



Campus COVID-19

Vaccination and Mitigation Initiative

AMERICAN COLLEGE HEALTH ASSOCIATION

## ARE CAMPUSES READY FOR OMICRON OR THE NEXT VARIANT?

Why requirements, boosters, and masking are key to safe campuses in early 2022

JANUARY 20, 2022

### Q: Tell us a bit about yourselves and your work in COVID-19 and higher education.

**A:** I'm **Ben Miller, PhD, MPH**, and I work as a public health consultant for the Acheson Group. Prior to my work in the private sector, I worked as an epidemiologist and public health official for the State of Minnesota, investigating infectious disease outbreaks. My doctoral work is in environmental health with a focus on infectious diseases. When the COVID pandemic started, I worked with several sectors, including higher education, to create response and testing plans for colleges and workplaces. I reached out to Dr. Hoyer-Leitzel in May of 2021 based on some influenza modeling work she had done while an undergraduate at St. Olaf College in Northfield, Minnesota. At that time, I worked with Dr. Hoyer-Leitzel to develop a model to look at the protective effects of a vaccination requirement on a campus like St. Olaf, and the results of this model helped inform vaccine policy for several colleges. As we discuss below, this model has been updated and refined to look at the collective benefits of booster and mask requirements against the highly transmissible Omicron variant.



I'm **Dr. Alanna Hoyer-Leitzel**, assistant professor of mathematics at Mount Holyoke College in South Hadley, MA. My PhD is in mathematics, and specifically dynamical systems. My usual focus is on ecological applications, but I jumped on this chance to apply my experience and expanded knowledge of modeling to create a simple but informative model for COVID infection, vaccines, masking, and boosters on a college campus. I believe that simple, rigorous models are a powerful tool for decision making.



## Q: Many colleges had relatively low case rates during the fall of 2021. Why is there a need for booster doses now?

**A:** When vaccines became widely available to the college-age population in late spring 2021, many campuses weighed the need for vaccine requirements to protect their campuses from the Alpha variant surge happening at the time and from future surges. As the Delta variant surged in many parts of the United States in the late summer and fall, campuses who required vaccines for students, staff, and faculty experienced relatively low infection rates, even as surrounding community case rates rose or remained high.

At the end of 2021, the Omicron variant showed up in force on some campuses in the Northeastern U.S., sending classes [online](#) and students home for an [early](#) winter break. Now, with case rates surging to record levels, some college campuses are delaying start dates and moving fully online.

In May 2021, we modeled the protective effects of a fully vaccinated population against a then-emerging and more highly transmissible Delta variant and found that vaccination rates of greater than 90% were needed to prevent large outbreaks in a closed campus of approximately 3,500 students and faculty. This modeling helped inform the vaccine policy for a handful of schools who in May and June 2021 were considering a requirement.

Research published in [Science](#) in November 2021 showed waning vaccine efficacy in all age groups after 6 months, with vaccine efficacy against symptomatic illness ranging from 13-58%, depending on the vaccine. Although Omicron was only identified in late November 2021, preliminary research from the United Kingdom show vaccine efficacy against symptomatic illness increases to over 70% two to four weeks after an mRNA booster.

We've updated our model to look at the effect of masking and booster doses on limiting case rates for the much more transmissible Omicron variant. This new model shows that consistent masking and mandating boosters are significant factors in reducing the rate of transmission on campuses. If case rates in students, staff, and faculty rise too quickly on a campus, the impacts to classroom instruction, food service, athletics, health clinics, and other core services will be severely limited, even with Center for Disease Control and Prevention's abbreviated isolation guidance.

## Q: What type of model did you use for your analysis and what does it show us about boosters and masking?

**A:** We use a compartmental SIR (Susceptible, Infectious, Recovered) differential equations model for our analysis, modified to include effects of vaccination, masking, and isolation when sick. (More details at the end.) We perform two types of analysis on the model. The first is to calculate a *nullcline* for the infectious population, i.e., the threshold corresponding to when the rate of new cases will change from positive to negative. The second is to consider several scenarios, solve the corresponding differential equations, and compare the cumulative case counts after 100 days.

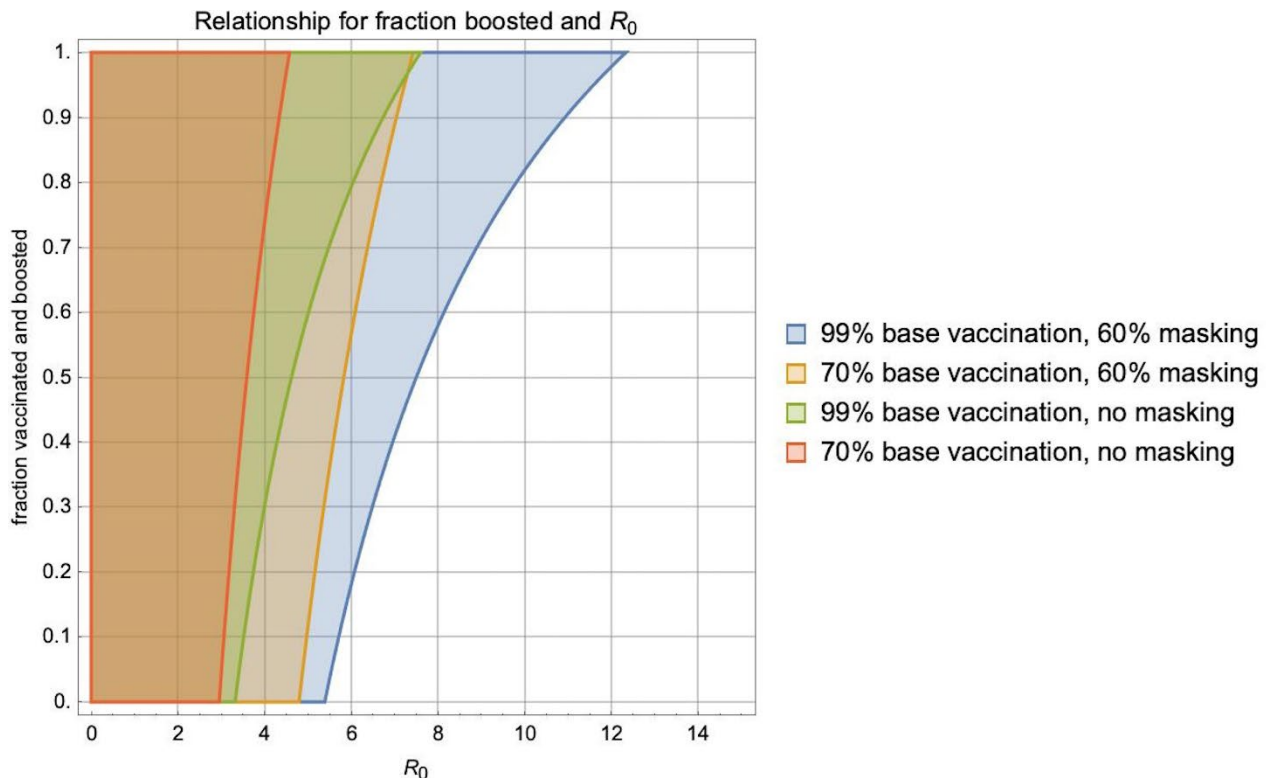
For the nullcline analysis, this threshold can be defined in terms of the basic reproduction number. The basic reproduction number of an infection is the expected number of cases directly generated by one case in a population where all individuals are susceptible to infection. The number, called  $R_0$  and written as  $R_0$ , was between 5 and 8 for the Delta variant and is estimated [to be as high as 10](#) for the Omicron variant. Our modeling shows the critical need for boosters on college campuses, given the infectiousness of the Omicron variant.

To account for mitigation measures (vaccinations, boosters, masking, and isolation when sick), we scale  $R_0$  and calculate “R effective,” written as  $R_{eff}$ . We find that the rate of new cases is negative when  $R_{eff}$  is less than one. The formula we use for  $R_{eff}$  is below, and the definition of each parameter is given in Table 2.

$$R_{eff} = \overbrace{(1 - \varepsilon_b V_b V - \varepsilon(V - V_b V))}^{\text{effect of vaccination and boosting}} \overbrace{((2b - b^2)P + 1)}^{\text{effect of masking}} \overbrace{\frac{\tilde{\ell}}{\gamma}}^{\text{effect of isolation when sick}} R_0$$

Assuming that preliminary vaccination is 30% effective against omicron ( $\varepsilon = 0.3$ ), boosting is 70% effective ( $\varepsilon_b = 0.7$ ), the average mask filtration is 40% ( $b = 0.4$ ), and  $\ell/\gamma = 0.43$  (isolation after 3 days and a 7-day infectious period), we can find the following thresholds for  $R_{eff}$  is less than one. The figure below shows that in a population that is already 99% fully vaccinated, that without masking, a fully boosted population protects against an  $R_0$  of almost 8. This was likely why we saw low levels of infection in fall 2021, because the initial vaccine series were effective against the more transmissible Delta variant.

Figure 1. The relationship between the fraction of the population boosted and  $R_0$ . If the  $R_0$  of Omicron is greater than 8, only a combination of boosting and masking in a 99% vaccinated population provides protection against large outbreaks.



In Figure 1 we see that if  $R_0$  is 10, we see that with a 99% base vaccination rate and a 60% masking rate (blue region), at least 82% of the population needs a booster shot in order to control the number of new cases.

Now let’s consider a scenario of 3,000 students, with 5 students infected at day 0. We can compare the cumulative case counts in nine different scenarios, as shown in Table 1 below. We compare different base vaccination rates, booster rates, and masking requirements. Given the transmissibility of the Omicron variant, this model shows that a fully boosted and masked population significantly protects against the risk of outbreaks on campuses.

Table 1. COVID transmission scenario where 5 infected students enter the population at Day 0 in a campus population of 3,000 students.

COVID Transmission Scenarios						
Scenario	Base vaccination rate	Boosted rate	Masking	$R_{eff}$	Percent of population infected after 100 days	Cumulative cases (out of 3,000)
scenario 1	99%	60%	required (P=0.8)	0.97	3.1%	93
scenario 2	99%	60%	optional (P=0.5)	1.36	47.7%	1431
scenario 3	99%	60%	no masking (P=0)	1.99	79.6%	2388
scenario 4	99%	90%	required	0.72	0.06%	18
scenario 5	99%	90%	optional	1.01	4.9%	147
scenario 6	99%	90%	no masking	1.49	57.5%	1725
scenario 7	70%	40%	required	1.41	52.3%	1582
scenario 8	70%	40%	optional	1.98	80.1%	2372
scenario 9	70%	40%	no masking	2.91	93.4%	2801

Figure 2. The number of cumulative cases in a student population of 3,000, over 100 days, where 5 students are initially infected at Day 0.

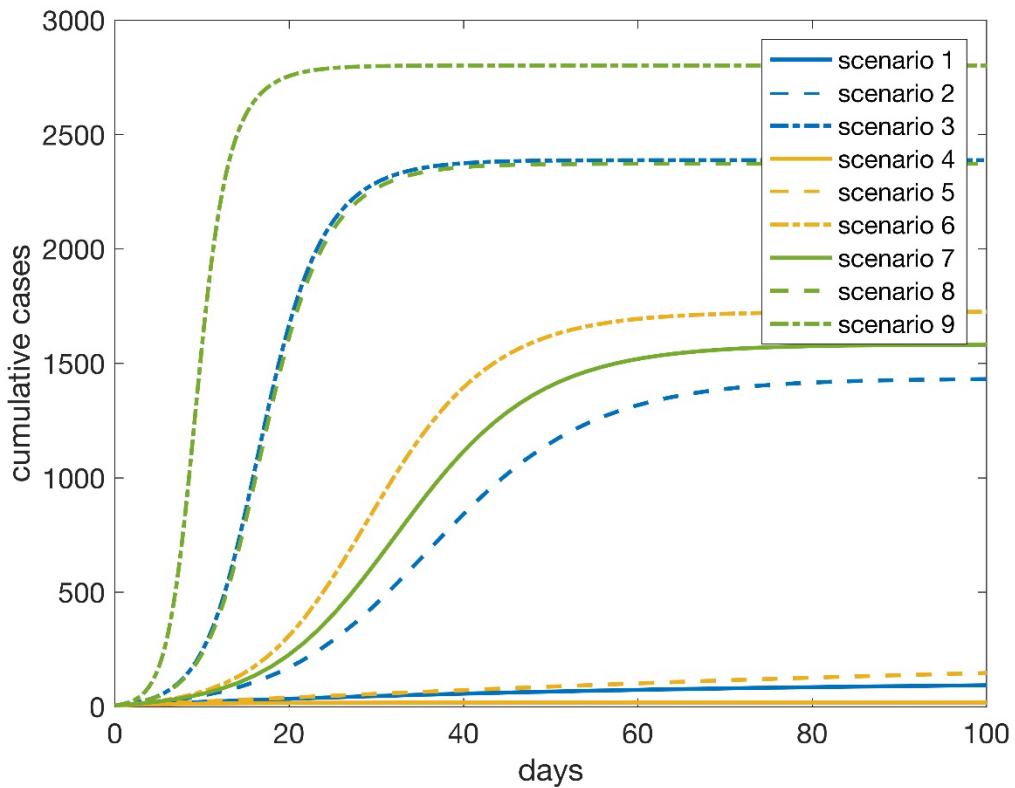


Figure 2 shows the progression over time for the nine scenarios in the table. We see three groupings of outcomes. Scenarios 1, 4, and 5 all have very low cumulative cases. This corresponds to  $R_{\text{eff}}$  less than or close to 1. Scenarios 2, 6, and 7 all end up with about 50% of students getting sick with an  $R_{\text{eff}}$  close to 1.5. Finally, there are scenarios 3, 8, and 9 in which almost all students get sick. These correspond to an  $R_{\text{eff}}$  of 2 or higher.

### **Q: Will a booster requirement still help, given how quickly Omicron is surging in the U.S.?**

**A:** Time is of the essence, and we're seeing dramatically rising case rates in many states. However, in many parts of the country case rates are still relatively low. Importantly, colleges also have the advantage of testing and isolating everyone as people return to campus from holiday break and can place a "bubble" around their population. This bubble will be tested throughout a term or semester, and we need to assume the Omicron variant will find its way into the population.

Mathematically, our model shows that in a closed population, boosters and consistent masking reduce the risk of outbreaks on campus. Unfortunately, booster doses are not immediately protective, and it takes several weeks after the booster shot is administered for antibodies to increase to levels that protect against symptomatic illness.

Booster efficacy will likely decrease over time and future boosters may be needed. As we move into the endemic stage of the pandemic, we need to be prepared to objectively consider the most effective tools to reduce the risk of disruptive outbreaks on campuses.

### **Q: If Omicron causes milder illness, especially in fully vaccinated and younger people, why should we care about limiting infections on campuses?**

**A:** While there is growing evidence that Omicron results in less severe illness, every community has immunocompromised or higher-risk members who may experience severe outcomes if infected. There is still an expectation and guidance from CDC that the infected isolate for at least five days, and having a significant proportion of the campus population in isolation is disruptive to in-person instruction, campus life, and mental well-being. We're currently seeing how isolation affects the healthcare, airline, and public safety sectors in the U.S., and a similar situation will likely play out on campuses if infection rates are not kept to manageable levels.

### **Q: What other measures should colleges be thinking about as they return to campus in January and beyond?**

**A:** In addition to requiring boosters and masking, colleges should continue to ensure they have adequate isolation space for those who test positive and be able to accommodate students who cannot attend in-person classes. Improved indoor ventilation rates and de-densifying classrooms and dining spaces can also help limit transmission. Regular testing of high-risk populations such as athletes and music performers three times a week with antigen tests can also help detect early clusters of infection. Many of the same measures that were successful against the Delta variant will also help protect against the Omicron variant, but it's important to recognize that Omicron is inherently much more transmissible and places and spaces that were safer in the past could now be the source of outbreaks and transmission. This includes spaces such as dining halls and poorly ventilated classrooms.

## Q: What does the spring of 2022 look like? Will the Omicron variant be with us for the foreseeable future?

**A:** Countries such as South Africa may provide some insight for campuses in the U.S. South Africa has a younger population, many of whom were previously infected with older variants of COVID-19. Case rates in South Africa appear to be decreasing almost as rapidly as they rose with Omicron, and it's likely that campuses may see a peak in illnesses that rises rapidly and then declines steeply. Some colleges may experience this increase soon after students return to campus, while others may be successful at "flattening the curve" and spreading infections out over a longer period. College communities that are fully boosted are more likely to see lower cumulative infections and fewer disruptions to campus life.

It's likely that Omicron may replace Delta as the predominate variant in the U.S., although in the coming months and years, future variants that evade vaccines and previous immunity are likely to emerge.

The best approach remains one that protects the public health of the campus community by trying to limit infections and protect those most susceptible to severe illness. Today, and for Omicron, that means boosters and masking.

### Explanation of the Model

Our model is a compartmental SIR model that considered the proportion of a population that is susceptible (S), infected (I), and have recovered (R):



The differential equations for this model are

$$\begin{aligned}\frac{dS}{dt} &= -\beta SI \\ \frac{dI}{dt} &= \beta SI - \gamma I \\ \frac{dR}{dt} &= \gamma I\end{aligned}$$

where  $\beta$  measures the rate of contagion and  $\gamma$  is dependent on the average amount of time a person is infectious in the general population before testing positive and isolating, or before isolating because of symptoms.

In a traditional SIR model,  $\beta = R_0\gamma$ , is the average number of people infected by one person per day. This assumes that the infected person is mixing with the general population for the entire time they are contagious. We adjust this in our model to account for earlier isolation. We also account for how mask wearing and vaccination affect the value of  $\beta$ .

Table 1. Modeling parameters, values, and source citations.

Model Parameters			
Parameter	Definition	Value	Citation
$\varepsilon, \varepsilon_b$	vaccine efficacies (with or without booster)	0.3-0.7	[3,7]
$V, V_b$	fraction of population vaccinated, fraction of vaccinated population that is also boosted	0-1 (varies)	
$P$	fraction of interactions where both people are wearing masks	0-0.8 (varies)	
$b$	(average) fraction of viral particles filtered by masks	0.4	[1]
$1/\ell$	average length of infectious period	7 days	[5]
$1/\gamma$	average time before infectious person is removed from the population	3 to 5 days	[6]
$R_0$	average number of people infected by one person over the entire time infectious, with no mitigation measures	4 for original wild-type covid-19 6.5 for delta variant 10-12 for omicron	[2,6]
$\beta$	average number of people infected by one person per day when including mitigation measures	$R_{eff}\gamma$	

Define  $R_{eff}$  as “R-effective” the average number of people infected by one person over the length of time they are infectious and part of the general population.[4] In the case of simple vaccination, we calculate  $R_{eff}$  as follows:

$$R_{eff} = \overbrace{(1 - \varepsilon V)}^{\text{effect of vaccination}} \overbrace{((2b - b^2)P + 1)}^{\text{effect of masking}} \overbrace{\frac{\ell}{\gamma}}^{\text{effect of isolation when sick}} R_0$$

In the case of boosters, we calculate  $R_{eff}$  as

$$R_{eff} = \overbrace{(1 - \varepsilon_b V_b V - \varepsilon(V - V_b V))}^{\text{effect of vaccination and boosting}} \overbrace{((2b - b^2)P + 1)}^{\text{effect of masking}} \overbrace{\frac{\ell}{\gamma}}^{\text{effect of isolation when sick}} R_0$$

We are scaling  $R_0$  by three factors to calculate  $R_{eff}$ . From right to left, we first see the effect of isolation when sick. In a typical SIR model, infectious individuals are assumed to be part of the general population during the entire infectious period. With the practice of isolating when symptomatic or testing positive, the number of individuals infected is reduced by the factor  $\ell/\gamma$ .

The next factor scales by the effect of masking. We assume that on a college campus, masking behavior is uniform by location e.g., most or all students wearing masks in class, but all students are not wearing masks when in the cafeteria. The average filtration of a mask is  $b$ , so reduce the chance of infection by  $1 - b$ . When two people are wearing masks, then the chance of infection is reduced by  $(1 - b)^2$ . If masks are worn for a fraction  $P$  of interactions, then the chance of infection is reduced by  $((1 - b)^2 P + (1 - P)) = (2b - b^2)P + 1$ .

The leftmost final factor scales by the effect of vaccination and boosting. Let  $\varepsilon$  and  $\varepsilon_b$  be the efficacies of the vaccine and the booster, and let  $V$  be the fraction of the population vaccinated and  $V_b$  be the fraction of the vaccinated population that is boosted. The probability of protection from infection is the vaccine efficacy multiplied by the fraction of the population vaccinated. When considering boosters, we need two terms, one for the effect of the boosted population and one for the rest of the vaccinated population. Because data reporting often gives the fraction of the population that is vaccinated but not boosted and the fraction of that subpopulation that is boosted, these terms are  $(V - V_b V)$  and  $V_b V$ , respectively. Thus, the chance of infection is reduced by  $(1 - \varepsilon_b V_b V - \varepsilon(V - V_b V))$ .

For questions about the modeling assumptions and methods, or for Matlab and Mathematica codes used to make the figures in this paper, please email Dr. Hoyer-Leitzel at [ahoyerle@mtholyoke.edu](mailto:ahoyerle@mtholyoke.edu). For questions about the epidemiological assumptions, please email Dr. Miller at [Ben.Miller@AchesonGroup.com](mailto:Ben.Miller@AchesonGroup.com).

## References for Table 2

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