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School of Nursing | McMaster University

Living Rapid Review Update 3: What is known about the risk of transmission of COVID-19 within post-secondary institutions and the strategies to mitigate on-campus outbreaks?

Prepared by: The National Collaborating Centre for Methods and Tools

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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/.

The authors declare they have no conflicts of interest to report.

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 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 July 6, 2021. This updated version includes evidence available up to July 29, 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 from the USA (n = 2), and Canada (n = 1). Findings from these studies are consistent with previously reported findings including post-secondary institutions with comprehensive infection prevention and control measures (IPAC) in place tend to report lower infection rates even with the occurrence of substantial in-person learning and on campus living.
- Furthermore, findings from two studies illustrate that wastewater surveillance is an effective strategy to quickly identify and isolate cases and close contacts, thereby reducing or eliminating further transmission.
- One study reported comprehensive IPAC measures were effective in limiting cases for on campus students and staff to 1% while resuming 75% student capacity for in-person learning, 100% capacity for on-campus living and full return to extracurricular activities.

- One study reported no difference in the number of cases amongst student athletes and athletic staff in high vs low contact sports; this same study reported student athletes and athletic staff had an average incidence of 14.7% vs. 1.5% in non-athletes.

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 2020-21 academic year ranging from 0.27% to 23%. A seroprevalence study from post-secondary institutions in the UK reported 17.5% seropositivity across five institutions with outbreaks (range: 7.6%-29.7%); a second study from the USA of 4 post-secondary institutions reported 11% seropositivity after close contact with a case; while a third study from Germany reported a 0.6% seropositivity rate when a comprehensive mitigation strategy was implemented. Nine studies reported rates below 3.9%, with several at or below 2%; five studies reported rates above 7.7%, which was higher than reported county/jurisdictional rates for some studies.
- When 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. Generally, studies reporting 3.9% positive cases or lower conducted symptomatic testing with rapid results (< 24 hours), contact tracing and on-campus isolation for positive cases and close contacts. Many studies also conducted surveillance testing (asymptomatic testing and/or wastewater monitoring). Institutions with the lowest case rates also conducted active screening, and temperature checks. All measures were implemented by internal institutional staff.
- Institutions with ≤2% positive cases implemented the following IPAC measures, in addition to mitigation strategies reported above: masks, physical distancing, and de-densification. Most also implemented hand hygiene and enhanced cleaning, and one implemented mandatory COVID-19 training. In comparison to institutions with ≥7.7% cases, 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

- Multifaceted mitigation and IPAC measures were implemented in many 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 high-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 growing number of studies that wastewater surveillance of on-campus residences and isolation facilities may be a useful strategy to identify and quickly isolate positive asymptomatic and pre-symptomatic cases, who then undergo testing, identify close contacts, 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.

On-campus Living

- The evidence is mixed on whether risk was 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 three high-moderate 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; one high quality study reported a statistically significant higher rate of cases in double occupancy dorm rooms compared to single occupancy; 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.
- Strict quarantine of close contacts resulted in a small reduction in seroconversions compared to those in non-strict quarantine, and close contacts released from quarantine 7 days after exposure to a case were unlikely to result in additional transmissions.

Education Approaches

- 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; one high quality and three moderate quality studies noted no evidence of classroom transmission. One moderate quality study with 75% in-person learning reported a positivity rate of 1%.

Athletics and Clubs

- 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.

- One moderate quality study reported similar positivity rates among student athletes engaged in high contact sports vs low contact. Student athletes were 5 times more likely to become infected than non-athlete students.

Modelling Studies

- 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

- Only one study in this update reports on VoCs. In that study only 1 case was identified as a VoC; it is not yet known how VOCs will impact the risk of on-campus transmission and effectiveness of mitigation and IPAC strategies.
- There were no studies identified in this update reporting on the impact of the availability of vaccines on transmission of COVID-19; 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.
- Few studies report on community rates, compare post-secondary rates to community rates or discuss what impact community rates may have had on on-campus transmission. This may, however, be an important source of variation across studies.

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 July 29, 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 second update 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
- 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. One guideline was identified and appraised using the AGREE II tool. The absence of methods for developing the guideline resulted in it being rated as not suitable for use, and therefore was excluded from further review.

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 a previous update 42 modelling studies identified from either the search on March 19 for the initial review or the update on May 3, were screened for inclusion. Of those 15 were deemed to address knowledge gaps identified in the original review and were included in the May 3rd update. A search for new modelling studies to include in the current update was not conducted.

	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 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
Guideline	Appraisal of Guidelines for Research and Evaluation (AGREE-II) Instrument
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 were added for a total of 44 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	Key Findings	
COVID-19 transmission (number of cases, number of outbreaks, number of cases per 100,000, number or percentage of seropositive individuals)	Observational	28	Institutions with comprehensive IPAC measures in place generally reported infection rates below 3.9% in comparison to those with fewer measures Some institutions with many measures in place had infection rates at or below 1%.	⊕◯◯◯ 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 August 13, 2021						
Hertel, A.T., Heeter, M.M., Wirfel, O.M., Bestram, M.J., & Mauro, S.A. (2021). Athletes drive distinctive trends of COVID-19 infection in a college campus environment. *International Journal of Environmental Research and Public Health, 18*(14), 7689.	Jul 20, 2021	Case report	Gannon University in Erie, Pennsylvania, United States * * * Learning modality/on-campus living • Blended learning (75% classes in-person, 20% hybrid and 5% online)	Surveillance/testing plan: • Surveillance (daily real time testing; results in 8-12 hrs of sample collection) • Testing (RT-PCR) Other IPAC measures: • Masks • Physical distancing • Temperature checks • Symptom screening • Daily testing • Enhanced cleaning	From Aug 2020 – May 12, 2021, 23,227 tests were completed with 235 confirmed cases (1.01%). Daily positivity rate closely reflected daily case count. There was no correlation (R^2 = 0.052) between the number of tests performed and the incidence of positive cases and there was no significant correlation (R^2 = 0.048) between the frequency of testing days and the incidence of positive cases in athletic teams. Increases in cases were not driven by changes in the volume of testing (exceptions were on days where total volume of testing was low). Temporal trends of new positive cases on-campus varied from state-wide trends with small outbreaks largely linked to student-athletes (100%, 40%, 90% respectively). Authors concluded that state guidance and enhanced protocols are necessary but not sufficient in preventing the spread of COVID-19 on a university campus. These trends are also not largely due to the number of daily tests, but instead arise from the unique features of the campus community. Student-athletes were nearly 5 times more likely to contract COVID-19 compared with non-athletes (45.9% of all positive cases on campus were student-athletes). Athletes were separated into	Moderate

					high-risk and low/intermediate risk based on the risk of transmission while participating in the activity. The percent of positive cases was comparable between high-risk athletes (incidence of 14.3) and low/intermediate risk athletes (incidence of 14.9). The average incidence of positive cases in athletic teams and staff was 14.7 compared to an incidence of 1.5 in non-athletes.	
Karthikeyan, S., Nguyen, A., McDonald, D., Zong, Y., Ronquillo, N., Ren, J. ... Knight, R. (2021). Rapid, large-scale wastewater surveillance and automated reporting system enabled early detection of nearly 85% of COVID-19 cases on a university campus. *Preprint.*	Jun 27, 2021	Case report	The University of California San Diego California, United States * * * Learning modality/on-campus living • On-campus living (approximately 9,700 students) • On-campus employees (approximately 4,000 employees)	Surveillance/testing plan: • Surveillance (continuous autosampling in 1 hr intervals, 24 hrs/day), mandated bi-weekly testing for on-campus residents • Testing (RT-qPCR) Other IPAC measures: • Masks • Enhanced cleaning • Hand hygiene • De-densification • Quarantine • Contact tracing	From Nov 23 – Dec 31, 2020, 1574 wastewater samples were collected from 68 randomly selected manholes associated with 239 campus buildings (with a focus on residential buildings). Samples were collected at one of two times (end of Nov or end of Dec 2020). • 692 (44.0%) were positive • 878 (55.8%) were negative • 34 (0.2%) were inconclusive • 96 were from isolation dorms 84.5% (n=50) of positive individual cases were preceded by a positive wastewater sample in the days prior to or on the day of testing. In 8% (n=5) of positive individual cases wastewater samples were negative preceding the positive case and 7% (n=4) of individual cases were missed because a wastewater sample was not taken prior to the positive case. Testing rates increased by 1.5-13 times following wastewater notifications of positive samples. The authors concluded that wastewater sampling could be an efficient and cost-effective surveillance system to reduce infection rates on university campuses.	Moderate ***PREPRINT***

Corchis-Scott, R., Geng, Q., Seth, R., Ray, R., Beg, M., Biswas, N. … McKay, R.M.L. (2021). Averting an outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in a university residence hall through wastewater surveillance. *Preprint.*	Jun 25, 2021	Case report	University of Windsor Windsor, Ontario, Canada * * * Learning modality/on-campus living: • Remote learning • On-campus (n= 1 dorm, 198 students and staff)	Surveillance/testing plan: • Surveillance (wastewater monitoring 3x/week; continuous autosampling 24 hrs/day) • Testing (RT-qPCR; B.1.1.7 assay) A typical monitoring timeline: • Collection (09:00 – 11:00 • Detection (12:00) • Report to University (17:00) • Public health unit response (no later than 20:00) • PCR/antigen testing for entire dormitory; shelter in place • Results; isolation for positive case and close contact Other IPAC measures: • De-densification (dorms) • Quarantine dorm	From Feb – Mar 2021, wastewater samples were taken from a wing (n=86) of a single utilized student campus residence hall housing 186 students. Initial testing revealed no presence of COVID-19. From Mar – Apr 2021, surveillance changed to passive autosampling for the full dorm (n=186) which detected the presence of COVID-19 within two days of implementation. Subsequent testing of all on-campus residents (n=198), resulted in 2 (1%) positive cases of the B.1.1.7 VOC. Cases were moved into isolation within 48 hours; no additional cases identified. Community cases of VoCs were also low at this time. Return to campus after a holiday weekend identified presence of COVID-19 in wastewater, resulting in 1 new case. Case was quarantined; no additional cases identified.	Low ***PREPRINT***
Previously reported evidence						
Schön, M., Lindenau, C., Böckers, A., Altrock, C.M., Krys, L., Nosanova, A., … Boeckers, T.M.	Jul 29, 2021	Cohort	Ulm University, Germany * * *	Surveillance/testing plan: • Surveillance (pre-semester, return to campus and post semester)	From Nov 2020 – Mar 2021, 402 staff (n=75) and students (n=327) of an in-person laboratory setting were tested at the beginning of the semester, after winter break and at the end of the winter semester. At baseline, there were 2/327 (0.6%) asymptomatic confirmed cases,	High ***PREPRINT***

(2021). [Longitudinal SARS-CoV-2 infection study at Ulm University](). *Preprint*.			Learning modality/on-campus living: • Blended learning • On-campus living not reported	• Testing (RT-PCR, antigen, and serology) Other IPAC measures: • Social distancing (>1.5m) • Masks • PPE – gloves, protective coats • Hand washing • Disinfection • Ventilation • Screening and self-isolation • Contact tracing • Information • Cohort	22/345 (6.4%) seropositive students; all staff tested negative. No new staff or student cases were identified on return to campus after winter break. End of semester testing revealed 2/342 (0.6%) students had seroconverted due to infection over the course of the semester. No further infection or active cases were detected. Authors concluded that with IPAC measures in place face-to-face events with more than 100 people and practical courses with less than 1.5m physical distancing are possible without an increased infection rate.	
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. *Journal of Infectious Diseases,* jiab386.	Jul 24, 2021	Cohort	University of Colorado Boulder Boulder, Colorado, United States * * * Learning modality/on-campus living: • Blended learning • 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
Travis, S. A., Best, A. A., Bochniak, K. S., Dunteman, N.	Jun 23, 2021	Case report	Hope College Holland, Michigan, United States	Surveillance/testing plan:	Between Jul 29 – Nov 24, 2020, 10,700 tests were conducted among students and staff (2.2% positive test percentage):	Moderate

D., Fellinger, J., Folkert, P. D., … Schuitema, A. J. (2021). [Providing a safe, in-person, residential college experience during the COVID-19 pandemic](). *Frontiers in Public Health, 9*, 672344.			* * * Learning modality/on-campus living: • In-person learning • On-campus living (unknown %)	• 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	• 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%).	
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]()	Jun 18, 2021	Prevalence	High risk of transmission (HROT) university athletic programs 11/12 Pacific Coast Conference schools Pacific Coast, United States * * *	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:	High

athlete population: A prospective cohort study with 123,362 tests and 23,463 paired RT-PCR/Antigen samples. *BMJ Open Sport & Exercise Medicine, 7*(2), e001137.			Learning modality/on-campus living: • Not reported		• Initial screening/re-entry after time away: 32/1526 (2.1%) • Contact tracing: 24/502 (4.8%) • 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 (52%) 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.	

Tian, D., Lin, Z., Kriner, E.M., Esneault, D.J., Tran, J., DeVoto, J.C., ... Yin, X.M. (2021). Ct values do not predict Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) transmissibility	Jun 5, 2021	Cohort	Tulane University
			
			New Orleans, Louisiana
			
			* * *
			
			Learning modality/on-campus living:
			• On-campus living
				Surveillance/testing plan:
				• Surveillance (2x/week)
				• Testing (RT-PCR)
				
				Other IPAC measures:
				• Quarantine for cases and contacts
					From Sep 1 – Oct 31, 2020, 7,440 students were tested twice per week. There were 602 confirmed cases (8.1%) (262 symptomatic, 113 asymptomatic):
					• 195 index cases
					  ○ 94/195 (48.2%) had ≥1 contact who tested positive
					  ○ 101/195 (51.8%) had no positive contacts
					
					Those who tested positive were more likely to be younger (freshman and
						Moderate

in college students. *The Journal of Molecular Diagnostics*. Epub ahead of print.					sophomore; data not provided) and male (10.65% vs. 6.56% female).	
Liu, C., Vyas, A., Castel, A.D., McDonnell, K.A., & Goldman, L.R. (2021). Implementing mandatory testing and a public health commitment to control COVID-19 on a college campus. *Preprint*.	Jun 3, 2021	Case report	George Washington University Washington, D.C., United States * * * Learning modality/on-campus living: • 4,435/25,000 (18%) students, faculty and staff on-campus • On-campus living; 500 students	Surveillance/testing plan: • Surveillance (weekly and symptomatic testing) • Testing (RT-PCR; anterior nasal swab) Other IPAC measures: • Contract between on-campus students and university to not gather in groups >10 • De-densification (class sizes and dorms) • Masks • Mandatory COVID-19 training and influenza vaccination for on-campus students, faculty and staff • Mass screening campaigns • Physical distancing • Quarantine policies for cases and close contacts and students returning to on-campus living • Temperature checks	From Aug 17 – Dec 4, 2020, 38,288 tests were conducted among students (21,573; 79.5%) and staff (16,713; 43.7%); 220 were positive: • 175/220 (79.5%) students • 45/220 (20.5%) staff Overall positivity rates for students (0.81%) and staff (0.27%) were much lower than the surrounding community positivity rates (not provided). Temporal clusters of positive cases mirrored community spread with increases after holiday gatherings.	Moderate ***PREPRINT***

Hamer, D. H., White, L. F., Jenkins, H. E., Gill, C. J., Landsberg, H. N., Klapperich, C., ... Brown, R. A. (2021). [Assessment of a COVID-19 control plan on an urban university campus during a second wave of the pandemic](). *JAMA Network Open, 4*(6), e2116425.	Jun 1, 2021	Case report	Boston University (BU) • Large, urban campus • 40,000 students Boston, United States * * * Learning modality/on-campus living: • 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

Wong, S.T., Romney, M., Matic, N., Haase, K., Ranger, M., Dhari, R., ... Sin, D. (2021). Feasibility and utility of rapid antigen testing for COVID-19 in a university residence: A cross sectional study. *Preprint*.	May 26, 2021	Cross-sectional	University of British Columbia; Orchard Commons Dormitory Vancouver, British Columbia, Canada * * * Learning modality/on-campus living: • Blended learning • On-campus living (n=1500, unknown %)	Surveillance/testing plan: • Surveillance (random testing) • Testing (rapid antigen testing with immediate nasopharyngeal testing for positive tests) Typical testing timeline: • Rapid antigen test collection (any time throughout the day) • Result ≤ 60 minutes • Positive rapid test result triggers PCR test • Students self-isolate • PCR result (8-10 hrs)	From Feb – Apr 2021, 3536 tests were provided to 1141 students. 25 cases were confirmed (2.2%), all of whom were asymptomatic. Each index case resulted in ±7 secondary cases. Positive tests identified 6 clusters with 5-16 cases/cluster. These clusters were found among: • Students playing musical instruments • Varsity athletes • On-campus dormitories	Moderate ***PREPRINT***

Rennert, L., & McMahan, C. (2021). Risk of SARS-CoV-2 reinfection in a university student population. *Clinical Infectious Diseases*. Epub ahead of print.	May 16, 2021	Cohort	Clemson University
			
			South Carolina, United States
			
			* * *
			
			Learning modality/on-campus living:
			• Blended learning
			• On-campus living: 5,313 (% unknown)
				Testing/surveillance plan:
				• Surveillance (weekly testing for non-residential students; two weeks of daily testing for residential students followed by repeated weekly testing)
				• Testing (PCR testing; anterior nasal swabs or saliva tests)
				
				Other IPAC measures:
				• Negative test or positive serologic antibody test prior to return to campus (≤40 days)
					From Aug 19 – Oct 5, 2020, on-campus and residential students aged 17-24 years were tested for COVID-19. Of those testing positive:
					• On-campus; 2021/16 101 (12.55%) tested positive
					• Residential students; 682/4,829 (14.12%)
					
					Students were re-tested from Dec 28 – May 5, 2021. In comparison to infection rates in the Fall of 2020:
					• On-campus re-infection rate; 44/2021 (2.2%)
					  ○ RR=0.16 (95%CI=0.12. 0.22)
					• Residential students re-infection rate; 20/982 (2.9%)
					  ○ RR=0.23 (95%CI=0.15,0.37)
					
					Estimated protection from previous infection was 84% for on-campus and 77% for residential students.
						High

Liu, A.B., Davidi, D., Landsberg, H.E., Francesconi, M., Platt, J.T., Nguyen, G.T., ... Springer, M. (2021). Seven-day COVID-19 quarantine may be too short: Assessing post-quarantine transmission risk in four university cohorts. *Preprint*.	May 15, 2021	Cohort	4 universities (Boston, Duke, Harvard, Northeastern) Northeast, United States * * * Learning modality/on-campus living: • In-person learning • On-campus living: n, % unknown	Testing/surveillance plan: • Surveillance (varied among universities; minimum was twice weekly testing for on-campus undergraduates • Testing (varied among universities; rapid antigen or PCR testing) Other IPAC measures not reported. Other considerations: • Non-strict quarantine included interactions with household members • Strict quarantine; single room, single washroom, meal delivery	From Sep – Feb 2021 3,641 students and staff identified as close contacts were quarantined, of which 418 (11.5%) eventually tested as seropositive. Conversion time was estimated to be 4 days in 78% of cases. 132 (10%) in strict quarantine converted and 286 (12%) in non-strict converted (10% vs. 12%, p=0.041). Overall 9% of conversions occurred after day 10. Significantly more conversions after day 10 occurred in those in non-strict quarantine than strict quarantine (11% vs 3%) p<0.01. Follow up data for those in non-strict quarantine who converted after day 10, found these individuals were re-exposed to a person with COVID-19 during quarantine. Strict quarantine was associated with shorter conversion times: 5.9%, 2.4% and <1% converted after days 7,10 and 14 respectively. Whereas for those in non-strict quarantine, 14%, 4.9% and 1.7% converted after days 7, 10 and 14.	Moderate ***PREPRINT***

Fox, M.D., Leiszler, M.S., Seamon, M.D., & Garmin, B.L. (2021). [Results of a shortened quarantine protocol on a Midwestern college campus](). *Clinical Infectious Diseases*, *73*(Suppl 1), S38-S41.	May 12, 2021	Case report	Midwestern University
			United States
			
			Learning modality/on-campus living:
			• On-campus living (% unknown)
				Surveillance/testing plan:
				• Surveillance (on-campus daily dashboard; methods not reported)
				• Testing (RT-PCR. Rapid antigen)
				
				*A shortened quarantine protocol is the focus of this study
				
				A typical monitoring timeline for asymptomatic quarantined students:
				• Day 4: RT-PCR testing; results ≤36 hours. Positive cases no longer eligible for short quarantine
				• Day 7 rapid antigen testing; negative cases were released from quarantine
				• Day 8: follow-up phone call from staff to assess for subsequent symptoms or exposure to potential cases
				
				Other IPAC measures not reported.
					From Sep 1 – Nov 11, 2020, 1310 close contact students participated in a shortened quarantine release protocol (QRP). By day 7 158 tested positive:143/1310 (10%) tested positive on day 4, and 15/1167 (1.3%) tested positive on day 7. 1152 students were released from quarantine on day 7 and an additional 74 (6.4%) subsequently tested positive:
					• 18 (24%) within 14 days
					  ○ 9 on routine screening tests
					  ○ (5 reported new exposure, 4 had no known exposure)
					  ○ 9 sought testing for symptoms and/or exposure
					• 56 (76%) after 14 days
					• Of the 176 testing positive within 14 days of initiation of quarantine, 9 (5.1%) tested positive the week following release from quarantine without additional known exposure
					
					There is no evidence of additional transmission attributed to individuals released on day 7 (these individuals were not identified as probable source of exposure based on contact tracing interviews).
						Low

Moreno, G. K., Braun, K. M., Pray, I. W., Segaloff, H. E., Lim, A., Poulson, K., ... O'Connor, D. H. (2021). Severe acute respiratory syndrome coronavirus 2 transmission in intercollegiate athletics not fully mitigated with daily antigen testing. *Clinical Infectious Diseases, 73* (Suppl 1), S45-S53.	May 12, 2021	Case report	University athletics program (de-identified data) United States * * * Open/available: • Athletic programs: ○ Indoor meetings ○ Practices ○ Scrimmages ○ Intercollegiate competitions *Some sports were considered "high-risk" due to frequent contact / collision.	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 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.	Moderate

Currie, D.W., Moreno, G.K., Delahoy, M.J., Pray, I.W., Jovaag, A., Braun, K.M., ... Killerby, M.E. (2021). Description of a university COVID-19 outbreak and interventions to disrupt transmission, Wisconsin, August – October 2020. *Preprint*.	May 10, 2021	Case report	University of Wisconsin Madison, Wisconsin, United States Learning modality/on-campus living: • Blended learning (45,540 enrolled students 23,917 staff) • On-campus living (19 residence halls, n=26-1195)	Surveillance/testing plan: • Surveillance (testing prior to move-in; screening test every 2 weeks) • Testing (RT-PCR) Other IPAC measures: • Suspending in-person classes and other events (upon identified outbreak) • Additional mass testing • Quarantine facilities in local hotels • Isolation facilities in designated residence halls • Masks • Physical distancing • Screening	From Aug 1 – Oct 31, 2020, 3485/45,540 (7.7%) students and 245/23,917 (1%) staff had a confirmed positive test At baseline (move-in week), 34/6162 (0.6%) students in residence tested positive Over the course of the semester (Aug 25 – Oct 31, 2020) 856/6162 (13.9%) resident students tested positive (81.4% symptomatic, 18.6% asymptomatic) Clusters (not defined) were affiliated with residence halls (25.9%) and fraternities/sororities (13.2%). Remaining clusters were off-campus Attack rates in residence halls ranged from 1.9% - 31.9% (15: ≤10%; 2:10-20%; 2>20%) Two residences accounted for 586/856 (68.5%) cases representing 2119/6162 (34.4%) of all residence students Percent positivity was higher in those with a roommate compared to those without (15.4% vs. 7.3%), p<0.001 • 32/33 (97.0%) roommate pairs had identical consensus sequences compared to the 3.1% randomly assigned pairs (p<0.0001)	High ***PREPRINT***

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, 83*(1), 104-111.	Apr 28, 2021	Cross-sectional	5 universities with COVID-19 outbreaks following Sep 2020 re-opening United Kingdom * * * Learning modality/on-campus living: • 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

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 * * * Learning modality/on-campus living: • On-campus living (3528 students at 82% capacity)	Surveillance/testing plan: • Surveillance (wastewater monitoring, 3x/week per residence) • 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***
Gibas, C., Lambirth, K., Mittal, N., Juel, M. A. I., Barua, V. B., Brazell, L. R., … Munir, M. (2021).	Mar 30, 2021	Prevalence	University of North Carolina at Charlotte • Large, urban campus * * *	Surveillance/testing plan: • Surveillance (wastewater monitoring, 3x/week per residence)	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).	Moderate

Implementing building-level SARS-CoV-2 wastewater surveillance on a university campus. *The Science of the Total Environment*, *782*, 146749.			Learning modality/on-campus living: • On-campus living (unknown %)	• 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	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.	

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 and modelling study](). *The Lancet Child & Adolescent Health, 5*(6), 428–436.	Mar 19, 2021	Cohort	Clemson University • Large, rural campus Clemson, South Carolina, United States * * * Learning modality/on-campus living: • 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 • Quarantine/isolation	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) • 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	Moderate

					daily tests, and twice weekly would have required four time the number of daily tests compared to SBIT.	
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 * * * Learning modality/on-campus living: • 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., … Pepper, I. L. (2021). COVID-19 containment on a college campus via wastewater-based epidemiology, targeted clinical testing and an intervention. *Science of the Total Environment, 779,* 146408.	Mar 13, 2021	Case report	University of Arizona Arizona, United States * * * Learning modality/on-campus living: • In-person learning (limited) • On-campus living (unknown %)	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 • Shelter-in-place policy	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) 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.	Moderate

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. *Disaster Medicine and Public Health Preparedness.* Epub ahead of print.	Mar 8, 2021	Case report	Baylor University • 19,297 students (14,399 undergrad, 4898 grad) • ~3400 staff Waco, Texas, United States • Population: 256,600 * * * Learning modality/on-campus living: • Hybrid learning (25% of classes) • In-person learning (39% of classes) • Online learning (36% of classes) • On-campus living (4,736 students)	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 • 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	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%) • 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.	Moderate

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 infections on a large, urban campus - Georgia Institute of Technology, Fall 2020]. *Preprint.*	Jan 31, 2021	Case report	Georgia Institute of Technology Georgia, United States * * * Learning modality/on-campus living: • On-campus living (7370 students) • On-campus visiting, 5000/day; staff, non-resident students • Online learning	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%. Students in shared double rooms had higher positivity risk (30% of double roommates tested positive; half of cases in Aug-Sep were in doubles).	Moderate ***PREPRINT***

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
			
			* * *
			
			Learning modality/on-campus living:
			• 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 * * * Learning modality/on-campus living: • 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 * * * Learning modality/on-campus living: • Hybrid learning • Online learning • % On-campus living unknown	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. 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).	Low ***PREPRINT***

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 * * * Learning modality/on-campus living: • 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 31, 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
Previously reported evidence						
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 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.	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 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.	High ***PREPRINT***

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 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						
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. *International Journal of Environmental Research and Public Health, 18*(16), 8260.	Aug 4, 2021	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
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	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	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	Moderate ***PREPRINT***

university settings. *Preprint.*			• Adherence to physical distancing • No virus particles linger in classroom air between classes		feasibility of distancing not considered. Shared dormitory rooms not considered, especially if one roommate is infected.	
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, 27,* 1-15.	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
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

References

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.*

Betancourt, W. Q., Schmitz, B. W., Innes, G. K., Prasek, S. M., Pogreba Brown, K. M., … Pepper, I. L. (2021). COVID-19 containment on a college campus via wastewater-based epidemiology, targeted clinical testing and an intervention. *Science of the Total Environment, 779,* 146408.

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. *journal of Infectious Diseases,* jiab386.

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.

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.*

Corchis-Scott, R., Geng, Q., Seth, R., Ray, R., Beg, M., Biswas, N. … McKay, R.M.L. (2021). Averting an outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in a university residence hall through wastewater surveillance. *Preprint.*

Currie, D.W., Moreno, G.K., Delahoy, M.J., Pray, I.W., Jovaag, A., Braun, K.M., … Killerby, M.E. (2021). Description of a University COVID-19 Outbreak and Interventions to Disrupt Transmission, Wisconsin, August – October 2020. *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.*

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.

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, 27,* 1-15.

Fox, M.D., Leiszler, M.S., Seamon, M.D., & Garmin, B.L. (2021). Results of a Shortened Quarantine Protocol on a Midwestern College Campus. *Clinical Infectious Diseases*, *73*(Suppl 1), S38-S41.

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.

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.*

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.

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 infections on a large, urban campus - Georgia Institute of Technology, Fall 2020. *Preprint.*

Hambridge, H.L., Kahn, R., & Onnela, J.-P. (2021). Examining SARS-COV-2 interventions in residential colleges using an empirical network. *Preprint.*

Hamer, D. H., White, L. F., Jenkins, H. E., Gill, C. J., Landsberg, H. N., Klapperich, C., … Brown, R. A. (2021). Assessment of a COVID-19 control plan on an urban university campus during a second wave of the pandemic. *JAMA Network Open, 4*(6), e2116425.

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: A prospective cohort study with 123,362 tests and 23,463 paired RT-PCR/Antigen samples. *BMJ Open Sport & Exercise Medicine, 7*(2), e001137.

Hertel, A.T., Heeter, M.M., Wirfel, O.M., Bestram, M.J., & Mauro, S.A. (2021). Athletes drive distinctive trends of COVID-19 infection in a college campus environment. *International Journal of Environmental Research and Public Health, 18*(14), 7689.

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.

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. *International Journal of Environmental Research and Public Health, 18*(16), 8260.

Karthikeyan, S., Nguyen, A., McDonald, D., Zong, Y., Ronquillo, N., Ren, J. … Knight, R. (2021). Rapid, large-scale wastewater surveillance and automated reporting system enabled early detection of nearly 85% of COVID-19 cases on a university campus. *Preprint.*

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.*

Liu, A.B., Davidi, D., Landsberg, H.E., Francesconi, M., Platt, J.T., Nguyen, G.T., ... Springer, M. (2021). Seven-day COVID-19 quarantine may be too short: assessing post-quarantine transmission risk in four university cohorts. *Preprint*.

Liu, C., Vyas, A., Castel, A.D., McDonnell, K.A., & Goldman, L.R. (2021). Implementing Mandatory Testing and a Public Health Commitment to Control COVID-19 on a College Campus. *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.

Moreno, G. K., Braun, K. M., Pray, I. W., Segaloff, H. E., Lim, A., Poulson, K., ... O'Connor, D. H. (2021). Severe acute respiratory syndrome coronavirus 2 transmission in intercollegiate athletics not fully mitigated with daily antigen testing. *Clinical Infectious Diseases, 73* (Suppl 1), S45-S53.

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.*

O'Toole, T., Burke, M.D., & Denny, T. (December 2020). *COVID-19 Testing Strategies for Colleges and Universities*. National Academies of Sciences, Engineering, and Medicine.

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.

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 institutional resources: A modeling study. *Preprint.*

Rennert, L., & McMahan, C. (2021). Risk of SARS-CoV-2 reinfection in a university student population. *Clinical Infectious Diseases*. Epub ahead of print.

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 and modelling study. *The Lancet Child & Adolescent Health, 5(6), 428–436.*

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.*

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.

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. *Disaster Medicine and Public Health Preparedness.* Epub ahead of print.

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*.

Schön, M., Lindenau, C., Böckers, A., Altrock, C.M., Krys, L., Nosanova, A., … Boeckers, T.M. (2021). Longitudinal SARS-CoV-2 infection study at Ulm University. *Preprint*.

Schünemann, H., Brożek, J., Guyatt, G., & Oxman, A. (2013). *Handbook for grading the quality of evidence and the strength of recommendations using the GRADE approach*.

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.*

Tian, D., Lin, Z., Kriner, E.M., Esneault, D.J., Tran, J., DeVoto, J.C., … Yin, X.M. (2021). Ct values do not predict Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) transmissibility in college students. *The Journal of Molecular Diagnostics*. Epub ahead of print.

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. *Frontiers in Public Health, 9*, 672344.

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, 83*(1), 104-111.

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.*

Wong, S.T., Romney, M., Matic, N., Haase, K., Ranger, M., Dhari, R., … Sin, D. (2021). Feasibility and utility of rapid antigen testing for COVID-19 in a university residence: a cross sectional study. *Preprint*.

Yeo, S.C., Lai, C.K.Y., 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.