted to bring staff back and now have to move to remote)

A.4 Results for vaccination coverage ranging from 40% to 80%

In this section, we provide epidemiological and cost projections for vaccination scenarios ranging from 40% to 80% of UT students fully vaccinated by August 25, 2021.

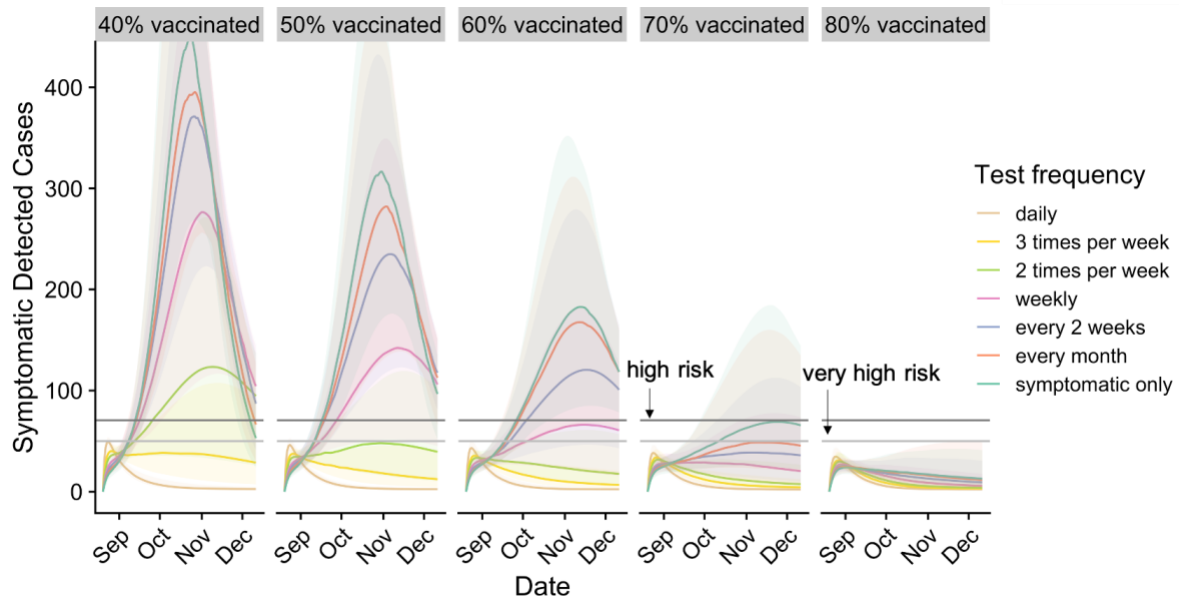


Figure A2. Projected COVID-19 cases among UT students through December 16, 2021 under different levels of proactive testing, assuming 40%, 50%, 60%, 70% or 80% of students are fully vaccinated by August 25, 2021. Graphs project the daily prevalence of symptomatic infections detected through December 16, 2021 through a combination of symptomatic and proactive testing. Colors indicate the testing frequency for the unvaccinated population, assuming 50% compliance. Shading indicates the 90% prediction intervals. Horizontal lines represent the risk thresholds.

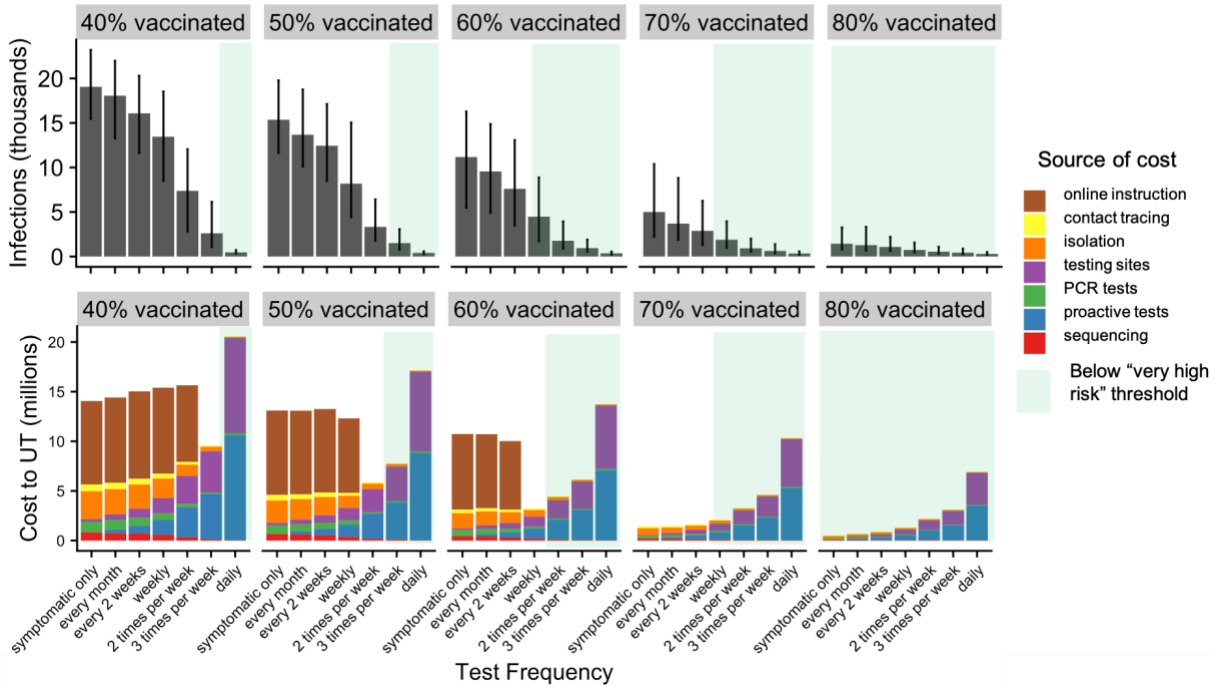


Figure A3. Projected health and economic costs through December 16, 2021 under different levels of proactive testing, assuming 40%, 50%, 60%, 70%, or 80% of students are fully vaccinated by August 25, 2021. The top graphs indicate the median and 90% predictive interval of projected cumulative infections. The bottom graphs indicate the projected costs, broken down by the source (colors). The green shading indicates testing frequencies that are expected to keep symptomatic prevalence below the *very high risk threshold*.

A.5 Sensitivity analysis: Correlation between prior infection and vaccination status

Above, we assume that an individual's probability of being vaccinated and their probability of having previously been infected are independent. However, it is possible that vaccination status and prior infection are anti-correlated. In other words, individuals who are less likely to vaccinate are also more likely to have been previously infected. As sensitivity analysis, we provide projections assuming different levels of correlation between prior infection and vaccination. We initialize the simulations based on population-level estimates of vaccine coverage, prior infection, and odds of being previously infected if unvaccinated as follows:

Assuming we only know the population level probability of being vaccinated, $P(V)$, and the population level probability of being previously infected $P(I)$, we varied the odds of being previously infected given you are not vaccinated and calculated the following:

$$P(R|!V) = O(R|!V)P(!V) = O(R|!V)(1 - P(V))$$

$$P(R|V) = \frac{P(R)}{P(V) + O(R|!V)(1 - P(V))}$$

From these, we can write out the proportion of all individuals initially that fall into the recovered unvaccinated compartment (R_u), the susceptible unvaccinated compartment (S_u), the recovered vaccinated compartment (R_v), the susceptible vaccinated compartment (S_v)

$$P(R_u) = P(R|!V)P(!V) = O(R|!V)(1 - P(V))(1 - P(V))$$

$$P(S_u) = P(!R|!V)P(!V) = (1 - O(R|!V)(1 - P(V)))(1 - P(V))$$

$$P(R_v) = P(R|V)P(V) = \frac{P(R)}{P(V) + O(R|!V)(1 - P(V))}P(V)$$

$$P(S_v) = (1 - P(R|V))P(V) = (1 - \frac{P(R)}{P(V) + O(R|!V)(1 - P(V))})P(V)$$

In Figure A4, we assume that the odds of prior infection conditional upon being unvaccinated range from 0.5 (unvaccinated individuals are 50% less likely to have been previously infected than vaccinated individuals) to 3 (unvaccinated individuals are three times as likely to have been previously infected than vaccinated individuals). The higher the correlation, the greater the fraction of the population that has some degree of immunity from either prior infection or vaccination. Although high levels of anticorrelation between prior infection and immunity substantially decrease the projected surges, we estimate that vaccination rates over 50% are required to remain below the very high risk threshold.

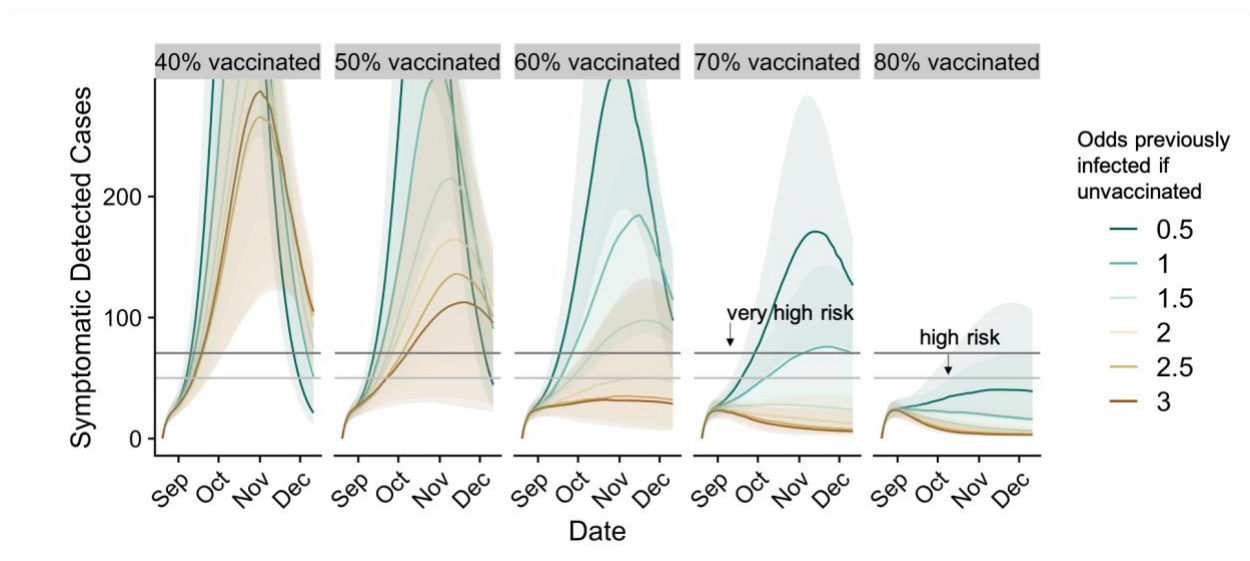


Figure A4. Projected COVID-19 cases among UT students through December 16, 2021 as a function of the odds of previous infection if unvaccinated (colors), assuming 40%, 50%, 60%, 70% or 80% of students are fully vaccinated by August 25, 2021. Graphs project the daily prevalence of symptomatic infections detected through December 16, 2021 through a combination of symptomatic and proactive testing. The projections assume symptomatic testing only. Shading indicates the 90% prediction intervals. Horizontal lines represent the risk thresholds.

A.6 Estimates of initial proportion of the population previously infected

To estimate cumulative infections in the UT student population through August 25, 2021, we used CDC Seroprevalence estimates by state and age group, which are available through mid-June, 2021 [13]. To account for more recent infections, we estimated the number of infections in the student age group in Austin from local agestratified COVID-19 hospitalization data and published age-specific infection hospitalization rates [30,31]. Using data prior to June 15, we estimated the ratio of prior infections in Austin versus the CDC seroprevalence estimates from Texas and then used the Austin data from June 15 to August 3 to estimate the additional infections that occurred in Texas during this period.

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