Rapid Review Update 1: What is known about the risk of transmission of COVID-19 within post-secondary institutions and the strategies to mitigate on-campus outbreaks?

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Please Note: An update of this review may be available. Access the most current version of this review by visiting the National Collaborating Centre for Methods and Tools COVID-19 Rapid Evidence Service at the above link.

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The synthesis of the modelling studies included in this update was completed by the MacTheobio COVID Research lab at McMaster University, which provides data analysis and forecasting https://mac-theobio.github.io/covid-19/.

Executive Summary

Background

The majority of post-secondary institutions in communities affected by coronavirus-2019 (COVID-19) shuttered their campuses during the 2019-2020 academic year in an effort to stem the spread of the virus. Learning was shifted to online platforms, on-campus activities and living options were restricted or barred altogether, and extracurricular activities and varsity sports were cancelled. Some post-secondary institutions reopened for the 2020-2021 academic year and implemented a variety of strategies to reduce on-campus transmission and outbreaks.

This rapid review summarizes evidence from post-secondary institutions that resumed and subsequently sustained their on-campus operations in 2020-2021, amid the ongoing pandemic, to inform safe and effective campus re-opening plans for 2021-2022. It seeks to identify, appraise, and summarize emerging research evidence, to augment the findings of an expert consultation released in December 2020 (see below), to support evidence-informed decision making.

A rapid expert consultation in the USA found that comprehensive mitigation strategies generally involved: fast, frequent testing with results communicated rapidly; rapid isolation of positive individuals and quarantine of those with potential exposure; contact tracing; masking; physical distancing; environmental management (cleaning, heating, ventilation and air-conditioning systems); and engagement with local public health officials helped mitigate the spread of COVID-19 (O'Toole, Burke, & Denny, 2020). Important components found to contribute to the success of mitigation strategies included: daily analysis of data to guide decision making; adoption of an information technology infrastructure that respects data transparency and privacy while rapidly providing accurate information; including students in the development and implementation of the strategy; and fostering a culture of shared responsibility.

This review is based on the most recent evidence available at the time of release. A previous version was completed on April 16, 2021. This updated version includes evidence available up to May 3, 2021, to answer the question: **What is known about the risk of transmission of COVID-19 within post-secondary institutions and the strategies to mitigate on-campus outbreaks?**

What Has Changed in This Version?

- This version includes three new studies all from the USA; findings from these studies are consistent with previously included studies: including wastewater surveillance can be an effective strategy to augment symptomatic and asymptomatic testing; wastewater surveillance is an effective approach for identifying the presence of asymptomatic or pre-symptomatic cases; close contact sports are associated with significant increases in cases (range 5.4%-23%); a combination of regular antigen and RT-PCR testing can reduce greatly the number of athlete days of infectiousness, however testing will not identify all cases thereby requiring augmentation with strategies such as masking and

distancing; and weekly targeted testing is two times more likely to identify positive cases than surveillance-based informative testing.
- This version includes 15 mathematical modelling studies that were excluded from the initial review on this topic, due to the team's lack of expertise in appraising and summarizing modelling studies. These studies specifically address gaps identified in the initial review. For example, they model the impact of de-densification on transmission risk, or the impact of mitigation and infection prevention and control (IPAC) measures on R_0.
- The results of the modelling studies are consistent with the findings of the initial and this updated review.

Key Points

- Overall, the certainty of evidence on the risk of transmission in post-secondary institutions is very low (GRADE); findings are very likely to change as new data become available. All studies concluded that return to in-person operations is possible for post-secondary institutions amid the ongoing COVID-19 pandemic. However, all studies reported on-campus positive cases and/or outbreaks with the percentage of students and/or staff testing positive during the Fall term (Aug-Dec 2020) ranging from 0.8% to 16.5%. In addition, a seroprevalence study from post-secondary institutions in the United Kingdom reported 17.5% seropositivity across five institutions with outbreaks (range of 7.6%-29.7%). Six studies reported rates below 3.9%; three studies reported rates above 8.4%, which was higher than reported county/jurisdictional rates at the time.
- Reported mitigation strategies were similar across most studies making it difficult to explain the variation in the percentage of positive cases or identify which combination of strategies resulted in the lowest transmission rates. However, all studies reporting 3.9% positive cases or lower conducted symptomatic testing and contact tracing and had on-campus isolation facilities for positive cases and contacts. Five of these studies also conducted surveillance testing (asymptomatic testing or wastewater monitoring or both). Institutions with the lowest case rates also conducted active screening. All measures were implemented by internal institutional staff.
- Institutions with 3.9% or lower positive cases implemented the following IPAC measures, in addition to the mitigation strategies reported above: masks, physical distancing, and de-densification. Most also implemented hand hygiene and enhanced cleaning. In comparison to institutions with 8.4% cases or higher, those with lower rates generally reported implementing a greater number of IPAC measures.
- The evidence is mixed in terms of the impact of single room vs. multiple occupancy on transmission, with some evidence suggesting unsafe gatherings were associated with greater transmission, rather than physical living arrangements.

Overview of Evidence and Knowledge Gaps

Mitigation and IPAC measures

- A multifaceted mitigation and IPAC approach was implemented in all settings and can be described as a "Swiss Cheese" model in which risk is reduced via multiple layers of protection: a weakness (i.e., "hole") in one layer is expected to be offset by the strength of another. Important components of this approach, in addition to those listed in the Key Points above, include coordinated interdisciplinary leadership, student buy-in and adherence to IPAC measures (e.g., formal agreements to follow IPAC measures), communication, and/or data-driven modelling approaches, as observed in several studies.

- Several moderate quality studies concluded that targeted testing, isolation of positive cases and quarantine of close contacts, can effectively contain and/or reduce transmission, especially following rapid increases in case numbers and clusters.
- There is evidence from a small number of studies that wastewater surveillance of on-campus residences and isolation facilities may be a useful strategy to identify positive asymptomatic and pre-symptomatic cases, who then undergo testing, as well as indicate when an outbreak is resolved.
- Enhanced ventilation was noted as an IPAC measure in two moderate quality studies but not described in detail; its impact on transmission risk is unknown.
- The evidence was mixed on whether risk is higher in shared on-campus accommodations (e.g., with roommates) and common areas (e.g., kitchens, bathrooms). Risk of transmission was higher for students living in multi-occupancy residence rooms in two moderate-high quality studies, while a third moderate quality study found no correlation between risk and occupancy. One high quality study estimated roommate-to-roommate spread occurred 20% of the time; two moderate quality studies noted that the majority of index cases were from off-campus sources. One high quality study concluded that individuals' behaviours (e.g., unsafe gatherings) were more likely to be associated with outbreak clusters rather than physical housing arrangements.

<u>Education Approaches</u>

- Most studies reported a hybrid learning approach (in-person and online) but few analyzed the relationship between the approach and transmission risk. One moderate quality study showed no impact of instruction mode on cumulative infection rate; three moderate quality studies noted no evidence of classroom transmission.

<u>Athletics and Clubs</u>

- One high quality study of athletes engaged in close contact sports noted that an optimal testing regimen included either daily antigen screening or RT-PCR testing two to three times per week. If RT-PCR is conducted four times per week daily antigen testing does not improve sensitivity. However, findings suggested that testing will not identify all cases prior to infectiousness, illustrating the importance of additional IPAC strategies such as masking and distancing.
- One moderate quality study noted that, even with mandatory daily testing, outbreaks occurred from asymptomatic athletes with false negative antigen tests. There was limited or no evidence related to campus dining facilities, libraries, or university clubs. More research is needed to understand if athletic and club activities can be safely implemented on-campus.

<u>Modelling Studies</u>

- Based on findings from mathematical modelling studies, conducting large classes online is likely to reduce the risk of transmission.
- Adherence to masking and distancing is important to reduce transmission risk.
- Testing (at least weekly), with results processed rapidly, and contact tracing conducted quickly results in reduced transmission.

- The importance of isolation of positive individuals (for example, in a dedicated residence on campus) and quarantine of direct contacts was shown in the modelling results.
- No studies included vaccination as a factor in the models.

Knowledge Gaps and Future Research

- The evidence in this report pre-dates the introduction of new variants of concern (VOCs); it is not yet known how VOCs will impact the risk of on-campus transmission and effectiveness of mitigation and IPAC strategies.
- The evidence in this report also pre-dates administration of vaccines; it is not yet known which and to what extent mitigation and IPAC measures will be required to prevent on-campus transmission as students and staff become fully vaccinated.

Methods

Research Question

What is known about the risk of transmission of COVID-19 within post-secondary institutions and the strategies to mitigate on-campus outbreaks?

Search

On May 3, 2021, the following databases were searched using key terms (colleg* OR "post secondary" OR "post-secondary" OR "vocational school" OR "technical school" OR campus OR universit* OR dormitor* OR residence* OR sororit* OR fraternit*) AND (open* OR reopen* OR outbreak* OR transmit* OR spread OR risk* OR seroprevalen* OR return OR "in person" OR "in-person"). This search builds upon the previous search conducted in the first version of this rapid review.

- MEDLINE database
- Trip Medical Database
- World Health Organization's Global literature on coronavirus disease
- Joanna Briggs Institute COVID-19 Special Collection
- COVID-19 Evidence Alerts from McMaster PLUS™
- COVID-19 Living Overview of the Evidence (L·OVE)
- McMaster Health Forum
- Cochrane Rapid Reviews Question Bank
- Prospero Registry of Systematic Reviews
- NCCMT COVID-19 Rapid Evidence Reviews
- MedRxiv preprint server
- NCCDH Equity-informed Responses to COVID-19
- NCCEH Environmental Health Resources for the COVID-19 Pandemic
- NCCHPP Public Health Ethics and COVID-19
- NCCID
- NCCID Disease Debrief
- NCCIH Updates on COVID-19
- Institute national d'excellence en santé et en services sociaux (INESSS)
- Uncover (USHER Network for COVID-19 Evidence Reviews)
- Morbidity and Mortality Weekly Report (MMWR)
- Institut national de santé publique du Québec (INSPQ)
- BC Centre for Disease Control (BCCDC)
- Public Health England

A copy of the full search strategy is available at this link.

Study Selection Criteria

The search results were first screened for recent guidelines and syntheses. When available, findings from syntheses and clinical practice guidelines are presented first, as these take into account the available body of evidence and, therefore, can be applied broadly to populations and settings.

Single studies were included if no syntheses were available, or if single studies were published after the search was conducted in the included syntheses. English-language, peer-reviewed sources and sources published ahead-of-print before peer review were included. Surveillance sources were excluded.

In this update 42 modelling studies identified from either the search on March 19 for the initial review or May 3, for this update were screened for inclusion. Of those 15 were deemed to address knowledge gaps identified in the original review and were included in this update.

	Inclusion Criteria	Exclusion Criteria
Population	Post-secondary institutions (including students, faculty, staff) that were open / had re-opened for on-campus activities	Residency training programs University hospitals Co-op placements Apprenticeships
Intervention	Mitigation strategies	-
Comparisons	-	-
Outcomes	COVID-19 transmission (including confirmed COVID-19 cases, seropositivity, outbreaks, and secondary infections)	-
Setting	On-campus activities	Off-campus activities (off campus student housing) Non-university events that occur on campus (e.g., renting space to community groups, on-campus daycare services, day camps)

Data Extraction and Synthesis

Data relevant to the research question, such as study design, setting, location, population characteristics, interventions or exposure and outcomes were extracted when reported. For the modelling studies the following data were additionally extracted: goal of study, model type, and model assumptions. We synthesized the results narratively due to the variation in methodology and outcomes for the included studies. The results of the modelling studies are reported separately.

Appraisal of Evidence Quality

We evaluated the quality of included evidence using critical appraisal tools as indicated by the study design below. Quality assessment was completed by one reviewer and verified by a second reviewer. Conflicts were resolved through discussion.

Study Design	Critical Appraisal Tool
Case Report	Joanna Briggs Institute (JBI) Checklist for Case Reports
Cohort	Joanna Briggs Institute (JBI) Checklist for Cohort Studies
Cross-sectional	Joanna Briggs Institute (JBI) Checklist for Analytical Cross-Sectional Studies
Prevalence	Joanna Briggs Institute (JBI) Checklist for Prevalence Studies

Completed quality assessments for each included study are available on request.

As we were unaware of a validated critical appraisal tool for modelling studies, we reached out to experts at the MacTheobio lab at McMaster University who have extensive experience in conducting mathematical modelling studies in infectious diseases. These expert reviewers conducted a semi-structured assessment of each study, noting each model's assumptions, limitations and any inconsistencies within the model. The quality assessment was completed by one reviewer and discussed with the larger team. Conflicts were resolved through discussion.

The Grading of Recommendations, Assessment, Development and Evaluations (GRADE) (Schünemann et al., 2013) approach was used to assess the certainty in the findings based on eight key domains.

In the GRADE approach to quality of evidence, **observational studies,** as included in this review, provide **low quality** evidence, and this assessment can be further reduced based on other domains:

- High risk of bias
- Inconsistency in effects
- Indirectness of interventions/outcomes
- Imprecision in effect estimate
- Publication bias

and can be upgraded based on:

- Large effect
- Dose-response relationship
- Accounting for confounding

The overall certainty in the evidence for each outcome was determined taking into account the characteristics of the available evidence (observational studies, some not peer-reviewed, unaccounted-for potential confounding factors, different tests and testing protocols, lack of valid comparison groups). A judgement of 'overall certainty is very low' means that the findings are very likely to change as more evidence accumulates.

Findings

Summary of Evidence Quality

In this update, three new single studies, two updated single studies and 15 modelling studies were identified for a total of 32 publications included in this review. The quality of the evidence included in this review is as follows:

Outcome	Studies included		Overall certainty in evidence (GRADE)
	Study design	n	
COVID-19 transmission (number of cases, number of outbreaks, number of cases per 100,000, number or percentage of seropositive individuals)	Observational	17	⨁◯◯◯ Very low*
COVID-19 transmission (cases, R_0,)	Modelling	15	Not graded

*In the GRADE approach to quality of evidence, **observational studies,** as included in this review, provide **low quality** evidence, and this assessment was further reduced to **very low** based on high risk of bias, inconsistency in effects and imprecision in effect estimate.

The GRADE approach was not applied to the mathematical modelling studies.

Warning

Given the need to make emerging COVID-19 evidence quickly available, many emerging studies have not been peer reviewed. As such, we advise caution when using and interpreting the evidence included in this rapid review. We have provided a summary of overall certainty of the evidence to support the process of decision making. Where possible, make decisions using the highest quality evidence available.

Table 1: Single Studies

Reference	Date Released	Study Design	Location, Context	Description of Virus Control	Summary of Findings	Quality Rating
New evidence reported on June 14, 2021						
Schmitz, B.W., Innes, G.K., Prasek, S.M., Betancourt, W.Q., Stark, E.R., Foster, A.R., … Pepper, I.L. (2021). Enumerating asymptomatic COVID-19 cases and estimating SARS-CoV-2 fecal shedding rates via wastewater-based epidemiology. *Preprint*.	Apr 18, 2021	Prevalence	University of Arizona Tuscon, Arizona, United States * * * Open/available: • On-campus living (3528 students at 82% capacity)	Surveillance/testing plan: • Surveillance (wastewater monitoring, 3x/week per residence between 09:30 and 10:00) • Testing (positive detection of N1 and N2 gene regions resulting in RT-PCR testing for symptomatic and antigen testing for asymptomatic cases) *Wastewater surveillance is the focus of this study A typical monitoring timeline: • Collection (09:00 – 10:30) • Detection (11:00) • PCR/antigen testing for entire dormitory; shelter in place • Results; isolation for positive case only; not roommate Other IPAC measures: • De-densification (residences; 2/room) • Isolation facilities for cases	From Aug 17 – Nov 17, 2020, 364 wastewater samples from 13 dormitories were processed (81 positive, 22.2%); 711 clinical cases were reported; 563 (79.2%) asymptomatic and 148 (20.8%) symptomatic. 68/81 (83.9%) of positive wastewater samples were associated with new reported cases of infection within a 6-day period.	High ***PREPRINT***

Harmon, K.G., de St Maurice, A.M. Brady, A.C., Sankar, S., Douglas, F.A., Rueda, M.A., … Kliethermes, S.A. (2021). Surveillance testing for SARS-CoV-2 infection in an asymptomatic athlete population; The experience of 123,362 tests and 23,463 paired RT-PCR/Antigen samples. *Preprint*.	Apr 16, 2021	Prevalence	High risk of transmission (HROT) university athletic programs 11/12 Pacific Coast Conference schools Pacific Coast, United States * * * Learning modality/on-campus living: • Not reported	Surveillance/testing plan: • Antigen testing on days where high risk of transmission activities occurred (6/7 days) • Diagnostic testing (1 test/week paired with the daily antigen test) Other IPAC measures: • Quarantine / isolation • Contact tracing	From Sep 29, 2020 – Feb 28, 2021, 81,175 antigen and 42,187 RT-PCR tests were conducted among 1931 HROT college athletes. 346/1931 (17.95%) tested positive with RT-PCR: • Football 258/1306 (19.8%) • Women's basketball 16/147 (10.9%) • Men's basketball 32/176 (18.1%) • Women's water polo 6/112 (5.4%) • Men's water polo 13/100 (13.1%) • Wrestling 21/90 (23.3%) Results by reasons for testing were: • Initial screening/re-entry after time away: 32/1526 (2.1%) • Contact tracing: 11/502 (2.2%) • Symptomatic: 74/405 (18.2%) • Surveillance: 172/39,293 (0.4%) Daily antigen testing produced similar results to RT-PCR 2-3x/week. Daily antigen testing did not increase sensitivity vs. RT-PCR 4x/week . 89/172 (51%) of surveillance cases were identified through antigen testing prior to RT-PCR, preventing an estimated 234 athlete days of infectiousness. Two football-related outbreaks at two schools occurred, resulting in 48/346(13.8%) of all athletic cases; 86% of cases were community-acquired. There was no transmission from one team to another team. Testing will not catch all cases before they are infectious and demonstrates the need for continued masking and social distancing when possible.	High ***PREPRINT***

Gibas, C., Lambirth, K., Mittal, N., Juel, M. A. I., Barua, V. B., Brazell, L. R., ... Munir, M. (2021). Implementing building-level SARS-CoV-2 wastewater surveillance on a university campus. *The Science of the Total Environment*, *782*, 146749.	Mar 30, 2021	Prevalence	University of North Carolina at Charlotte • Large, urban campus * * * Open/available: On-campus living (unknown %)	Surveillance/testing plan: • Surveillance (wastewater monitoring, 3x/week per residence) • Testing (symptomatic; athletes) • Contact tracing • Screening (daily symptom self-reporting) *Wastewater monitoring is the focus of this study A typical monitoring timeline: • Collection • Detection • Testing, sheltering-in-place • Results, resolution Other IPAC measures: • De-densification (residences) • Isolation facilities	From Sep 28 – Nov 23, 2020, 332 wastewater samples from 19 building sites were processed; 40 were positive (12.1%) and 15 were labeled as "suspicious" (i.e., probable positive). Over the study period, the number of positive samples gradually increased (as did the positivity rates in the surrounding county, Pearson correlation coefficient=0.769). Wastewater monitoring identified smaller clusters than were reported in other types of cluster events ($p<0.001$); able to detect asymptomatic individuals in residences of 150-200 students. Wastewater monitoring detected pre-symptomatic cases, corroborated contact tracing cases, and indicated when an outbreak had been contained.	Moderate
Rennert, L., McMahan, C., Kalbaugh, C.A., Yang, Y., Lumsden, B., Dean, D., ... Colenda, C.C. (2021). Surveillance-based informative testing for detection and containment of SARS-CoV-2 outbreaks on a public university campus: An observational	Mar 19, 2021	Cohort	Clemson University • Large, rural campus Clemson, South Carolina, United States * * * Open/available: • In-person learning • On-campus living	Surveillance/testing plan: • Daily surveillance based-informative testing (SBIT) followed by weekly targeted testing • SBIT included random tests, followed by targeted tests in residences or residence floors, if threshold for positive cases was identified from random samples. Other IPAC measures: • Staggered residence arrival • In residence students must provide a negative COVID-19 test within 10 days of arrive and a negative test upon arrival • Restricted access	From Aug 19 – Sep 20, 2020 (pre-in-person learning) 326/6273 (5.2%) on-campus students tested positive. From Sept 21 – Nov 20, 2020, prevalence of COVID-19 in residence dropped from 8.7% (week 1) to 0.8% (week 9). The greatest decrease took place between weeks 1 (8.7%) and 3 (5.6%), weeks 5-8 were stable (1.4-1.2) to week 9 (0.8%). From Sep 23 – Oct 5, 2020, SBIT was implemented across 8 residence buildings and 45 residence halls: • Random tests (n=3420, 63.6%) identified 179/3420 (5.2% positivity rate)	Moderate

and modelling study. *The Lancet Child & Adolescent Health, 5*(6), 428–436.				• Quarantine/isolation	• Targeted tests (n=1959, 36.4%) identified 208/1959 (10.6%) ○ Outbreaks in 8 residence halls ○ 5/8 residence halls had a case positivity rate >10% ○ 13/45 residence hall floors with a positivity rate >10% ○ targeted tests were 2.03 times more likely to detect a COVID-19 positive case (95%CI= 1.67-2.47). Random surveillance testing alone would have resulted in 24% more infections throughout the semester. Voluntary testing alone would have resulted in 154% more infections throughout the semester Weekly testing would have resulted in 36% fewer infections, and twice weekly testing would have resulted in 72% fewer infections. However, weekly testing would have required two times the number of daily tests, and twice weekly would have required four time the number of daily tests compared to SBIT.	

Previously reported evidence						

Vusirikala, A., Whitaker, H., Jones, S., Tessier, E., Borrow, R., Linley, E., ... Amirthalingam, G. (2021). Seroprevalence of SARS-CoV-2 antibodies in university students: Cross-sectional study, December 2020, England. *Journal of Infection.* Epub ahead of print.	Apr 28, 2021	Cross-sectional	5 universities with COVID-19 outbreaks following Sep 2020 re-opening
			
			United Kingdom
			
			* * *
			
			Open/available:
			• On-campus living (30% of participants)
				Rapid serological evaluation (i.e., serosurveillance) to assess prior infection (captures asymptomatic, symptomatic, and mild transient infections) and provide estimate of spread of infection.
				
				IPAC measures not reported.
					In Dec 2020, seroprevalence in 2905 students (aged ≤ 25) from universities that had experienced outbreaks was 17.8% (95% CI=16.5,19.3) (range across universities: 7.6 – 29.7%).
					
					This was higher than age-matched healthy community blood donors (13.7%, 95% CI=11.1,16.9) and across England (12.1%, 95% CI=11.6,12.7).
					
					49% of students who lived in residences that had reported infection rates >8% were seropositive, suggesting widespread transmission in this setting.
					
					Seropositivity was associated with:
					• 1st year students (adjusted OR=3.16, 95% CI=2.02,4.93)
					• On-campus living (adjusted OR=2.14, 95% CI=1.7,2.68)
					• Shared kitchen with:
					  ○ 4-7 people (adjusted OR=1.43, 95% CI=1.12,1.82)
					  ○ 8+ people (adjusted OR=1.53, 95% CI=1.04,2.24)
					• Being symptomatic (adjusted OR=4.3, 95% CI=3.43,5.38)
					• Confirmed case within shared accommodation (adjusted OR=3.57, 95% CI=2.86,4.44)
					
					Sharing a bedroom (adjusted OR=0.73, 95%CI=0.45,1.19) or bathroom (adjusted OR=0.73, 95%CI=0.57,0.95) had lower odds.
						Moderate

Weil, A. A., Sohlberg, S. L., O'Hanlon, J. A., Casto, A. M., Emanuels, A. W., Lo, N. K., ... Chu, H. Y. (2021). SARS CoV-2 epidemiology on a public university campus in Washington State. *Preprint.*	Mar 17, 2021	Cohort	Large, urban public university • 60,000 students • 30,000 staff Seattle, Washington, United States * * * Open/available: • Hybrid learning • On-campus living (unknown %)	Surveillance/testing plan: • Testing (symptomatic, exposure) • Screening (daily self-report symptoms) • Contact tracing Other IPAC measures: • De-densification (on-campus living) • Enhanced cleaning and disinfection • Hand hygiene • Isolation facilities • Masks • Physical distancing	From Sep 24 – Dec 18, 2020, 29,783 tests were performed on 11,644 individuals; 265 tested positive (0.80%). • Fraternities/sororities (1.5%; 1,796/12,045) • Students living on-campus (1.2%; 43/3,507) • Staff / faculty (0.4%; 23/5,884) Among the 265 positive cases, 60.8% were symptomatic, 19.6% pre-symptomatic, 3.4% asymptomatic, and 16.2% possible asymptomatic. 34.7% reported exposures and 21.5% reported high-risk behaviours. Risk factors for testing positive: • Fraternity/sorority affiliation (OR=2.71, 95% CI=1.84,4.00) • Latinx/Hispanic ethnicity (OR=2.12, 95% CI=1.28,2.18) • Self-reported symptoms (OR=1.86, 95% CI=1.43,2.41) 88.1% of viral genomes sequenced from fraternity/sorority-affiliated students were genetically identical, vs. 37.9% of genomes from non-fraternity/sorority students. Transmission was thought to have then occurred within outbreaks (i.e., within groups), with no evidence of further spread.	Moderate ***PREPRINT***
Betancourt, W. Q., Schmitz, B. W., Innes, G. K., Prasek, S. M., Pogreba Brown, K. M., Stark, E. R., ... Pepper, I. L. (2021). COVID-19 containment on a college campus via wastewater-	Mar 13, 2021	Case report	University of Arizona Arizona, United States * * * Open/available: • In-person learning (limited)	Surveillance/testing plan: • Wastewater monitoring (residences) • Testing (upon arrival, symptomatic, or if identified through wastewater) • Contact tracing Other IPAC measures: • Isolation data platforms and communication • Isolation facilities	Between Aug – Nov 2020: • 91/111 (82.0% positive predictive value) positive wastewater samples lead to targeted identification of at least one positive case • 185/208 (88.9% negative predictive value) negative wastewater samples concurred with no positive tests • 43/319 total wastewater samples were discordant with clinical testing (suggesting samples not provided during testing or non-residents using washrooms)	Moderate

based epidemiology, targeted clinical testing and an intervention. *Science of the Total Environment, 779,* 146408.			• On-campus living (unknown %)	• Shelter-in-place policy	From Sep 15 – 29, 2020, students remained on campus, but a shelter-in place policy was implemented, due to increasing cases, resulting in a decrease of new cases and virus detections in wastewater. Cases remained low (often zero) thereafter.	
Bjorkman, K. K., Saldi, T. K., Lasda, E., Bauer, L. C., Kovarik, J., Gonzalez, P. K., … Parker, R. (2021). Higher viral load drives infrequent SARS-CoV-2 transmission between asymptomatic residence hall roommates. *Preprint.*	Mar 12, 2021	Cohort	University of Colorado Boulder Boulder, Colorado, United States * * * Open/available: • On-campus living (6408 students) *Students provided proof of negative test result at move-in.	Surveillance/testing plan: • Surveillance (asymptomatic; mandatory, weekly for students living on-campus (exempt after a COVID-19 diagnosis)) • Testing (symptomatic, exposed) • Contact tracing IPAC measures: • Isolation facilities	From Aug 17 – Nov 25, 2020, 1058 (16.5%) students living on-campus tested positive for COVID-19: • 198/1916 (10.3%) of students in single residence rooms • 860/4492 (19.1%) of students in multiple occupancy residence rooms • Cases usually asymptomatic at time of diagnosis While students in multiple occupancy residence rooms had a greater infection rate than those in single rooms, only 116/574 multiple occupancy rooms had likely in-room transmission (i.e., roommate-to-roommate; secondary attack rate (SAR): 20.2%), suggesting transmission occurred elsewhere the majority of the time.	High ***PREPRINT***
Ryan, B. J., Muehlenbein, M. P., Allen, J., Been, J., Boyd, K., Brickhouse, M., … Brickhouse, N. (2021). Sustaining university operations during the COVID-19 pandemic.	Mar 8, 2021	Case report	Baylor University • 19,297 students (14,399 undergrad, 4898 grad) • ~3400 staff Waco, Texas, United States • Population: 256,600 * * *	Surveillance/testing plan: • Surveillance (asymptomatic; random, surge (i.e., increased temporary testing capacity with government-provided tests), targeted) • Wastewater monitoring (on-campus living, isolation facilities) • Testing (symptomatic, exposed) • Contact tracing	From Aug 1-Dec 8, 2020, 1435/62,970 individuals tested positive (2.28% positivity rate) and 235 self-reported (total 1670 cases): • 1416 students • 140 staff/faculty • 90 athletes • 22 contractors • 2 others Testing completed: • Pre-arrival (135/13,621; 0.99%) • Clinic (i.e., symptomatic/exposed) (798/11,188; 7.13%)	Moderate

Disaster Medicine and Public Health Preparedness. Epub ahead of print.			Open/available: • Hybrid learning (25% of classes) • In-person learning (39% of classes) • Online learning (36% of classes) • On-campus living (4,736 students)	• Screening Other IPAC measures: • Compliance monitoring • De-densification (athletics crowd capacities) • Enhanced cleaning and disinfecting • Isolation facilities • Limited non-university events • Masks • Physical distancing Other components of approach: • Communication • In-house dashboard • Multisectoral systems approach • Population-based management • "Swiss Cheese" risk mitigation model	• Surveillance (360/21,435; 1.68%) • Surge (29/4362; 0.66%) • Athletics (91/8901; 1.02%) • Contractor (22/3463; 0.64%) 246 positive students used isolation facilities (peaked at 30% of capacity). All staff cases and 76% of student cases were from off-campus sources.	
Moreno, G. K., Braun, K. M., Pray, I. W., Segaloff, H. E., Lim, A., Poulson, K., ... O'Connor, D. H. (2021). [SARS-CoV-2 transmission in intercollegiate athletics not fully mitigated with daily antigen testing]. *Preprint.*	Mar 6, 2021	Case report	University athletics program (de-identified data) United States * * * Open/available: • Athletic programs: ○ Indoor meetings ○ Practices ○ Scrimmages ○ Intercollegiate competitions	Surveillance/testing plan: • Antigen testing (daily) • Diagnostic testing (if positive antigen test) • Contact tracing (household and social close contacts only) Other IPAC measures: • Masks • Physical distancing • Program suspension • Quarantine / isolation	Outbreaks occurred affecting high-risk sport programs: Outbreak 1: • 32 cases (22 students, 10 staff) • Index case (antigen test negative) attended meeting infectious; IPAC measures were followed • 4 contacts developed symptomatic infection • Contact tracing identified: ○ 13 (40%) attended team meeting with a case ○ 6 (13%) were roommates ○ 8 (25%) no identified exposure • 24 of 26 (92%) sequences were closely related, suggesting a single viral introduction	Moderate ***PREPRINT***

			*Some sports were considered "high-risk" due to frequent contact / collision.		Outbreak 2: • 12 cases occurred among athletes during a two-team competition: ○ Sequences were closely related and unique from strains circulating in the community Antigen testing, as a sole surveillance measure, may not be sufficient to prevent outbreaks.	
Travis, S. A., Best, A. A., Bochniak, K. S., Dunteman, N. D., Fellinger, J., Folkert, P. D., ... Schuitema, A. J. (2021). [Providing a safe, in-person, residential college experience during the COVID-19 pandemic](). *Preprint.*	Mar 5, 2021	Case report	Hope College Holland, Michigan, United States * * * Open/available: • In-person learning • On-campus living (unknown %)	Surveillance/testing plan: • Wastewater monitoring (residences) • Surveillance (asymptomatic; random and identified by wastewater monitoring) • Testing (symptomatic and on arrival, i.e., baseline) • Contact tracing (household and social close contacts only) • Screening Other IPAC measures: • Adapted instructional spaces • Isolation facilities Other components of approach: • Communication • Earlier class start, reduced break days for earlier class completion • Mathematical modelling	Between Jul 29 – Nov 24, 2020, 10,700 tests were conducted among students and staff (2.2% positive test percentage): • 38/3878 baseline tests (0.98% positivity rate*) • 57/5696 random and targeted asymptomatic tests (from wastewater identification) (1% positivity rate) • 124/960 symptomatic tests (12.9% positivity rate) • Additional subset testing (e.g., athletes) not reported here (*Compared to national (6.1%) and state (2.5%) positivity rates, at the time.) Contact tracing identified 670 contacts (average 4-5 per positive case); 21 tested positive (SAR: 3.1%).	Moderate ***PREPRINT***

Hamer, D. H., White, L. F., Jenkins, H. E., Gill, C. J., Landsberg, H. N., Klapperich, C., … Brown, R. A. (2021). [Control of COVID-19 transmission on an urban university campus during a second wave of the pandemic](). *Preprint.*	Mar 2, 2021	Case report	Boston University (BU) • Large, urban campus • 40,000 students Boston, United States * * * Open/available: • Hybrid learning • On-campus living (7131 students at 67% capacity)	Surveillance/testing plan: • Surveillance (asymptomatic) • Testing (symptomatic) • Contact tracing • Screening (daily self-report symptoms) Other IPAC measures: • De-densification (classrooms, common areas, residences) • Enhanced ventilation • Hand hygiene • Isolation facilities • Masks • Physical distancing Other components of approach: • Coordinated leadership and management structures • Communication • Mathematical modeling • Multiple data systems / data-driven strategy refinements	From Aug – Dec 2020, 719/>500,000 COVID-19 tests at BU were positive • 496 students (69%) • 11 faculty (1.5%) • 212 staff (29.5%) Approximately 1.8% of the 40,000 BU community tested positive; 37.7% of total cases were asymptomatic. Test positivity rate for those with self-reported symptoms was higher (4.9%) than those who were asymptomatic (0.10%). Incidence rate was less than but followed trends in county. Contact tracing identified: • 86/837 positive contacts (10.3%) • 51.5% of total 719 cases had a known source (non-BU source, 55.7% of known exposures) • No classroom transmission Isolation facility occupancy peaked at 12.9%. Multi-pronged response (surveillance / testing, contact tracing, isolation) controlled campus spread.	Moderate ***PREPRINT***
Gibson, G., Weitz, J. S., Shannon, M. P., Holton, B., Bryksin, A., Liu, B., … García, A. J. (2021). [Surveillance-to-diagnostic testing program for asymptomatic SARS-CoV-2]()	Jan 31, 2021	Case report	Georgia Institute of Technology Georgia, United States * * * Open/available: • On-campus living (7370 students)	Surveillance/testing plan: • Surveillance • Testing (focused case cluster) • Contact tracing Other IPAC measures: • Isolation facilities • Masks • Physical distancing	In Fall 2020, 1508/18,029 individuals providing 112,500 saliva samples tested positive (8.4% cumulative positive): • Students: 1351 (90%); 9.7% cumulative positive • Staff: 157 (10%); 3.8% cumulative positive Targeted testing after two outbreaks (Aug return to campus, Oct high community levels) steadily reduced peak asymptomatic positivity rates from 2-4% to <0.5%.	Moderate ***PREPRINT***

infections on a large, urban campus - Georgia Institute of Technology, Fall 2020. *Preprint.*			• On-campus visiting, 5000/day; staff, non-resident students • Online learning		Students in shared double rooms had higher positivity risk (30% of double roommates tested positive; half of cases in Aug-Sep were in doubles).	

Fox, M. D., Bailey, D. C., Seamon, M. D., & Miranda, M. L. (2021). Response to a COVID-19 outbreak on a university campus - Indiana, August 2020. *Morbidity and Mortality Weekly Report, 70*(4), 118-122.	Jan 29, 2021	Case report	Indiana University
			• 12,000 students (8000 undergrad)
			• Medium-sized
			
			Indiana, United States
			
			* * *
			
			Open/available:
			• In-person learning
			• On-campus living (85% of undergrad)
				Surveillance/testing plan:
				• Testing (symptomatic, athletes)
				• Contact tracing
				
				Other IPAC measures:
				• De-densification (classrooms, common areas)
				• Education
				• Enhanced cleaning and disinfection
				• Isolation facilities
				• Masks
				• Physical distancing (6 feet)
				
				Other components of approach:
				• Communication
				• Enhanced data systems
				• Outbreak control measures:
				  ○ Switch to online learning
				  ○ Restricting on-campus access
				  ○ Additional testing, tracing, IPAC
					Baseline student testing prior to semester start:
					• 11,836 tested; 33 (0.28%) positive
					
					From Aug 3-15, 2020:
					• 56 tested positive (4.3 cases per day, 11.7% of all tests performed)
					• 90% of cases were symptomatic
					
					From Aug 16-22 an outbreak occurred:
					• 371 confirmed cases (26.5 per day, 15.3% of all tests performed)
					  ○ 355 (96%) undergrad
					  ○ 13 (3%) grad students
					  ○ 1 faculty and 2 staff
					• 62% of undergrad cases lived off-campus
						Moderate

O'Donnell, C., Brownlee, K., Martin, E., Suyama, J., Albert, S., Anderson, S., ... Williams, J. (2021). SARS-CoV-2 control on a large urban college campus without mass testing. *Preprint.*	Jan 25, 2021	Prevalence	University of Pittsburgh
			• Large, urban campus
			• 28,234 students
			• 13,264 staff
			
			Pittsburgh, United States
			• 1.2 million in neighbourhood
			
			* * *
			
			Open/available:
			• Hybrid learning
			• In-person final exams
			• On-campus living (6300 students)
			• Organized student activities
				Targeted plan:
				• Mitigation (with emphasis on student commitment)
				• Communication
				• Containment
				  ○ Testing (symptomatic; focused cluster)
				  ○ Surveillance (asymptomatic, random)
				  ○ Contact tracing
				  ○ Isolation
				
				Other IPAC measures:
				• De-densification (residences)
				• Enhanced cleaning
				• Enhanced ventilation
				• Hand hygiene
				• Isolation facilities
				• Masks
				• Physical distancing
				• PPE
				• Staggered re-entry with shelter-in-place requirements
					In Fall 2020, 445/11,505 students tested positive (3.9%, 95% CI=3.5,4.2):
					• 383/3102 symptomatic students (12.3%, 95% CI=11.2,13.6)
					• 31/7389 asymptomatic students (0.42%, 95% CI=0.29,0.59); slight increase during arrival, remained low throughout semester
					• 15/228 close contacts (0.31%, 95 %CI=0.11,0.68)
					• 16/786 focused testing (e.g., cluster) (0.46%, 95% CI=0.30,0.68)
					
					During 2 case surges in the community, campus count also increased but 5-day rolling average did not exceed 20 cases/day.
					
					Use of isolation facilities peaked at 33.6% occupancy (97/289 beds).
					
					Bathroom type (communal vs. private) had no impact on infection incidence; no classroom transmission.
					
					Clusters occurred in association with unsafe gatherings or within shared residences not observing IPAC measures (e.g., behaviours greater risk than physical arrangements).
						Moderate
						
						PREPRINT

Stubbs, C. W., Springer, M., & Thomas, T. S. (2020). The impacts of testing cadence, mode of instruction, and student density on Fall 2020 COVID-19 rates on campus. *Preprint.*	Dec 9, 2020	Cohort	9 colleges / universities (Boston-area), 4 comparison schools • Small, large; rural, urban United States * * * Open/available:	Surveillance/testing plan: • Weekly high-cadence PCR testing of all students living on-campus (asymptomatic and/or symptomatic) • Isolation • Contact tracing Other specific IPAC measures not described.	From Aug 15 – Nov 22, 2020, estimated COVID-19 prevalence in Boston-area schools, based on publicly available data, was 16 $\pm$ 3 new cases/100,000 person-days; the mean case rate for the surrounding county was 10.8/100,000. There was no correlation between positive cases and total number of students living on-campus or dormitory occupancy density.	Low ***PREPRINT***

			• Hybrid learning • Online learning • % On-campus living unknown		There was no significant impact of mode of instruction (online, hybrid) on cumulative infection rate. Testing more frequently (e.g., 2-3x/week vs. 1x/week) was correlated with lower infection rates (p=0.017).	

Denny, T. N., Andrews, L., Bonsignori, M., Cavanaugh, K., Datto, M. B., Beckard, A., ... Wolfe, C. R. (2020). Implementation of a pooled surveillance testing program for asymptomatic SARS-CoV-2 infections on a college campus- Duke University, Durham, North Carolina, August 2-October 11, 2020. *Morbidity and Mortality Weekly Report, 69*(46), 1743-1747.	Nov 20, 2020	Cohort	Duke University
			
			Durham, North Carolina, United States
			
			* * *
			
			Open/available:
			• Hybrid learning
			• On-campus living (unknown %)
			  ○ Quarantine before arrival
			  ○ Staggered arrivals
				Surveillance/testing plan:
				• Testing (symptomatic, entry)
				• Surveillance (asymptomatic; pooled testing; 1-2x/week, focus on cohorts where data suggested an increased risk for transmission)
				• Contact tracing
				• Screening (daily symptom self-monitoring (smartphone app; results linked to testing))
				
				Other IPAC measures:
				• De-densification (residences, all single; classrooms, common areas)
				• Hand hygiene
				• Masks
				• Physical distancing
				• Quarantine policy
				
				*Students signed formal agreement to follow IPAC measures; testing was mandatory (could lose access to campus facilities / services).
					From Aug 2 – Oct 11, 2020, 68,913 tests from 10,265 students identified 84 positive cases:
					• 17 (20.2%) upon entry (8873 tests)
					• 29 (34.5%) pooled (59,476 tests)
					• 15 (17.9%) symptomatic (185 tests)
					• 23 (27.4%) close contacts (379 tests)
					
					51% of positive cases were asymptomatic.
					
					Weekly per-capita infection incidence averaged 0.08% (vs. 0.1% in the county, at the time).
					
					Asymptomatic and testing of close contacts accounted for 73% of identified positive COVID-19 cases.
					
					Student compliance for testing was 95%.
					
					No classroom transmission; no substantial outbreaks.
						Moderate

Table 2: In-progress Single Studies

Title	Anticipated Release Date	Setting	Description of Document
Previously reported evidence			
Fretheim, A., Flatø, M., Helleve, A., Helseth, S., Jamtvedt, G., Løyland, B., … Walte, S. S. V. (2020). Relationship between in-person instruction and COVID-19 incidence among university students: A prospective cohort study. *Preprint.*	Aug 2021	Universities and university-colleges in Norway	This study will explore whether on campus learning, with infection control measures in place, is associated with higher COVID-19 incidence than online instruction.

Table 3: Modelling Studies

Reference	Date Released	Model Type	Model Assumptions	Summary	Limitations	Quality Rating
New evidence reported on June 14, 2021						
Syntheses						
Christensen, H., Turner, K., Trickey, A., Booton, R.D., Hemani, G., Nixon, E., ... Brooks-Pollock, E. (2020). COVID-19 transmission in a university setting: a rapid review of modelling studies. *Preprint.*	Sep 9, 2020	5 included modelling studies: • 4 compartmental • 1 ABM	N/A; assumptions vary among models considered	Rapid review authors suggest effective outbreak control requires: • Rapid testing of symptomatic individuals • Screening of asymptomatic individuals • Rapid contact tracing • Support for students to adhere to isolation and quarantine • Other established mitigation measures, e.g., hand hygiene, physical distancing	Included studies completed prior to vaccine availability.	Low ***PREPRINT***
Modelling Studies exploring Testing Strategies						
Hambridge, H.L., Kahn, R., & Onnela, J.-P. (2021). Examining SARS-COV-2 interventions in residential colleges using an empirical network. *Preprint.*	Apr 10, 2021	Compartmental SEIR separating symptomatic and asymptomatic individuals	• Empirical network based on pre-pandemic Bluetooth signal data from 692 Danish students • Baseline exposure rate 0.002/day • 50% infections asymptomatic • No longer infectious after 7 days if asymptomatic and 12 days if symptomatic • Zero mortality • Mask wearing reduced transmission probability 15% • Distancing reduced transmission probability by 18%	Testing every 3 days can reduce percentage of infected individuals during an outbreak event from 25% to 10% when mask-wearing and distancing are not widely implemented. Mask wearing and distancing can reduce percentage of infected individuals during an outbreak event from 25% to 10% without testing. Combining frequent testing with mask wearing and distancing has largest effect on percentage of infected individuals reducing percentage to 5%.	Assumption that asymptomatic and symptomatic infections are equally likely is not consistent with other evidence.	Moderate ***PREPRINT***

Lopman, B., Liu, C. Y., Le Guillou, A., Handel, A., Lash, T. L., Isakov, A. P., & Jenness, S. M. (2021). A modeling study to inform screening and testing interventions for the control of SARS-CoV-2 on university campuses. *Scientific Reports*, *11*(1), 5900.	Mar 15, 2021	Compartmental SEIR separating students and staff/faculty	• 15,000 students and 15,000 staff/faculty • Off campus students at greater risk of acquiring infection in community • 65% student cases and 49% staff/faculty cases asymptomatic • Public health measures, e.g., mask wearing, distancing, reduced transmission probability by 35%	Limiting transmission during an outbreak requires effective quarantine and contact tracing. Monthly screening of students reduced number of infections by 59%, while weekly screening of students reduced number of infections by 87%.	Model uses relatively small population of students and staff/faculty.	Moderate
Rogers, W., Ruiz-Aravena, M., Hansen, D., Madden, W., Kessler, M., Fields, M.W., … Plowright, R.K. (2021). High-frequency screening combined with diagnostic testing for control of SARS-CoV-2 in high-density settings: an economic evaluation of resources allocation for public health benefit. *Preprint.*	Mar 9, 2021	Compartmental SEIR with stochastic transition rates	• 20,000 students on campus for 15-week term • Screening with rapid tests • Diagnostic testing with rapid and standard tests • Any positive rapid tests confirmed with standard tests	4 screening strategies were modelled: 1. Screening only symptomatic 2. Screening asymptomatic and symptomatic, but only during the first 30 days of the term 3. "Front-loaded" screening where the same number of screens were performed in the first 30 days as in the last 120 days 4. Uniform screening throughout the term Screening frequency had largest effect on outbreak size, compared to test sensitivity, compliance, contact tracing capacity, and test return time. Testing only symptomatic individuals resulted in largest outbreaks.	The effect of increasing vaccine coverage in the population on rapid test sensitivity was not considered (vaccination is thought to increase the likelihood of an asymptomatic infection, if an infection occurs, which may impact rapid test sensitivity)". It's not that "Rapid test sensitivity for asymptomatic or pre-symptomatic infections was not considered" at all, it's that the proportions of asymptomatic, pre-symptomatic, and symptomatic infections in an	High ***PREPRINT***

				The cost of increased screening frequency is initially higher, however a daily screening rate of >10% throughout the semester maintains a low number of infections and the resulting cost of the testing program is lower than the cost of a testing program without rapid screening.	unvaccinated population are relatively fixed, and that gets embedded into test sensitivity estimates, but increasing vaccine coverage could change these proportions, which could then change rapid test sensitivity.	
Rennert, L., Kalbaugh, C. A., Shi, L., & McMahan, C. (2020). Modelling the impact of presemester testing on COVID-19 outbreaks in university campuses. *BMJ Open*, *10*(12), e042578.	Dec 15, 2020	SEIR	• 17,500 students on campus, 7500 students off campus • Initial infection rate 2% • 10% students infected and recovered prior to attendance • 50% infections asymptomatic; only 2/3 symptomatic cases detected	Mandated testing 7-days prior to attendance delayed the peak number of infections and reduced the peak number of infections by 1.5% when public health measures are not implemented and 7.8% when public health measures are implemented.	Effect of public health measures were included in modelling but not described. Transmission amongst staff/faculty and between students and staff/faculty not considered. Vaccine coverage was not considered.	Low-Moderate
Rennert, L., Kalbaugh, C. A., McMahan, C., Shi, L., & Colenda, C. C. (2020). The urgent need for phased university reopenings to mitigate the spread of COVID-19 and conserve 2 institutional resources: A modeling study. *Preprint.*	Aug 31, 2020	SEIR	• 17,500 students on campus, 7500 students off campus • Initial infection rate 2% • 10% students infected and recovered prior to attendance • 50% infections asymptomatic; only 2/3 symptomatic cases detected	A 3-phase reopening where 1/3 of the student population arrives on campus 1-month apart was compared to non-phased re-opening. Phased reopening reduced the peak number of infections by 18% when public health measures are implemented.	Effect of public health measures were included in modelling but not described. Transmission amongst staff/faculty and between students and staff/faculty not considered.	Low-Moderate ***PREPRINT***

Modelling Studies exploring On-Campus Pedestrian Traffic and Crowding						
Yeo, S. C., Lai, C., Tan, J., & Gooley, J. J. (2021). A targeted e-learning approach for keeping universities open during the COVID-19 pandemic while reducing student physical interactions. *PloS One*, *16*(4), e0249839.	Apr 8, 2021	Natural experiment	• Empirical network based on WiFi data on campus with 24,000 students during pandemic • Cluster of students defined as >25 students connected to single WiFi access point • Potential for transmission driven by mixing of students	In-class learning accounted for 91% of the variance in the daily number of students on-campus; 9% accounted for variance due to other on-campus activities. Implementation of remote learning reduced spatiotemporal overlap of students and duration of student clustering.	Individuals not connected to local WiFi are not captured in network. Locations of each WiFi access point not determined. No confirmed cases of COVID-19 during study period to validate model.	Moderate
Ambatipudi, M., Gonzalez, P. C., Tasnim, K., Daigle, J. T., Kulyk, T., Jeffreys, N., ... Koh, E. (2021). Risk quantification for SARS-CoV-2 infection through airborne transmission in university settings. *Preprint.*	Apr 6, 2021	Quantitative model of infection probability	• Maximum risk of infection 1% • Cases exhale 35-70 viral particles/minute • Adherence to masking except while eating in dining hall or alone in dormitory room • Adherence to physical distancing • No virus particles linger in classroom air between classes	Probability of infection increases as number of students on campus increases. Probability of infection decreases as indoor air exchange rate increases, and as face mask efficiency (e.g., N95 vs. surgical mask) increases.	Non-adherence or partial adherence to public health measures, e.g., masking, distancing, not considered. Size of classrooms and feasibility of distancing not considered. Shared dormitory rooms not considered, especially if one roommate is infected.	Moderate ***PREPRINT***

Das Swain, V., Xie, J., Madan, M., Sargolzaei, S., Cai, J., De Choudhury, M., ... Prakash, B. A. (2021). WiFi mobility models for COVID-19 enable less burdensome and more localized interventions for university campuses. *Preprint.*	Mar 24, 2021	ABM	• Empirical network based on pre-pandemic WiFi data from Georgia Institute of Technology campus with 25,000 students and 7600 staff/faculty. • Mobility behaviour, movement equal for all individuals	WiFi-based analysis of mobility used to develop contact networks allowed for localized closures (e.g., buildings) rather than campus-wide closures. Localized closures based on WiFi mobility data had equal reduction in transmission as campus-wide closure.	Individuals not connected to local WiFi are not captured in network. Individual mobility patterns not considered.	Moderate ***PREPRINT***
D'Orazio, M., Bernardini, G., & Quagliarini, E. (2021). A probabilistic model to evaluate the effectiveness of main solutions to COVID-19 spreading in university buildings according to proximity and time-based consolidated criteria. *Building Simulation.* Epub ahead of print.	Feb 27, 2021	ABM	• 5000 students and staff/faculty • Probably of infection increases with proximity and exposure time • Some asymptomatic infections	Multiple mitigation strategies, e.g., masking, limiting population density, must be combined to limit transmission to <25% of the population during an outbreak.	Transmission amongst staff/faculty and between students and staff/faculty not considered.	Moderate
Borowiak, M., Ning, F., Pei, J., Zhao, S., Tung, H. R., & Durrett, R. (2020). Controlling the spread of COVID-19 on college campuses. *Mathematical Biosciences and Engineering, 18*(1), 551–563.	Dec 14, 2020	Reed-Frost	• All rooms and residences of equal size • Individuals attend 3 classes each with between 10 and 120 classmates	Probability of outbreak is lower when students reside in single-occupancy dormitory rooms instead of double-occupancy dormitory rooms. Outbreak incidence and size can be limited if maximum class size is limited.	Reed-Frost assumptions based on household vs. community contacts and may not accurately represent contacts on campuses.	Low

Johnson, S. S., Jackson, K. C., Mietchen, M. S., Sbai, S., Schwartz, E. J., & Lofgren, E. T. (2020). Excess risk of COVID-19 to university populations resulting from in-person sporting events. *Preprint.*	Sep 28, 2020	SEIAR and ST	• Students have equal chance of exposure to visitors during sporting events • 10,000 visitors during 6 scheduled 2-day sporting events • Size of student population not specified	On-campus sporting events where visitors mixed lightly with the campus community results in a 25% increase in cases on campus. On-campus sporting events where visitors mixed heavily with the campus community resulted in an 822% increase in cases on campus. When transmission rates in community are high, median number of infections following an event was approximately 1.5 times higher than when community transmission rates are low.	Partial vs. full capacity of events was not considered.	Low ***PREPRINT***
Romero, V., Stone W. D., & Ford, J. D. (2020). COVID-19 indoor exposure levels: An analysis of foot traffic scenarios within an academic building. *Transportation Research Interdisciplinary Perspectives, 7,* 100185.	Aug 6, 2020	Simple Case Model	• Probably of infection increases with proximity and exposure time • Adherence to masking • Adherence to distancing	This model compares 1-way and 2-way pedestrian traffic within buildings. Minimizing the time spent travelling within buildings had a greater impact on reducing transmission risk than adopting a 1-way traffic flow pattern.	Only linear travel considered. Spacing between individuals traveling in same direction not considered.	Low

Modelling Studies exploring Other Factors related to On-Campus Transmission of COVID-19						
Jarvis, K. F., & Kelley, J. B. (2021). Temporal dynamics of viral load and false negative rate influence the levels of testing necessary to combat COVID-19 spread. *Scientific Reports*, *11*(1), 9221.	Apr 28, 2021	Stochastic ABM	• Likelihood of transmission proportional to viral load • Likelihood of accurate detection of infection proportional to viral load • No longer infectious after 14 days if asymptomatic	This model explores how viral load could affect transmission and accurate detection of infection. False negatives may occur during early infection when viral load is low.	Possible contradiction in assumptions where likelihood of transmission and detection of virus are both proportional to viral load, that there can be cases of increased transmission when the viral load is so small as to be undetected by PCR.	High
Linka, K., Peirlinck, M., Schäfer, A., Tikenogullari, O. Z., Goriely, A., & Kuhl, E. (2021). Effects of B.1.1.7 and B.1.351 on COVID-19 dynamics. A campus reopening study. *Preprint.*	Apr 27, 2021	Network SEIR with Bayesian inference	• 6500 students on campus • B.1.1.7 variant 56% more transmissible • B.1.351 variant 50% more transmissible	This model explores effects of introducing variants of concern during campus reopening. Introduction of new variants of concern results in a much steeper infection rate curve, peaking at much higher total numbers of infections, between 15 and 57 times greater depending on the semester or variant.	Public health measures, e.g., masking, distancing, not considered.	Moderate ***PREPRINT***

ABM: Agent-based model

SEIR: Susceptible-Exposed-Infectious-Removed

SEIAR: Susceptible-exposed-infected-asymptomatically infected-removed

ST: Susceptible/Transmitting

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Ambatipudi, M., Gonzalez, P. C., Tasnim, K., Daigle, J. T., Kulyk, T., Jeffreys, N., … Koh, E. (2021). Risk quantification for SARS-CoV-2 infection through airborne transmission in university settings. *Preprint.*

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Bjorkman, K. K., Saldi, T. K., Lasda, E., Bauer, L. C., Kovarik, J., Gonzalez, P. K., … Parker, R. (2021). Higher viral load drives infrequent SARS-CoV-2 transmission between asymptomatic residence hall roommates. *Preprint.*

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