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The role of housing characteristics in racial and ethnic disparities in SARS-CoV-2 antibody seropositivity among New York City adults: A population representative study

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ABSTRACT

Black and Latino populations have been disproportionately burdened by COVID-19 morbidity and mortality. Subsidized housing, crowding, and neighborhood poverty might be associated with increased COVID-19 transmission and play a role in observed racial and ethnic disparities, yet research is limited. Our study investigated whether these housing variables mediate the relationship between race and ethnicity and SARS-CoV-2 antibody seropositivity among New York City (NYC) adults. We analyzed data from a SARS-CoV-2 serosurvey ($n = 1074$), nested within the 2020 cross-sectional NYC Community Health Survey (June–October 2020). We defined SARS-CoV-2 seropositivity as either a positive blood test for SARS-CoV-2 antibodies or a self-reported positive test result. We used causal mediation analyses to test whether subsidized housing, crowding, and neighborhood poverty mediate a relationship between race and ethnicity and seropositivity. After controlling for potential confounding, we found elevated prevalence ratios of SARS-CoV-2 seropositivity among Black (APR = 1.74, 95% CI = 1.10–2.73) and Latino (APR = 1.58, 95% CI = 1.05–2.37) residents compared with White residents and for those living in crowded housing (APR = 1.48, 95% CI = 1.03–2.12) and high-poverty neighborhoods (APR = 1.54, 95% CI = 1.12–2.11) but not for subsidized housing. We observed statistically significant natural direct effects for all three mediators. While living in crowded housing and high-poverty neighborhoods contributed to racial and ethnic disparities in seropositivity the estimated contribution from living in subsidized housing was −9% (Black) and − 14% (Latino). Our findings revealed racial and ethnic disparities in seropositivity of SARS-CoV-2 antibodies among NYC adults. Unlike crowding and neighborhood poverty, living in subsidized housing did not explain racial and ethnic disparities in COVID-19.

1. Introduction

COVID-19 infection and death rates have been disproportionately high among certain racial and ethnic groups in the United States. Numerous reports have documented how Black Americans continue to face an excessive COVID-19 burden of illness and death (Mahajan and Larkins-Pettigrew, 2020; Yancy, 2020; Yaya et al., 2020). A nationwide, county-level analysis of COVID-19 and race found a significant association between the percentage of Black Americans living in a county and the percentage of confirmed COVID-19 cases, confirmed deaths, and case mortality rates (Mahajan and Larkins-Pettigrew, 2020). Hispanic Americans also have high hospitalization and mortality rates. As of June 2020, the Centers for Disease Control and Prevention reported that Hispanic Americans have 2.8 times the risk of being hospitalized for COVID-19 and 2.3 times the risk of dying due to COVID-19 compared with Non-Hispanic White persons (CDC, 2021). Other research found that the COVID-19 death ratio and infection ratio, defined as the ratio of COVID-19 deaths or infections in a county to its population, were positively associated with income inequality and race and ethnicity (Pham and Mitra, 2020). A serosurvey of New York City (NYC) residents found a higher prevalence of SARS-CoV-2 antibodies among Black and Latino residents compared with White residents, indicating higher rates of COVID-19 transmission in those groups (Parrott et al., 2021).

Housing type, meaning subsidized housing versus owned or rented homes/apartments, is a potential mechanism for explaining COVID-19 racial and ethnic disparities. In NYC and many other municipalities,

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public housing residents are disproportionately low-income people of color (Bravve and Bolton, 2012; New York University Furman Center, 2019). Poor housing conditions, such as immediate needs for kitchen and bathroom repairs and widespread mold issues, are highly prevalent in NYC Housing Authority (NYCHA) buildings (Gates, 2020; Gandour, 2022). Significant research supports the association between poor housing conditions and increased risk for chronic illnesses and infectious diseases (Krieger and Higgins, 2002; Mood, 2005; Taylor, 2018). These poor housing conditions could put residents at an increased risk for COVID-19. One study found that counties with a higher percentage of households with poor housing had higher incidences of COVID-19 and COVID-19 deaths (Ahmad et al., 2020).

In addition, neighborhood poverty could contribute to racial and ethnic disparities in COVID-19 outcomes. A disproportionate number of Black and Latino New Yorkers live in poor neighborhoods that suffer from long-term disinvestment of health-promoting resources and services, which could lead to higher risk of COVID-19. According to a California study (Azar et al., 2020), higher odds of COVID-19 hospitalization among Black versus White individuals were partially attributed to neighborhood-level poverty, suggesting a role of mistrust and limited access to culturally appropriate care in the observed racial inequity.

Crowding is another potential mechanism that could explain racial and ethnic COVID-19 disparities. According to the World Health Organization's Housing and Health Guidelines, crowded housing increases risk of exposure to infectious diseases (World Health Organization, 2018). Living in a crowded household makes it more difficult for individuals with COVID-19 to self-isolate, putting other household members at risk (Grijalva et al., 2020; Madewell et al., 2020; Metlay et al., 2021). In NYC, ZIP codes in the highest quintile of per capita COVID-19 infections had notably higher shares of crowded units compared to ZIP codes in the lowest quintile— 15.2% and 7.3%, respectively (New York University Furman Center, 2019). Another study found that average household size was the most important explanatory variable for variations in COVID-19 infection rates in NYC, with higher case rates in ZIP codes with a larger average household size (Federgruen and Naha, 2021).

Inequities in the ability to work from home throughout the pandemic may also explain differential COVID-19 outcomes by race and ethnicity. A demographic breakdown of NYC's essential workers shows that over 75% of frontline workers were people of color, and of those individuals, most were Black or Hispanic (Stringer, 2020). One study found that people of color, particularly Black people, were more vulnerable to COVID-19 infection than White people due to their employment in occupations with frequent exposure to infections and proximity to others (Hawkins, 2020). Thus, it is possible that racial and ethnic inequities in employment in occupations that allow people to work from home may explain observed inequities in COVID-19 outcomes.

Despite theoretical pathways between housing type, neighborhood poverty, and crowding and increased risk for COVID-19 infection, there is limited research exploring these variables as potential mechanisms for explaining racial and ethnic inequities in COVID-19 outcomes. Our study examined whether these housing variables mediate the relationship between race and ethnicity and SARS-CoV-2 antibody seropositivity among NYC adults. In our secondary analysis, we explored how differences in work from home status by race and ethnicity may contribute to additional risk for COVID-19 infection.

2. Methods

The current study used data from a SARS-CoV-2 serosurvey, nested within the cross-sectional, phone-based 2020 NYC Community Health Survey (CHS). 1074 individuals participated in the serosurvey from June – October 2020, and of these, 497 provided whole blood specimens which were then tested for SARS-CoV-2 IgG antibodies, and 577 participants self-reported SARS-CoV-2 antibody test results on the CHS (Parrott et al., 2021). Weights were created for making inferences to the NYC adult population. Additional details about the CHS and the serosurvey can be found elsewhere (Alroy et al., 2021; Parrott et al., 2021). The NYC Department of Health and Mental Hygiene (DOHMH) Institutional Review Board determined that this work was exempt from review as a secondary data analysis.

The study outcome was a binary indicator of having either a positive blood test for SARS-CoV-2 antibodies or a self-report of a positive antibody test result. The exposure variable was race and ethnicity, defined as White (including Middle Eastern or North African); Black; Asian or Pacific Islander; and "other" race. Latino or Hispanic was its own ethnic category. We used race and ethnicity as a proxy for structural racism and its impact on COVID-19 outcomes. Notably, our racial and ethnic analysis excluded two categories (Asian or Pacific Islander and "other") due to small sample sizes.

We considered three possible mediators. The first mediator was subsidized housing, defined as residing in a NYCHA unit or receiving rental assistance such as Section 8 versus another type of housing (including a rent controlled/rent stabilized unit, owned/rented units, or another housing situation). Second, we examined crowding, which we defined as five or more persons in the household. While crowding is often assessed using a ratio of persons per bedroom or room (Blake et al., 2007), our survey did not ask about the number or types of rooms in one's unit. Given that a crowded unit in NYCHA is defined as one where the ratio of person/bedroom is greater than two, and according to NYC Housing and Vacancy Survey, in 2017, 74% of occupied units had less than three bedrooms (U. S. Census Bureau, 2021; New York City Housing Authority, 2020; Gaumer, 2022), our definition of crowding was appropriate. Finally, we examined neighborhood poverty, classified as the proportion of residents whose income was <100% of federal poverty level. Neighborhoods were categorized into one of two groups: low poverty (<20% of residents with incomes below poverty levels) or high poverty (≥20%).

For our secondary analysis, we examined whether working from home versus outside the home during the pandemic modified the relationship between housing and seropositivity. This analysis was limited to those who reported that they were currently employed or who had been employed but lost a job due to COVID-19.

2.1. Statistical analysis

We first calculated the prevalence of SARS-CoV-2 antibody seropositivity and the three mediators by race and ethnicity. We further tested racial and ethnic disparities in seropositivity and three mediators by performing multivariable regression analyses with age group, gender, nativity, employment status, health insurance, and underlying health conditions as potential confounders. We also tested the association between seropositivity and each mediator via multivariable regression using the same set of covariates. The prevalence of seropositivity was >10%, indicating violation of the rare disease outcome assumption, where the odds ratio from logistic regression overestimates the prevalence ratio. To obtain a less biased prevalence ratio, we used Poisson regression models (Zou, 2004; Martinez et al., 2017).

To test mediation by subsidized housing, crowding, or neighborhood poverty, we performed causal mediation analyses. Specifically, we computed mediation weights (i.e., inverse of probability of a mediator value) by using each of three potential mediators as an outcome and the same set of covariates from the main multivariable regression analyses. We then multiplied mediation weights with survey weights and estimated natural direct and indirect effects after accounting for complex sample design. Using the formula proposed by VanderWeele and Vansteelandt, we estimated percent mediated for each of three potential mediators (Vanderweele and Vansteelandt, 2010).

Lastly, to test the effect modification of working from home status, we restricted our sample to those who were employed and further divided them into two subgroups (working from home vs working outside the home) and repeated the main multivariable regression

analysis where the prevalence ratio of seropositivity by race and ethnicity was estimated and tested for each subgroup.

All analyses were conducted using SAS Enterprise Guide version 7.15 (Cary, NC), SUDAAN 11.0.1 software (Research Triangle Park, NC), and R software 3.5.2 (Vienna, Austria) Medflex package (Steen et al., 2017). Complex sample design and survey weights were accounted for to make inference to the NYC adult population. Statistical significance was determined by a two-sided p-value <0.05.

3. Results

We found that 12% of New York City adults lived in subsidized housing, 16% lived in crowded housing, and 39% lived in high poverty neighborhoods (Table 1). Higher proportions of Black and Latino New Yorkers lived in subsidized housing (23% and 18%, respectively) compared with White residents (4%). Similarly, a higher proportion of Black and Latino residents lived in crowded housing (17% and 22% compared with White residents (11%) and more than half of all Latino and Black New Yorkers lived in high poverty neighborhoods (54% and 56%, respectively), compared with only 24% of White residents. These racial and ethnic disparities, except for differences in crowding between Black and White residents, remained after accounting for potential confounding (data not shown).

A higher proportion of those 65 years and older lived in subsidized housing compared with younger age groups. While 42% of households with children were crowded, only 2% of those without children were crowded. Additionally, foreign-born individuals were more likely to live in crowded housing than U.S.-born individuals (20% vs 12%) though there were no meaningful differences between these two groups in subsidized housing or neighborhood poverty. A higher proportion of people with underlying health conditions lived in subsidized housing than those without such conditions (17% vs 7%). This disparity did not exist for crowded housing or neighborhood poverty. Only a small proportion of employed persons lived in subsidized housing, whereas nearly half of those who were unemployed or out of the labor force lived in high poverty neighborhoods.

We observed racial and ethnic disparities in seropositivity of SARS-CoV-2 antibodies (Table 2). The seropositivity for Black and Latino residents (30.7%, 95% CI = 21.9–41.2 and 30.7%, 95% CI = 24.1–38.2, respectively) was higher than it was for White residents (17.4%, 95% CI = 12.5–23.7). After accounting for potential confounding, prevalence ratios of COVID-19 seropositivity were higher for Black (Adjusted Prevalence Ratio (APR) = 1.74, 95% CI = 1.10, 2.73) and Latino (APR = 1.58, 95% CI = 1.05, 2.37) New Yorkers compared with White New Yorkers.

The negative association between subsidized housing and seropositivity was not statistically significant. We observed higher SARS-CoV-2 seropositivity among those living in crowded housing (33.2%, 95% CI = 23.9–44.1) compared with those not in crowded housing (22.6%, 95% CI = 18.8–27.0) and among residents in high poverty neighborhoods (31.6%, 95% CI = 25.4–38.6) versus low-medium poverty neighborhoods (20.2%, 05% CI = 16.0–25.3). We also observed higher seropositivity prevalence ratio for both living in crowded housing (APR = 1.48, 95% CI = 1.03–2.12) and high poverty neighborhoods (APR = 1.54, 95% CI = 1.12–2.11).

According to the causal mediation analysis for subsidized housing residence (Table 3), excess burden of COVID-19 among Latino versus White New Yorkers (APR = 1.58, 95% CI = 1.05, 2.37) further increased if the prevalence of living in subsidized housing was fixed at the level that would be observed among White New Yorkers (PR for natural direct effect = 1.67, 95% CI = 1.39, 2.01). Similarly, higher seropositivity further increased among Black versus White New Yorkers if the prevalence of living in subsidized housing was fixed at the level that would be observed among White New Yorkers (APR = 1.74, 95% CI = 1.10, 1.74 vs PR for natural direct effect = 1.88, 95% CI = 1.53, 2.30). However, the natural indirect effect was <1. Although it was not statistically

Table 1
Demographic and health characteristics by housing among adults living in New York City, June–October 2020.

	Subsidized housing*	Crowded housing**	High neighborhood poverty†
	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)
Total	12.1 (9.5, 15.3)	15.7 (12.7, 19.1)	38.9 (34.9, 43.1)
Race and ethnicity			
Asian or Pacific Islander	6.5 (2.4, 16.4)	16.7 (10.1, 26.5)	26.8 (16.91, 39.8)
Black of African American	22.9 (15.5, 32.4)	16.5 (10.1, 26.0)	56.0 (45.7,65.8)
Latino or Hispanic	18.1 (12.6, 25.4)	21.8 (16.0, 29.0)	54.1 (46.4, 61.6)
White	4.2 (2.2, 7.7)	10.9 (7.0, 16.5)	23.7 (17.9, 30.6)
Others	1.4 (0.2, 10.1)	5.3 (1.1, 22.2)	44.1 (20.5, 70.7)
Age			
18–24	9.0 (4.4, 17.6)	13.6 (7.9, 22.2)	45.6 (35.1, 56.5)
25–44	6.8 (3.9, 11.8)	17.9 (12.9, 24.4)	39.9 (32.7, 47.6)
45–64	14.1 (10.1, 19.5)	18.4 (13.4, 24.7)	35.4 (29.5, 41.8)
65+	22.6 (14.5, 33.5)	9.0 (4.0, 19.0)	39.8 (30.3, 50.1)
Sex assigned at birth			
Male	9.7 (6.3, 14.7)	14.8 (10.7, 20.2)	35.8 (29.7, 42.3)
Female	13.9 (10.4, 18.4)	16.4 (12.6, 21.2)	43.2 (37.7, 48.9)
Nativity			
US-born	12.7 (9.3, 17.2)	12.2 (8.7, 16.8)	38.6 (33.2, 44.4)
Foreign-born	11.4 (7.7, 16.4)	20.2 (15.6, 25.7)	41.2 (35.0, 47.7)
Marital status			
Single and never married	12.7 (8.4,18.7)	10.0 (6.4, 15.3)	42.2 (34.9, 49.9)
Married	5.4 (3.0, 9.6)	24.2 (18.5, 31.1)	32.2 (26.1, 39.0)
Living with a partner (but not married)	15.6 (7.4, 30.0)	21.4 (11.6, 36.1)	53.8 (38.7, 68.2)
Widowed	26.5 (13.2, 46.1)	4.9 (1.5, 15.0)	44.0 (28.4, 60.8)
Divorced or separated	19.4 (12.4, 29.1)	10.7 (5.6, 19.6)	43.2 (33.5, 53.5)
Children living in household			
Yes	16.1 (11.0, 22.9)	42.2 (35.0, 49.8)	45.0 (37.7, 52.6)
No	10.1 (7.5, 13.6)	2.4 (1.4, 4.3)	37.2 (32.4, 42.4)
Employment status			
Employed	7.8 (5.2, 11.5)	15.0 (11.4, 19.4)	34.9 (29.6, 40.6)
Not employed	15.7 (9.1, 25.7)	16.5 (9.9, 26.1)	46.8 (36.3, 57.5)
Not in labor force	19.1 (13.4, 26.5)	16.8 (11.2, 24.4)	46.1 (38.1, 54.3)
Health insurance			
Yes	11.8 (9.2, 15.1)	14.9 (12.0, 18.5)	39.4 (35.2, 43.8)
No	16.9 (7.6, 33.4)	23.4 (12.9, 38.5)	46.3 (31.7, 61.6)
Any underlying health condition			
Yes	17.4 (13.2, 22.6)	15.6 (11.5, 20.7)	40.2 (34.5, 46.1)
No	7.1 (4.4, 11.1)	15.7 (11.9, 20.6)	39.5 (33.6, 45.7)
Working from home			
Yes	3.1 (1.3, 7.3)	8.3 (5.2, 13.1)	28.3 (22.0, 35.6)
No	13.1 (8.8,19.0)	21.2 (15.8, 27.8)	43.6 (36.3, 51.2)

(continued on next page)

Table 1 (*continued*)

	Subsidized housing*	Crowded housing**	High neighborhood poverty†
	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)
Not employed	19.1 (13.4, 26.5)	16.8 (11.2, 24.4)	46.1 (38.1, 54.3)

* Subsidized housing was defined as residing in a NYC housing authority (NYCHA) unit or receiving rental assistance such as Section 8.

** Crowded households were those with 5 or more persons residing in one unit/household.

† High neighborhood poverty was defined as neighborhoods where ≥20% of households had income below the federal poverty line.

Table 2
SARS-CoV-2 seropositivity and adjusted* prevalence ratios among New York City adults, June–October 2020.

Characteristic	Weighted % positive (95% CI)	APR (95% CI)
Race and ethnicity		
Black or African American	30.7 (21.9–41.2)	1.74 (1.10–2.73)
Latino	30.7(24.1–38.2)	1.58 (1.05–2.37)
White	17.4 (12.5–23.7)	1.00
Housing type		
Subsidized housing**	20.4 (12.5–31.6)	0.75 (0.45–1.25)
Other housing	24.6 (20.7–28.9)	1.00
Crowded housing		
Household size ≥5	33.2 (23.9–44.1)	1.48 (1.03–2.12)
Household size <5	22.6 (18.8–27.0)	1.00
Neighborhood poverty†		
High poverty	31.6 (25.4–38.6)	1.54 (1.12–2.11)
Low-medium poverty	20.2 (16.0–25.3)	1.00

* Adjusted for age, sex assigned at birth, marital status, health insurance status, underlying physical health conditions, employment status, and nativity.

** Subsidized housing was defined as residing in a NYC housing authority (NYCHA) unit or receiving rental assistance such as Section 8.

† High neighborhood poverty was defined as neighborhoods where ≥20% of households had income below the federal poverty line.

Table 3
Causal mediation analysis* of housing on the association between race and ethnicity and COVID-19 seropositivity among NYC adults, June–October 2020.

Race and ethnicity by housing mediator	Natural direct effect PR (95% CI)	Natural indirect effect PR (95% CI)	Percent mediated
Subsidized housing**			
Black or African American vs white	1.88 (1.53–2.30)	0.96 (0.80–1.16)	−9%
Latino vs white	1.67 (1.39–2.01)	0.95 (0.80–1.13)	−14%
Crowded housing†			
Black or African American vs white	1.74 (1.42–2.13)	1.03 (0.86–1.23)	11%
Latino vs white	1.51 (1.26–1.82)	1.04 (0.88–1.24)	7%
Neighborhood poverty†			
Black or African American vs white	1.64 (1.33–2.02)	1.07 (0.88–1.29)	15%
Latino vs white	1.38 (1.14–1.67)	1.07 (0.90–1.28)	20%

Abbreviations: PR = Prevalence ratio; CI = confidence interval.

* Adjusted for age, sex assigned at birth, marital status, health insurance status, underlying physical health conditions, employment status, and nativity.

** Subsidized housing was defined as residing in a NYC housing authority (NYCHA) unit or receiving rental assistance such as Section 8.

† Crowded households were those with 5 or more persons residing in one unit/household. †Neighborhood poverty was defined as neighborhoods where ≥20% of households had income below the federal poverty line.

significant, this indicated that living in subsidized housing could be associated with lower seropositivity if we hypothetically assume that everyone living in subsidized housing is a Black or Latino adult. The percent of the observed racial and ethnic disparities in seropositivity mediated by subsidized housing residence was −14% (Latino versus White) and − 9% (Black versus White). While the natural direct effects for crowding and neighborhood poverty for Latino or Black versus White were smaller than the overall disparities in seropositivity, the natural indirect effects were >1. These indicated that crowding and neighborhood poverty contributed to racial and ethnic disparities in seropositivity, although these were not statistically significant.

Lastly, focusing on adults who were employed during the study period, we tested effect modification by working from home status. The magnitude of the association between race and ethnicity and seropositivity was higher among those who worked outside the home versus worked from home (data not shown). We observed statistically significant seropositivity disparities between Black and White residents among those who worked outside the home (PR = 2.36, 95% CI = 1.04, 5.33).

4. Discussion

Our analysis reveals, in concordance with existing literature, that race and ethnicity are associated with an increased risk for COVID-19 infection (Mahajan and Larkins-Pettigrew, 2020; Yaya et al., 2020). We found that Black and Latino residents had a higher prevalence of COVID-19 antibodies than White residents. Living in crowded homes and living in high-poverty neighborhoods were also associated with higher COVID-19 seropositivity; however, living in subsidized housing was not.

Contrary to existing literature that links subsidized housing to poor health outcomes, our causal mediation analysis indicated that living in subsidized housing could be a protective factor against COVID-19 seropositivity. We hypothesize that subsidized housing, more specifically NYCHA residence, may improve social environment (e.g., receiving support from neighbors in times of need), which in turn may generate positive health effects. To our knowledge, no studies exist that explore the role of social environment in reducing or increasing the risk of COVID-19 among individuals from particular racial and ethnic groups. Assuming that persons living in NYC subsidized housing are more likely to live in poor housing conditions (New York State Department of Health, 2018; Gates, 2020; Gandour, 2022), these findings contrast with those of Ahmad et al. (2020) who concluded that households with poor housing conditions had a higher risk of COVID-19; however, there are key differences between the two studies. Ahmad et al., analyzed publicly available county-level data on poor housing conditions from 2010 to 2014 and county-level COVID-19 case data. Our analysis examined individual-level seropositivity and housing-related data, allowing us to account for potential confounding. Additionally, Ahmad et al. defined poor housing conditions as one or more of the following: overcrowding, high housing cost, incomplete kitchen facilities, or incomplete plumbing facilities whereas we tested subsidized housing residence and crowding as separate mediators. Lastly, our seropositive outcome included asymptomatic cases whereas Ahmad and colleagues only included symptomatic cases.

Several studies have concluded that household size is correlated with increased COVID-19 transmission (Metlay et al., 2021; Sun et al., 2021). In a cohort study of individuals living in Leicester, UK, the authors found that area-based estimated household size was associated with polymerase chain reaction positivity three weeks following government mandated mobility restrictions (i.e., "lockdown") but not before (Martin et al., 2020). Another study concluded that lockdown interventions in Hunan, China increased transmission risk in households and families (Sun et al., 2021). Models by Liu et al. (2021) suggest that larger household sizes were associated with both increased region-level COVID-19 incidence and individual-level infection risk during lockdown.

While our study did not examine seropositivity prevalence during lockdown months in NYC (March–May 2020), our results support these previous findings' conclusion that household size was associated with

increased COVID-19 prevalence. These results have important implications for creating public health policy that addresses how to quarantine at home safely and effectively in large households. One solution could be to implement interventions similar to the NYC Health and Hospitals Take Care Hotel Program, which transformed over 700 hotel rooms to meet people's isolation needs, including clinical monitoring and case management (Jordan-Martin et al., 2020). Under this program, any New Yorker who tested positive for COVID-19 or may have been exposed to the virus was eligible for a free hotel room for up to 10 days (Seiferth et al., 2021).

Living in high-poverty neighborhoods compared to low- or medium-poverty neighborhoods was also significantly associated with increased COVID-19 seropositivity. Additionally, a higher percentage of non-Latino Black and Latino individuals lived in high-poverty neighborhoods compared with White individuals in NYC. Our findings are consistent with those of other studies looking at state and local levels, further supporting the conclusion that COVID-19 positivity rates are higher among communities with majority non-White residents and communities with high poverty rates (Li and Yuan, 2021; Sehra et al., 2020; Millett et al., 2020).

Several studies posit that historic and present-day racial residential segregation is the most salient factor influencing disparate COVID-19 outcomes (Li and Yuan, 2021; Lieberman-Cribbin et al., 2020). Patterns of discrimination have left many communities of color without access to essential resources that would mitigate the social, physical, and economic burden of the COVID-19 pandemic. For instance, according to NYC DOHMH data from March–April 2020, the availability of COVID-19 tests increased proportionally to the number of White residents living in specific NYC ZIP code tabulation areas, but not in proportion to a socioeconomic status index score (Lieberman-Cribbin et al., 2020). Our causal mediation analysis provides evidence that neighborhood-level poverty contributed to observed racial and ethnic disparities in COVID-19 outcomes. More research is needed to understand the causal links between living in high-poverty neighborhoods and increased COVID-19 prevalence.

According to our effect modification analysis, we found statistically significant COVID-19 disparities between Black and White individuals among those who worked outside the home. Our finding provides empirical support for the argument that increased risk of COVID-19 among Black and Latino persons is attributable to occupational segregation, whereby a higher percentage of people of color are employed in occupations with more frequent exposures to infected persons because of proximity to others (Hawkins, 2020).

5. Limitations and strengths

Our study has some limitations. First, CHS data were self-reported, which might be affected by recall and social desirability bias, specifically affecting recall of antibody test results, and potentially underreporting of household sizes. However, an analysis of our respondents who provided both a blood sample and a self-reported test result found that 89% of the results were in concordance (Parrott et al., 2021). Moreover, other studies have found self-reported medical test results for influenza and HIV to be valid (King et al., 2018; McCusker et al., 1992).

Second, the inclusion of self-reported antibody tests may have overestimated antibody prevalence by including individuals who were positive at the time of testing but seroconverted by the start of our study period (Parrott et al., 2021). However, this is less of an issue with our serosurvey since the period between infection and the serosurvey was relatively short. Third, research shows that some individuals with asymptomatic or mild SARS-CoV-2 infections may mount a weaker immune response, which leads to development of fewer antibodies or to a faster waning of antibodies compared to those with severe illness (Bajema et al., 2021; Choe et al., 2021; Long et al., 2020; Shioda et al., 2021). Although the serological data from this survey were not meant to estimate cumulative incidence of SARS-CoV-2 infection, some relationships presented here may have been affected by uneven waning across racial and ethnic groups possibly caused by disparities in disease severity.

Another limitation with our study is that we only tested three mediators. There are likely other mediators that could explain racial and ethnic disparities not captured by our data. For instance, working from home is a potential mediator; however, our sample size was not large enough to conduct a mediation analysis since many people in our sample were unemployed or not in the workforce. Additionally, our racial and ethnic analysis excluded two categories (Asian or Pacific Islander and "other") due to small sample sizes. Lastly, we could not assess whether a respondent lived in a unit that was crowded relative to the number of occupants per bedroom or whether they could successfully quarantine or isolate in their home; rather we could only analyze total household size.

Despite these limitations, our study has several strengths. First, we uniquely linked COVID-19 seropositivity data with survey data, allowing us to analyze potential mediating variables between race and ethnicity and COVID-19 outcomes. Second, survey data were collected using complex sample design and were representative of all NYC adults. Third, since we queried seropositivity rather than diagnoses, our results were less likely to be biased by disparate and changing COVID-19 testing policies and access during the study period.

6. Conclusion

We observed racial and ethnic disparities in COVID-19 seropositivity rates among NYC adults between June–October 2020. Our results demonstrate that living in high-poverty neighborhoods and living in crowded homes contributes to an excess burden of COVID-19 among Black and Latino New Yorkers. Conversely, we found that living in subsidized housing could potentially mitigate the risk of COVID-19 infection among Black and Latino New Yorkers. Given our understanding of the roles of crowding and neighborhood poverty in shaping racial and ethnic COVID-19 inequities, our findings highlight the importance of NYC's public health efforts to allocate resources (e.g., increased access to testing, vaccination, and treatment) to high poverty neighborhoods and alleviate crowding via hoteling. The observed protective impact of subsidized housing suggests that housing subsidies are important for addressing health inequity and should be expanded.

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CRediT authorship contribution statement

Isabel Gouse: Supervision, Conceptualization, Visualization, Formal analysis, Writing – original draft. **Sarah Walters:** Writing – review & editing. **Sara Miller-Archie:** Formal analysis, Writing – review & editing. **Tejinder Singh:** Data curation, Formal analysis. **Sungwoo Lim:** Supervision, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

None.

Data availability

The authors do not have permission to share data.

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