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2022-06-23
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Journal of Adolescent Health 71 (2022) 559–569

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JOURNAL OF ADOLESCENT HEALTH

www.jahonline.org

Original article

SARS-CoV-2 Seroprevalence: Demographic and Behavioral Factors Associated With Seropositivity Among College Students in a University Setting

Karen Diepstra, M.P.H. [a,*], Brooke W. Bullington [a,b], Lakshmanane Premkumar, Ph.D. [c], Bonnie E. Shook-Sa, Dr.P.H. [d], Corbin Jones, Ph.D. [e], and Audrey Pettifor, Ph.D. [a]

[a] *Department of Epidemiology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina*
[b] *Carolina Population Center, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina*
[c] *Department of Microbiology and Immunology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina*
[d] *Department of Biostatistics, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina*
[e] *Department of Biology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina*

Article history: Received January 18, 2022; Accepted June 23, 2022
Keywords: SARS-CoV-2; COVID-19; Serology; Seroprevalence; Campus life; College life

A B S T R A C T

Purpose: Examine SARS-CoV-2 seroprevalence and the association of seropositivity with demographic, geographic, and behavioral variables among University of North Carolina Chapel Hill (UNC-CH) undergraduate students enrolled in the fall 2020 semester.
Methods: All UNC-CH undergraduate students were invited to participate in the Heelcheck study; participants were weighted to the UNC-CH undergraduate population using raking methods. We estimate SARS-CoV-2 seroprevalence at study entrance (11/12/2020–12/10/2020) and bivariable associations using log-binomial regression.
Results: SARS-CoV-2 seroprevalence was 7.3% (95% confidence interval (CI): 5.4%–9.2%) at baseline. Compared to students who were living off-campus in the Chapel Hill/Carrboro area (CH) for the Fall 2020 semester (8.6% seroprevalence), students who never returned to CH had lower seroprevalence (1.9%, prevalence ratio (PR), 95% CI: 0.22, 0.06–0.81), whereas, students who started the semester on-campus and moved to off-campus CH housing had 18.9% seroprevalence (PR, 95% CI: 2.21, 1.04–4.72) and students who spent the semester living in a Sorority/Fraternity house had 46.8% seroprevalence (PR, 95% CI: 5.47, 2.62–11.46). Those who predicted they would join an indoor party unmasked had 3.8 times the seroprevalence of those who indicated they would not attend (PR, 95% CI: 3.80, 1.58–9.16). Compared to students who disagreed with the statement "…I am not going to let COVID-19 stop me from having fun…", those who agreed had higher seroprevalence (14.0% vs. 5.7%; (PR, 95% CI: 2.45, 1.13–5.32)).
Discussion: Increased seroprevalence was associated with congregate living and participation (actual or endorsed) in social activities. During pandemics, universities must create safe socializing opportunities while minimizing transmission.

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IMPLICATIONS AND CONTRIBUTION

Increased SARS-CoV-2 was observed for undergraduate students in certain congregate living settings (e.g., Sorority/Fraternity housing) and those who participated (actual or endorsed) in social activities. This work should inform the creation of safe socializing opportunities in university settings during waves of the COVID-19 pandemic and future pandemics.

The COVID-19 pandemic has caused significant morbidity and mortality globally. In the United States alone, the Centers for Disease Control and Prevention estimate that nearly 53 million SARS-CoV-2 infections and 2.4 million hospitalizations may have

Conflicts of interest: The authors declare that no competing interests exist.

* Address correspondence to: Karen Diepstra, M.P.H., CB 7435 McGavran-Greenberg Hall, Chapel Hill, NC 27599.
E-mail address: karenlyn@live.unc.edu (K. Diepstra).

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https://doi.org/10.1016/j.jadohealth.2022.06.015

occurred during February-September 2020 [1]. While many subgroups are at risk of becoming infected with SARS-CoV-2, young adults (<30), especially those living in congregate settings such as universities, are particularly at risk of acquiring and transmitting SARS-CoV-2 [2–4]. In addition, young adults play an important role in overall community transmission dynamics [2]. While COVID-19 vaccines have transformed our capacity to inhibit SARS-CoV-2 transmission and mitigate the pandemic's effects, the possibility for genetic variants to emerge and potentially escape natural and vaccine-induced immunity exists [5–7]. Furthermore, vaccination coverage rates are currently suboptimal, particularly among young people, even in the U.S. where vaccine accessibility is high [8,9]. As such, there is a need for continued use of additional prevention measures, including masking and physical distancing, especially in transmission-prone settings, such as college campuses.

College campuses and many of the typical activities associated with campus life are ideal settings for SARS-CoV-2 transmission [10–12]. Previous studies have identified Greek life event participation and off-campus social settings as predictors of SARS-CoV-2 acquisition [13–15]. Many U.S. colleges were eager to bring students back to campus for in-person instruction in Fall 2020, and quickly returned to distanced learning following rapid transmission of SARS-CoV-2 among the students on campus [4,16]. At one large public university, SARS-CoV-2 prevalence among students tested on campus increased from 3% during the week before Fall 2020 classes began to 32% 2 weeks after classes resumed [16]. Many college students have adopted COVID-19 prevention measures; in a survey of 725 full-time college students in the U.S., 95% were sheltering in place per public health guidelines as of late April 2020 [11]. Nevertheless, the experience of college life is a unique and important time of development for young adults, especially undergraduate students who are likely leaving their home environment for the first time, and social interactions are a typical component of that experience [17–19]. It is essential to understand the unique risk factors for SARS-CoV-2 transmission in the college campus setting, especially within social contexts characteristic of undergraduate campus life, to inform policies and procedures that support in-person instruction and student life. This understanding will be vital as we navigate potential surges in the current COVID-19 pandemic and during future pandemics [20].

The University of North Carolina at Chapel Hill (UNC-CH), like many campuses across the U.S., transitioned to remote learning in March 2020, shifted to a combination of in-person, online, and hybrid classes for the Fall 2020 semester (which started on August 10, 2020), and, shortly after, on August 19, returned to online learning exclusively after a significant rise in COVID-19 cases. The Heelcheck cohort study was designed to determine the seroprevalence of SARS-CoV-2 and identify demographic and behavioral predictors of seroprevalence among undergraduate students enrolled in the fall 2020 semester at UNC-CH. Here, we had three descriptive aims: to (1) estimate SARS-CoV-2 seroprevalence among undergraduate students; (2) describe the distribution of characteristics uniquely tied to the undergraduate college experience during COVID-19, including location of residence and decision-making around COVID-19 prevention behaviors; and (3) identify demographic, behavioral, and social variables associated with SARS-CoV-2 seroprevalence among undergraduate students at a large, public university in the Southern U.S.

Methods

Heelcheck cohort study

The Heelcheck cohort study consisted of a series of three online questionnaires (administered at three separate time points over 11 months) and three corresponding serology tests. The overarching study objective was to estimate SARS-CoV-2 seroprevalence over time, and to identify demographic and behavioral predictors of seroprevalence among UNC-CH undergraduate students. All UNC-CH undergraduate students enrolled in the Fall 2020 semester (n = 19,395) were sent an email invitation to participate in the Heelcheck study on 11/12/2020. The Heelcheck study received approval from the UNC-CH Institutional Review Board.

Baseline heelcheck questionnaire

The first (baseline) Heelcheck questionnaire was programmed using Qualtrics and included 64 questions. We used multiple-choice, multiple answer, and open-ended question formats. The baseline questionnaire took approximately 20 minutes to complete and covered a wide range of topics including socio-demographics, involvement in campus activities (e.g., Greek life, UNC athletics), COVID-19 symptoms and prior diagnoses, adherence and compliance with COVID-19 guidelines, COVID-19-related exposures (e.g., attending parties, sporting events) and perceived risk, and attitudes toward vaccination and other prevention measures.

We used two, unique, scenario-based questions to examine decision-making in social contexts specific to undergraduate campus life [21]. We asked respondents to place themselves in two different situations and indicate (via multiple choice) the behavior they think they would most likely exhibit in the situation (Appendix).

Finally, we asked two questions about location of residence during the Fall 2020 semester (Appendix) and used the two responses to construct a single variable capturing location of residence type throughout the Fall 2020 semester.

Seropositivity measure—the Tasso-SST device

To collect blood and assess SARS-COV-2 seropositivity among the participants, we used the Tasso-SST device—a capillary blood collection device that can be self-administered at home without supervision (Appendix) [22]. Blood samples were received at UNC-CH between 11/18/2020 and 01/19/2021 where they underwent anti-SARS-CoV-2 Spike antibody testing. The serology assay is based on spike receptor-binding domain antigen and measures total Ig (IgG, IgA and IgM) with an estimated sensitivity of 95% and specificity of 96% [23,24]. Serology test results were categorized as positive, negative, indeterminate, or non-viable (due to poor sample quality). Baseline seropositivity was defined as at least one positive serology result (as some individuals submitted two Tasso samples at baseline).

Analytic sample and statistical analysis

For this descriptive analysis, our analytic sample included individuals who consented to the baseline questionnaire and for whom we also had a serology result (n = 680). To minimize the

Table 1
Demographic and geographic characteristics in the unweighted and weighted populations[a]

Characteristic	heelcheck respondents with baseline serology result (N = 680)	Weighted population (n = 19,395)[b]
Survey completion date, range[c]	11/12/2020–12/10/2020	11/12/2020–12/10/2020
Sex at birth		
Female	490 (72%)	11,636 (60%)
Male	190 (28%)	7,759 (40%)
Race/Ethnicity		
Asian	81 (12%)	2,931 (15%)
Black or African American	23 (3%)	1,716 (9%)
Hispanic or Latinx (all races)	63 (9%)	1,868 (10%)
White	459 (68%)	11,092 (57%)
Other[d]	54 (8%)	1,788 (9%)
Age		
<21 years	392 (61%)	10,982 (60%)
21+ years	254 (39%)	7,196 (40%)
Missing	34	1,216
Current year at UNC		
First year	150 (22%)	3,211 (17%)
Sophomore	134 (20%)	4,296 (22%)
Junior	167 (25%)	5,572 (29%)
Senior	229 (34%)	6,316 (33%)
Location and housing Fall 2020[e]		
CH off campus Aug 10 and end	316 (47%)	9,157 (48%)
Campus housing/dorm Aug 10 and left CH by end	136 (20%)	3,464 (18%)
Not in CH Aug 10 or end	123 (18%)	3,850 (20%)
Campus housing/dorm Aug 10 and CH off campus at end	33 (5%)	687 (4%)
Campus housing/dorm Aug 10 and end	25 (4%)	801 (4%)
Chapel Hill off campus Aug 10 and left CH by end	23 (3%)	690 (4%)
Sorority/Fraternity house Aug 10 and end	11 (2%)	356 (2%)
Other[f]	6 (1%)	153 (1%)
Missing	7	236
Member of UNC Athletic Team		
Yes	14 (2%)	377 (2%)
No	658 (98%)	18,777 (98%)
Missing/no response	8	241
Member of Sorority or Fraternity		
Yes	88 (13%)	2,518 (13%)
No	582 (87%)	16,563 (87%)
Missing/no response	10	313
Tasso date, range[g]	11/18/2020–01/19/2021	11/18/2020–01/19/2021
Missing	83	2,178
SARS-CoV-2 seropositivity		
Positive	60 (9%)	1,415 (7%)
Negative or inconclusive	620 (91%)	17,980 (93%)
Missing	0	0

[a] Missing data was imputed based on logical imputation when possible, otherwise the mode response was used.
[b] Weighted frequencies might not sum to the weighted sample size total given use of a consistent rounding rule.
[c] The date of the earliest baseline questionnaire record; for individuals with two baseline records, only the first was analyzed.
[d] Other includes American Indian or Alaska Native, Native Hawaiian or Pacific Islander, two or more races, and no response/missing.
[e] Survey respondents were asked to report on their location/housing type on "August 10" (2020) and their location "up until the semester ended", (November 24, 2020).
[f] Other includes: Not in CH Aug 10 and living in CH off campus by end; Sorority/Fraternity Aug 10 and living in CH off campus by end; Not in CH Aug 10 and campus housing/dorm by end; Sorority/Fraternity Aug 10 and left CH by end.
[g] The date on which the Tasso kit and blood specimen was received at the UNC-CH laboratory, which was likely 2–3 weeks after the specimen was collected by the participant.

potential for nonresponse bias, weighting techniques were used such that the weighted respondents represented the target population based on a set of characteristics thought to be associated with both study participation and the variables of interest. Using demographic data from the UNC-CH Registrar's Office (as of August 2020), we used iterative proportional fitting (i.e., raking) methods to weight the analytic sample to the marginal distributions of the entire UNC-CH undergraduate population with respect to three characteristics: sex (female, male), class year (first year, sophomore, junior, senior), and Race/Ethnicity (Asian, Black/African-American, Hispanic (all races), White, other)—the latter of which we considered a socio-political rather than biological construct [25–27]. The iterative raking procedure continued until the weighted marginal proportions differed from the target population's proportions by <0.5% for each raking variable. Race/Ethnicity was collapsed into a five-level variable to ensure adequate sample sizes for weighting.

We calculated descriptive statistics, including estimation of SARS-CoV-2 seropositivity, for both the analytic sample consisting of baseline Heelcheck respondents who had a viable baseline serology sample (n = 680) and the weighted population. We described the distribution of COVID-19 related attitudes, exposures, and behaviors, and the scenario-based responses for the weighted population. Next, we used log-binomial regression

Table 2
Weighted distribution of COVID-19-related exposures, perceptions, and risk-related behaviors

Heelcheck survey question	Weighted N	Weighted %, (95% CI)
What do you think your risk or chance of getting COVID-19 is in the next year?		
Almost no chance	435	2%, (1.1%, 3.5%)
Slight chance	7,186	38%, (33.5%, 41.8%)
Moderate chance	9,804	51%, (47.2%, 55.6%)
High chance	1,577	8%, (6.0%, 10.5%)
No Response	85	0%, (0.0%, 1.0%)
Missing	307	
Have you ever had or been suspected of having Coronavirus/COVID-19?		
Yes, positive blood test	92	0%, (0.0%, 1.0%)
Yes, a positive nasal swab or saliva test	940	5%, (3.3%, 6.5%)
Yes, a medical diagnosis, but no test	20	0%, (0.0%, 0.3%)
Yes, possible symptoms, but no diagnosis by a test	3,455	18%, (14.6%, 21.4%)
No, not to my knowledge	14,554	76%, (72.3%, 79.6%)
No Response	104	1%, (0.0%, 1.2%)
Missing	229	
Was anyone in your household ever diagnosed with Coronavirus/COVID-19 while you were living together?		
Yes	2,149	11%, (8.8%, 13.6%)
No	17,003	89%, (86.1%, 91.1%)
No response	37	0%, (0.0%, 0.6%)
Missing	207	
Have you lived with any essential workers since COVID-19 began?		
Yes	8,654	45%, (41.0%, 49.3%)
No	10,379	54%, (50.0%, 58.3%)
No response	131	1%, (0.0%, 1.4%)
Missing	232	
Once the first coronavirus vaccine becomes widely available, how likely are you to get vaccinated?		
Very or somewhat unlikely	793	4%, (2.5%, 5.8%)
Unsure	1,464	8%, (5.3%, 10.1%)
Very or somewhat likely	16,780	88%, (85.3%, 91.0%)
Missing	358	
Within the past month, how often have you done the following when leaving your home:		
Worn a mask inside when you're around other people not in your household		
Never or rarely	856	4%, (2.8%, 6.2%)
Occasionally or often	2,830	15%, (11.7%, 17.9%)
Most or all of the time	15,452	81%, (77.3%, 84.1%)
Missing	257	
Maintained physical distancing (at least 6 feet of distance) between yourself and others not in your household		
Never or rarely	423	2%, (1.0%, 3.4%)
Occasionally or often	4,729	25%, (21.0%, 28.4%)
Most or all of the time	13,998	73%, (69.3%, 76.9%)
Missing	246	
Only met with others in a group of 10 people or less		
Never or rarely	716	4%, (2.2%, 5.4%)
Occasionally or often	2,199	12%, (8.8%, 14.4%)
Most or all of the time	16,051	85%, (81.5%, 87.8%)
Missing	429	
Please indicate your level of agreement with the following statements:		
I am not worried about getting COVID-19 because I'm not living with or interacting with high risk people		
Disagree or strongly disagree	13,598	72%, (68.3%, 76.0%)
Neither agree nor disagree	2,363	13%, (9.8%, 15.3%)
Agree or strongly agree	2,883	15%, (12.1%, 18.5%)
Missing	551	
It is important to take part in contact tracing and quarantine as an essential part of controlling the spread of COVID-19		
Disagree or strongly disagree	304	2%, (0.6%, 2.7%)
Neither agree nor disagree	554	3%, (1.6%, 4.3%)
Agree or strongly agree	18,076	95%, (93.8%, 97.1%)
Missing	460	
Young people should get COVID-19 so that they get immunity to the virus and then can get on with their normal activities		
Disagree or strongly disagree	15,979	84%, (81.3%, 87.6%)
Neither agree nor disagree	2,292	12%, (9.3%, 15.0%)
Agree or strongly agree	647	3%, (2.0%, 4.9%)
Missing	476	
I am not worried about getting COVID-19 because I think COVID-19 is a hoax		
Disagree or strongly disagree	18,697	99%, (97.9%, 99.5%)
Neither agree nor disagree	220	1%, (0.4%, 2.0%)
Agree or strongly agree	20	0%, (0.0%, 0.3%)
Missing	458	
College only happens one time and I am not going to let COVID-19 stop me from having fun or from doing the social activities that are part of the college experience		
Disagree or strongly disagree	15,145	80%, (76.5%, 83.1%)
Neither agree nor disagree	2,425	13%, (10.1%, 15.4%)

Table 2
Continued

Heelcheck survey question	Weighted N	Weighted %, (95% CI)
Agree or strongly agree	1,408	7%, (5.3%, 9.6%)
Missing	417	
Please rate the following concerns about COVID-19 contact tracing programs:		
My friends being angry at me for sharing their names and contact information		
Not at all concerned	11,453	62%, (57.7%, 65.8%)
Slightly or somewhat concerned	5,247	28%, (24.6%, 32.0%)
Moderately or extremely concerned	1,842	10%, (7.6%, 12.3%)
Missing	854	
My friends having to be in quarantine if I report them as my contact		
Not at all concerned	9,010	48%, (43.7%, 52.2%)
Slightly or somewhat concerned	6,144	33%, (28.8%, 36.7%)
Moderately or extremely concerned	3,619	19%, (16.1%, 22.5%)
Missing	622	
Getting in trouble with UNC if I report being at a gathering or some other event I am not supposed to be at		
Not at all concerned	10,863	58%, (53.9%, 62.2%)
Slightly or somewhat concerned	4,848	26%, (22.3%, 29.5%)
Moderately or extremely concerned	3,002	16%, (13.1%, 19.0%)
Missing	682	
My health and personal information being shared with the University		
Not at all concerned	10,922	58%, (53.6%, 62.0%)
Slightly or somewhat concerned	5,894	31%, (27.3%, 35.1%)
Moderately or extremely concerned	2,085	11%, (8.4%, 13.6%)
Missing	494	
Having to be in isolation/quarantine if I test positive or report being a close contact to someone who has tested positive		
Not at all concerned	7,611	40%, (36.1%, 44.4%)
Slightly or somewhat concerned	6,474	34%, (30.3%, 38.2%)
Moderately or extremely concerned	4,827	26%, (21.9%, 29.1%)
Missing	483	
My organization/club/team/fraternity/sorority getting in trouble or being closed as a result of something I report		
Not at all concerned	13,951	79%, (75.5%, 82.4%)
Slightly or somewhat concerned	2,087	12%, (9.1%, 14.6%)
Moderately or extremely concerned	1,631	9%, (6.8%, 11.6%)
Missing	1,726	
In the past month, have you:		
Been in a car with people you do not live with, no masks		
Yes	11,903	62%, (57.9%, 66.1%)
No	7,285	38%, (33.9%, 42.1%)
Missing	207	
Been to an indoor party with 10 or more people, no masks		
Yes	3,943	21%, (17.1%, 24.0%)
No	15,245	79%, (76.0%, 82.9%)
Missing	207	
Been to a restaurant or bar indoors		
Yes	10,716	56%, (51.7%, 60.0%)
No	8,472	44%, (40.0%, 48.3%)
Missing	207	
Been to an athletic event such as a football or soccer game		
Yes	2,668	14%, (11.2%, 16.6%)
No	16,520	86%, (83.4%, 88.8%)
Missing	207	
Scenarios		
You and two roommates decide to go out on a Friday night. You all leave the house and are wearing masks. You go to a friend's house who invited you over for a socially distanced, outdoor party. When you get there everyone is inside, no one is wearing a mask. Do you:		
Go inside with your mask on	1,788	9%, (7.1%, 11.6%)
Go inside with your mask on, but eventually take if off	1,792	9%, (7.0%, 11.8%)
Go inside and take your mask off	858	4%, (2.7%, 6.3%)
Talk to the host and see if you could move the party outside	2,391	13%, (9.8%, 15.3%)
Leave because there are too many people and no masks inside	11,697	61%, (57.1%, 65.3%)
No response	577	3%, (1.5%, 4.5%)
Missing	291	
You're studying late in the common space of your house. One of your roommates comes home with three friends who do not live in your household. They all start hanging out in the room you are in. None of them are wearing masks. Do you:		
Hang out with them with; no mask on	2,845	15%, (12.0%, 17.7%)
Hang out with them, but put a mask on	1,211	6%, (4.3%, 8.3%)
Ask the friends to put on masks	3,774	20%, (16.4%, 23.0%)
Ask the friends to leave	1,798	9%, (6.9%, 11.8%)
Leave the room to go somewhere else	9,171	48%, (43.7%, 52.1%)
No response	343	2%, (0.6%, 3.0%)
Missing	254	

95% CI: 95% confidence interval.

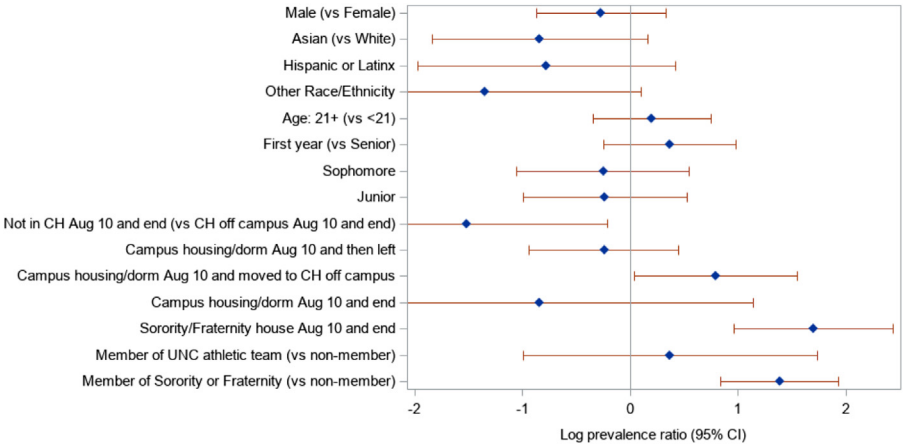


Figure 1. Estimated associations between SARS-CoV-2 seropositivity and demographic/geographic characteristics in the weighted sample. CH: Chapel Hill; Weighted prevalence ratio (PR) estimates and 95% CIs were calculated using log-binomial regression with a robust error variance; PR presented on the log scale; Reference group remains constant until noted; PR not estimated if group had five or fewer individuals and/or zero outcomes (subgroups: Black/African-American, students who were in CH off campus on Aug 10 and then left CH).

to estimate the unadjusted prevalence ratios and 95% confidence intervals for the associations between COVID-19 seropositivity and each of the demographic/behavioral variables in the weighted population [28,29]. The 95% confidence intervals in the weighted analysis were calculated using the Taylor Series Linearization method for proportions and the empirical sandwich (robust) variance estimator for prevalence ratios. The results among the analytic sample (n = 680) can be found in the Tables A1–A3. All statistical analyses were conducted using SAS 9.4 (Cary, NC), and the weighting procedure used the SAS macro, RAKING [25].

Results

Demographic characteristics

According to data from the UNC-CH Registrar's office, there were 19,395 undergraduate students enrolled in the Fall 2020 semester (as of August 2020), of whom 1,147 (6%) consented to the baseline Heelcheck questionnaire. Of the 1,147 baseline respondents, 680 (59%) provided at least one viable blood sample using the Tasso device and were included in the analytic sample (Table 1). Members of the analytic sample completed the baseline questionnaire between 11/12/2020 and 12/10/2020.

Among baseline respondents in the analytic sample, the majority were female at birth (72%) and identified their Race/Ethnicity as White (68%) (Table 1). After the iterative weighting procedure, the distribution of sex, Race/Ethnicity, and class year in the weighted population was nearly identical to that of the entire UNC-CH undergraduate population indicating successful weighting.

SARS-COV-2 seroprevalence

The serology specimens were received at UNC-CH between 11/18/2020 and 01/19/2021 (median: 12/21/2020). In the weighted sample, 1,415 of 19,395 students (7.3%, 95% CI: 5.4%, 9.2%) had at least one positive SARS-COV-2 serology test at Heelcheck study entrance.

COVID-19-related exposures, risk perceptions, and behaviors in the weighted population of undergraduate students

Among undergraduate students, 377 (2%) were current UNC-CH athletes and 2,518 (13%) were members of a Sorority or Fraternity (Table 1). When comparing where students were living at the beginning of the semester (August 10, 2020) to where they were located at the conclusion of the semester (November 2020), nearly half (48%) were living off-campus in the Chapel Hill/Carrboro area (CH) at both time points. An additional 20% were not living on-campus or in CH at either time point, and 18% started the semester on-campus (dorms), but had left CH by the end of the semester. The remaining 14% started and concluded the semester at a combination of on-campus and off-campus settings in CH and elsewhere, including 2% who started and concluded the semester living in a Sorority/Fraternity house.

Twenty-three percent of students reported a possible history of SARS-CoV-2 infection, though the majority of this group (77%) had not received a positive test or physician's diagnosis, and only suspected infection due to possible symptoms (Table 2). When asked about their perceived risk of getting COVID-19 in the next year, only 8% responded that there was a high chance; 51% responded moderate chance, 38% slight chance, and 2% indicated almost no chance.

A large majority of respondents expressed a strong commitment to COVID-19 prevention measures. When asked about behavior in the month preceding the questionnaire, 81% reported mask wearing indoors most or all of the time when around non-household contacts, 73% reported maintaining physical distance with non-household contacts most or all of the time, and 85% reported meeting in groups of $\leq$10 people most or all of the time. Furthermore, 88% confirmed that they were "very or somewhat likely" to get the COVID-19 vaccine once it became available.

Decision-making and social contexts related to campus life. In the first scenario question, which asked participants how they would respond if they showed up to a party that they thought was going to be held outdoors with social distancing and instead was being held indoors without face masking, the majority of students

Table 3
Estimated associations between SARS-CoV-2 seropositivity and COVID-19-related exposures, perceptions, and risk-related behaviors in the weighted sample

Heelcheck survey question	Seropositivity	
	%	PR (95% CI)
What do you think your risk or chance of getting COVID-19 is in the next year?		
Almost no chance	12.2%	1.00 (ref)
Slight chance	5.9%	0.49 (0.12, 2.03)
Moderate chance	6.6%	0.54 (0.13, 2.22)
High chance	10.8%	0.88 (0.19, 4.21)
Have you ever had or been suspected of having Coronavirus/COVID-19?		
Yes, positive blood test	31.4%	9.72 (2.25, 41.93)
Yes, a positive nasal swab or saliva test	73.4%	22.76 (13.81, 37.51)
Yes, a medical diagnosis, but no test	[a]	—
Yes, possible symptoms, but no diagnosis by a test	5.4%	1.66 (0.68, 4.07)
No, not to my knowledge	3.2%	1.00 (ref)
Was anyone in your household ever diagnosed with Coronavirus/COVID-19 while you were living together?		
Yes	28.7%	6.43 (3.89, 10.61)
No	4.5%	1.00 (ref)
Have you lived with any essential workers since COVID-19 began?		
Yes	8.1%	1.25 (0.74, 2.12)
No	6.5%	1.00 (ref)
Once the first coronavirus vaccine becomes widely available, how likely are you to get vaccinated?		
Very or somewhat unlikely	1.8%	0.25 (0.03, 1.83)
Unsure	8.1%	1.11 (0.44, 2.79)
Very or somewhat likely	7.3%	1.00 (ref)
Within the past month, how often have you done the following when leaving your home:		
Worn a mask inside when you're around other people not in your household		
Never or rarely	8.4%	1.18 (0.35, 3.99)
Occasionally or often	8.9%	1.25 (0.63, 2.49)
Most or all of the time	7.1%	ref (1.00)
Maintained physical distancing (at least 6 feet of distance) between yourself and others not in your household		
Never or rarely	17.9%	3.15 (0.96, 10.31)
Occasionally or often	11.5%	2.03 (1.17, 3.52)
Most or all of the time	5.7%	ref (1.00)
Only met with others in a group of 10 people or less		
Never or rarely	26.8%	4.19 (1.97, 8.92)
Occasionally or often	7.8%	1.22 (0.55, 2.70)
Most or all of the time	6.4%	ref (1.00)
Please indicate your level of agreement with the following statements:		
I am not worried about getting COVID-19 because I'm not living with or interacting with high risk people		
Disagree or strongly disagree	7.0%	ref (1.00)
Neither agree nor disagree	7.2%	1.04 (0.47, 2.27)
Agree or strongly agree	6.3%	0.91 (0.38, 2.20)
It is important to take part in contact tracing and quarantine as an essential part of controlling the spread of COVID-19		
Disagree or strongly disagree	20.9%	3.03 (0.81, 11.25)
Neither agree nor disagree	6.9%	1.00 (0.24, 4.18)
Agree or strongly agree	6.9%	ref (1.00)
Young people should get COVID-19 so that they get immunity to the virus and then can get on with their normal activities		
Disagree or strongly disagree	6.2%	ref (1.00)
Neither agree nor disagree	8.3%	1.34 (0.63, 2.85)
Agree or strongly agree	26.6%	4.31 (1.96, 9.47)
I am not worried about getting COVID-19 because I think COVID-19 is a hoax		
Disagree or strongly disagree	7.1%	ref (1.00)
Neither agree nor disagree	10.9%	1.53 (0.23, 10.04)
Agree or strongly agree	[a]	—
College only happens one time and I am not going to let COVID-19 stop me from having fun or from doing the social activities that are part of the college experience		
Disagree or strongly disagree	5.7%	ref (1.00)
Neither agree nor disagree	11.7%	2.05 (1.08, 3.90)
Agree or strongly agree	14.0%	2.45 (1.13, 5.32)
Please rate the following concerns about COVID-19 contact tracing programs:		
My friends being angry at me for sharing their names and contact information		
Not at all concerned	4.7%	ref (1.00)
Slightly or somewhat concerned	8.4%	1.79 (0.95, 3.37)
Moderately or extremely concerned	18.8%	3.99 (2.11, 7.55)
My friends having to be in quarantine if I report them as my contact		
Not at all concerned	5.1%	ref (1.00)
Slightly or somewhat concerned	7.2%	1.40 (0.74, 2.67)
Moderately or extremely concerned	11.4%	2.22 (1.15, 4.30)
Getting in trouble with UNC if I report being at a gathering or some other event I am not supposed to be at		
Not at all concerned	3.8%	ref (1.00)

(*continued on next page*)

Table 3
Continued

Heelcheck survey question	Seropositivity	
	%	PR (95% CI)
Slightly or somewhat concerned	9.6%	2.50 (1.28, 4.88)
Moderately or extremely concerned	13.9%	3.61 (1.89, 6.90)
My health and personal information being shared with the University		
Not at all concerned	5.8%	ref (1.00)
Slightly or somewhat concerned	9.4%	1.62 (0.91, 2.88)
Moderately or extremely concerned	7.9%	1.37 (0.62, 3.02)
Having to be in isolation/quarantine if I test positive or report being a close contact to someone who has tested positive		
Not at all concerned	6.3%	ref (1.00)
Slightly or somewhat concerned	6.7%	1.06 (0.55, 2.05)
Moderately or extremely concerned	9.1%	1.44 (0.76, 2.74)
My organization/club/team/fraternity/sorority getting in trouble or being closed as a result of something I report		
Not at all concerned	4.9%	ref (1.00)
Slightly or somewhat concerned	12.4%	2.54 (1.26, 5.11)
Moderately or extremely concerned	18.9%	3.86 (2.01, 7.44)
In the past month, have you:		
Been in a car with people you do not live with, no masks		
Yes	8.2%	1.49 (0.82, 2.70)
No	5.5%	ref (1.00)
Been to an indoor party with 10 or more people, no masks		
Yes	13.0%	2.31 (1.34, 3.98)
No	5.6%	ref (1.00)
Been to a restaurant or bar indoors		
Yes	9.1%	1.95 (1.07, 3.55)
No	4.7%	ref (1.00)
Been to an athletic event such as a football or soccer game		
Yes	11.8%	1.83 (0.99, 3.38)
No	6.4%	ref (1.00)
Scenarios		
You and two roommates decide to go out on a Friday night. You all leave the house and are wearing masks. You go to a friend's house who invited you over for a socially distanced, outdoor party. When you get there everyone is inside, no one is wearing a mask. Do you:		
Go inside with your mask on	9.0%	1.74 (0.76, 3.98)
Go inside with your mask on, but eventually take if off	9.2%	1.78 (0.79, 4.03)
Go inside and take your mask off	19.6%	3.80 (1.58, 9.16)
Talk to the host and see if you could move the party outside	8.1%	1.57 (0.67, 3.66)
Leave because there are too many people and no masks inside	5.2%	ref (1.00)
You're studying late in the common space of your house. One of your roommates comes home with three friends who do not live in your household. They all start hanging out in the room you are in. None of them are wearing masks. Do you:		
Hang out with them with; no mask on	13.3%	1.85 (0.99, 3.45)
Hang out with them, but put a mask on	3.4%	0.47 (0.07, 3.34)
Ask the friends to put on masks	3.7%	0.51 (0.22, 1.22)
Ask the friends to leave	6.0%	0.83 (0.32, 2.15)
Leave the room to go somewhere else	7.2%	ref (1.00)

Weighted prevalence ratio estimates and 95% CIs were calculated using log-binomial regression with a robust error variance; Reference category is subgroup with least theoretical risk of SARS-CoV-2 acquisition; % = prevalence; PR = prevalence ratio.
[a] Insufficient sample size for estimation (value suppressed); PR not estimated if group had five or fewer individuals and/or zero outcomes.

reported that they would leave (61%), while 13% reported that they would talk to the host and see if the party could be moved outside (Table 2). The remainder predicted that they would go inside masked (9%), go inside masked, but eventually remove the mask (9%), go inside unmasked (4%), or had no response (3%).

In the second scenario, which asked students to imagine what they would do if one of their roommates brought three friends, all unmasked, to hang out in the common space of the house that the student was studying in, the three most common responses were: leave the room to go somewhere else (48%), ask the friends to put on masks (20%), and join them and hang out without a mask (15%). In addition, 9% said they would ask the three friends to leave, 6% would hang out with them, but put on a mask, and 2% indicated no response.

Ninety-nine percent disagreed or strongly disagreed with the statement: "…*COVID-19 is a hoax*". When asked their level of agreement with the following statement "*College only happens one time and I am not going to let COVID-19 stop me from having fun or from doing the social activities that are part of the college experience*", 80% disagreed or strongly disagreed, however 20% either agreed or did not have an opinion. When asked about contact tracing-related concerns, 26% were extremely or moderately concerned about having to be in isolation/quarantine if they or a close contact tested positive, and 19% were extremely or moderately concerned about "*my friends having to be in quarantine if I report them as my contact*".

In the month before questionnaire completion, 62% had been in a car, unmasked, with people outside of their household, 21%

had been to an indoor party, unmasked, with 10+ people, 56% had visited an indoor restaurant or bar, and 14% had attended an athletic event.

Predictors of seroprevalence in the weighted sample of undergraduate students

SARS-COV-2 seroprevalence varied by housing location status, and attitudes and behaviors related to COVID-19 risk and prevention (Figure 1, Tables 3 and A4). Compared to students who were living off-campus in the Chapel Hill/Carrboro area (CH) at the beginning and end of semester (8.6% seroprevalence), students who started in campus housing and left CH had a seroprevalence of 5.7% (prevalence ratio (PR), 95% confidence interval (CI): 0.79, 0.39–1.56), and students who never reported living in CH had a seroprevalence of 1.9% (PR, 95% CI: 0.22, 0.06–0.81) (Figure 1). Whereas students who started the semester on-campus and moved to off-campus CH housing had a seroprevalence of 18.9% (PR, 95% CI:2.21, 1.04–4.72) and students who spent the entire semester living in a Sorority/Fraternity house had seroprevalence 46.8% (PR, 95% CI:5.47, 2.62–11.46). Members of a Sorority/Fraternity had four times the prevalence of SARS-COV-2 antibodies compared to nonmembers (20.3% vs. 5.1% (PR, 95% CI:4.00, 2.32–6.88)), and having a household contact with a COVID-19 diagnosis was associated with higher seroprevalence compared to those without (28.7% vs. 4.5% (PR, 95% CI: 6.43, 3.89–10.61)).

In the scenario of the indoor party with no masking, those who replied that they would go inside and join the party without a mask had the highest seroprevalence, 19.6% – 3.8 times the seroprevalence of those who would leave the party (PR, 95% CI: 3.80, 1.58–9.16). Compared to students who disagreed/strongly disagreed with the statement "College only happens one time and I am not going to let COVID-19 stop me from having fun…", those who agreed/strongly agreed had roughly 2.5 times the prevalence of COVID-19 antibodies (14.0% vs. 5.7%; (PR, 95% CI: 2.45, 1.13–5.32)). Students who were moderately or extremely concerned about "*My friends being angry at me for sharing their names and contact information*" had four times the seroprevalence compared to those who were not at all concerned (18.8% vs. 4.7% (PR, 95% CI: 3.99, 2.11–7.55)). Those who recently went to an indoor party, unmasked, had 13% seroprevalence (vs. 5.6% (PR, 95% CI: 2.31, 1.34–3.98)); those who recently went to an indoor restaurant or bar had 9.1% seroprevalence (vs. 4.7% (PR, 95% CI: 1.95, 1.07–3.55)); and those who had recently been to an athletic event had 11.8% seroprevalence (vs. 6.4% (PR, 95% CI: 1.83, 0.99–3.38)).

Discussion

In this analysis, 7.3% of undergraduates were estimated to be seropositive for SARS-COV-2 at the end of the Fall 2020 semester, eventhough 23% self-reported a possible history of SARS-CoV-2 infection. While prevention measures were supported by the vast majority of students, COVID-19-related risk behaviors and attitudes/beliefs supportive of these behaviors were also prevalent. Importantly, many of these behaviors and attitudes were associated with SARS-COV-2 seroprevalence.

Many institutions, including UNC-CH, returned to some degree of in-person instruction for the Fall 2020 semester [4]. Even with the implementation of an array of COVID-19 mitigation strategies, rapid transmission of SARS-CoV-2 resulted in a shift to solely online instruction for UNC-CH on August 19, 2020 [4,16]. The impact of increased SARS-CoV-2 transmission on college campuses is not restricted to the campus setting itself. Leidner et al. [30] compared county-level SARS-CoV-2 incidence during two periods, one before and one after the Fall 2020 semester started, and found decreased incidence in counties containing no university or a large university with remote-only instruction, but a relative *increase* of 56% in counties containing a large university that initiated in-person instruction. Furthermore, campus closures following a period of in-person learning may inadvertently seed communities far from campus with infected (possibly asymptomatic) students as they relocate post-closure [4,13,31]. In our analysis, we found that one-quarter of UNC-CH students reported living on campus at the beginning of the semester. However, the majority (70%) of these students reported having left CH by the end of the semester. SARS-COV-2 seroprevalence was high (18.9%) among students who started on campus and transitioned to CH off-campus housing while it was lower (6.7%) among students who started on campus and transitioned to living at home or outside of CH and was lowest, just 1.9%, among students who never returned to UNC-CH for the fall semester. Our survey highlights the possible COVID-19 risk related to congregate living settings and suggests that individuals who stayed in the community surrounding campus experienced higher risk than those who left or never returned, likely due to continued socialization and behaviors that put them at risk for COVID-19 acquisition. University policies that detail the approach for a rapid transition to remote instruction, such as testing for COVID-19 before leaving the campus community or recommending that students self-isolate and practice safer behaviors in their new location when relocating, should be in place to minimize the community-level impact of future pandemic-related university closures.

The COVID-19 pandemic disrupted the typical U.S. college experience for millions of young adults [32]. Engagement in campus life is often an experience of unprecedented independence for students, and social connectivity supports their well-being during this time [33,34]. There is clear evidence of an association between social isolation or loneliness and negative mental health outcomes, such as depression and anxiety, among young adults [35–37]. In our study, nearly every respondent (99%) disagreed with the statement that "…*COVID-19 is a hoax*", but only 80% disagreed with the statement: "*College only happens one time and I am not going to let COVID-19 stop me from having fun or from doing the social activities that are part of the college experience*". This finding highlights the importance placed on the college experience—a large part of which includes social events and activities—not just the academic classroom learning. Students in this study reported good adherence to COVID-19 prevention measures including masking, physical distancing, and limiting the size of gatherings. However, many had concerns about participating in contact-tracing programs due to concern around how peers would react. Furthermore, in the scenarios we posed regarding social situations with friends, many reported participating in the situation even if it posed risk of COVID-19 rather than leaving the situation or confronting peers with requests to make the situation safer. Interestingly, very few participants perceived themselves as having a "high chance" of getting COVID-19 in the next year despite 10% of the participants being sero-positive—the discrepancy between actual risk and perceived risk, especially among young adults, has been described in the context of infectious and noninfectious disease

[38,39]. While undergraduate students may strongly support COVID-19 prevention measures, there may be a discrepancy between support of prevention methods and their actual implementation—the desire to experience "normal" social lives and the potential to underestimate risk must be recognized and incorporated into realistic mitigation efforts [40]. As opposed to completely restricting social activities, colleges should create and encourage safe opportunities to socialize and experience "college life" while minimizing COVID-19 transmission.

We identified several activities, attitudes, and settings that were associated with SARS-COV-2 seroprevalence. Greek life membership was associated with four times the seroprevalence of SARS-COV-2 and living in Sorority/Fraternity housing (vs. CH off-campus) was associated with over five times the seroprevalence. Previous studies have highlighted the COVID-19 risk associated with Greek life event participation [14,15]. In fact, Segaloff et al. [15] identified just *planning* to attend a Greek life event as a predictor of SARS-CoV-2 infection. We also observed higher SARS-COV-2 seroprevalence among individuals who reported attending an indoor party, indoor bar or restaurant, or an athletic event. Many college campuses have implemented strict standards regarding masking and physical distancing on campus, however much of the COVID-19 risk is likely encountered in off-campus social settings [13]. Partnering with influential student organizations (e.g., Greek life organizations) and community partners to promote and uphold COVID-19 prevention measures (while allowing for safer socializing) may help reduce the impact of future pandemics or new waves of COVID-19 in university settings [4,14].

Several limitations should be noted. First, we inquired about behavior at a single time point and determined seroprevalence using an antibody test; therefore, we were unable to determine the temporal order of SARS-CoV-2 infection and self-reported exposures/behaviors. Future work should use additional data sources and multivariable methods to estimate causal effects for the associations we identified. Next, due to waning antibody levels, our estimate of seroprevalence may underestimate the true history of SARS-CoV-2 infection in the UNC-CH undergraduate population. Additionally, an unknown number of Heelcheck serology specimens were lost in the mail or destroyed in transit before arriving at UNC-CH, however we think this would be independent of serology result. Finally, our choice of raking variables for the weighting procedure was limited to the variables available from the Registrar's office. Non-response bias may still be affecting our estimates due to differential response rates for variables that predict seropositivity (and other characteristics we studied) and could not be accounted for using the Registrar's data.

In conclusion, those who returned to UNC-CH, lived in congregate housing, had concerns related to prevention strategies/contact-tracing, and attended or condoned attending large social events without masks were more likely to have a history of SARS-CoV-2 infection. Universities must acknowledge students' need to socialize, discuss and alleviate student concerns about participating in public health prevention methods, and support and participate in the creation of safer activities that allow for socializing while minimizing COVID-19 risk.

Funding Sources

This work was supported by the North Carolina Policy Collaboratory through appropriation from the North Carolina General Assembly (NCGA) in support of research on treatment, community testing, and prevention of COVID-19 (as mandated by the NCGA in subdivision (23) of Section 3.3 of Session Law 2020-4).

Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jadohealth.2022.06.015.

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