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Short Communication

Effect of a two-dose vs three-dose vaccine strategy in residential colleges using an empirical proximity network

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When SARS-CoV-2 escalated to a pandemic in early 2020, universities and colleges were forced to pivot to virtual instruction. As of fall 2021, many institutions of higher education had reopened, adopting and often mandating mitigation measures like indoor masking, social distancing, regular testing, and vaccination. However, the emergence of the Omicron B.1.1.529 variant in November 2021 disrupted this new routine. The Omicron variant has been shown to be highly transmissible, with researchers estimating the effective reproduction number of Omicron as 3.19 times higher than that of the Delta strain (Ito et al., 2021). Furthermore, due to immune evasion, SARS-CoV-2 vaccines have reduced effectiveness against Omicron relative to previous variants (Cele et al., 2021).

Given the continued societal and educational interest in keeping college campuses open, we reran the models in our recent paper, adjusting parameter values to reflect the current COVID-19 situation (Hambridge et al., 2021). In brief, we modeled the spread of SARS-CoV-2 over an empirical contact network of students on a college campus taken from the Copenhagen Network Study (Sapiezynski et al., 2019). The Copenhagen Network Study enrolled 706 students from the Technical University of Denmark and issued each student a smartphone configured to be Bluetooth discoverable at all times. We used a modified individual-level stochastic susceptible-exposed-infectious-recovered (SEIR) model to simulate disease spread over the course of a 16-week semester. To reflect the increased transmissibility of the Omicron variant, we increased the probability of transmission per 5 min interaction, roughly corresponding to a basic reproduction number of $R_0 \approx 6.0$. Based on updated research, we also adjusted the recovery rate, leading to an average infectious period of 10 days for both symptomatic and asymptomatic cases (Hay et al., 2022). Additionally, in order to align with the latest U.S. Centers for Disease Control and Prevention (CDC) guidelines, we shortened the student isolation period to 5 days (Centers for Disease Control and Prevention, 2022).

Given Omicron's considerable escape from vaccine elicited immunity, we modified our model to use the proportion effectively immune. We explored population vaccine adoption rates of 40%, 60%, 80%, and 90%. Since many schools have already mandated vaccination, we were particularly interested in how a third booster dose would affect spread on college campuses. As such, we ran models with both two and three dose vaccination, assuming a vaccine efficacy of 30% for 2 doses and 70% for 3 doses (UK Health Security Agency, 2021). To obtain the proportion of the population effectively immune against the Omicron variant, we simply multiply the vaccine efficacy with the adoption rate. Full parameter values are shown in the supplement; see Table 1.

Results from our updated models without social distancing or masking are shown in the supplement; see supplemental Figure 1. We find that a third dose of a SARS-CoV-2 vaccine, shown with

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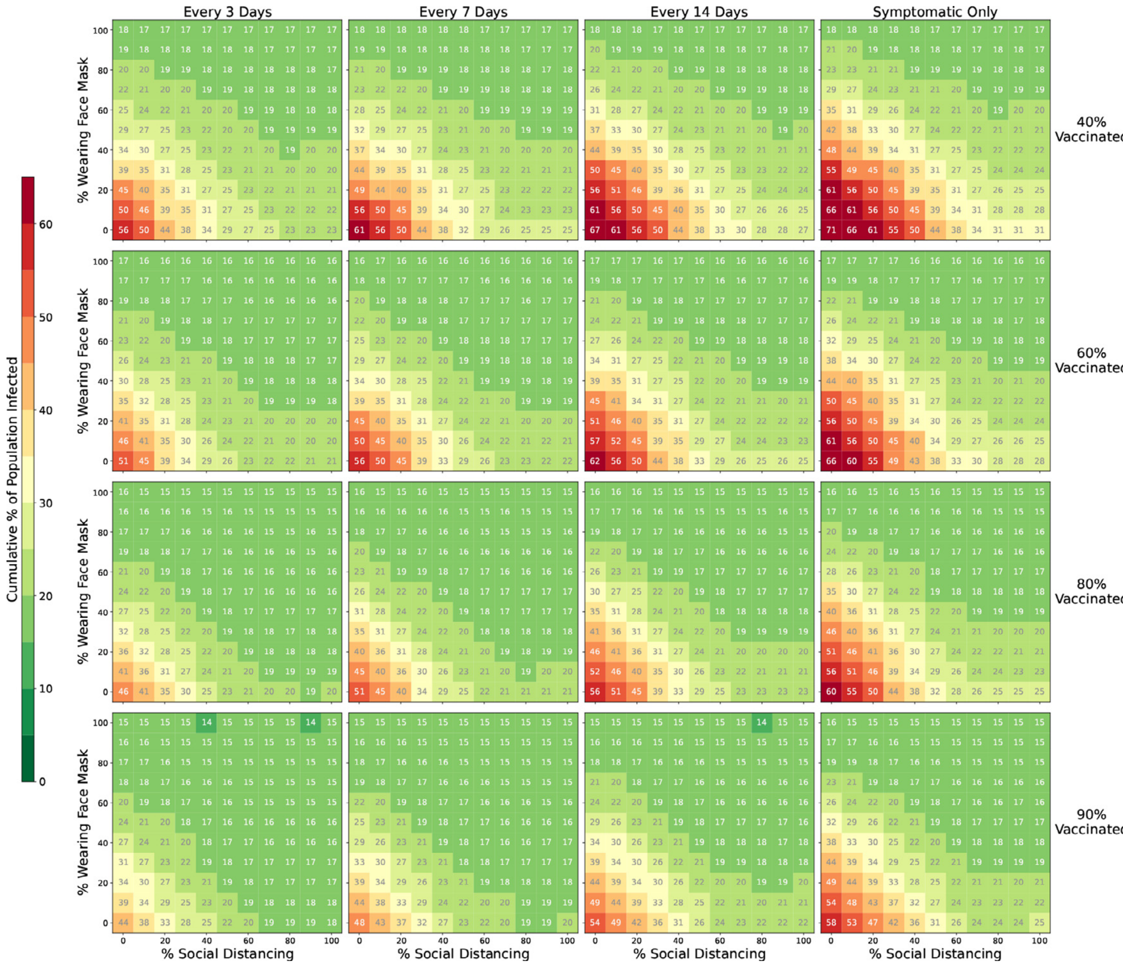

Fig. 1. Cumulative percentage infected for a two-dose vaccine strategy with various percentages of the population social distancing and/or wearing masks for $R_0 \approx 6.0$. Cell values indicate the percentage of the population infected by the end of a simulated 16-week semester over 100 replicates. Rows show different percentages of the population vaccinated with two doses, annotated at right. Columns show scenarios where scheduled testing was done every three, seven, and 14 days, respectively, and where no scheduled testing was done.

dotted lines, effectively flattens the curve of infections over time, particularly if a higher proportion of the population is vaccinated. Increased testing frequency reduces the number of infections but does not have as drastic an effect as vaccination, particularly with three vaccine doses.

Figure 1 shows results from our two-dose model after incorporating masking and social distancing. High levels of masking and social distancing can lead to a drastic reduction in cumulative incidence, even with testing every 3 days. However, this effect is reduced if more than 80% of the population is vaccinated. We observe a similar trend with the three-dose model but high levels of masking and social distancing are even less effective in the presence of high vaccination rates; see Figure 2.

Comparing Figures 1 and 2, we can see that at 60%, 80%, and 90% vaccinated, a three-dose vaccination strategy is always superior to a two-dose strategy. At these vaccination adoption rates, a three-dose strategy with symptomatic testing results in a lower cumulative incidence than a two-dose strategy with testing every three days, regardless of compliance with masking and social distancing. However, with 40% of the population vaccinated, the three-dose strategy with symptomatic testing performs comparably to a two-dose strategy with testing every three days. Thus, universities and students may be able to alleviate themselves of the burden of regular testing if they can convince their vaccinated students to receive a third dose.

Supplemental Figure 2 shows the excess proportion of the student population infected with two doses of vaccine relative to three doses. Excess infections denote the number of additional students infected by the end of simulated 16-week semester that would not have been infected if the vaccinated population had received three doses instead of two. Somewhat surprisingly, we see the highest excess infections with 90% of the population vaccinated, likely due to greatly increased effectiveness of a third dose, particularly when a large proportion of the population is vaccinated. With 40% of the population vaccinated, the difference is much less drastic, particularly with a high testing cadence and prevalent masking and distancing.

The CDC recommends universities provide vaccine information, promote vaccine trust and confidence, and establish supportive policies and practices to ensure getting vaccinated is as simple and convenient as possible (Centers for Disease Control and Prevention, 2022). Our results further reiterate the importance of encouraging students, faculty, and staff to get vaccinated against SARS-CoV-2. We find that on a college campus with high vaccination rates and symptomatic testing, three vaccine doses with no scheduled testing performs better than two vaccine doses with testing every three days. Thus, colleges that have already mandated vaccination might consider requiring a third dose to save valuable resources and further protect the health and well-being of their students, staff, and faculty.

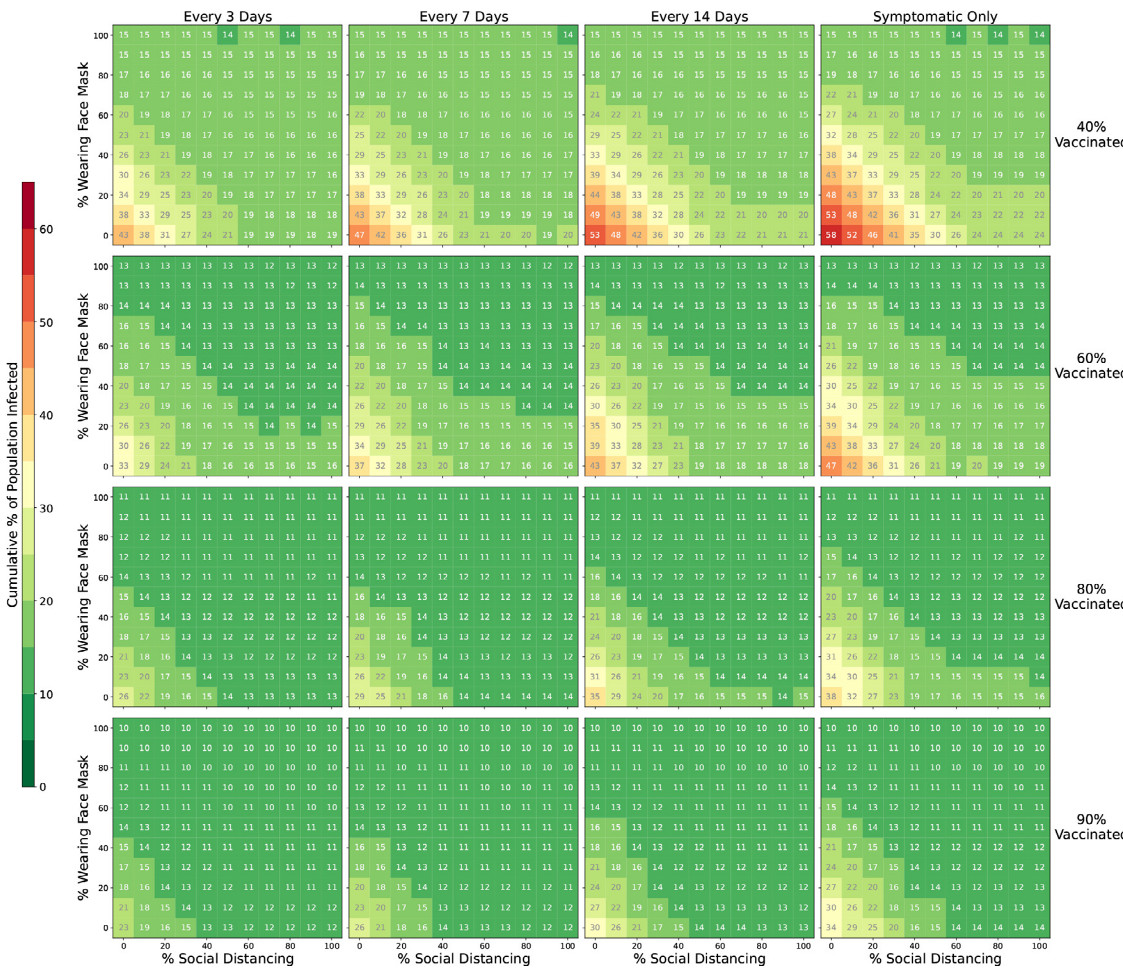

Fig. 2. Cumulative percentage infected for a three-dose vaccine strategy with various percentages of the population social distancing and/or wearing masks for $R_0 \approx 6.0$. Cell values indicate the percentage of the population infected by the end of a simulated 16-week semester over 100 replicates. Rows show different percentages of the population vaccinated with three doses, annotated at right. Columns show scenarios where scheduled testing was done every three, seven, and 14 days, respectively, and where no scheduled testing was done.

Declaration of Competing Interest

Authors declare that they have no competing interests.

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Ethical approval

Separate medical ethical clearance not mandatory.

Data sharing

Proximity network data from the Copenhagen Network Study are in the public domain (https://doi.org/10.6084/m9.figshare.7267433). All models and code for this project, written in version 3.7 of the Python programming language, are available through GitHub (https://github.com/onnela-lab/covid-campus).

Contributors

HH and JPO had full access to all data in the study. JPO conceptualized and supervised the study. HH, RK, and JPO contributed to the methodology, investigation, and visualization. HH drafted the manuscript with critical revision done by RK and JPO. All authors have read and approved the final version.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.ijid.2022.04.007.

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