

**Seroprevalence of SARS-CoV-2 following the largest initial epidemic wave in the United States:**

**Findings from New York City, May 13-July 21, 2020**

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Summary: A large serosurvey following the first wave of the COVID-19 epidemic in New York City found that just under one-quarter of adults were infected. Observed disparities in infection risk highlight needs for ongoing, effective interventions in at-risk groups.

## Abstract

**Background:** New York City (NYC) was the U.S. epicenter of the Spring 2020 COVID-19 pandemic. We present seroprevalence of SARS-CoV-2 infection and correlates of seropositivity immediately after the first wave.

**Methods:** From a serosurvey of adult NYC residents (May 13-July 21, 2020), we calculated the prevalence of SARS-CoV-2 antibodies stratified by participant demographics, symptom history, health status, and employment industry. We used multivariable regression models to assess associations between participant characteristics and seropositivity.

**Results:** Seroprevalence among 45,367 participants was 23.6% (95% CI, 23.2%-24.0%). High seroprevalence (>30%) was observed among Black and Hispanic individuals, people from high poverty neighborhoods, and people in health care or essential worker industry sectors. COVID-19 symptom history was associated with seropositivity (adjusted relative risk=2.76; 95% CI, 2.65-2.88). Other risk factors included sex, age, race/ethnicity, residential area, employment sector, working outside the home, contact with a COVID-19 case, obesity, and increasing numbers of household members.

**Conclusions:** Based on a large serosurvey in a single U.S. jurisdiction, we estimate that just under one-quarter of NYC adults were infected in the first few months of the COVID-19 epidemic. Given disparities in infection risk, effective interventions for at-risk groups are needed during ongoing transmission.

Key words: SARS-CoV-2, seroprevalence, seroepidemiology

## Background

New York City (NYC) was the earliest U.S. epicenter of the coronavirus disease 2019 (COVID-19) pandemic. The first known COVID-19 case in a NYC resident was reported on March 1, 2020. NYC schools closed on March 16, and all non-essential businesses statewide closed on March 22 when Governor Cuomo announced the "New York State on PAUSE" executive order. However, daily case counts rapidly rose in NYC, reaching a peak of 6,365 reported cases (76 per 100,000) on April 6, and returning to fewer than 500 cases (<6 per 100,000) in early June 2020. By July 21, there were 219,128 NYC residents diagnosed using nucleic acid testing for SARS-CoV-2 (the virus that causes COVID-19), yielding a cumulative incidence of approximately 2,628 per 100,000 for confirmed COVID-19 infections among NYC residents. This estimate did not include people who were infected but unable or chose not to seek testing (e.g., those with asymptomatic or mildly symptomatic infections), and thus was not reflective of true cumulative COVID-19 incidence.

Compared with studies that use diagnostic tests, seroprevalence surveys can provide more complete estimates of the burden of infection by identifying people who were infected with SARS-CoV-2 but not reported as COVID-19 cases. If antibodies are a marker of total or partial immunity, they may also provide information on the proportion and characteristics of people who remain susceptible to the virus. Early reported seroprevalence estimates for communities in several geographic areas within the U.S. ranged from 1-20% [1–6]. Most published studies lack details on the characteristics of tested persons useful for determining risk factors for infection and seroconversion. From mid-May through late-July 2020, widespread SARS-CoV-2 immunoglobulin G (IgG) antibody testing was offered to all adult NYC residents. We present the seroprevalence of SARS-CoV-2 infection and correlates of seropositivity among a large sample of the City's population.

## Methods

### *Specimen and data collection*

Opportunities for no-cost antibody testing were made available for NYC residents aged  $\geq 18$  years during May 13-July 21, 2020. BioReference Laboratories, a large commercial laboratory, conducted specimen collection and testing. SARS-CoV-2 IgG testing was conducted using the Liaison SARS-CoV-2 S1/S2 assay (DiaSorin, Saluggia, Italy; 97.6% sensitivity and 99.3% specificity), which had received Emergency Use Authorization from the U.S. Food and Drug Administration [7].

Media, the internet, and local advertisement were used to disseminate information to the public on testing locations and registration procedures. Serosurvey participants made appointments for testing using BioReference Laboratories' online platform, where a survey form was available for them to complete at the time of booking an appointment. Testing sites were set up at City-operated facilities, one in each of the five boroughs (counties) of NYC. The testing sites were rotated to expand catchment areas, such that five specific sites were in operation from May 13-June 2 and a different set of five sites was set up for collections during June 26-July 21.

### *Serosurvey eligibility and data elements*

During online self-registration, required screening questions identified persons who may have had very recent infections and were either potentially infectious or had insufficient time to develop antibodies to SARS-CoV-2. Those who self-reported that they tested positive for SARS-CoV-2 by nasal or throat swab, or had fever, new onset or worsening cough, shortness of breath, or loss of taste (ageusia) or smell (anosmia) in the prior two weeks were not eligible for serosurvey participation.

Results of antibody testing were paired with participant characteristics and potential COVID-19 exposures from the self-administered survey. Survey data included demographics; industry and occupation; whether or not participants worked outside of the home during the PAUSE period (March 23-June 7); if they had exposure to a person diagnosed with COVID-19 (within 6 feet for  $\geq 10$  minutes); symptoms and symptom onset date; health care seeking and hospitalization for COVID-like

illness; whether they had a history of a prior SARS-CoV-2 polymerase chain reaction (PCR)-positive test; housing type and number of household members (measure of crowding); and health status (height, weight, and chronic underlying medical conditions).

Age and address were required for obtaining serology testing; completion of other survey questions was voluntary. Overall, 14.3% of participants (n=7,574) did not complete surveys. Among those who provided survey data, missing data across 12 categories of questions ranged from 2.7% to 14.0%.

#### *Data analysis*

Participants' ZIP codes of residence were mapped to neighborhood poverty levels. Neighborhood poverty was defined as the percent of a ZIP code's population with household incomes <100% of the Federal Poverty Level, per the 2013-2017 American Community Survey (low poverty: <10%, medium: 10%-19.9%, high: 20%-29.9%, very high:  $\geq$ 30%) [8].

We collected information on 9 underlying chronic conditions: diabetes, hypertension, heart disease, kidney disease, liver disease, asthma, chronic obstructive pulmonary disease/emphysema/chronic bronchitis, immunosuppressive condition, and immunosuppressive therapy. Reported height and weight were used to calculate participants' body mass index (BMI), (kilogram/meter<sup>2</sup>); weight status categories were defined as underweight or normal (BMI<25), overweight (25 $\leq$ BMI<30), obesity (30 $\leq$ BMI<40), and severe obesity (BMI $\geq$ 40). Participants with implausible weight or height values were excluded from BMI calculation (n=357).

We collected self-reported information on 11 symptoms of COVID-like illness (CLI) and categorized them into three groups. They were 1) those meeting the current Council of State and Territorial Epidemiologists (CSTE) COVID-19 case definition, which includes cough, shortness of breath/difficulty breathing, loss of taste, loss of smell, or any two of: chills, fever, headache, diarrhea, vomiting, sore throat, or body aches [9]; 2) non-CSTE: one or more of the following: chills, fever, headache, diarrhea, vomiting, sore throat, or body aches; and 3) asymptomatic: report of no symptoms.

Industry and occupation data were collected using the questions: “What kind of business or industry do you currently work in?” and “What kind of work do you currently do?” The industry question had dropdown options with the ability to provide a free text response. The Centers for Disease Control and Prevention’s National Institute for Occupational Safety and Health Industry and Occupation Computerized Coding System (NIOCCS) assigned industry codes from 2012 North American Industry Classification System (NAICS) and occupation codes from 2010 Standard Occupational Classification (SOC) [10, 11]. Free text responses that autocoded below a predetermined probability threshold were reviewed by professionally trained coders.

In analyses, we combined participant NAICS sectors to examine seroprevalence for 5 broad categories: 1) health care and social assistance (NAICS Sector 62); 2) essential workers, considered for our local context to comprise individuals in sectors that were largely operational during New York on PAUSE (accommodation and food services (NAICS 722), administrative support and waste management and remediation services (NAICS 56), construction (NAICS 23), selected retail trade consisting of grocery and drug stores and pharmacies (NAICS 4451-4561), and transportation and warehousing (NAICS 48-49)); 3) educational services (NAICS 61); 4) all other NAICS industry sectors; and 5) not working (unemployed, retired, student).

For participants who tested more than once (n=200), we included test and survey data from the first testing event. Using population denominator estimates, we calculated testing rates per 100,000 NYC residents, stratified by age group, race/ethnicity, borough of residence, and neighborhood poverty level. We calculated the prevalence of SARS-CoV-2 antibodies among those with available survey data (85.7% of all participants), stratified by participant characteristics. Finally, we used robust Poisson regression to examine associations between seropositivity and correlates of interest for the entire sample, as well as subgroups of health care workers and essential workers. Significant variables in bivariate analyses ( $p < 0.05$ ) were included in separate multivariable regression models that adjusted for sex (male, female), age group (18-44, 45-64,  $\geq 65$ ), race/ethnicity (non-Hispanic white, non-Hispanic Black, Hispanic, non-Hispanic Asian/Pacific Islander, other non-Hispanic

racess), borough of residence (Bronx, Brooklyn, Manhattan, Queens, Staten Island), and poverty level (low, medium, high, very high). The model for employment and seropositivity also adjusted for working outside the home during PAUSE.

Serosurvey data were submitted to the NYC Department of Health and Mental Hygiene (DOHMH) and analyzed using SAS v. 9.4 (Cary, NC). The DOHMH Institutional Review Board determined this project to be public health surveillance that does not meet the Office of Human Research Protections definition of human subjects research.

## **Results**

### *Serosurvey sample*

The seroprevalence among 52,941 serosurvey participants was 24.8%; 7,574 did not complete surveys and were excluded from further analysis. While seroprevalence among everyone tested was similar to that among those included in the final analytic sample, participants with missing survey data were older than those with any survey data (44% vs 39% aged  $\geq 45$  years) and higher proportions of them lived in Brooklyn, Queens, or the Bronx (versus in Manhattan or Staten Island).

There were 45,367 participants in the final sample, representing an overall testing rate of 680 per 100,000 adult NYC residents. Testing rates varied by key demographics, with substantially higher testing levels among non-Hispanic White individuals (908/100,000) and those residing in Staten Island (2,512/100,000), and very low testing rates among people aged  $\geq 65$  years (260/100,000), non-Hispanic Black individuals (236/100,000), and those residing in Brooklyn, the Bronx, and in areas of very high poverty (all below 460/100,000) (Figure 1).

### *Seroprevalence estimates*

Of the 45,367 participants in the final sample, 10,725 had antibodies to SARS-CoV-2, yielding an overall seropositivity of 23.6% (95% confidence interval [CI], 23.2%-24.0%). An extrapolation of seroprevalence based on this convenience sample to the population of approximately 6.6 million adult NYC residents would yield an estimate of 1,557,000 individuals having evidence of prior COVID-

19 infection. Participant characteristics and associated seroprevalence estimates are shown in Table 1. Approximately one-third of non-Hispanic Black and Hispanic participants were seropositive (33.5% and 35.3%, respectively). There was no appreciable variability in seroprevalence according to participant sex at birth, gender identity, sexual orientation, or age. Geographically, the highest seroprevalence was observed among residents in the Bronx (37.0%) and very high poverty neighborhoods (35.3%). Lower than average seroprevalence (<20%) was noted among residents in Manhattan, Staten Island, and low poverty neighborhoods.

One-quarter of participants (10,455/41,037) with comorbidity information reported at least one chronic condition, most commonly hypertension (47%), followed by asthma (38%) and diabetes (18%). Seroprevalence did not vary by chronic disease status (Table 1). Participants who were overweight to severely obese had higher seroprevalence compared with those who were in the normal to underweight range (>25% versus 19.7%). Of participants with information on exposure, 21% reported prolonged, close contact with someone who had tested positive for COVID-19 infection; seroprevalence among this group was substantially higher (35.6%; 95% CI, 34.6%-36.6%) compared with seroprevalence among participants without exposure to a COVID-19 patient (20.4%; 95% CI, 20.2%-20.9%).

A total of 24,506 (60%) participants reported having had symptoms after January 1, 2020. Of them, the vast majority (87%; 21,239/24,506) experienced symptoms meeting the CSTE definition for CLI; roughly one-third of them were seropositive (34.0%; 7,254/21,239), compared with approximately 12% of participants who either had no symptoms or symptoms that did not meet the CSTE definition. While participants with selected key symptoms in the two weeks before scheduled antibody testing were instructed not to test, 221 with CSTE CLI symptoms during that period did, in fact, get tested; seroprevalence for this group was 17.2%. Table 2 shows increasing seroprevalence estimates with longer intervals between symptom onset and testing, as well as relatively high seroprevalence by healthcare seeking (43.9%) and hospitalization (81.2%) status. Of key isolated symptoms or symptomology, loss of taste or smell was associated with the highest seroprevalence



(28.2%). Only 4% of all participants (5% of those with CSTE-defined CLI symptoms and 2% with no or non-CSTE CLI symptoms) reported having had a prior positive COVID-19 diagnostic test; seroprevalence among participants with self-reported histories of confirmed COVID-19 infection was 79.2% (1,219/1,539).

Of 39,502 participants who provided industry and occupation data, 28,549 (72%) were employed at the time of the serosurvey. Seroprevalence by industry category ranged from 19.4% (95% CI, 18.8%-20.1%) to 31.6% (95% CI, 30.3%-33.0%) (Table 1). Approximately one-quarter of participants (26%) worked outside of the home during PAUSE: 58% of health care workers, 55% of essential workers, 12% of those in educational services, and 25% of those in other sectors. Seroprevalence was higher among individuals who reported working outside of the home during the time of New York on PAUSE (27.4%; 95% CI 26.6%-28.3%) compared with those who did not (22.2%; 95% CI, 21.8%-22.7%). Figure 2 shows a detailed breakdown of seroprevalence by industry within the health care and social assistance and essential worker categories.

#### *Correlates of seropositivity*

Of 13 variables we examined, only two - underlying conditions and type of housing - were not statistically significantly associated with seropositivity in bivariate analyses (Table 3). Male sex, age 44-64 years, non-White race/ethnicity, living in a borough other than Manhattan or Staten Island, and living in neighborhoods with high or very high poverty levels were significantly associated with seropositivity in a multivariable regression model that included sex, age group, race/ethnicity, borough, and poverty. Adjusting for these 5 demographic variables in separate multivariable models, the following factors were associated with seropositivity: employment in a health care or essential worker category, or being unemployed at the time of the serosurvey; working outside of the home during PAUSE; having close contact with someone with COVID-19; having had CLI symptoms (the factor most strongly associated with seropositivity; adjusted relative risk 2.76 (95% CI, 2.65-2.88); being overweight, obese, or severely obese; and increasing numbers of household members.

For healthcare workers and essential workers specifically, correlates of seropositivity were largely the same as those observed for the entire serosurvey sample. Key differences for health care workers were that seropositivity was not associated with sex or living in very high poverty. For essential workers, seropositivity was not associated with: age, living in Brooklyn, the Bronx, Manhattan, or Staten Island, or with working outside the home during PAUSE.

## **Discussion**

From the largest SARS-CoV-2 serosurvey in a single U.S. jurisdiction to date, we estimate that the number of persons infected with SARS-CoV-2 may have been as much as 7 times higher than the number of reported cases in the first five months of the pandemic. Almost one-quarter of people tested had evidence of acquired SARS-CoV-2 in the initial period of the pandemic. Amid continued SARS-CoV-2 transmission, layered interventions including rigorous and extensive monitoring, testing, contact tracing, promotion of individual prevention measures (e.g., face coverings, social distancing, frequent handwashing), and community restrictions on indoor activities have been implemented as an attempt to slow its spread.

Geographic and demographic characteristics of serosurvey participants with SARS-CoV-2 antibody tracked with the epidemiology of reported COVID-19 cases in NYC [12]. The highest seroprevalence was observed among Black and Hispanic people, and those living in Queens and the Bronx. Communities with higher poverty levels were disproportionately affected; more than one-third of participants living in ZIP codes where >30% of the population was living below the federal poverty level had antibodies to the SARS-CoV-2 virus. Elevated risks of testing seropositive persisted for these groups after accounting for other individual characteristics. Drivers of COVID-19 risk in urban areas include population density, transportation, employment with frequent public contact, crowded housing, and other socioeconomic and environmental factors [13-15]. Differential exposure to various forms of structural oppression, including structural racism - centuries of racist policies and discriminatory practices across institutions, including government agencies, and society - also negatively affects the overall health and well-being of Black and Hispanic individuals [16]. While

interventions have aimed to optimize access and convenience to diagnostic testing and support services (e.g., venues for isolation/quarantine), these interventions have not halted ongoing transmission. More research on the complex interplay of underlying social, environmental, economic, and structural inequities is needed to understand increased risk of COVID-19 in communities of color in NYC and elsewhere, in order to effect interventions and policies that can reduce observed health disparities.

Our survey collected information on industry and occupation. Knowledge about risks for infection among people in various work settings is important for planning, implementing, evaluating, and improving prevention interventions. Studies have reported on seroprevalence among staff in healthcare settings [17, 18], which was found to be as high as 31% in one NYC medical center in late Spring-Summer 2020 [18]. We report a similar prevalence among serosurvey participants who worked in the health care and social assistance sector (30%), and further found 45-50% seropositivity among subsets in nursing home or home health care services. Essential workers with exposure to the public, as defined for this study, had seropositivity over 30%. Our data support vaccine prioritization for workers in industries of accommodations and food services (e.g., restaurant workers), transportation and warehousing (e.g., public transit, drivers, postal workers, couriers), retail trade (e.g., grocery store workers), and those of other essential workers [19]. Until vaccines are widely available and taken, preventive measures to reduce workplace exposures to SARS-CoV-2 should continue to be emphasized [20].

While it has been suggested that 40–45% of SARS-CoV-2 infections are asymptomatic [21], we found that 21% of serosurvey participants with antibodies to SARS-CoV-2 did not report a COVID-19-like illness. More than one in ten participants with either no symptoms or symptoms not meeting the clinical case definition for COVID-19 were seropositive. While symptoms meeting the CSTE COVID-19 definition captured three-quarters of antibody-positive people and had suboptimal prediction (positive predictive value: 34%), there was an almost three-fold risk of testing seropositive among participants with CSTE-consistent symptoms compared to those without such

symptoms. Among the CSTE symptoms, loss of taste and/or smell as sole symptom(s) was more predictive of seropositivity compared with only fever or only cough. Our experience with investigating SARS-CoV-2 clusters has revealed presentations with few and mild symptoms, making early recognition and control a significant challenge.

There are limitations to our analysis. We used a convenience sample, therefore it is possible that people who sought out testing perceived themselves to have been more likely to have been exposed to SARS-CoV-2; indeed, 60% of participants reported a history of CLI symptoms. A considerably biased sample could overestimate seroprevalence. On the other hand, lower representation of certain subgroups with higher infection rates – such as Black and Hispanic individuals – could underestimate true seroprevalence. However, our overall seroprevalence estimate was very similar to published estimates derived from a number of other NYC-based convenience samples during roughly the same time period; these include a New York State serosurvey of almost 6,000 NYC residents recruited at grocery stores (seroprevalence: 22.7%) [6], testing of residual clinical specimens obtained from two commercial laboratories that serve NYC (ranging from 17.6%-23.2% depending on the week of collection between April and July) [22, 23], and a serosurvey of NYC first responders and public safety personnel (seroprevalence: 22.5%) [24]. Our estimate also aligns well with the overall percent of NYC residents who tested positive for SARS-CoV-2 antibodies across NYC health care facilities, which was roughly 20% as of the third week of July 2020 [25]. Population-based, representative serosurveys will yield the most accurate measures of seroprevalence for NYC; results from a series of citywide population-based serosurvey being conducted by the DOHMH since early in the pandemic are forthcoming. The earliest of those serosurveys (June-October 2020) has found a weighted seroprevalence of 24.3%, a very similar estimate to ours [Manuscript submitted for publication].

Complete survey data were missing for approximately 15% of records and there were additional, partially missing data across survey fields. We chose not to impute missing values as we could not know the source and/or extent of any biases related to missing data and did not want to

risk magnifying them. We did not pre-test questions and there was the potential for issues related to comprehension. For example, approximately 20% of participants who reported having tested positive using a swab or saliva test for SARS-CoV-2 did not have detectable antibodies. Some people, particularly those with mild or clinically inapparent infection, may not develop detectable serum antibodies following infection or have antibodies that persist [26-30], perhaps accounting for no IgG antibody detection by the time the serosurvey took place. It is possible though that some of these participants reported having received a diagnostic test, and not necessarily a positive test result, leading to our misclassification of their prior diagnosis.

Seroprevalence studies are useful for understanding the true prevalence of infection. We found that after the first several months of the pandemic, a substantial proportion of people in NYC had evidence of prior infection with SARS-CoV-2. However, it was less than what would lead to herd immunity needed to prevent future large outbreaks of COVID-19, which is estimated to be as much as 70% assuming that: 1) the basic reproductive number for SARS-CoV-2 is between 2 and 3.5, and 2) infection confers long-lasting immunity [31-33].

While population-based samples that are not subject to selection bias are ideal, convenience samples such as ours can be informative when they more fully characterize tested individuals and their risk exposures. Some strengths of this seroprevalence survey are that it captured descriptors such as sexual orientation and gender identity and included large samples from racial/ethnic minority populations. Estimates of seroprevalence can be combined with other measures of disease burden such as diagnoses and mortality to monitor trends and geographical distribution over time, identify hotspots and at-risk populations needing special attention, and ultimately aid in assessing the effectiveness of interventions.

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**Table 1. Characteristics of participants and proportion with antibodies to SARS-CoV-2.**

|                                     | Number of<br>persons<br>tested | Percent of<br>persons<br>tested | Seroprevalence     |                                 |
|-------------------------------------|--------------------------------|---------------------------------|--------------------|---------------------------------|
|                                     |                                |                                 | Number<br>positive | Percent<br>positive (95%<br>CI) |
| <b>All</b>                          | 45367                          | 100%                            | 10725              | 23.6 (23.2-<br>24.0)            |
| <b>Race/ethnicity (n=42158)</b>     |                                |                                 |                    |                                 |
| Non-Hispanic White                  | 20368                          | 48%                             | 3269               | 16.0 (15.5-<br>16.6)            |
| Non-Hispanic Black                  | 3467                           | 8%                              | 1162               | 33.5 (32.0-<br>35.1)            |
| Hispanic                            | 11629                          | 28%                             | 4106               | 35.3 (34.4-<br>36.2)            |
| Non-Hispanic Asian/Pacific-Islander | 5028                           | 12%                             | 1017               | 20.2 (19.1-<br>21.4)            |
| Non-Hispanic other/multiple races   | 1666                           | 4%                              | 392                | 23.5 (21.5-<br>25.6)            |
| <b>Sex at birth (n=44164)</b>       |                                |                                 |                    |                                 |
| Male                                | 20519                          | 46%                             | 4964               | 24.2 (23.6-<br>24.8)            |
| Female                              | 23645                          | 54%                             | 5445               | 23.0 (22.5-<br>23.6)            |
| <b>Gender identity (n=43831)</b>    |                                |                                 |                    |                                 |
| Man                                 | 20285                          | 46%                             | 4895               | 24.1 (23.5-                     |

|                                       |       |      |             |
|---------------------------------------|-------|------|-------------|
|                                       |       |      | 24.7)       |
| Woman                                 | 23286 | 5356 | 23.0 (22.5- |
|                                       |       | 53%  | 23.5)       |
| Transgender/gender non-               | 260   | 47   | 18.1 (13.9- |
| conforming                            |       | 1%   | 23.2)       |
| <b>Sexual orientation (n=41525)</b>   |       |      |             |
| Straight                              | 37115 | 8676 | 23.4 (22.9- |
|                                       |       | 89%  | 23.8)       |
| Lesbian, gay, bisexual, queer, and    |       |      |             |
| other non-heterosexual                | 4410  | 895  | 20.3 (19.1- |
| orientations                          |       | 11%  | 21.5)       |
| <b>Age Group (n=45367)</b>            |       |      |             |
| 18-44 years                           | 27667 | 6411 | 23.2 (22.7- |
|                                       |       | 61%  | 23.7)       |
| 45-64 years                           | 14457 | 3617 | 25.0 (24.3- |
|                                       |       | 32%  | 25.7)       |
| 65+ years                             | 3243  | 697  | 21.5 (20.1- |
|                                       |       | 7%   | 22.9)       |
| <b>Borough of residence (n=45367)</b> |       |      |             |
| Bronx                                 | 4828  | 1789 | 37.0 (35.7- |
|                                       |       | 11%  | 38.4)       |
| Brooklyn                              | 8766  | 2038 | 23.2 (22.4- |
|                                       |       | 19%  | 24.1)       |
| Manhattan                             | 10674 | 2076 | 19.4 (18.7- |
|                                       |       | 24%  | 20.2)       |

|   |       |     |      |             |
|---|-------|-----|------|-------------|
| Queens  | 11736 |     | 3334 | 28.4 (27.6- |
|   |       | 26% |      | 29.2)       |
| Staten Island                                       | 9363  |     | 1488 | 15.9 (15.2- |
|   |       | 21% |      | 16.6)       |
| <b>Poverty level (n=45363)</b>                      |       |     |      |             |
| Low (<10% below Federal Poverty Level)              | 10961 |     | 1933 | 17.6 (16.9- |
|   |       | 24% |      | 18.4)       |
| Medium (10%-<20% below Federal Poverty Level)       | 18030 |     | 4262 | 23.6 (23.0- |
|   |       | 40% |      | 24.3)       |
| High (20%-<30% below Federal Poverty Level)         | 11708 |     | 2882 | 24.6 (23.8- |
|   |       | 26% |      | 25.4)       |
| Very high ( $\geq$ 30% below Federal Poverty Level) | 4664  |     | 1647 | 35.3 (33.9- |
|   |       | 10% |      | 36.7)       |
| <b>Symptoms (n=40880)</b>                           |       |     |      |             |
| Meeting CSTE definition <sup>a</sup>                | 21329 |     | 7254 | 34.0 (33.4- |
|   |       | 52% |      | 34.6)       |
| Symptomatic but not meeting CSTE definition         | 3177  |     | 359  | 11.3 (10.2- |
|   |       | 8%  |      | 12.4)       |
| Asymptomatic  | 16374 |     | 2062 | 12.6 (12.1- |
|   |       | 40% |      | 13.1)       |
| <b>Employment sector (n=39502)</b>                  |       |     |      |             |
|   |       |     |      | 30.0 (28.6- |
| Healthcare and social assistance                    | 4297  | 11% | 1289 | 31.4)       |
|   |       |     |      | 20.2 (19.0- |
| Educational services                                | 4220  | 11% | 854  | 21.5)       |

|   |       |     |      |             |
|---|-------|-----|------|-------------|
|   |       |     |      | 31.6 (30.3- |
| Essential worker <sup>b</sup>                                       | 5205  | 13% | 1644 | 33.0)       |
|   |       |     |      | 19.4 (18.8- |
| Other industries  | 14827 | 37% | 2878 | 20.1)       |
|   |       |     |      | 23.8 (23.0- |
| Not working   | 10953 | 28% | 2605 | 24.6)       |
| <b>Worked outside of the home (March 23-June 6, 2020) (n=40581)</b> |       |     |      |             |
| Yes   | 10768 |     | 2953 | 27.4 (26.6- |
|   |       | 26% |      | 28.3)       |
| No  | 29813 |     | 6630 | 22.2 (21.8- |
|   |       | 73% |      | 22.7)       |
| <b>Underlying medical conditions</b>                                |       |     |      |             |
| <b>(n=41037)</b>  |       |     |      |             |
| Yes <sup>c</sup>  | 10455 |     | 2538 | 24.3 (23.5- |
|   |       | 25% |      | 25.1)       |
| No  | 30582 |     | 7173 | 23.4 (23.0- |
|   |       | 75% |      | 23.9)       |
| <b>Weight Status (n=39031)</b>                                      |       |     |      |             |
| Under/normal weight   | 16896 |     | 3324 | 19.7 (19.1- |
|   |       | 43% |      | 20.3)       |
| Overweight  | 13139 |     | 3303 | 25.1 (24.4- |
|   |       | 34% |      | 25.9)       |
| Obese   | 7883  |     | 2213 | 28.1 (27.1- |
|   |       | 20% |      | 29.1)       |
| Severely obese  | 1113  | 3%  | 295  | 26.5 (24.0- |

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|   |       |      |             |
|---|-------|------|-------------|
|   |       |      | 29.2)       |
| <b>Close proximity to person with COVID-19 (n=40260)<sup>d</sup></b>  |       |      |             |
| Yes   | 8464  | 3011 | 35.6 (34.6- |
|   |       | 21%  | 36.6)       |
| No/Don't Know   | 31796 | 6500 | 20.4 (20.0- |
|   |       | 79%  | 20.9)       |
| <b>Self-reported prior positive COVID-19 diagnosis test (n=40568)</b> |       |      |             |
| Yes   | 1539  | 1219 | 79.2 (77.1- |
|   |       | 4%   | 81.2)       |
| No/Don't know   | 39029 | 8355 | 21.4 (21.0- |
|   |       | 96%  | 21.8)       |
| <b>Housing type (n=39746)</b>   |       |      |             |
| Single Family   | 14932 | 3454 | 23.1 (22.5- |
|   |       | 38%  | 23.8)       |
| Multi-unit Housing  | 24814 | 5852 | 23.6 (23.1- |
|   |       | 62%  | 24.1)       |
| <b>Number in household (n=39535)</b>                                  |       |      |             |
| 1 (live alone)  | 6963  | 1252 | 18.0 (17.1- |
|   |       | 18%  | 18.9)       |
| 2   | 12416 | 2381 | 19.2 (18.5- |
|   |       | 31%  | 19.9)       |
| 3   | 7635  | 1868 | 24.5 (23.5- |
|   |       | 19%  | 25.4)       |
| 4   | 6680  | 1799 | 26.9 (25.9- |
|   |       | 17%  | 28.0)       |

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|    |      |      |             |
|----|------|------|-------------|
| 5  | 3253 | 1054 | 32.4 (30.8- |
|    |      | 8%   | 34.0)       |
| 6  | 1393 | 493  | 35.4 (32.9- |
|    |      | 4%   | 37.9)       |
| 7  | 593  | 187  | 31.5 (27.9- |
|    |      | 1%   | 35.4)       |
| 8+ | 602  | 259  | 43.0 (39.1- |
|    |      | 2%   | 47.0)       |

CI: confidence interval

<sup>a</sup> Council for State and Territorial Epidemiologists definition: cough, shortness of breath/difficulty breathing, loss of taste, or loss of smell, or any two of the following captured in serosurvey: chills, fever, headache, diarrhea, vomiting, sore throat, or body aches

<sup>b</sup> Includes workers considered essential during the period of New York on PAUSE (March 23-June 7, 2020). Includes food services, administrative and support and waste management and remediation services, construction, retail trade (grocery, pharmacy/drug stores only), transportation and warehousing

<sup>c</sup> Includes one or more of the following: diabetes, hypertension, chronic heart disease, chronic kidney disease, chronic liver disease, asthma, chronic obstructive pulmonary disease/emphysema/chronic bronchitis, immunosuppressive condition (e.g. HIV, autoimmune disease), immunosuppressive therapy (e.g. cancer treatment)

<sup>d</sup> Exposure within 6 feet for >10 minutes to a person diagnosed with COVID-19



**Table 2. Seroprevalence among participants with symptoms meeting the Council for State and Territorial Epidemiologists clinical case definition.**

|  | Number of<br>persons<br>tested | Percent of<br>persons<br>tested | Seroprevalence     |                     |
|--|--------------------------------|---------------------------------|--------------------|---------------------|
|  |                                |                                 | Number<br>positive | Percent<br>positive |
| <b>All</b>                             | 21,329                         | 100%                            | 7254               | 34.0%               |
| <b>Time from symptom onset</b>         |                                |                                 |                    |                     |
| 0-14 days                              | 221                            | 1%                              | 38                 | 17.2%               |
| 15-28 days                             | 385                            | 2%                              | 84                 | 21.8%               |
| 29-42 days                             | 817                            | 4%                              | 302                | 37.0%               |
| 43+ days                               | 12832                          | 60%                             | 5582               | 43.5%               |
| Don't know/missing                     | 7074                           | 33%                             | 1248               | 17.6%               |
| <b>Sought Healthcare</b>               |                                |                                 |                    |                     |
| Yes                                    | 4764                           | 22%                             | 2347               | 49.3%               |
| No                                     | 16565                          | 78%                             | 4907               | 29.6%               |
| <b>Hospitalized</b>                    |                                |                                 |                    |                     |
| Yes                                    | 181                            | 1%                              | 147                | 81.2%               |
| No                                     | 21148                          | 99%                             | 7107               | 33.6%               |
| <b>Symptoms</b>                        |                                |                                 |                    |                     |
| Cough (n=9,630)                        |                                |                                 |                    |                     |
| Cough only                             | 178                            | 2%                              | 32                 | 18.0%               |
| Cough plus other symptoms <sup>a</sup> | 9452                           | 98%                             | 4452               | 47.1%               |
| Shortness of breath (n=11,785)         |                                |                                 |                    |                     |
| Shortness of breath only               | 675                            | 6%                              | 71                 | 10.5%               |
| Shortness of breath plus other         | 11110                          | 94%                             | 3747               | 33.7%               |

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symptoms<sup>a</sup>

New loss of smell and/or taste (n=13,224)

|                                    |       |     |      |       |
|------------------------------------|-------|-----|------|-------|
| New loss of smell/taste only       | 500   | 4%  | 141  | 28.2% |
| New loss of smell/taste plus other | 12724 | 96% | 5915 | 46.5% |

symptoms<sup>a</sup>

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<sup>a</sup>Symptoms include one or more of: cough, shortness of breath/difficulty breathing, loss of taste, loss of smell, chills, fever, headache, diarrhea, vomiting, sore throat, body aches

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**Table 3. Factors associated with seropositivity.**

|                          | No./total (%) with SARS-CoV-2 antibodies |                    | Relative risk             |                               |
|--------------------------|--|--------------------|---------------------------|-------------------------------|
|                          |  |                    | (95% confidence interval) |                               |
|                          | Exposure present                         | Exposure absent    | Bivariate                 | Multivariable                 |
| <b>Sex at birth</b>      |  |                    |                           |                               |
| Male                     | 4964/20519 (24.2)                        | 15555/20519 (75.8) | 1.00 (reference)          | 1.00 (reference)              |
| Female                   | 5445/23645 (23.0)                        | 18200/23645 (77.0) | 0.95 (0.92-0.98)          | 0.94 (0.90-0.97) <sup>b</sup> |
| <b>Age group (years)</b> |  |                    |                           |                               |
| 18-44                    | 6411/27667 (23.2)                        | 21256/27667 (76.8) | 1.00 (reference)          | 1.00 (reference)              |
| 45-64                    | 3617/14457 (25.0)                        | 10840/14457 (75.0) | 1.08 (1.04-1.12)          | 1.08 (1.04-1.12) <sup>b</sup> |
| ≥65                      | 697/3243 (21.5)                          | 2,546/3243 (78.5)  | 0.93 (0.87-0.99)          | 0.98 (0.92-1.05)              |
| <b>Race/ethnicity</b>    |  |                    |                           |                               |
| Non-Hispanic White       | 3269/20368 (16.0)                        | 17099/20368 (84.0) | 1.00 (reference)          | 1.00 (reference)              |

|  |                   |                     |                  |                               |
|--|-------------------|---------------------|------------------|-------------------------------|
| Non-Hispanic Black                             | 1162/3467 (33.5)  | 2305/3467 (66.5)    | 2.09 (1.97-2.21) | 1.83 (1.72-1.94) <sup>a</sup> |
| Hispanic                                       | 4106/11629 (35.3) | 7523/11629 (64.7)   | 2.20 (2.11-2.29) | 1.84 (1.76-1.92) <sup>a</sup> |
| Non-Hispanic Asian/Pacific Islander            | 1107/5028 (20.2)  | 4011/5028 (79.8)    | 1.26 (1.18-1.34) | 1.13 (1.06-1.21) <sup>a</sup> |
| Non-Hispanic other/multiple races              | 392/1666 (23.5)   | 1274/1666 (76.5)    | 1.47 (1.34-1.61) | 1.31 (1.19-1.44) <sup>a</sup> |
| <b>Borough of Residence</b>                    |                   |                     |                  |                               |
| Bronx  | 1789/4828 (37.1)  | 3039/4828 (62.9)    | 2.33 (2.20-2.47) | 1.43 (1.33-1.54) <sup>a</sup> |
| Brooklyn                                       | 2038/8766 (23.2)  | 6728/8766 (76.8)    | 1.46 (1.38-1.55) | 1.19 (1.11-1.27) <sup>a</sup> |
| Manhattan                                      | 2076/10674 (19.4) | 8598/10674 (80.6)   | 1.22 (1.15-1.30) | 1.02 (0.96-1.09)              |
| Queens   | 3334/11736 (28.4) | 8402/11736 (71.6)   | 1.69 (1.79-1.89) | 1.52 (1.43-1.62) <sup>a</sup> |
| Staten Island                                  | 1488/9363 (15.9)  | 7875/9363 (84.1)    | 1.00 (reference) | 1.00 (reference)              |
| <b>Neighborhood poverty level</b>              |                   |                     |                  |                               |
| Low poverty (<10% below Federal Poverty Level) | 1933/10961 (17.6) | 9028/10961 (82.4)   | 1.00 (reference) | 1.00 (reference)              |
| Medium (10%-<20% below Federal Poverty Level)  | 4262/18030 (23.6) | 13,768/18030 (76.4) | 1.34 (1.28-1.41) | 1.03 (0.98-1.08)              |

|  |                   |                    |                  |                               |
|--|-------------------|--------------------|------------------|-------------------------------|
| High (20%-<30% below Federal Poverty Level)                | 2882/11708 (24.6) | 8826/11708 (75.4)  | 1.40 (1.33-1.47) | 1.24 (1.17-1.31) <sup>a</sup> |
| Very high ( $\geq$ 30%) below Federal Poverty Level)       | 1647/4664 (35.3)  | 3017/4664 (64.7)   | 2.00 (1.89-2.12) | 1.31 (1.22-1.41) <sup>a</sup> |
| <b>Employment sector</b>                                   |                   |                    |                  |                               |
| Educational services                                       | 854/4220 (20.2)   | 3366/4220 (79.8)   | 1.04 (0.97-1.12) | 1.05 (0.98-1.13)              |
| Essential workers <sup>d</sup>                             | 1644/5205 (31.6)  | 3561/5205 (68.4)   | 1.63 (1.55-1.71) | 1.33 (1.26-1.40) <sup>a</sup> |
| Health care and social assistance                          | 1289/4297 (30.0)  | 3008/4297 (70.0)   | 1.55 (1.46-1.63) | 1.35 (1.27-1.43) <sup>a</sup> |
| Other industries   | 2878/14827 (19.4) | 11949/14827 (80.6) | 1.00 (reference) | 1.00 (reference)              |
| Not working  | 2605/10953 (23.8) | 8348/10953 (76.2)  | 1.23 (1.17-1.28) | 1.16 (1.10-1.21) <sup>a</sup> |
| <b>Worked outside of home (3/23/20-6/7/20)</b>             |                   |                    |                  |                               |
| No   | 6630/29813 (22.2) | 23183/29813 (77.8) | 1.00 (reference) | 1.00 (reference)              |
| Yes  | 2953/10768 (27.4) | 7815/10768 (72.6)  | 1.23 (1.19-1.28) | 1.14 (1.10-1.19) <sup>a</sup> |
| <b>Close proximity to person with COVID-19<sup>e</sup></b> |                   |                    |                  |                               |
| No   | 6500/31796 (20.4) | 25296/31796 (79.6) | 1.00 (reference) | 1.00 (reference)              |

|   |                   |                    |                  |                               |
|---|-------------------|--------------------|------------------|-------------------------------|
| Yes   | 3011/8464 (35.6)  | 5453/8464 (64.4)   | 1.74 (1.68-1.80) | 1.65 (1.59-1.71) <sup>a</sup> |
| <b>Symptoms meeting CSTE definition<sup>f</sup></b> |                   |                    |                  |                               |
| No  | 2421/19551 (12.4) | 17130/19551 (87.6) | 1.00 (reference) | 1.00 (reference)              |
| Yes   | 7254/21329 (34.0) | 14075/21329 (66.0) | 2.75 (2.63-2.86) | 2.76 (2.65-2.88) <sup>a</sup> |
| <b>Weight status</b>                                |                   |                    |                  |                               |
| Underweight/normal                                  | 3324/16896 (19.7) | 13572/16896 (80.3) | 1.00 (reference) | 1.00 (reference)              |
| Overweight  | 3303/13139 (25.1) | 9836/13139 (74.9)  | 1.28 (1.22-1.33) | 1.13 (1.08-1.18) <sup>a</sup> |
| Obese   | 2213/7883 (28.1)  | 5670/7883 (71.9)   | 1.43 (1.36-1.50) | 1.21 (1.15-1.28) <sup>a</sup> |
| Severe obesity                                      | 295/1113 (26.5)   | 818/1113 (73.5)    | 1.35 (1.22-1.49) | 1.14 (1.03-1.27) <sup>c</sup> |
| <b>Underlying medical conditions<sup>g</sup></b>    |                   |                    |                  |                               |
| No  | 7173/30582 (23.5) | 23409/30582 (76.5) | 1.00 (reference) |                               |
| Yes   | 2538/10455 (24.3) | 7917/10455 (75.7)  | 1.03 (0.99-1.08) |                               |
| <b>Type of housing</b>                              |                   |                    |                  |                               |

|                                    |                   |                    |                  |                               |
|------------------------------------|-------------------|--------------------|------------------|-------------------------------|
| Single family home                 | 3454/14932 (23.1) | 11478/14932 (76.9) | 1.00 (reference) |                               |
| Multi-unit dwelling                | 5852/24814 (23.6) | 18962/24814 (76.4) | 1.02 (0.98-1.06) |                               |
| <b>Number of household members</b> |                   |                    | 1.14 (1.13-1.16) | 1.11 (1.10-1.12) <sup>a</sup> |

Model for sex at birth adjusted for age group, race/ethnicity, borough of residence, and neighborhood poverty level; model for age group adjusted for sex at birth, race/ethnicity, borough of residence, and neighborhood poverty level; model for race/ethnicity adjusted for sex at birth, age group, borough of residence, and neighborhood poverty level; model for borough of residence adjusted for sex at birth, age group, race/ethnicity, and neighborhood poverty level; model for neighborhood poverty level adjusted for sex at birth, age group, race/ethnicity, and borough of residence; employment model adjusted for sex at birth, age group, race/ethnicity, borough of residence, and neighborhood poverty level, and working outside the home during the period of PAUSE (March 23-June 7, 2020); all other models adjusted for sex at birth, age group, race/ethnicity, borough of residence, and neighborhood poverty level.

<sup>a</sup> p<.0001; <sup>b</sup> p<.001; <sup>c</sup> <.05

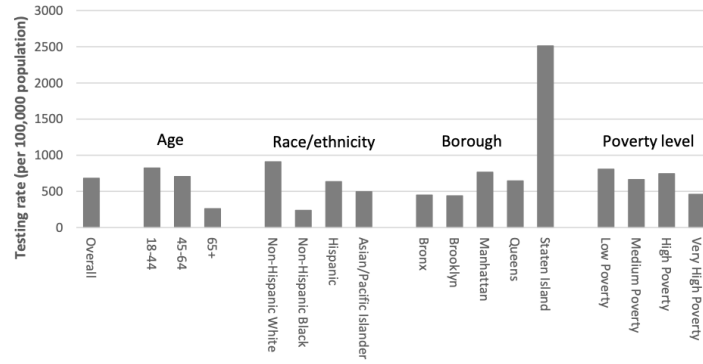
<sup>d</sup> Includes workers considered essential during the period of New York on PAUSE (March 23-June 7, 2020). Includes food services, administrative and support and waste management and remediation services, construction, retail trade (grocery, pharmacy/drug stores only), transportation and warehousing

<sup>e</sup> Exposure within 6 feet for >10 minutes to a person diagnosed with COVID-19

<sup>f</sup> Council for State and Territorial Epidemiologists definition: cough, shortness of breath/difficulty breathing, loss of taste, or loss of smell, or any two of the following captured in serosurvey: chills, fever, headache, diarrhea, vomiting, sore throat, or body aches

<sup>g</sup> Includes one or more of the following: diabetes, hypertension, chronic heart disease, chronic kidney disease, chronic liver disease, asthma, chronic obstructive pulmonary disease/emphysema/chronic bronchitis, immunosuppressive condition (e.g. HIV, autoimmune disease), immunosuppressive therapy (e.g. cancer treatment)

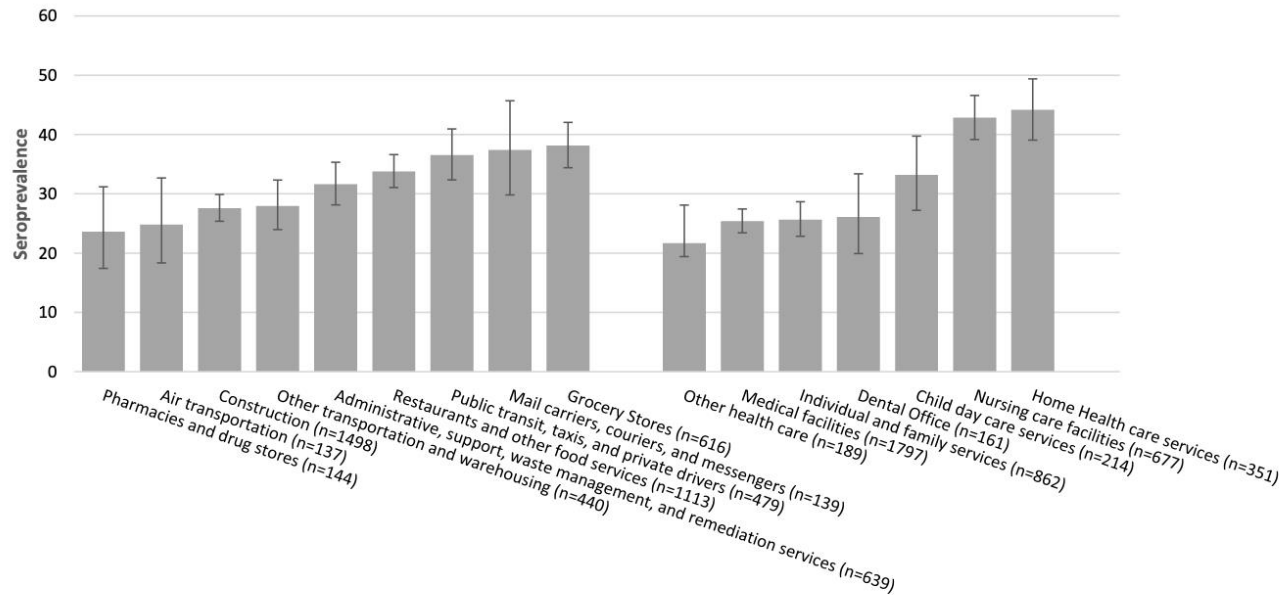
**Figure 1. Rate per 100,000 adult New York City residents tested for antibodies to SARS-CoV-2, by age group, race and ethnicity, borough, and neighborhood poverty level --- May 13-July 21, 2020.**



AC



**Figure 2. Seroprevalence among participants working in health care, social assistance, and essential worker settings.**



**Essential workers (overall seroprevalence: 31.6%)**

**Healthcare workers (overall seroprevalence: 30.0%)**

Other health care includes offices of other health practitioners, optometrists, chiropractors, community food and housing, rehabilitation services