2020-08-06

Seroprevalence of SARS-CoV-2-Specific IgG Antibodies Among Adults Living in Connecticut Between March 1 and June 1, 2020: Post-Infection Prevalence (PIP) Study

Shiwani Mahajan
Yale University

Et al.

Seroprevalence of SARS-CoV-2-Specific IgG Antibodies Among Adults Living in Connecticut Between March 1 and June 1, 2020: Post-Infection Prevalence (PIP) Study

Shiwani Mahajan, MBBS, MHS;[1,2] Rajesh Srinivasan, PhD;[3] Carrie A. Redlich, MD, MPH;[4] Sara K. Huston, BS;[3] Kelly M. Anastasio, COC;[5] Lisa Cashman, MPH;[6] Dan Witters, MS;[3] Jenny Marlar, PhD;[3] Shu-Xia Li, PhD;[1] Zhenqiu Lin, PhD;[1,2] Domonique Hodge, PhD;[3] Manas Chattopadhyay, PhD;[3] Mark D. Adams, PhD;[7] Charles Lee, PhD;[7] Lokinendi V. Rao, PhD;[6,8] Chris Stewart, BS;[3] Karthik Kuppusamy, PhD, MBA;[6] Albert I. Ko, MD;[9] Harlan M. Krumholz, MD, SM[1,2,10]

[1] Center for Outcomes Research and Evaluation, Yale-New Haven Hospital, New Haven, CT

[2] Section of Cardiovascular Medicine, Department of Internal Medicine, Yale School of Medicine, New Haven, CT

[3] The Gallup Organization, Washington, DC

[4] Yale Occupational and Environmental Medicine Program, Department of Internal Medicine, Yale School of Medicine, New Haven, CT

[5] Yale Center for Clinical Investigation, Yale School of Medicine, New Haven, CT

[6] Quest Diagnostics, Marlborough, MA

[7] The Jackson Laboratory for Genomic Medicine, Farmington, CT

[8] Department of Pathology, University of Massachusetts Medical School, Worcester, MA

[9] Department of Epidemiology of Microbial Diseases, Yale School of Public Health, New Haven, CT

[10] Department of Health Policy and Management, Yale School of Public Health, New Haven, CT

Address for correspondence:

Harlan M. Krumholz MD, SM

1 Church Street, Suite 200, New Haven, CT 06510 USA

Telephone: 203-764-5885; Fax: 203-764-5653

Email: harlan.krumholz@yale.edu; Twitter: @hmkyale

Word count: 3734 (main text)

ABSTRACT

Importance: A seroprevalence study can estimate the percentage of people with SARS-CoV-2 antibodies in the general population. Most existing reports have used a convenience sample, which may bias their estimates.

Objective: To estimate the seroprevalence of antibodies against SARS-CoV-2 based on a random sample of adults living in Connecticut between March 1 and June 1, 2020.

Design: Cross-sectional.

Setting: We sought a representative sample of Connecticut residents who completed a survey between June 4 and June 23, 2020 and underwent serology testing for SARS-CoV-2-specific IgG antibodies between June 10 and July 6, 2020.

Participants: 505 respondents, aged ≥18 years, residing in non-congregate settings who completed both the survey and the serology test.

Main outcomes and measures: We estimated the seroprevalence of SARS-CoV-2-specific IgG antibodies among the overall population and across pre-specified subgroups. We also assessed the prevalence of symptomatic illness, risk factors for virus exposure, and self-reported adherence to risk mitigation behaviors among this population.

Results: Of the 505 respondents (mean age 50 [±17] years; 54% women; 76% non-Hispanic White individuals) included, 32% reported having at least 1 symptom suggestive of COVID-19 since March 1, 2020. Overall, 18 respondents had SARS-CoV-2-specific antibodies, resulting in the state-level weighted seroprevalence of 3.1 (90% CI 1.4–4.8). Individuals who were asymptomatic had significantly lower seroprevalence (0.6% [90% CI 0.0–1.5]) compared with the overall state estimate, while those who reported having had ≥1 and ≥2 symptoms had a seroprevalence of 8.0% (90% CI 3.1–12.9) and 13.0% (90% CI 3.5–22.5), respectively. All 9 of

the respondents who reported previously having a positive coronavirus test were positive for SARS-CoV-2-specific IgG antibodies. Nearly two-third of respondents reported having avoided public places (74%) and small gatherings of family or friends (75%), and 97% reported wearing a mask outside their home, at least part of the time.

Conclusions and relevance: These estimates indicate that most people in Connecticut do not have detectable levels of antibodies against SARS-CoV-2. There is a need for continued adherence to risk mitigation behaviors among Connecticut residents, to prevent resurgence of COVID-19 in this region.

INTRODUCTION

Connecticut was one of the first states in the United States (US) to be severely affected by Coronavirus Disease 2019 (COVID-19), with COVID-19 activity peaking in late April of 2020. Connecticut reported its first confirmed case of COVID-19 on March 8, 2020, and as of June 1, 2020, Connecticut had about 43,000 COVID-19 positive cases and nearly 4,000 COVID-19 deaths.[1] It is not possible from this information to project the percentage of the Connecticut population with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) antibodies. A seroprevalence study can provide an estimate of the percentage of people in Connecticut with antibodies against SARS-CoV-2 and may provide a more accurate estimate of the percent of the population in Connecticut who have evidence of a prior infection from COVID-19. This information is critical not only to guide the current ongoing mitigation efforts but also to inform the public health response.

Since late March 2020, many have used serology testing to estimate the spread of COVID-19 in different regions of the country.[2-8] Most of these studies have taken advantage of blood samples collected for other reasons or used a convenience sample, which limits their ability to estimate rates in the entire community. In Connecticut, as part of an effort across the nation, the Centers for Disease Control and Prevention (CDC) has conducted a seroprevalence surveys using convenience sample of blood specimens collected at commercial laboratories for reasons unrelated to COVID-19.[8] However, these specimens were produced as part of routine or sick visit and may represent a biased sample. Moreover, this effort had no information about the reason for the blood collection nor information about recent symptomatic illness, underlying conditions, relevant mitigation behaviors, and possible COVID-19 exposures, which may be important predictors for detection of antibodies against SARS-CoV-2. The CDC has written that

"it is possible that specimens were drawn from patients seeking care for suspected COVID-19 symptoms, potentially biasing results."

Accordingly, with support from the Connecticut Department of Public Health (DPH) and the CDC, we conducted the Post-Infection Prevalence (PIP) Study, a public health surveillance project to determine the seroprevalence of SARS-CoV-2 among adults residing in community-non-congregate settings in Connecticut. This study focused on the period before June by initiating survey field work on June 4, 2020, blood draws start on June 10, and culminating with the last of follow up lab work on July 6, 2020. We sought to understand prior spread in the community, since the epidemiology of COVID-19 in congregate settings such nursing homes, assisted living facilities and correctional facilities is distinct. We concomitantly collected information about the prevalence of symptomatic illness, risk factors for virus exposure, and self-reported adherence to risk mitigation behaviors. Finally, we also sought to compare our seroprevalence estimates with other available estimates on Connecticut residents (from people tested by Quest Diagnostics in Connecticut during this time period). Future studies will focus on estimates within minority populations.

METHODS

Study cohort and sample selection

For the state-level estimate of seroprevalence, i.e. the first phase of the PIP study, we calculated that we would require a sample size of 609, assuming a state level seroprevalence of 10%, to obtain prevalence estimates at 90% confidence level with a precision of 2% (details in **eMethods 1**). Between June 4 and June 23, 2020, we enrolled 727 adults residing in non-congregate settings (i.e. excluding individuals living in long-term care facilities, assisted living

facilities, nursing homes, and prisons or jails), aged 18 years and older, from different counties in Connecticut using a dual-frame Random Digit Dial (RDD) methodology.[9] Briefly, this involves drawing a random sample of landline and cell phone numbers from among all potential landline and cell phone numbers with valid area codes assigned to Connecticut. To ensure that residents of Connecticut who moved from another area in the country and ported their cellphone number were still eligible to participate in this survey, we supplemented the RDD sample with a random sample of listed cellular numbers of residents with an address in the state but a cell phone number with area code that is not assigned to Connecticut.

Details of data source and participant recruitment are described in the Supplemental Appendix (**eMethods 2**). Briefly, a multi-call design was implemented whereby up to 5 attempts were made to each randomly selected telephone number, spread over different days of the week, including the weekend and different times of day to achieve a representative sample of adults. If after 5 attempts, we were unable to make a human contact or encountered a refusal to participate, the number was retired, and new sample replicates were released. We contacted a total of 7272 respondents at the state-level between June 4 and June 23, 2020, and successfully completed 727 interviews (details in **eMethods 2**). Informed consent was obtained from all participants.

The study was deemed not to be research by the Institutional Review Board at Yale University because of the public health surveillance activity exclusion and was approved by the Institutional Review Board at Gallup.

Survey components

Individuals selected were provided study details and informed consent was obtained from all study participants by trained interviewers. Participants were interviewed using a questionnaire

that collected information on demographics, social determinants of health, prior history of influenza-like illness, symptoms experienced by self and others in the household, and other COVID-19-related topics. The average survey time was 15 minutes.

Specimen collection and serology test details

Within 24-48 hours of completing the interview, the respondents were contacted to schedule their blood draw appointment at their nearest Quest Diagnostics Patient Service Center (PSC). Up to 5 attempts were made to each household where the participant agreed to be tested to ensure they followed through with the blood test. Upon confirmation that the participant had completed the test, an incentive payment of $50 was sent as a gift card via email or mail.

Of the total 727 participants enrolled, 29 participants refused to participate when re-contacted for scheduling their blood draw appointment and 505 participants completed blood sample testing at 93 Quest Diagnostics PSCs throughout Connecticut between June 10 and July 6, 2020. Detailed flow chart of the current study sample selection and the distribution of the timing of the blood draws are shown in **eFigure 1 and eFigure 2**, respectively.

Sera was obtained from blood samples that were collected in BD Hemogard serum separator tubes. All samples were processed at the Quest Diagnostics Marlborough Laboratory. Samples were run at room temperature using the primary collection tube. We measured IgG antibodies against SARS-CoV-2 using a commercially available Ortho-Clinical Diagnostics Vitros anti-SARS-CoV-2 IgG test, which detects antibodies against the spike glycoprotein of the virus.[10] Antibody levels were expressed as the ratio of the chemiluminescence signal over the cutoff (S/CO) value. An S/CO value ≥1.00 was reported as positive according to the manufacturer's instructions.[11] The Ortho-Clinical Diagnostics Vitros anti-SARS-CoV-2 IgG test

had a reported sensitivity and specificity of 90% and 100%, respectively, for IgG antibody.[10] We also internally validated the sensitivity of this test in a small subset of SARS-CoV-2 positive patients (n=36) with variable disease severity, using reverse transcription polymerase chain reaction testing as the gold standard.[12]

Additionally, given the concern about the accuracy of serology tests,[13] we re-tested the negative samples from 5 high risk cities of Connecticut (i.e. Bridgeport, Hartford, New Haven, Stamford, and Waterbury) with the Abbott Architect SARS-CoV-2 IgG test that detects antibodies aimed at a different SARS-CoV-2 antigen (nucleocapsid protein).[14]

Finally, summary-level data was provided by Quest Diagnostics for all SARS-CoV-2 serology tests performed at various locations throughout Connecticut between the same time period (i.e. June 10 and July 6, 2020) for comparison.

Statistical analysis

The sample data were weighted to approximate the Connecticut population. Details of the weighting methodology are described in the Supplemental Appendix (**eMethods 3**). Briefly, the base weight (or selection probability weight) assigned to each completed survey was derived as the inverse of the probability of selection of that respondent in the sample. Next, post-stratification weighting adjustments were done to account for survey non-response and to match the weighted sample estimates to known population characteristics for Connecticut. Post-stratification weighting was carried out using raking (or Iterative Proportional Fitting) procedures to adjust for demographic variables such as age (18-39, 40-49, 50-59, 60-69 and ≥70), gender (male, female), race/ethnicity (Hispanic, non-Hispanic White/Other, non-Hispanic Black) and education (high school or less, some college/no 4 year college degree, college

graduate, post-graduate degree). The distribution of the final weights was examined and trimming of weights (5th percentile at the bottom and 97th percentile at the top) was carried out to reduce the effect of extreme weights on sampling variance. The margin of error (MOE) for this study was calculated at the 90% confidence level (CI) taking into consideration the design effect introduced by variability of weights on each survey estimate. Overall study design effect as estimated by the Kish approximation equals 1.78, however, it varies by each survey estimate.

Next, we reported the raw frequencies of positive antibody tests as a proportion of the final sample size. The unweighted seroprevalence was calculated for both the overall state sample and by subgroups of interest. Finally, we estimated the weighted seroprevalence and MOE of these estimates, both overall for the state and for subgroups with sufficient sample size. Subgroups where sample size was <30 were too small to calculate accurate estimates and were thus not reported. We also estimated the MOE at 95% CI for seroprevalence estimates as a secondary outcome.

All statistical analyses were performed using SPSS 24.0 (SPSS, Inc. Chicago, IL) and R version 4.0.2. We considered 2-sided P-values <0.05 as statistically significant.

RESULTS

Population characteristics

The final study sample comprised of 505 respondents who completed both the survey and the serology test. The mean age of our weighted sample was 50 (±17) years and 54% of the weighted sample were women (**Table 1**). Majority (76%) of the participants were non-Hispanic White and 39% participants had a bachelor's degree or higher education. Regional representation across various counties was very close to expected levels based on population counts, with

Hartford (28%), New Haven (25%), and Fairfield (21%) counties accounting for about three-fourths of all respondents. Comparison of the unweighted demographic distribution of individuals who completed the survey but not the blood test with those who completed both the survey and the antibody test has been provided in **eTable 1**. While the 2 groups were not significantly different in regional representation, a significantly greater number of individuals from younger age groups and Hispanic and Black subgroups did not complete blood testing. However, our weighted study sample was closer to the target sample in terms of distribution of subgroups by age, sex, race/ethnicity, education level, and health insurance (**Table 1**).

The large majority (97%) of respondents reported having health insurance at the point of the interview with only 3% being uninsured (**Table1**). Nearly half (48%) of the participants were full-time employees and 11% were unemployed. Nearly 26% of respondents reported having an essential job (i.e., exempt from stay-at-home orders), representing 47% of working respondents. About 71% of respondents lived in single-family houses or townhomes, with another 27% living in apartments. About two-thirds of respondents reported excellent (31%) or very good (34%) overall health and 10% reported fair or poor health. Nearly 12% of respondents reported having been diagnosed with diabetes, 29% with high blood pressure, 14% with asthma, 10% with cancer, 8% with heart disease, and 9% as immune compromised. The large majority (97%) of the respondents reported having lived in Connecticut at least 11 of the prior 12 weeks at the point of the interview.

Prevalence of symptomatic illness and risk mitigation behaviors since March 1, 2020

As shown in **Table 2**, cough, diarrhea, fever, sore throat and new onset loss of taste or smell was reported by 19, 17%, 10%, 11%, and 4% respondents, respectively, at some point

between March and June. About 15% individuals reported having previously had at least 1 coronavirus test at the time of the interview. Of these, 11% tested positive, representing 2% of the entire sample population.

The majority of respondents reported observing risk mitigation practices, at least some of the time, since March 1, 2020. Social isolation had been observed by about three-quarters of survey respondents, with 74% reporting that they have avoided public places such as stores or restaurants and another 75% reporting that they have avoided small gatherings of family and friends. Notably, 97% respondents reported wearing mask outside their home at least part of the time. About one-third (35%) of all respondents reported having worked from home at least part of the time due to the coronavirus pandemic, representing 61% of working respondents. Only 5% Connecticut residents reported having traveled by airplane and 4% reported using public transportation such as a bus or train since March 1, 2020.

We compared the prevalence of symptomatic illness, risk factors and behaviors among individuals who completed the survey but not the blood test with those who completed the survey and the antibody test in **eTable 2**. The prevalence of symptomatic illness was not significantly different between the 2 groups. Overall 19% of individuals who completed the survey but not the blood test reported receiving a coronavirus test and 4% reported testing positive, compared with 15% and 2%, respectively, among individuals who completed both the survey and the antibody test, though the difference was not statistically significant. Those who did not complete the blood test were significantly less likely to work from home (26% vs 39%; $P<0.001$) and more likely to use public transportation (7% vs 3%; $P=0.02$) that those who completed the blood test.

Seroprevalence of SARS-CoV-2 antibodies

Seroprevalence estimates for the overall population and by prevalence of symptomatic illness and risk mitigation behaviors is shown in **Table 3**. Overall, 18 respondents tested positive for anti-SARS-CoV-2 antibodies, yielding a weighted seroprevalence of 3.1% (90% CI 1.4–4.8). Among individuals who reported having symptomatic illness since March 1, 2020, those with fever, cough, sore throat, and diarrhea had a weighted seroprevalence of 22.6% (90% CI 8.2–37.0), 10.8% (90% CI 3.0–18.6), 10.5% (90% CI 0.8–20.2), and 7.1% (90% CI 0.4–13.8), respectively. Among the 19 individuals who reported loss of taste or smell, 10 individuals tested positive for SARS-CoV-2-specific IgG antibodies.

Individuals who were asymptomatic during this period (n=366) had significantly lower weighted seroprevalence 0.6% (90% CI 0.0–1.5) compared with the overall state estimate, while those who reported having had 1 or more of these symptoms (n=139) had a seroprevalence of 8.0% (90% CI 3.1–12.9) and those who reported 2 or more symptoms (n=60) had a seroprevalence of 13.0% (90% CI 3.5–22.5). Of the 9 (2%) respondents reported having a positive coronavirus test, all tested positive for SARS-CoV-2-specific IgG antibodies. Individuals who had any household members with symptomatic illness had a seroprevalence of 13.3% (90% CI 2.5–24.1). Given the sample size limitations, we cannot draw any definitive statistical inference around differences between the subgroup and state estimates, however, we have presented these exploratory results in **eTable 3**. Additionally, seroprevalence estimates at 95% MOE have also been shown in **eTable 3**.

Among the 45 negative samples from 5 high risk cities of Connecticut (i.e. Bridgeport, Hartford, New Haven, Stamford, and Waterbury) that were re-tested with a second serology assay (Abbott Architect), all samples tested negative the second time. Additionally, of the total

15,596 antibody tests conducted by Quest Diagnostics in Connecticut during this time period, 1341 (8.6%) samples tested positive.

DISCUSSION

These results from the first phase of the PIP study provide estimates on the seroprevalence of SARS-CoV-2-specific IgG antibodies as well as the prevalence of symptomatic illness and adherence to risk mitigation behaviors among adults living in Connecticut between March 1 and June 1 of 2020. Our study has several notable findings. First, our results show that despite Connecticut being an early COVID-19 hotspot, the vast majority of people in Connecticut lack detectable antibodies to SARS-CoV-2. Second, individuals who reported having symptomatic illness between March and June of 2020 had higher seroprevalence rates but over 90% of these individuals did not have SARS-CoV-2-specific IgG antibodies. Third, a high percentage of people interviewed reported following risk mitigation strategies, which may be partly responsible for the reduction in the number of new COVID-19 cases being reported in Connecticut.

Our findings are consistent with other information from the testing of blood samples in Connecticut by the CDC and the evaluation of routine antibody tests done by Quest Diagnostics. The CDC conducted a seroprevalence study using commercial laboratory data and reported a seroprevalence of 4.9% (95% CI 3.6-6.5) between April 26 and May 3 and 5.2% (95% CI 3.8–6.6) between May 21 and May 26 among people in Connecticut who had blood drawn for other purposes. However, these estimates were from people who had blood specimens tested for reasons unrelated to COVID-19, such as for a routine or sick visit, and as such would be expected to be biased higher than estimates for the general population. Similarly, data for all

antibody tests conducted by Quest Diagnostics in Connecticut between June 10 and July 6, showed a seropositivity rate of 8.6%. Since these estimates were also among people who had a serology test done at a commercial laboratory, it is likely that these specimens were drawn from individuals who had higher suspicion of disease exposure than the general population, and as such, were expected to have higher seroprevalence estimates than the general population.

Overall, our findings are consistent with other reports of population-level seroprevalence of SARS-CoV-2 in Europe and the US, though the burden of disease in these regions may have varied. A recent report from Spain,[15] one of the European countries most affected by the COVID-19 pandemic, reported a seroprevalence of 4.6% (95% CI 4.3–5.0) at the national level using representative data. Another population-based study from Switzerland ,[16] reported that less than 10% of the population had detectable antibodies against SARS-CoV-2, despite the high prevalence of COVID-19 in the region. Reports from regions within the US have also shown similar numbers. A recent report from Indiana assessed the prevalence of SARS-CoV-2 infection among a random sample of individuals selected from a list of Indiana residents derived from tax returns,[5] and found a seropositivity rate of 1.01% (95% CI, 0.76–1.45), which was lower than our state-level seropositivity rate. Another community seroprevalence survey conducted in two counties in Atlanta[4] estimated seroprevalence of 2.5% (95% CI, 1.4–4.5) among their population, using a two-stage cluster sampling design. These estimates indicate that most people in these areas do not have antibodies against SARS-CoV-2.

There are several explanations for why our estimates are lower than what one might expect given that Connecticut had nearly 43,000 positive cases and nearly 4000 COVID-19 deaths by June 1, 2020, though majority of the reported deaths were among residents of congregate facilities. First, there is growing evidence suggesting a short-lived antibody response,

especially among individuals with mild or asymptomatic illness,[17,18] and it is possible that more people were infected who, however, lost antibodies over time. In a study of people with asymptomatic and symptomatic infections with SARS-CoV-2, 40% and 13%, respectively, sero-reverted during convalescence.[17] However, some recent studies[19] suggest that in this timeframe the decline may be small, and all 9 people who reported receiving a previous coronavirus test in our study tested positive for antibodies. Second, the response rate may have influenced the result. Only 7% of those contacted by phone (cell or landline) completed the survey and blood test. The serology testing rate among those who completed interviews was 70% and it is possible that those who were more likely to have a positive test failed to complete the blood draw in higher proportions. Third, the accuracy of the serology tests has been a concern[13] and the available serology tests may not fully detect antibodies amongst all of the people who were infected. However, all negative serology samples from the highest risk regions of Connecticut that we re-tested with Abbott Architect serology assay tested negative a second time. Finally, the other estimates from Connecticut do not reflect a random cross-section of the population but rather individuals who had a prior reason for getting their blood tested, which may be why their estimates were slightly higher.

Nevertheless, our findings among the studies are concordant in indicating that the vast majority of the population in Connecticut does not have detectable levels of antibodies against SARS-CoV-2. At present, we do not know whether anti-SARS-CoV-2 antibodies confer immunity. If such antibodies, as detected by ELISA, are a marker of immunity, more than 95% of the people in Connecticut would be susceptible to the virus. It is true that there may be other ways, beyond antibodies, that people's immune system might protect them. Some studies[20,21] have suggested a possible role of T-cell immunity and more recent vaccine trials have also

demonstrated both humoral and cellular response to SARS-CoV-2.[22] However, these forms of immunity to SARS-CoV-2 are not yet well enough understood, and at this point, we should assume that we are far from herd immunity in Connecticut. As such, there is continued need for strong public health efforts encouraging Connecticut residents to adhere to risk mitigation behaviors so as to prevent a second wave of spread in the region.

An additional limitation of our study is that though our study was powered to determine an overall state-level seroprevalence estimate, we are unable to provide accurate estimates for most demographic subgroups at this time due to inadequate sample size. However, enrollment of minority populations is ongoing, and we should be able to provide a more detailed seroprevalence estimate for Black and Hispanic subpopulations in the future. Nevertheless, this study provides new population-based information to date about seroprevalence and indicates that the vast majority of the Connecticut population remains naïve to the virus and susceptible to infection.

Conclusion

Our findings suggest that even in one of the early areas of SARS-CoV-2 outbreak in the US, most of the population does not have detectable antibodies against SARS-CoV-2, and as such, remains vulnerable to infection. At present, we do not know whether antibodies against SARS-CoV-2 confer immunity. If such antibodies, as detected by ELISA, are a marker of immunity, more than 95% of the people in Connecticut would be susceptible to the virus. People in these areas need to continue to be vigilant about practices that can slow the spread in order to prevent resurgence of the virus in these regions.

REFERENCES

1. CT Department of Public Health. COVID-19 Data Resources. https://data.ct.gov/stories/s/COVID-19-data/wa3g-tfvc/. Accessed August 03, 2020.
2. Havers FP, Reed C, Lim T, et al. Seroprevalence of Antibodies to SARS-CoV-2 in 10 Sites in the United States, March 23-May 12, 2020. *JAMA Intern Med.* 2020.
3. Sood N, Simon P, Ebner P, et al. Seroprevalence of SARS-CoV-2–Specific Antibodies Among Adults in Los Angeles County, California, on April 10-11, 2020. *JAMA.* 2020.
4. Biggs HM, Harris JB, Breakwell L, et al. Estimated Community Seroprevalence of SARS-CoV-2 Antibodies — Two Georgia Counties, April 28–May 3, 2020. *MMWR Morb Mortal Wkly Rep.* ePub: 21 July 2020.
5. Menachemi N, Yiannoutsos CT, Dixon BE, et al. Population Point Prevalence of SARS-CoV-2 Infection Based on a Statewide Random Sample — Indiana, April 25–29, 2020. *MMWR Morb Mortal Wkly Rep.* ePub: 21 July 2020.
6. Rosenberg ES, Tesoriero JM, Rosenthal EM, et al. Cumulative Incidence and Diagnosis of SARS-CoV-2 Infection in New York. *Ann Epidemiol.* 2020.
7. Bryan A, Pepper G, Wener MH, et al. Performance Characteristics of the Abbott Architect SARS-CoV-2 IgG Assay and Seroprevalence in Boise, Idaho. *J Clin Microbiol.* 2020.
8. CDC. Commercial Laboratory Seroprevalence Survey Data. Coronavirus Disease 2019 (COVID-19): Serology Suveillance. https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/commercial-lab-surveys.html. Accessed August 03, 2020.
9. Cummings KM. Random Digit Dialing: A Sampling Technique for Telephone Surveys. *Public Opinion Quarterly.* 1979;43(2):233-244.

10. EUA Authorized Serology Test Performance. U.S. Food & Drug Administration. https://www.fda.gov/medical-devices/emergency-situations-medical-devices/eua-authorized-serology-test-performance. Accessed August 03, 2020.

11. Ortho-Clinical Diagnostics VITROS Anti-SARS-CoV-2 IgG test. Instructions To Use. U.S. Food and Drug Administration. EUA Authorized Serology Test Performance. https://www.fda.gov/media/136967/download. Accessed August 03, 2020.

12. Mahajan S, Redlich CA, Wisnewski AV, et al. Performance of Abbott Architect, Ortho Vitros, and Euroimmun Assays in Detecting Prior SARS-CoV-2 Infection. *medRxiv.* 2020:2020.2007.2029.20164343.

13. Deeks JJ, Dinnes J, Takwoingi Y, et al. Antibody Tests for Identification of Current and Past Infection with SARS-CoV-2. *Cochrane Database of Systematic Reviews.* 2020(6).

14. Abbott Architect SARS-CoV-2 IgG. Instructions To Use. U.S. Food and Drug Administration. EUA Authorized Serology Test Performance. https://www.fda.gov/media/137383/download. Accessed August 03, 2020.

15. Pollán M, Pérez-Gómez B, Pastor-Barriuso R, et al. Prevalence of SARS-CoV-2 in Spain (ENE-COVID): A Nationwide, Population-Based Seroepidemiological Study. *The Lancet.*

16. Stringhini S, Wisniak A, Piumatti G, et al. Seroprevalence of Anti-SARS-CoV-2 IgG Antibodies in Geneva, Switzerland (SEROCoV-POP): A Population-Based Study. *The Lancet.*

17. Long Q-X, Tang X-J, Shi Q-L, et al. Clinical and Immunological Assessment of Asymptomatic SARS-CoV-2 Infections. *Nat Med.* 2020.

18. Ibarrondo FJ, Fulcher JA, Goodman-Meza D, et al. Rapid Decay of Anti–SARS-CoV-2 Antibodies in Persons with Mild Covid-19. *NEJM.* 2020.

19. Wajnberg A, Amanat F, Firpo A, et al. SARS-CoV-2 Infection Induces Robust, Neutralizing Antibody Responses That are Stable for At Least Three Months. *medRxiv.* 2020:2020.2007.2014.20151126.

20. Le Bert N, Tan AT, Kunasegaran K, et al. SARS-CoV-2-Specific T Cell Immunity in Cases of COVID-19 and SARS, and Uninfected Controls. *Nature.* 2020.

21. Grifoni A, Weiskopf D, Ramirez SI, et al. Targets of T Cell Responses to SARS-CoV-2 Coronavirus in Humans with COVID-19 Disease and Unexposed Individuals. *Cell.* 2020;181(7):1489-1501.e1415.

22. Folegatti PM, Ewer KJ, Aley PK, et al. Safety and Immunogenicity of the ChAdOx1 nCoV-19 Vaccine Against SARS-CoV-2: A Preliminary Report of a Phase 1/2, Single-blind, Randomised Controlled Trial. *The Lancet.*

ACKNOWLEDGEMENTS

We are thankful to Matt Cartter, Josh Geballe, and Deidre Gifford from the Connecticut Department of Public Health for their support and assistance with the funding for this project. We are also thankful to Michael F. Murray, Saad B. Omer, Alan Gerber, Adam Wisnewski, Richard Torres, Nathan Grubaugh, Wade Schulz, Tesheia Johnson, Cesar Caraballo-Cordovez, Yuan Lu, Dorothy S. Massey, Erica S. Spatz, and Karthik Murugiah from Yale University for their help with this project. Finally, we are in debt to those who participated in the surveys and completed the serology test, and the many people at our organizations who spent countless hours ensuring the success of the project and contributing to the public's health.

FUNDING

This project was supported by the Centers for Disease Control and Prevention through the CARES Act and the Beatrice Kleinberg Neuwirth Fund.

DISCLOSURES

Dr. Krumholz works under contract with the Centers for Medicare & Medicaid Services to support quality measurement programs; was a recipient of a research grant, through Yale, from Medtronic and the United States Food and Drug Administration to develop methods for post-market surveillance of medical devices; was a recipient of a research grant with Medtronic and is the recipient of a research grant from Johnson & Johnson, through Yale University, to support clinical trial data sharing; was a recipient of a research agreement, through Yale University, from the Shenzhen Center for Health Information for work to advance intelligent disease prevention and health promotion; collaborates with the National Center for Cardiovascular Diseases in

Beijing; receives payment from the Arnold & Porter Law Firm for work related to the Sanofi clopidogrel litigation, from the Ben C. Martin Law Firm for work related to the Cook Celect IVC filter litigation, and from the Siegfried and Jensen Law Firm for work related to Vioxx litigation; chairs a Cardiac Scientific Advisory Board for UnitedHealth; was a participant/participant representative of the IBM Watson Health Life Sciences Board; is a member of the Advisory Board for Element Science, the Advisory Board for Facebook, and the Physician Advisory Board for Aetna; and is a co-founder of HugoHealth, a personal health information platform, and co-founder of Refactor Health, an enterprise healthcare artificial intelligence-augmented data management company. Dr. Lee is an Adjunct Professor at The First Affiliated Hospital of Xi'an Jiaotong University. The other co-authors report no potential competing interests.

Table 1. Sociodemographic and clinical characteristics of adults included in the study.

Characteristics	Unweighted N	Unweighted Proportion, %	Weighted Proportion, %	Target Percentage[1], %
Overall	505	-	505	-
Age group, years				
18-29	36	7.1%	14.1%	19.9%
30-44	76	15.0%	25.0%	22.9%
45-54	93	18.4%	18.1%	17.5%
55-64	128	25.3%	19.8%	18.1%
≥65	170	33.7%	22.9%	21.6%
Sex				
Men	212	42.1%	46.3%	48.1%
Women	292	57.9%	53.7%	51.9%
Don't know/Refused	1	0.2%	0%	N/A
Race/Ethnicity				
Hispanic	38	7.5%	12.9%	14.4%
Non-Hispanic White	426	84.4%	75.9%	69.4%
Non-Hispanic Black	30	5.9%	9.1%	9.8%
Non-Hispanic Asian	9	1.8%	1.5%	4.7%
Non-Hispanic Other	4	0.8%	1.6%	1.7%
Education level				
Less than high school	5	1.0%	3.1%	9.3%
High school or GED	68	13.5%	32.9%	27.4%
Some college	117	23.2%	24.7%	26.5%
Bachelor's degree or more	314	62.2%	39.2%	36.8%
Don't know/Refused	1	0.2%	0.1%	N/A
Income level				
Less than $24,000	34	6.7%	11.1%	N/A
$24,000 to $59,999	92	18.3%	24.5%	N/A
$60,000 to $119,999	159	31.5%	29.6%	N/A
$120,000 or more	176	34.9%	28.3%	N/A
Don't know/Refused	44	8.5%	6.5%	N/A
Health insurance				
Yes	496	98.2%	97.1%	94.0%
No	8	1.6%	2.9%	6.0%
Unknown	1	0.2%	0.0%	N/A
Employment status				
Employed full-time	231	45.7%	48.3%	63.8%
Employed part-time	48	9.5%	8.5%	
Unemployed	41	8.1%	10.9%	3.5%
Retired/Student/Homemaker	160	31.7%	25.0%	N/A
Disabled	0	0%	0%	N/A
Unknown	25	5.0%	7.3%	N/A
Essential job (exempt from stay-at-home orders)				

Yes	115	22.8%	25.9%	N/A
No	156	30.9%	29%	N/A
Don't know/Refused/Not employed	234	46.4%	45.2%	N/A
Region/County				
Fairfield	113	22.4%	20.9%	25.8%
Hartford	137	27.1%	28.4%	24.9%
Litchfield	39	7.7%	7.3%	5.2%
Middlesex	29	5.7%	5.9%	4.7%
New Haven	119	23.6%	24.5%	24.1%
New London	37	7.3%	6.9%	7.6%
Tolland	19	3.8%	3.7%	4.4%
Windham	11	2.2%	1.7%	3.3%
Unknown	1	0.2%	0.6%	N/A
Type of home				
Mobile home	2	0.4%	1.0%	N/A
Single family house or townhouse	400	79.2%	70.6%	N/A
Apartment or condo	97	19.2%	27.2%	N/A
Group facility	1	0.2%	0.2%	N/A
Don't know/Refused	5	1.0%	1.0%	N/A
Self-reported health status				
Excellent	160	31.7%	31.2%	N/A
Very good	204	40.4%	33.9%	N/A
Good	110	21.8%	25.3%	N/A
Fair	26	5.1%	8.0%	N/A
Poor	4	0.8%	1.6%	N/A
Unknown	1	0.2%	0.0%	N/A
Chronic conditions				
Diabetes	52	10.3%	12.3%	N/A
Asthma, COPD or another lung disease	52	10.3%	14.1%	N/A
Heart disease	35	6.9%	7.8%	N/A
Cancer	64	12.7%	10.1%	N/A
High blood pressure	149	29.5%	28.6%	N/A
Immune compromised	39	7.7%	8.8%	N/A
Lived in Connecticut in past 12 weeks				
<6 weeks	8	1.6%	0.9%	N/A
6-10 weeks	12	2.4%	2.0%	N/A
11-12 weeks	483	95.6%	96.6%	N/A
Don't know/Refused	2	0.4%	0.5%	N/A

1 Source for age, sex, race, ethnicity, education, employment, county targets: American Community Survey 2018. Source for health insurance: Reference information for health insurance coverage is obtained from the Current Population Survey estimates, 2018. Target percentage is based on expected proportions for a perfectly random sample, based on credible external sources.

Abbreviations: COPD, Chronic Obstructive Pulmonary Disease; GED, General Educational Development test; N/A, Not Available.

Table 2. Prevalence of symptomatic illness, risk factors for possible exposure, and adherence to social-distancing behaviors since March 1, 2020.

Characteristics	Unweighted N	Unweighted Proportion, %	Weighted Proportion, % (MOE)
Symptoms			
Fever	41	8.1%	10.4% (±3.0%)
Cough	73	14.5%	18.5% (±3.8%)
Sore throat	48	9.5%	11.3% (±3.1%)
New loss of taste or smell	19	3.8%	4.0% (±1.9%)
Diarrhea	62	12.3%	16.9% (±3.7%)
Risk Factors/Behaviors			
Received coronavirus test	78	15.4%	15.4% (±3.5%)
Tested positive for coronavirus	9	1.8%	1.7% (±3.1%)
Anyone in household (other than respondent) had symptoms of coronavirus	42	8.3%	9.0% (±2.8%)
Anyone in household (other than respondent) tested positive for coronavirus	9	1.8%	2.0% (±1.4%)
Avoided going to public places, such as stores or restaurants	376	74.5%	73.4% (±4.3%)
Avoided small gatherings of people, with family or friends	377	74.7%	74.8% (±4.2%)
Worked from home (among all respondents, regardless of employment status)	198	39.2%	34.5% (±4.8%)
Worn a mask on your face when outside your home	496	98.2%	97.0% (±1.6%)
Traveled by airplane	33	6.5%	5.4% (±2.2%)
Traveled using public transportation, such as bus or train	17	3.4%	4.3% (±2.0%)
Abbreviations: MOE, Margin of Error at the 90% confidence level			

Table 3. Unweighted and weighted seroprevalence of SARS-CoV-2-specific IgG antibodies among adults in Connecticut, overall and by symptoms and risk factors and behaviors.

Characteristics	Sample Size, N	Unweighted Seroprevalence, N (%)	Weighted Seroprevalence, % (MOE)
Overall	505	18 (3.6%)	3.1% (±1.7%)
Symptoms			
Fever	41	12 (29.3%)	22.6% (±14.4%)
Cough	73	10 (13.7%)	10.8% (±7.8%)
Sore throat	48	5 (10.4%)	10.5% (±9.7%)
New loss of taste or smell†	19	*	*
Diarrhea	62	4 (6.5%)	7.1% (±6.7%)
Symptoms aggregate			
Asymptomatic	366	4 (1.1%)	0.6% (±0.9%)
1 or more symptoms	139	14 (10.1%)	8.0% (±4.9%)
2 or more symptoms	60	11 (18.3%)	13.0% (±9.5%)
Risk Factors/Behaviors			
Received coronavirus test	78	10 (12.8%)	13.0% (±8.6%)
Tested positive for coronavirus †	9	*	*
Anyone in household (other than respondent) had symptoms of coronavirus	42	8 (19.0%)	13.3% (±10.8%)
Anyone in household (other than respondent) tested positive for coronavirus	9	*	*
Avoided going to public places, such as stores or restaurants	376	13 (3.5%)	3.0% (±1.9%)
Avoided small gatherings of people, with family or friends	377	13 (3.4%)	3.2% (±2.0%)
Worked from home (among all respondents, regardless of employment status)	198	11 (5.6%)	4.0% (±2.9%)
Worn a mask on your face when outside your home	496	18 (3.6%)	3.3% (±1.8%)
Traveled by airplane	33	0 (0.0%)	0.0%
Traveled using public transportation, such as bus or train	17	*	*

* Sample size is <30 and too small to report.
† Though the sample size was too small to report seroprevalence estimates, all 9 of these individuals tested positive for SARS-CoV-2-specific IgG antibodies. Among the 19 individuals who reported loss of taste or smell, 10 individuals tested positive for SARS-CoV-2-specific IgG antibodies.
Abbreviations: MOE, Margin of Error at the 90% confidence level