

# Cumulative Incidence of SARS-CoV-2 Infections Among Adults in Georgia, United States, August to December 2020

Allison T. Chamberlain,<sup>1</sup> Kathleen E. Toomey,<sup>2</sup> Heather Bradley,<sup>3</sup> Eric W. Hall,<sup>1,a</sup> Mansour Fahimi,<sup>4</sup> Benjamin A. Lopman,<sup>1</sup> Nicole Luisi,<sup>1</sup> Travis Sanchez,<sup>1</sup> Cherie Drenzek,<sup>2</sup> Kayoko Shioda,<sup>5</sup> Aaron J. Siegler,<sup>1,○</sup> and Patrick Sean Sullivan<sup>1</sup>

<sup>1</sup>Department of Epidemiology, Rollins School of Public Health, Emory University, Atlanta, Georgia, USA, <sup>2</sup>Georgia Department of Public Health, Atlanta, Georgia, USA, <sup>3</sup>Department of Population Health Sciences, Georgia State University School of Public Health, Atlanta, Georgia, USA, <sup>4</sup>Marketing Systems Group, Philadelphia, Pennsylvania, USA, and <sup>5</sup>Gangarosa Department of Environmental Health, Rollins School of Public Health, Emory University, Atlanta, Georgia, USA

**Background.** Reported coronavirus disease 2019 (COVID-19) cases underestimate true severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infections. Data on all infections, including asymptomatic infections, are needed. To minimize biases in estimates from reported cases and seroprevalence surveys, we conducted a household-based probability survey and estimated cumulative incidence of SARS-CoV-2 infections adjusted for antibody waning.

**Methods.** From August to December 2020, we mailed specimen collection kits (nasal swabs and blood spots) to a random sample of Georgia addresses. One household adult completed a survey and returned specimens for virus and antibody testing. We estimated cumulative incidence of SARS-CoV-2 infections adjusted for waning antibodies, reported fraction, and infection fatality ratio (IFR). Differences in seropositivity among demographic, geographic, and clinical subgroups were explored with weighted prevalence ratios (PR).

**Results.** Among 1370 participants, adjusted cumulative incidence of SARS-CoV-2 was 16.1% (95% credible interval [CrI], 13.5%–19.2%) as of 16 November 2020. The reported fraction was 26.6% and IFR was 0.78%. Non-Hispanic black (PR, 2.03; 95% confidence interval [CI], 1.0–4.1) and Hispanic adults (PR, 1.98; 95% CI, .74–5.31) were more likely than non-Hispanic white adults to be seropositive.

**Conclusions.** As of mid-November 2020, 1 in 6 adults in Georgia had been infected with SARS-CoV-2. The COVID-19 epidemic in Georgia is likely substantially underestimated by reported cases.

**Keywords.** COVID-19; SARS-CoV-2; seroprevalence; cumulative incidence; Georgia.

Like many states in the United States, Georgia has experienced substantial morbidity and mortality due to coronavirus disease 2019 (COVID-19). Comprehensive, unbiased estimates of the extent of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infections in Georgia are challenging because not all people who are infected have symptoms, and not all people who are symptomatic get tested. Although Georgia's robust testing efforts have diagnosed over 1 million cases [1], no scientifically rigorous estimate of how many Georgians have been infected with SARS-CoV-2 exists. Seroprevalence studies conducted from

remnant samples in clinical settings (eg, dialysis centers and other settings in which specimens are collected for routine screening or clinical management) can detect people who have been infected, but such studies can have biased data if they are not representative of the general population and because antibodies can become undetectable over time (antibody waning) [2].

For Georgia, ascertaining the total number of people who have been infected has implications for understanding the impact of COVID-19 to date and for reaching herd immunity. Having these data also can support and inform vaccination strategies. We describe findings from the COVIDVu Georgia study, a state-specific seroprevalence survey conducted among a probability-based sample of Georgia households from August to December 2020, to develop a representative estimate of the cumulative incidence of SARS-CoV-2 infection among Georgia's adult population after adjusting for antibody waning.

## METHODS

### Sampling

Our sampling methods have been previously described as part of the national COVIDVu study [3]. We used a national

Received 7 May 2021; editorial decision 7 October 2021; accepted 15 October 2021; published online 18 October 2021.

<sup>a</sup>Present affiliation: School of Public Health, Oregon Health & Science University, Portland, OR.  
Correspondence: Allison T. Chamberlain, PhD, 1518 Clifton Road NE, Room CNR 3047, Rollins School of Public Health, Emory University, Atlanta, GA 30322 (allison.chamberlain@emory.edu).

The Journal of Infectious Diseases® 2022;225:396–403

© The Author(s) 2021. Published by Oxford University Press for the Infectious Diseases Society of America. This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs licence (<https://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits non-commercial reproduction and distribution of the work, in any medium, provided the original work is not altered or transformed in any way, and that the work is properly cited. For commercial re-use, please contact journals.permissions@oup.com <https://doi.org/10.1093/infdis/jiab522>

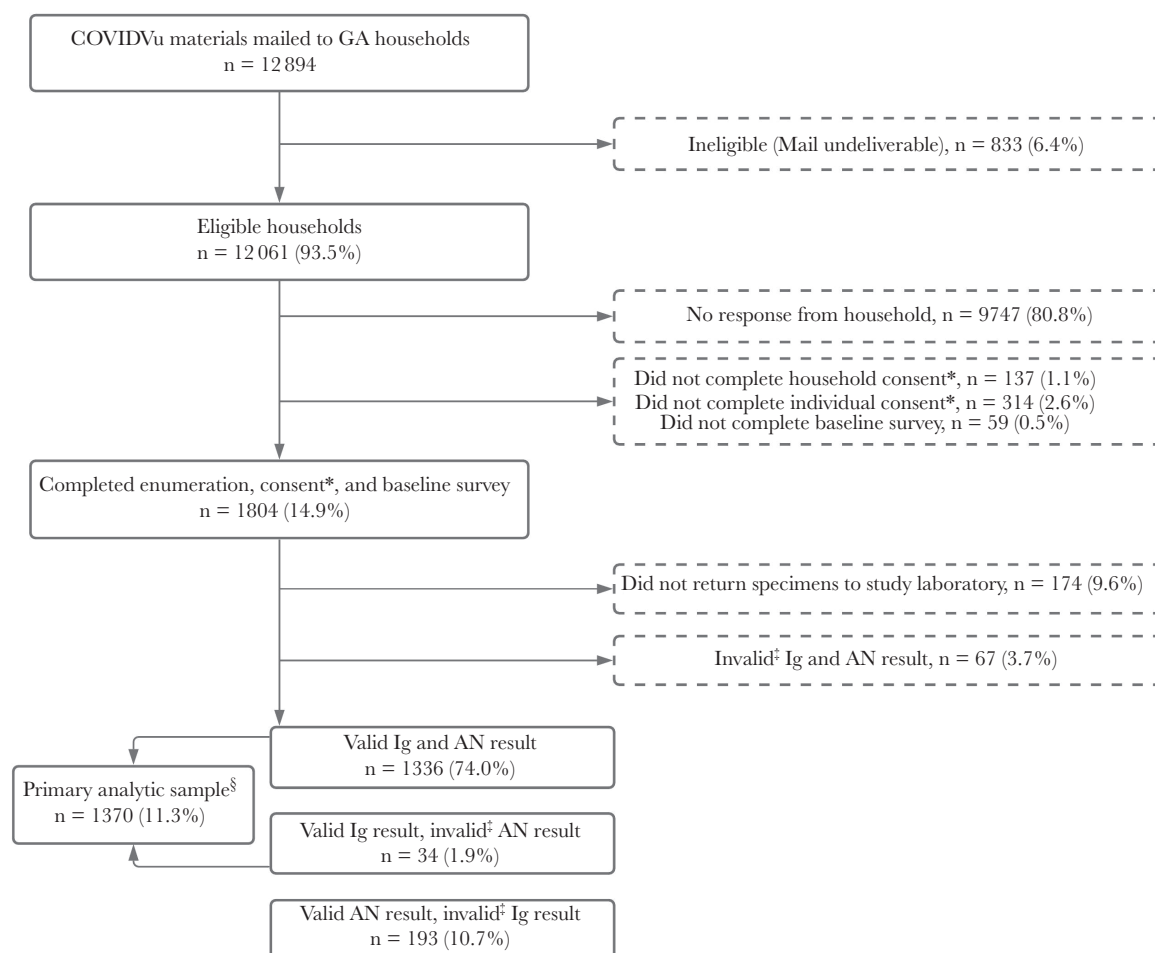
address-based household sample derived from the United States Postal Service Computerized Delivery Sequence File, which contains about 130 million residential addresses and covers all residential delivery points in the United States. This sampling frame has been used in numerous health research studies [4–6]. To achieve a total sample of 1400 responding households from Georgia, 12 894 addresses were shipped COVIDVU study materials (Figure 1). If interested in participating, respondents were directed to a website through which a household member could take a survey to enumerate household membership. A similar survey was available via phone if households preferred to relay study participation information over the phone [3].

Analogous to our national study, we oversampled households in census tracts with >50% black residents and households with surnames likely to represent Hispanic ethnicity to overcome differentially low early response rates by black and Hispanic

persons [4]. We oversampled Fulton and Dekalb counties to facilitate estimation of seroprevalence in the City of Atlanta.

### Survey and Laboratory Procedures

One adult ≥18 years in each household listed household members by gender and age, and an adult household member was then randomly selected for participation by the electronic data system. Following an online consent procedure, participants completed a behavioral survey with domains including demographics, comorbidities, and symptoms; the survey instrument has been previously published [3]. Participants self-collected an anterior nares (AN) swab and a dried blood spot (DBS) card, a method we previously validated based on clinician observation of specimen collection and laboratorian assessment of specimen quality [7, 8]. Specimens were returned to a central laboratory with a prepaid mailer [8]. Polymerase chain reaction (PCR) testing of AN swabs used the Thermo EUA version 2 kit (Thermo



\*Consent was required at the household level for household enumeration, and then at the individual level for the randomly selected member of an enumerated household.

‡Test results considered invalid for the following reasons: Sample not sufficient to process, processing incomplete by study closeout, sample collection date outside of range 9 August 2020–8 December 2020.

§Wave 1 pilot participants were excluded from the Consort, however the analytic sample includes n = 1 wave 1 participants that completed the study within the eligible timeframe.

**Figure 1.** Consort diagram for a national household probability sample of US households to estimate the cumulative incidence of SARS-CoV-2 infection in Georgia, 2020. Abbreviations: AN, anterior nares; COVIDVU, coronavirus disease study; Ig, immunoglobulin; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

Fisher Scientific). Antibody testing of DBS specimens used the BioRad Platelia Total Antibody test that targets the nucleocapsid protein (ie, IgA, IgM, IgG; BioRad). Testing protocols were validated under Clinical Laboratory Improvement Amendments/College of American Pathologists (CLIA/CAP) protocols for the development of laboratory-developed tests. Further detail has been previously described, including approaches taken to quantify the direction and magnitude of potential biases associated with antibody waning [3]. In short, our model estimates cumulative incidence by taking into account the fact that some people will have been infected but lost detectable antibodies because the infection was long ago and some people very recently infected might not have developed detectable antibodies yet.

Participants in the oversample were provided with a \$100 electronic gift card incentive and all other participants were provided with a \$40 electronic gift card incentive. The COVIDVU study was approved by the Emory University Institutional Review Board (STUDY00000695).

### Sample Weights

We developed 3 sets of sample weights to allow for estimation of key parameters representing noninstitutionalized and housed adults in 3 areas: Georgia, Fulton/Dekalb counties, and all other counties in Georgia. Each set of weights was developed using the same method as previously described. In brief, hierarchical hot deck imputation [9] was performed to ensure no participants were missing data for key variables needed for weighting, such as gender, education, race, ethnicity, and marital status, that each had less than 3% missingness. Design weights, adjusted with classification and regression tree (CART) analysis for differential nonresponse, were developed to facilitate population inference. A raking procedure aligned weighted distributions to the observed distributions from the census along the lines including age, race-ethnicity, education, and income [10]. To address outlier weights, those at the 99th percentile of each side of the distribution were trimmed. Additional detail on the weighting process can be found in our protocol paper [3].

We estimated weighted seroprevalence and 95% confidence limits of total Ig for the entire sample and by demographic factors and reported preexisting comorbidities, month of sampling, and symptoms. To identify significant differences in seroprevalence among groups, we estimated prevalence ratios (PRs) and corresponding 95% Wilson modified confidence intervals (CIs) using weighted logistic regression. All analyses were conducted in SAS version 9.4 and SUDAAN.

### Georgia SARS-CoV-2 Cumulative Incidence, Infection Fatality Ratio, and Reported Fraction

Given the considerable evidence from population-based surveys that SARS-CoV-2 antibodies wane over time to levels below detection by numerous laboratory tests [11–13], our analysis

includes a Bayesian model that accounts for waning [14]. By accounting for (1) the time between infection and seroconversion to detectable antibodies (2), the time between seroconversion and seroreversion to undetectable antibody test results, and (3) the time from symptom onset to death, the model estimates infection fatality ratio (IFR) and cumulative incidence of SARS-CoV-2 based on the Georgia weighted seroprevalence estimate from this study as well as the reported daily counts of COVID-19-associated deaths. The model applies cumulative density functions for the time from seroconversion to seroreversion, estimated by a previous study [14] to adjust for antibody waning. Cumulative incidence is calculated from the total number of modeled infections since the beginning of the epidemic until the median specimen collection date of our sample (16 November 2020). This cumulative incidence also serves as the denominator for the IFR. The ratio of the cases reported to cumulative incidence cases (the reported fraction) was developed from confirmed PCR-positive cases in Georgia as of 16 November 2020 using data for adults aged  $\geq 18$  years from Georgia Department of Public Health's public use dataset [15].

## RESULTS

### Study Sample

A total of 12 894 household addresses in Georgia were selected and mailed study materials from July to October 2020 (Figure 1). Of these, 6.4% ( $n = 833$ ) were unable to receive mail and excluded from the sample. Behavioral surveys were completed by 14.9% ( $n = 1804$ ) households. A total of 11.3% ( $n = 1370$ ) of sampled households completed a behavioral survey and returned a valid specimen for antibody testing during the study period of 9 August to 8 December 2020 (Table 1). Of participating households, 43% ( $n = 585$ ) were in the oversampled area of Fulton/Dekalb and 57% ( $n = 785$ ) were from other counties in Georgia.

### Serology and PCR Results Unadjusted for Antibody Waning

The weighted seroprevalence in Georgia was 8.6% (95% CI, 6.3%–11.8%), representing the period prevalence of detectable antibodies for 9 August to 8 December 2020 (Table 2). This suggests that 687 450 out of 8 113 542 adults in Georgia had prevalent anti-SARS-CoV-2 Ig at the time they provided a sample. Unweighted, a total of 7.2% of all specimens tested (99/1370) were reactive for total Ig.

### Associations with Prevalence of Antibody Response

For the state of Georgia, the weighted seroprevalence was 2 times higher for black, non-Hispanic participants than for white, non-Hispanic participants (Table 2). A non-significant effect of similar magnitude was observed for Hispanic participants relative to white, non-Hispanic participants. Those reporting cold or flu-like symptoms after 1 January 2020 were nearly 5 times more likely than those without symptoms to

**Table 1. SARS-CoV-2 Serology and Total Immunoglobulin (IgA, IgM, or IgG) Viral Detection Results for a Probability Sample of 1370 Households and Weighted Results, Compared to the Population Aged ≥18 Years, Georgia, 2020**

Characteristic	Sample		Weighted Sample		GA Population <sup>a</sup>	
	n	Column %	Weighted n <sup>b</sup>	Column %	n	Column %
Overall	1370	100	7 981 539	100	8 113 542	100
Sex						
Male	523	38.2	3 754 083	47.0	3 886 408	47.9
Female	847	61.8	4 227 457	53.0	4 227 134	52.1
Race/ethnicity						
Hispanic	91	6.6	596 425	7.5	673 103	8.3
Non-Hispanic white	747	54.5	4 395 985	55.1	4 485 895	55.3
Non-Hispanic black	483	35.3	2 502 158	31.3	2 558 139	31.5
Non-Hispanic Asian	33	2.4	333 509	4.2	374 149	4.6
Non-Hispanic other	16	1.2	153 463	1.9	22 256	0.3
Age, y						
18–34	313	22.8	2 394 183	30.0	2 508 449	30.9
35–44	235	17.2	1 393 889	17.5	1 380 954	17.0
45–54	229	16.7	1 393 699	17.5	1 399 652	17.3
55–64	272	19.9	1 279 288	16.0	1 307 533	16.1
65+	321	23.4	1 520 481	19.0	1 516 954	18.7

<sup>a</sup>2019 Bridged-Race Estimates (National Vital Statistics System).

<sup>b</sup>Weighted n, sum of the weights of participants.

be seropositive. Among those who were seropositive, 66/99 (weighted percent, 75%; 95% CI, 58%–86%) reported cold or flu symptoms since 1 January 2020. There were no observed differences in seroprevalence by education, income, or urbanicity.

For Fulton and DeKalb counties, point estimates of disparities in seroprevalence by race were higher than in the state as a whole, but not statistically significant (Supplementary Table 1). Antibody prevalence for residents in Fulton and DeKalb counties (7.8%; 95% CI, 5.1%–11.7%) was similar to prevalence in other parts of Georgia (8.8%; 95% CI, 6.1%–12.6%). Experiencing cold or flu-like systems since the beginning of 2020 was the only variable significantly associated with seropositivity among participants not residing in Fulton or DeKalb (PR = 5.2; 95% CI, 2.0–13.8; Supplementary Table 2).

#### SARS-CoV-2 Cumulative Incidence

Adjusting estimates for waning detectable antibody levels, the estimated number of cumulative new SARS-CoV-2 infections among Georgian adults was 1 307 518 (95% credible interval [CrI], 1 081 788–1 541 200) as of 16 November 2020. The cumulative incidence was 16.1% (95% CrI, 13.5%–19.2%; Figure 2). The estimated IFR was 0.78% (95% CrI, 0.66%–0.94%). The Georgia Department of Health reported 348 204 COVID-19 cases as of 16 November 2020, indicating that about one-quarter (26.6%; 95% CrI, 22.6%–32.2%) of SARS-CoV-2 infections among adults was reported.

Among specimens tested with PCR, a total of 16/1529 (1.0%) were positive. Of these 16, 8 (50.0%) were also reactive for total Ig.

#### DISCUSSION

A statewide probability sample of Georgia households conducted between August and December 2020 allowed for robust estimation of the cumulative incidence of SARS-CoV-2 infection among adults, finding that over 16% of Georgia's adult population (about 1 in 6) had been infected with the virus as of November 2020. Seroprevalence was highest among Hispanic and non-Hispanic black persons, and similar for the Atlanta-metro counties of Fulton and DeKalb compared to the rest of the state.

The data obtained through this household-based, representative survey complement data on reported COVID-19 cases and overcome key limitations associated with data available through traditional state-based COVID-19 surveillance activities and seroprevalence surveys. Because our household sampling strategy was not restricted to individuals experiencing COVID-19 symptoms or seeking SARS-CoV-2 testing, biases associated with testing availability, test-seeking behaviors, and the inability to identify asymptomatic individuals were minimal. Additionally, because these data were obtained from a random, representative sample of Georgia residents, the findings can provide reliable inference to all adult Georgia residents. Due to the finding that, as of mid-November 2020, Georgia had only recognized approximately 26% of adults infected with SARS-CoV-2, there is an ongoing need to lower barriers for testing. Our data also validate efforts made thus far in the pandemic response to encourage and invest in frequent, ample testing, despite pushback by lawmakers and certain segments of the general public who may have viewed public health mitigation strategies to have been excessive [16].

**Table 2. Unweighted and Weighted SARS-CoV-2 Antibody Prevalence for a Probability Sample of 1370 Households and Weighted Results and Prevalence Ratios for Persons Aged ≥18 Years, Georgia, 2020**

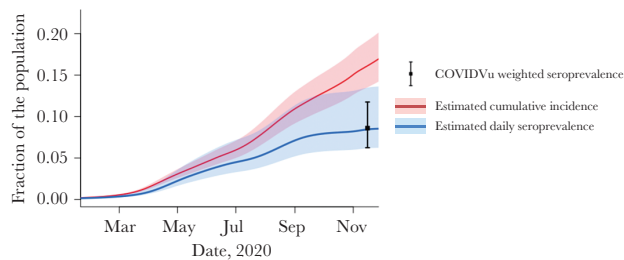
Characteristic	Unweighted			Weighted					
	n	N	%	n	N	%	95% CI <sup>a</sup>	PR	95% CI
Overall	99	1370	7.23	687 450	7 981 539	8.6	6.3–11.8	NA	
Sex									
Male	39	523	7.46	342 239	3 754 083	9.1	5.4–15.0	Reference	
Female	60	847	7.08	345 211	4 227 457	8.2	5.7–11.6	0.90	.47–1.70
Race/ethnicity									
Hispanic	11	91	12.09	76 221	596 425	12.8	5.8–26.0	1.98	.74–5.31
Non-Hispanic white	34	747	4.55	283 580	4 395 985	6.5	3.6–11.2	Reference	
Non-Hispanic black	54	483	11.18	327 649	2 502 158	13.1	8.7–19.3	2.03	1.00–4.11
Non-Hispanic Asian	0	33	0.00	...	333 509	...	...	NA	
Non-Hispanic other	0	16	0.00	...	153 463	...	...	NA	
Age, y									
18–34	29	313	9.27	197 654	2 394 183	8.3	4.8–13.8	0.89	.34–2.35
35–44	20	235	8.51	175 628	1 393 889	12.6	5.8–25.2	1.36	.44–4.15
45–54	15	229	6.55	91 647	1 393 699	6.6	3.5–12.0	0.71	.35–1.99
55–64	17	272	6.25	118 766	1 279 288	9.3	4.1–19.5	Reference	
65+	18	321	5.61	103 757	1 520 481	6.8	3.6–12.7	0.74	.26–2.09
Urbanicity									
Micropolitan/small-town/rural	6	100	6.00	83 765	944 170	8.9	3.2–22.3	Reference	
Metropolitan	93	1270	7.32	603 686	7 037 370	8.6	6.1–11.9	0.97	.32–2.91
Education									
High school/GED or less	21	219	9.59	243 356	3 177 708	7.7	4.4–13.0	0.99	.47–2.09
Some college/associate degree	31	424	7.31	281 978	2 414 045	11.7	6.7–19.7	1.50	.71–3.20
Bachelor degree	28	433	6.47	116 831	1 505 106	7.8	4.7–12.7	Reference	
Graduate degree	19	294	6.46	45 285	884 681	5.1	2.8–9.1	0.66	.30–1.45
Annual income									
\$0 to \$24 999	19	251	7.57	94 554	1 333 565	7.1	3.7–13.1	0.86	.36–2.02
\$25 000 to \$49 999	23	305	7.54	139 713	1 481 431	9.4	4.6–18.3	1.14	.46–2.82
\$50 000 to \$99 999	32	436	7.34	209 258	2 531 646	8.3	4.8–14.0	Reference	
\$100 000 to \$199 999	22	278	7.91	223 184	1 914 525	11.7	6.2–20.8	1.41	.61–3.24
\$200 000+	3	100	3.00	20 742	720 372	2.9	0.9–8.5	0.35	.09–1.28
Health insurance									
No health insurance	8	135	5.93	56 569	949 522	6.0	2.4–14.2	0.57	.20–1.60
Medicare/Medicaid/other government plan	30	388	7.73	138 711	2 058 645	6.7	4.3–10.7	0.64	.34–1.22
Private insurance/parent's plan	57	767	7.43	467 906	4 476 289	10.5	6.8–15.7	Reference	
Don't know	4	80	5.00	24 265	497 084	4.9	1.4–15.5	0.47	.12–1.86
Comorbidities									
Diabetes <sup>b</sup>	19	162	11.73	103 120	871 502	11.8	6.1–21.8	1.44	.68–3.07
Heart condition <sup>b</sup>	4	95	4.21	32 682	790 917	4.1	1.2–13.5	0.45	.11–1.81
Chronic lung disease <sup>b</sup>	8	110	7.27	23 390	460 127	5.1	2.3–11.1	0.58	.23–1.42
Hypertension <sup>b</sup>	31	368	8.42	160 939	1 939 383	8.3	5.1–13.3	0.95	.51–1.78
Symptoms since 1 January 2020									
No symptoms	11	265	4.15	52 306	1 601 249	3.3	1.6–6.7	Reference	
Cold/flu	69	534	12.92	515 699	3 195 392	16.1	11.3–22.5	4.94	2.17–11.26
Any COVID-19 symptom <sup>c</sup>	19	571	3.33	119 445	3 184 898	3.8	1.6–8.6	1.15	.36–3.64
Any COVID-19 symptoms in past 30 d <sup>b,c</sup>	56	818	6.85	451 632	4 838 367	9.3	6.2–13.8	1.24	.65–2.38
Month of sample collection									
Aug/Sep/Oct	7	119	5.88	79 564	854 227	9.3	3.3–23.5	Reference	
Nov/Dec	92	1251	7.35	607 887	7 127 313	8.5	6.1–11.8	0.92	.30–2.78

Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019; GED, general educational development; n, number of participants reactive for total SARS-CoV-2 Ig; N, number of participants; NA, not applicable; PR, prevalence ratio; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

<sup>a</sup>Confidence intervals were calculated using the modified Wilson method.

<sup>b</sup>Reference group is persons without characteristic.

<sup>c</sup>Symptoms include: cough, itchy eyes, shortness of breath, runny/stuffy nose, fever, headache, chills, diarrhea, muscle pain, sore throat, vomiting, nausea, or loss of taste or smell.



**Figure 2.** Estimated cumulative incidence of SARS-CoV-2 infection among adults adjusted for waning antibodies and daily seroprevalence in Georgia, 2020. Abbreviations: COVIDVU, coronavirus disease study; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

Population-based COVID-19 data at the state level allows for a more nuanced understanding of the continuum of infection, diagnosis, and mortality and the relationship of these metrics to programmatic priorities. For example, as of 16 November 2020, Georgia's estimated case fatality ratio (CFR) was 2.1% [17]. Because the CFR is calculated from diagnosed cases (and practically from reported cases), having an IFR (which includes people who were asymptomatic in the denominator) advances our understanding of how common death is among all people infected with COVID-19, regardless of whether those infections were symptomatic. The result is that the CFR overstates how common death is among all those infected in the state. Our more comprehensive IFR that was estimated around the same time was about a third of the CFR. Accordingly, SARS-CoV-2 infections may not be as fatal as had been previously reported; nonetheless, based on the IFR estimated in this study, 1 out of every 130 adult Georgians who are infected with SARS-CoV-2 will die.

Knowing that Georgia went into its winter surge with 16% of the adult population having had a SARS-CoV-2 infection is informative. This estimated proportion was similar to, but slightly higher than, the 12.4% and 11.9% derived from commercial laboratory data [18] and blood donor samples [19], respectively, in November 2020 for Georgians. It provides a reliable lower bound on how many adults have been infected, and despite waning antibodies, the proportion infected will only increase. When coupled with increasing data on duration of immunity, these more robust estimates of cumulative SARS-CoV-2 infection can help decision-makers understand how natural immunity contributes to a Georgia-specific herd immunity metric. To that end, data from our study suggest persons older than 65 years have experienced far less infection than other age groups (and are therefore still susceptible), validating the state's decision to prioritize that demographic for vaccination first. Our study also found the highest seroprevalence among Hispanic and non-Hispanic black persons, suggesting that similar findings from diagnosed cases are not the result of biases in testing. These findings illustrate patterns of

high seroprevalence among these minority populations that not only convey the unequal toll this pandemic, but can be used to strengthen messaging around why vaccination remains important for these demographic groups despite previous infection. The results can also add urgency to investments in increasing education and reducing barriers to access for Hispanic and black Georgians.

Although we lack power to examine differences in seroprevalence by other meaningful geographic units (eg, health district or state region), the results stratified by Fulton/DeKalb versus the rest of the state offer some useful local insights into differences in infection by metropolitan versus nonmetropolitan areas. Fulton and DeKalb comprise all of the City of Atlanta, Georgia's capital and most populated city. The populations of these 2 counties comprise 17% of Georgia's population [20]. Observing that the seroprevalence was similar among residents of those 2 counties compared to the rest of the state was notable, given that national data show consistently lower diagnosis rates for micropolitan and noncore areas through July 2020, with a switch in the pattern starting in August 2020 such that more infections were reported in less-urbanized areas [21]. Thus, our finding of similar seroprevalence levels in urban and rural areas of Georgia might represent a combination of more historical infections in urban areas earlier in the year, and a higher concentration of infections in more rural areas during the period of the specimen collection. Infection rates (and subsequently antibody seroprevalence) are also related to risk mitigation behaviors. Although the use of face coverings has always been strongly encouraged across Georgia, the City of Atlanta issued a mask mandate in July 2020. With increasing ecological evidence suggesting the benefits masking can have on reducing community spread of SARS-CoV-2 [22, 23], Atlanta's mask mandate may have limited the propagation of the virus in Fulton and DeKalb counties, where higher levels of transmission might have been favored by higher population density.

Our study is subject to a number of limitations. While we utilized a representative sampling frame, our response rate was 11.3%, which is low but typical for mailed surveys using address-based sampling frames [24]. The only other 2 household samples reported were conducted through door to door offer of enrollment (versus mailout enrollment packages in our study) and also had relatively low response rates (23.6% to 23.7% [25]). Our results are likely subject to some degree of differential response bias; we addressed this by oversampling specific groups (eg, black and Hispanic households) with lower response rates, and by weighting for nonresponse of households, a procedure with validity facilitated by the nature of an address-based sampling frame. Importantly, we were only able to address differential nonresponse using characteristics of the population that were available to us on the frame (eg, population distributions by race/ethnicity or household income levels). Characteristics that may be associated with COVID-19 risk but not available

at the population level, such as higher general propensity to take risks, were not available for extrapolation to the underlying population from sample data and therefore may contribute to unaddressed selection bias in estimates. Misclassification of antibody status was possible due to waning antibodies [2, 26], but unlike other studies reported to date, we accounted for these biases through our modeling approach [14]. Our model used an estimated average time of seropositivity from a previous study conducted for New York City [14]. This estimate was generated for an enzyme-linked immunosorbent assay (ELISA) kit against the SARS-CoV-2 spike protein that detects the total immunoglobulin response [27], which is different from what we used in this study, but this was the only estimate of the timeline of the population-level waning antibody available at the point we conducted this study. That said, the finding of antibody waning has been robust to multiple different assays measuring antibody concentrations [2, 28, 29]; the observation of waning antibodies seems to be a biological phenomenon rather than a biased detection of antibodies specific to certain assays.

Knowing the true proportion of people who have been previously infected with SARS-CoV-2 is useful both epidemiologically and practically. Past seroprevalence studies from convenience samples and biased samples of residual blood provide important information, but the results are subject to selection biases associated with the sources of specimens. For Georgia, having reliable estimates of the cumulative incidence of SARS-CoV-2 infection among adults allows for more informed decision-making about risk mitigation and vaccination strategies. Data collections will be repeated in March and June of 2021, and results will be examined in an ongoing way as knowledge advances on topics ranging from duration of immunity to implications of antibodies for protection against novel variants.

#### Supplementary Data

Supplementary materials are available at *The Journal of Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

#### Notes

**Acknowledgments.** The authors thank Salesforce for its donation of Salesforce.org licenses and system development for the project, and to acknowledge the contributions of development team members Lee Evans, John Thrasher, Stephen Noe, Anurag Jaiswal, Ryan Williams, David Affentranger, and Todd Siegler. They also thank the Kaiser Family Foundation for their design and thoughtful contributions.

**Disclaimer.** The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

**Financial support.** This work was supported by the National Institute of Allergy and Infectious Diseases (grant number 3R01AI143875-02S1); the Center for AIDS Research at Emory University (grant number P30AI050409); a grant from the California Department of Health; and the Robert W. Woodruff Foundation through a grant to the Emory Covid-19 Response Collaborative.

**Potential conflicts of interest.** A. C. reports a paid consultancy with the Fulton County Board of Health, outside the submitted work. M. F. reports consulting fees paid by Emory University for providing statistical support during the conduct of this study. E. H. reports consulting fees from Merck & Co. outside of the submitted work. P. S. reports consulting fees from Gilead Science and Merck. All other authors report no potential conflicts.

All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

#### References

1. Georgia Department of Public Health. COVID-19 dashboard. <https://dph.georgia.gov/>. Accessed 30 August 2021.
2. Choe PG, Kang CK, Suh HJ, et al. Waning antibody responses in asymptomatic and symptomatic SARS-CoV-2 infection. *Emerg Infect Dis* **2021**; 27:327–9.
3. Siegler AJ, Sullivan PS, Sanchez T, et al. Protocol for a national probability survey using home specimen collection methods to assess prevalence and incidence of SARS-CoV-2 infection and antibody response. *Ann Epidemiol* **2020**; 49:50–60.
4. Lavange LM, Kalsbeek WD, Sorlie PD, et al. Sample design and cohort selection in the Hispanic Community Health Study/Study of Latinos. *Ann Epidemiol* **2010**; 20:642–9.
5. Chido-Amajuoyi OG, Yu RK, Agaku I, Shete S. Exposure to court-ordered tobacco industry antismoking advertisements among US adults. *JAMA Netw Open* **2019**; 2:e196935.
6. Cerel J, Maple M, van de Venne J, Moore M, Flaherty C, Brown M. Exposure to suicide in the community: prevalence and correlates in one U.S. State. *Public Health Rep* **2016**; 131:100–7.
7. Sullivan PS, Sailey C, Guest JL, et al. Detection of SARS-CoV-2 RNA and antibodies in diverse samples: protocol to validate the sufficiency of provider-observed, home-collected blood, saliva, and oropharyngeal samples. *JMIR Public Health Surveill* **2020**; 6:e19054.
8. Guest JL, Sullivan PS, Valentine-Graves M, et al. Suitability and sufficiency of telehealth clinician-observed, participant-collected samples for SARS-CoV-2 testing: the iCollect cohort pilot study. *JMIR Public Health Surveill* **2020**; 6:e19731.

9. Andridge RR, Little RJ. A review of hot deck imputation for survey non-response. *Int Stat Rev* **2010**; 78:40–64.
10. Pierce C. American Community Survey (ACS). In: Lavrakas PJ, ed. *Encyclopedia of survey research methods*. Thousand Oaks, CA: Sage, **2008**.
11. National Academies of Sciences, Engineering, Medicine. *Rapid expert consultations on the COVID-19 pandemic: March 14, 2020–April 8, 2020*. Washington, DC: National Academies Press, **2020**.
12. Long QX, Tang XJ, Shi QL, et al. Clinical and immunological assessment of asymptomatic SARS-CoV-2 infections. *Nat Med* **2020**; 26:1200–4.
13. Self WH, Tenforde MW, Stubblefield WB. Decline in SARS-CoV-2 antibodies after mild infection among frontline health care personnel in a multistate hospital network—12 states, April–August 2020. *MMWR Morb Mortal Wkly Rep* **2020**; 69:1762–6.
14. Shioda K, Lau MS, Kraay AN, et al. Estimating the cumulative incidence of SARS-CoV-2 infection and the infection fatality ratio in light of waning antibodies. *Epidemiology* **2021**; 32:518–24.
15. Georgia Department of Public Health. Georgia COVID-19 status report. [https://ga-covid19.ondemand.sas.com/docs/ga\\_covid\\_data.zip](https://ga-covid19.ondemand.sas.com/docs/ga_covid_data.zip). Accessed 25 March 2021.
16. Burke M. Georgia state lawmaker removed from House chamber after refusing Covid test. *NBC News*, **2021**. <https://www.nbcnews.com/news/us-news/georgia-state-lawmaker-removed-house-chamber-after-refusing-covid-test-n1255700>. Accessed 1 June 2021.
17. The COVID tracking project. Totals for the US. <https://covidtracking.com/data/us-daily>. Accessed 25 March 2021.
18. Centers for Disease Control and Prevention. COVID data tracker: nationwide commercial laboratory seroprevalence survey. <https://covid.cdc.gov/covid-data-tracker/#national-lab>. Accessed 27 September 2021.
19. Centers for Disease Control and Prevention. COVID data tracker: nationwide blood donor seroprevalence survey. <https://covid.cdc.gov/covid-data-tracker/#nationwide-blood-donor-seroprevalence>. Accessed 27 September 2021.
20. United States Census Bureau. QuickFacts: Georgia. <https://www.census.gov/quickfacts/fact/table/GA,dekalbcountygeorgia,fultoncountygeorgia/PST045219>. Accessed 25 March 2021.
21. COVID-19 stats: COVID-19 incidence,\* by urban-rural classification†—United States, January 22–October 31, 2020§. *MMWR Morb Mortal Wkly Rep* **2020**; 69:1753.
22. Lyu W, Wehby GL. Community use of face masks and COVID-19: evidence from a natural experiment of state mandates in the US. *Health Aff (Millwood)* **2020**; 39:1419–25.
23. Guy GP Jr, Lee FC, Sunshine G, et al; CDC COVID-19 Response Team, Mitigation Policy Analysis Unit; CDC Public Health Law Program. Association of state-issued mask mandates and allowing on-premises restaurant dining with county-level COVID-19 case and death growth rates—United States, March 1–December 31, 2020. *MMWR Morb Mortal Wkly Rep* **2021**; 70:350–4.
24. Fahimi M, Link M, Mokdad A, Schwartz DA, Levy P. Tracking chronic disease and risk behavior prevalence as survey participation declines: statistics from the behavioral risk factor surveillance system and other national surveys. *Prev Chronic Dis* **2008**; 5:A80.
25. Biggs HM, Harris JB, Breakwell L, et al; CDC Field Surveyor Team. Estimated community seroprevalence of SARS-CoV-2 antibodies—two Georgia counties, April 28–May 3, 2020. *MMWR Morb Mortal Wkly Rep* **2020**; 69:965–70.
26. Perreault J, Tremblay T, Fournier MJ, et al. Waning of SARS-CoV-2 RBD antibodies in longitudinal convalescent plasma samples within 4 months after symptom onset. *Blood* **2020**; 136:2588–91.
27. 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**; 180:1576–86.
28. Lim T, Delorey M, Bestul N, et al. Changes in SARS CoV-2 seroprevalence over time in ten sites in the United States, March–August, 2020 [published online ahead of print 26 February 2021]. *Clin Infect Dis*. doi: [10.1093/cid/ciab185](https://doi.org/10.1093/cid/ciab185).
29. Lumley SF, Wei J, O'Donnell D, et al; Oxford University Hospitals Staff Testing Group. The duration, dynamics and determinants of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) antibody responses in individual healthcare workers. *Clin Infect Dis* **2021**; 73:e699–e709.