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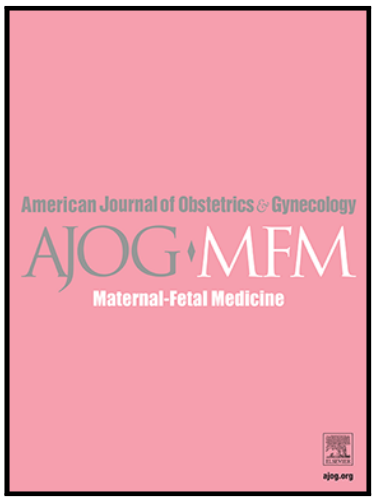

The influence of structural racism, pandemic stress, and SARS-CoV-2 infection during pregnancy with adverse birth outcomes

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The influence of structural racism, pandemic stress, and SARS-CoV-2 infection during pregnancy with adverse birth outcomes

Teresa Janevic, PhD[1,2,3], Whitney Lieb, MD, MPH[1,2,3], Erona Ibroci, MPH[4], Jezelle Lynch, MPH[3], Molly Lieber, MPH, LCSW,[1] Nina M. Molenaar, MD, PhD[4], Anna-Sophie Rommel, PhD[4], Lotje de Witte, MD, PhD[4], Sophie Ohrn[1], Juan Manuel Carreño[5], Krammer Serology Core Study Group[5,*], Florian Krammer, PhD[5], Lauren B. Zapata, PhD[6], Margaret Christine Snead, PhD[6], Rachel I. Brody, MD, PhD[7], Rebecca H. Jessel, MD[1], Stephanie Sestito, MPH[1], Alan Adler, MD[1], Omara Afzal, DO[1], Frederieke Gigase[4], Roy Missall[4], Daniel Carrión, PhD, MPH[8], Joanne Stone, MD[1], Veerle Bergink, MD, PhD[1,2,4] Siobhan M. Dolan, MD, MPH, MS, MBA[1,2], Elizabeth A. Howell, MD, MPP[9]

Affiliation[1]

[1] Department of Obstetrics, Gynecology and Reproductive Science, Icahn School of Medicine at Mount Sinai, New York City, NY, USA

[2] Blavatnik Family Women's Health Research Institute, Icahn School of Medicine at Mount Sinai, New York City, NY, USA

[3] Department of Population Health Science and Policy, Icahn School of Medicine at Mount Sinai, New York City, NY, USA

[4] Department of Psychiatry, Icahn School of Medicine at Mount Sinai, New York City, NY, USA

[5] Department of Microbiology, Icahn School of Medicine at Mount Sinai, New York City, NY, USA

[6] COVID-19 Response, Centers for Disease Control and Prevention, Atlanta, GA, USA

[7] Department of Pathology, Molecular and Cell Based Medicine, Icahn School of Medicine at Mount Sinai, New York City, NY, USA

[8] Department of Environmental Health Sciences, Yale School of Public Health, New Haven, CT, USA

[9] Department of Obstetrics and Gynecology, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA, USA

*Study group members: Dominika Bielak, Hisaaki Kawabata, Ariel Raskin, Gagandeep Singh, Johnstone Tcheou

Corresponding author

Teresa Janevic, MPH PhD, Icahn School of Medicine at Mount Sinai, 1 Gustave Levy Place, Box 1077, New York, NY 10029, Teresa.janevic@mountsinai.org

Disclosure statement

Mount Sinai has licensed serological assays to commercial entities and has filed for patent protection for serological assays. F.K. is listed among inventors on the pending patent application. The other authors have nothing to declare.

Disclosure statement

One author is listed among inventors on the pending patent application. The other authors have nothing to report.

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Condensation

Short title: Structural racism, COVID-19, and adverse birth outcomes

At a Glance

A. Why was this study conducted?

- To understand how existing structures of racism and socioeconomic inequity, as well as pandemic-related social and economic stressors, influence SARS-CoV-2 infection during pregnancy and adverse birth outcomes.

B. What are the key findings?

- Structural racism and community unemployment were associated with both SARS-CoV-2 infection and preterm birth. The adjusted relative risk of preterm birth for high vs. low structural disadvantage was 1.7 (95%CI=1.0, 2.9), for racial-economic segregation 2.0

(95%CI=1.3, 3.2), and for community unemployment 1.6 (95%CI=1.0, 2.8). No associations were found for SGA.

- We found no interaction between SARS-CoV-2 infection and structural racism or social-economic stress on birth outcomes.

What does this study add to what is already known?

- During the COVID-19 pandemic in New York City, structural racism and community unemployment were associated with increased risk of SARS-CoV-2 infection and PTB.
- SARS-CoV-2 infection did not explain or exacerbate associations between structural racism and community unemployment with PTB.

Abstract

Background: Structural racism and pandemic-related stress from the COVID-19 pandemic may increase risk of adverse birth outcomes.

Objective: Our objective was to examine associations between neighborhood measures of structural racism and pandemic stress with three outcomes: SARS-CoV-2 infection, preterm birth (PTB) and delivering a newborn small-for-gestational-age (SGA). Our secondary objective was to investigate the joint associations of SARS-CoV-2 infection during pregnancy and neighborhood measures on PTB and SGA.

Study Design: We analyzed data for 967 patients from a prospective cohort of pregnant persons in New York City, comprised of 367 White persons (38%), 169 Black persons (17%), 293 Latina persons (30%), 87 Asian persons (9%), 41 persons of unknown race-ethnicity (4%), and 10 of unknown race-ethnicity (1%). We evaluated structural racism (social/built structural

disadvantage, racial-economic segregation) and pandemic-related stress (community COVID-19 mortality, community unemployment rate increase) in quartiles by zip code. SARS-CoV-2 serologic enzyme-linked immunosorbent assay was performed on blood samples from pregnant persons. We ascertained preterm birth (PTB) and small-for-gestational age (SGA) from an electronic medical record database. We used log-binomial regression with robust standard error for clustering by zip code to estimate associations of each neighborhood measure separately with three outcomes: SARS-CoV-2 infection, PTB, and SGA. Covariates included maternal age, parity, insurance status, and BMI. Models with PTB and SGA as the dependent variables additionally adjusted for SARS-CoV-2 infection.

Results: 193 (20%) persons were SARS-CoV-2 seropositive, and the overall risk of PTB and SGA were 8.4% and 9.8%, respectively. Among birthing persons in neighborhoods in the highest quartile of structural disadvantage (n=190), 94% were non-White, 50% had public insurance, 41% were obese, 32% were seropositive, 11% delivered preterm, and 12% delivered an infant SGA. Among birthing persons in neighborhoods in the lowest quartile of structural disadvantage (n=360), 39% were non-White, 17% had public insurance, 15% were obese, 9% were seropositive, 6% delivered preterm, and 10% delivered an infant SGA. In adjusted analyses structural racism measures and community unemployment were associated with both SARS-CoV-2 infection and PTB, but not SGA. High vs. low structural disadvantage was associated with an adjusted relative risk (aRR) of 2.6 for infection (95% Confidence Interval (CI)=1.7, 3.9) and 1.7 for PTB (95%CI=1.0, 2.9); high vs. low racial-economic segregation was associated with aRR of 1.9 (95% CI=1.3, 2.8) for infection and 2.0 (95%CI=1.3, 3.2) for PTB; high vs. low community unemployment increase was associated with aRR of 1.7 (95% CI=1.2, 1.5) for infection and 1.6 (95%CI=1.0, 2.8) for PTB. COVID-19 mortality rate was associated with

SARS-CoV-2 infection, but not PTB or SGA. SARS-CoV-2 infection was not independently associated with birth outcomes. We found no interaction between SARS-CoV-2 infection and neighborhood measures on PTB or SGA.

Conclusions: Neighborhood measures of structural racism were associated with both SARS-CoV-2 infection and PTB, but these associations were independent and did not have a synergistic effect. Community unemployment rate increases were also associated with an increased risk of PTB independently of SARS-CoV-2 infection. Mitigating these factors might reduce the impact of the pandemic on pregnant people.

Keywords: preterm birth, small-for-gestational-age, COVID-19, racism, unemployment, SARS-CoV-2

Introduction

The coronavirus disease 2019 (COVID-19) pandemic is exacerbated by pre-existing structures of racism and socioeconomic inequity.[1] In March 2020, New York City (NYC) emerged as the first epicenter of the pandemic in the US and one of the first regions where stark pandemic-related inequities became apparent, including among pregnant people.[2] Black and Latina pregnant persons are more likely to test positive for the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) at delivery than non-Latina White persons,[3–5] and pregnant Black and Latina pregnant persons have increased risks for ICU admission and invasive ventilation compared with non-pregnant Black and Latina pregnant persons.[6] Many studies have found that asymptomatic or mild SARS-CoV-2 infection does not seem to increase risk of adverse birth outcomes, but moderate to severe COVID-19 is associated with higher rates of adverse birth

outcomes including stillbirth and PTB.[7–10] It is plausible that SARS-CoV-2 infection interacts synergistically with social determinants of health to increase risk of adverse birth outcomes, potentially explaining disparate findings across study populations, but this hypothesis has not been rigorously tested.

Besides direct health effects from SARS-CoV-2 infection, persons of color are also more likely to experience pandemic-related psychosocial and economic impacts during and after pregnancy.[11,12] Further, evidence suggests that individuals reporting high levels of perceived prenatal stress during the pandemic have a higher risk of preterm birth (PTB) and delivering infants small for gestational age (SGA).[13] Stress might also operate at the community-level. Scholars have described the "collective trauma" of the COVID-19 pandemic on communities, particularly communities of color.[14] Understanding the impact of structural and social changes due to the pandemic on perinatal outcomes has been identified as a research priority.[15]

The purpose of this study is to understand how existing structures of racism and socioeconomic inequity, as well as pandemic-related social and economic stressors, influence SARS-CoV-2 infection during pregnancy and adverse birth outcomes. We analyzed data from 967 persons from the Generation C study, a prospective pregnancy cohort. Our first objective was to examine associations between neighborhood measures of structural racism and pandemic stress with three primary outcomes: SARS-CoV-2 infection, PTB and delivering a newborn SGA. Our second objective was to investigate the joint associations of SARS-CoV-2 infection during pregnancy and neighborhood measures on adverse birth outcomes.

Materials and Methods

Data source and study population

The Generation C Study is a prospective cohort study of SARS-CoV-2 infection during pregnancy, details of which have been previously published.[16] Birthing patients aged 18 years or older receiving obstetrical care in the Mount Sinai Health System were recruited starting in April 2020. We obtained informed consent per study protocol approved by Icahn School of Medicine at Mount Sinai Program for the Protection of Human Subjects. The activity was reviewed by the US Centers for Disease Control and Prevention (CDC) and was conducted consistent with applicable federal law and CDC policy. Patients were invited by clinical or research staff to participate at either a prenatal care visit or upon admission to labor and delivery. We analyzed blood samples collected of 1137 participants expected to deliver in 2020 based on 40 week gestational length. We limited the sample to live births and excluded participants with twin pregnancies and those who did not reside in NYC, resulting in an analytic sample of 967 persons residing in 144 NYC zip codes.

Exposures

Structural racism measures

We used an established index to quantify structural disadvantage leading to increased risk of infection.[17] In brief, the index was created using Bayesian Weighted Quantile Sums (BWQS) regression using 2018 U.S. census data and publicly available NYC SARS-CoV-2 test data as of May 7, 2020 from NYC Open and New York Open.[18] The index, henceforth referred to as the Covid Disadvantage Index (CDI), is composed of 10 indicators of the built and social environment, weighted for their contribution to variation in the NYC SARS-CoV-2 infection rate, e.g. the number of people in a household, the proportion of the population who are essential

workers, the proportion of the population who rely on public transit to commute, the proportion of people without health insurance, median income, percent working from home, percent unemployed, population density by residential volume, and number of grocers per 1,000 residents. The CDI has not previously been tested in association with SARS-CoV-2 seropositivity.

The Index of Concentration at the Extremes (ICE) is a measure of racial and economic segregation that portrays a form of extreme segregation known as spatial polarization.[19] It measures the concentration of Black, low-income households relative to White, high-income households. The ICE has been studied as a proxy for structural racism in association with adverse maternal and infant outcomes.[20–22] We used ICE measures based on 2014-2018 American Community Survey (ACS) data made available by the Public Health Disparities Geocoding Project.[23]

Pandemic Community Stress Measures

We use the term "community stress" to represent neighborhood-level social and economic impacts of the pandemic. The first measure we used was the COVID-19 mortality rate as a marker of community trauma due to death of neighbors, friends, and loved ones. We obtained COVID-19 mortality rates by zip code as of December 2020 from the NYC Department of Health and Mental Hygiene website. The second measure of pandemic stress was increased unemploymentrate. We obtained monthly unemployment rates from Catalist, LLC[24] by census tract and converted them to zip code using the U.S. Department of Housing and Urban Development (HUD) crosswalk.[25] We calculated community unemployment rate changes by subtracting December 2020 from January 2020.

Outcomes

Measures of SARS-CoV-2 infection

We obtained blood specimens from pregnant patients during routine prenatal care and/or admission to labor and delivery. We analyzed SARS-CoV-2 antibody titers using serologic enzyme-linked immunosorbent assays (ELISA).[26] The test has high sensitivity (95.0%) and specificity (100%), as determined with an initial validation panel of samples, with a positive predictive value of 100%, and a negative predictive value of 97.0%. Although SARS-CoV-2 vaccines became available to health care workers in New York in early December 2020, it is unlikely that any participant was vaccinated prior to serum collection in this analysis.

MSHS conducts universal molecular testing for pregnant people prior to admission as standard care.[27] A nucleic acid reverse transcription polymerase chain reaction (RT-PCR) test to detect SARS-CoV-2 is performed on a nasopharyngeal RT-PCR swab sample using the Roche Cobas 6800 System. All patients with a positive RT-PCR result (n=25) also had a positive SARS-CoV-2 antibody result, and were categorized together as "seropositive".

Preterm Birth and Small-for-Gestational-Age

We obtained gestational age and birth weight at delivery from the electronic medical record (EMR). PTB was defined as delivery prior to 37 completed weeks gestation based on the best clinical estimate of gestational age. SGA was calculated at the 10^{th} sex-specific percentile based on the 2017 U.S. birth standard.[28]

Covariates

Race and ethnicity were based on participant self-report in the EMR and categorized: White, non-Latina White (henceforth "White"); Black, non-Latina (henceforth "Black"); Latina; Asian, non-Latina; and Other, non-Latina. We further categorized all categories except non-Latina White as Black, Indigenous, and people of color (BIPOC). We extracted covariates from

the EMR: maternal age (continuous), insurance type (private/self-pay, public), parity (nulliparous, multiparous), pre-pregnancy BMI (underweight [<18.5 kg/m^2], normal [18.5-24.9], overweight [25.0-29.9], obese [>=30]).

Statistical analysis

We divided neighborhood measures into quartiles based on the distribution in the analytic sample and used choropleth maps to describe the geographic distribution (Supplemental Figure 1). We used log-binomial marginal regression with a robust variance estimator to account for clustering by zip code to estimate the relative risk for each outcome (SARS-CoV-2 seropositivity, PTB, SGA) by neighborhood measure quartile. We tested for the presence of spatial autocorrelation using Moran's I and Geary's C, using the centroid coordinates for zip code tabulation areas.[29,30] The residuals from associations between both CDI and ICE with seropositivity showed spatial correlation using Geary's C (p=0.007 for CDI, p=0.003 for ICE), but not Moran's I (p=0.32 for CDI, p=0.74 for ICE). To determine if accounting for this spatial correlation influenced our estimates, we estimated multilevel log binomial models with a Gaussian covariance structure. Estimates and standard errors were similar within two decimal places, so we elected to use the marginal model with an unstructured covariance matrix across models. Covariates were selected based on examining theoretical causal relationships pictorially in a directed acyclic graph, i.e. factors which are plausibly associated with both neighborhood measures and outcomes, but not on the causal pathway.[31] We did not include race/ethnicity as a covariate in adjusted models because we view race/ethnicity as a social construct, a downstream effect of structural racism,[32] and therefore inclusion in multivariable models would dilute the influence of structural racism. We instead stratified associations by non-Latina White vs. BIPOC and tested an interaction term in the total population model. We did not have sufficient sample

size to stratify by BIPOC groups; although we acknowledge that this category might encompass a diverse range of exposure to structural racism and pandemic stress.

To test the joint association of each neighborhood measure and SARS-CoV-2 infection during pregnancy with adverse birth outcomes, we collapsed structural racism and pandemic stress measures into dichotomous categories, then created a 4-level variable to examine each joint association (e.g., high stress/seropositive, high stress/seronegative, low stress/seropositive, low-stress/seronegative). We then tested associations between these joint association terms and adverse birth outcomes.

We performed several sensitivity analyses. For analyses with SGA as the outcome, we excluded preterm infants (n=81) to disentangle preterm birth and SGA so any observed associations would better reflect intra-uterine growth restriction. We also limited analyses to persons for whom measures were collected prospectively, i.e., persons enrolled before 37 weeks.

Results

Participant characteristics

In our analytic sample, 193 (20%) persons tested positive and 774 (80%) tested negative for SARS-CoV-2 antibodies. Participant demographic and obstetric characteristics are shown overall and by level of structural disadvantage in Table 1. A higher proportion of persons in Q1 (high disadvantage index) self-identified as Black (29%) or Latina (56%) while a higher proportion of persons in Q4 (low disadvantage index) self-identified as non-Latina White (61%). More persons in Q1 had public health insurance (50%) than persons in Q4 (17%). Compared to persons in Q4, a higher proportion of persons in Q1 were overweight or obese and were nulliparous.

SARS-CoV-2 seropositivity

In unadjusted analyses, across neighborhood measures, higher risk of SARS-CoV-2 seropositivity during pregnancy was seen for Q1 compared to Q4 (Table 2). Q1 vs. Q4 risk ratios were 3.6 for structural disadvantage (95% CI=2.5, 5.2), 2.7 for racial-economic segregation (95% CI=1.9, 3.8), 2.3 for COVID-19 mortality rate (95% CI=1.6, 3.4), and 2.6 for increased community unemployment (95% CI=1.8, 3.7). Risk ratios were partially attenuated in adjusted analyses (aRR [adjusted risk ratio] for CDI Q1 vs. Q4=2.6, 95% CI=1.7, 3.9; aRR for ICE Q1 vs. Q4=1.9, 95% CI=1.3, 2.8; aRR for COVID-19 mortality Q1 vs. Q4=1.8, 95% CI=1.2, 2.6); and aRR for community unemployment rate increase Q1 vs. Q4= 1.7, 95% CI=1.2, 2.5). The Q4 vs. Q1 adjusted risk ratios were of greater magnitude for BIPOC than for non-Latina White persons for all measures (Table 2), but the interaction term was statistically significant only for community COVID-19 mortality rate (P<0.001).

Preterm birth

Overall, 8.4% of births were preterm. SARS-CoV-2 seropositivity was not associated with PTB (Supplemental Figure 2). Risk ratios for Q1 vs. Q4 in association with PTB were 1.8 for structural disadvantage (95% CI=1.1, 3.0), 2.2 for racial-economic segregation ICE (95% CI=1.4, 3.4), 1.7 for COVID-19 mortality rate (95% CI=1.0, 2.8), and 1.8 for community unemployment rate increase (95% CI=1.1, 2.9) (Table 3). Risk ratios were partially attenuated in adjusted analyses. Among persons identifying as BIPOC, the magnitude of Q1 vs. Q4 adjusted risk ratios was diminished and confidence intervals overlapped 1 for all measures, with the exception of racial and economic segregation, for which the aRR remained of the same magnitude as the overall estimate (aRR=2.0, 95% CI=1.0, 4.0).

Small for gestational age

SARS-CoV-2 seropositivity was not associated with SGA (Supplemental Figure 2). In unadjusted and adjusted analyses, risk ratios for structural racism and pandemic stress measures and SGA (Q1, Q2, and Q3 vs. Q4) were null (Table 4).

Joint association analysis

For structural racism measures, pregnant individuals residing in "highly" (Q1) disadvantaged or segregated neighborhoods who were seropositive had the highest risk of PTB (Figure 1), but the joint association was not greater than the combined risk of each risk individually, so no evidence of interaction was present. For pandemic stress measures, no clear pattern of risk was found. Joint association risk ratios for SGA were uniformly null.

Sensitivity analysis

In the sensitivity analysis restricting SGA models to term infants, associations remained null (Supplemental Table 1). Results were also similar when restricting the sample to prospectively collected serum samples (Supplemental Table 2).

Comment

Principal findings

We found that markers of structural racism and inequities were associated with SARS-CoV-2 infection in pregnant persons in NYC. The same structural inequities were also associated with adverse birth outcomes; however, associations were not explained by SARS-CoV-2 infection. Community unemployment was also modestly associated with both SARS-CoV-2 infection and PTB. We did not find interaction between SARS-CoV-2 infection and structural measures of racism and pandemic stress on adverse birth outcomes. Overall, a pattern was seen in which non-Latina White pregnant persons in the most privileged neighborhoods had the lowest risk of adverse outcomes.

Results in the context of what is known

We found that neighborhood structural and socioeconomic inequities profoundly influenced the risk of SARS-CoV-2 infection, but that neighborhood inequity and infection did not work synergistically to worsen pregnancy outcomes. This finding adds to the body of evidence on structural racism and the COVID-19 pandemic.[33] Birthing persons in neighborhoods with a higher relative concentration of Black, low-income households and high structural disadvantage were more likely to have SARS-CoV-2 antibodies. This was true regardless of individual patient characteristics, including race/ethnicity. Most notably, our findings regarding community unemployment suggest that the economic crisis accompanying the COVID-19 pandemic was associated with PTB, consistent with existing evidence on the negative impact of unemployment and economic downturns on birth outcomes. Finch *et al*. found exposure to the Great Recession increased risk of PTB.[34] Similar associations have been reported between macroeconomic conditions and PTB.[35] Notably, pandemic economic stress and PTB in our cohort appeared to be higher for BIPOC persons. Black and Hispanic women in the COVID-19 pandemic were most affected by unemployment.[36] This differential impact of the economic crisis at the individual level could explain our findings.

Clinical Implications

Both structural racism and pandemic stress were associated with higher risk of PTB but did not appear to be worsened in combination with SARS-CoV-2 infection. A major goal of our analysis was to test if SARS-CoV-2 infection interacted with social vulnerability on the risk of adverse pregnancy outcomes, which might have in part explained conflicting findings regarding SARS-CoV-2 infection and PTB.[37] The mechanism supporting a potential synergistic effect is plausible. Both psychosocial stress in highly impacted neighborhoods and SARS-CoV-2

infection might trigger an inflammatory response in both the mother and fetus, which in turn might influence parturition or impaired fetal growth.[38] Our findings do not support this hypothesis. However, clinicians should be aware of the potential negative effects of structural racism and the economic crisis on patients.

Research Implications

A major challenge in researching adverse birth outcomes during the COVID-19 pandemic is that etiology is difficult to detect due to the likely co-occurrence of both protective and harmful factors. Protective factors due to COVID-19 related lockdown measures include, but are not limited to working from home, limited commuting, reduced physical stress, wearing of masks, all of which can decrease the risk of infection and environmental pollutants.[39] Others have suggested a potential decrease in iatrogenic PTB given reduced antepartum surveillance.[40] Additionally, policies to mitigate the economic impact of the pandemic such as enhanced unemployment benefits and eviction moratorium might also have lessened the stress of these structural factors and therefore buffered risk of PTB. Future research might test at the individual level if pregnant persons experiencing social and economic stressors such as unemployment were at higher risk of PTB.

Strengths and limitations

This analysis had several limitations. First, we did not have information on spontaneous vs. medically indicated PTB. However, both PTB subtypes might be elevated by SARS-CoV-2 seropositivity and/or social disadvantage.[41,42] Second, we had no information on the timing of SARS-CoV-2 infection; the antibody assays used did not indicate when an infection occurred. An important limitation is that did we have information on disease severity; it is possible that a synergistic effect of infection and disadvantage is limited to moderate or severe cases. We also

were not able to systematically capture PTB or SGA still births due to enrollment after 20 weeks gestation. Another limitation was the inability to robustly examine associations within all racial-ethnic subgroups, which would have allowed stronger testing of mechanisms. Finally, our prospective cohort was not population-based.

The study does have several strengths. The Generation C study leverages high numbers of infected patients and can classify patients as ever vs. never infected through antibody testing, which allows us to disentangle community stress exposures from infection. Further, the study population is diverse, with a substantial number of Black and Latina patients across neighborhood types. White patients, however, clustered in the more privileged neighborhoods and had low risk of adverse outcomes. This strong imprint of structural racism on our data created statistical limitations for some analyses, underscoring the need for COVID-19 research to focus within populations of those most affected—Black and Latina individuals. Further, NYC might not be representative of other urban populations. Also, out-migration of pregnant persons from NYC during the pandemic limits generalizability.[43]

Conclusions

In our study of pregnant persons in NYC, the same neighborhoods most affected by structural racism and pandemic stress experienced the highest risk of PTB. However, no evidence was found that SARS-CoV-2 infection and pandemic stress had synergistic effects on adverse birth outcomes. Nonetheless, our study demonstrates that pregnant persons of color are disproportionately impacted by SARS-CoV-2 infection and pandemic-related community stressors. Mitigating structural racism and socioeconomic inequity could reduce the impact of the pandemic on pregnant persons.

References

1. Webb Hooper M, Nápoles AM, Pérez-Stable EJ. COVID-19 and Racial/Ethnic Disparities. *JAMA - Journal of the American Medical Association*. 2020;323(24):2466-2467. doi:10.1001/jama.2020.8598

2. Tekbali A, Grünebaum A, Saraya A, McCullough L, Bornstein E, Chervenak FA. Pregnant vs nonpregnant severe acute respiratory syndrome coronavirus 2 and coronavirus disease 2019 hospital admissions: the first 4 weeks in New York. *American Journal of Obstetrics and Gynecology*. 2020;223(1):126-127. doi:10.1016/j.ajog.2020.04.012

3. Lokken EM, Taylor GG, Huebner EM, et al. Higher severe acute respiratory syndrome coronavirus 2 infection rate in pregnant patients. *American Journal of Obstetrics and Gynecology*. Published online February 16, 2021. doi:10.1016/j.ajog.2021.02.011

4. Janevic T, Glazer KB, Vieira L, et al. Racial/Ethnic Disparities in Very Preterm Birth and Preterm Birth before and during the COVID-19 Pandemic. *JAMA Network Open*. 2021;4(3). doi:10.1001/jamanetworkopen.2021.1816

5. Emeruwa UN, Spiegelman J, Ona S, et al. Influence of Race and Ethnicity on Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Infection Rates and Clinical Outcomes in Pregnancy. *Obstet Gynecol*. 2020;136(5):1040-1043. doi:10.1097/AOG.0000000000004088

6. Zambrano LD, Ellington S, Strid P, et al. *Update: Characteristics of Symptomatic Women of Reproductive Age with Laboratory-Confirmed SARS-CoV-2 Infection by Pregnancy*

Status — United States, January 22–October 3, 2020.; 2020. Accessed May 4, 2021. https://www.cdc.gov/coronavirus/2019-ncov/downloads/cases-updates/case-

7. Allotey J, Stallings E, Bonet M, et al. Clinical manifestations, risk factors, and maternal and perinatal outcomes of coronavirus disease 2019 in pregnancy: living systematic review and meta-analysis on behalf of the PregCOV-19 Living Systematic Review Consortium. *BMJ*. 2020;370:3320. doi:10.1136/bmj.m3320

8. Villar J, Ariff S, Gunier RB, et al. Maternal and Neonatal Morbidity and Mortality Among Pregnant Women With and Without COVID-19 Infection The INTERCOVID Multinational Cohort Study Editorial Supplemental content Downloaded From: https://jamanetwork.com/ by a Mount Sinai School of Medicine User on 05/05/2021. Published online 2020. doi:10.1001/jamapediatrics.2021.1050

9. Metz TD, Clifton RG, Hughes BL, et al. Disease Severity and Perinatal Outcomes of Pregnant Patients With Coronavirus Disease 2019 (COVID-19). *Obstet Gynecol*. 2021;137(4):571-580. doi:10.1097/AOG.0000000000004339

10. Lai J, Romero R, Tarca AL, et al. SARS-CoV-2 and the subsequent development of preeclampsia and preterm birth: evidence of a dose-response relationship supporting causality. *American Journal of Obstetrics & Gynecology*. 2021;225(6):689-693.e1. doi:10.1016/J.AJOG.2021.08.020

11. Janevic T, Maru S, Nowlin S, et al. Pandemic Birthing: Childbirth Satisfaction, Perceived Health Care Bias, and Postpartum Health During the COVID-19 Pandemic. *Maternal and Child Health Journal*. 2021;25(6):860-869. doi:10.1007/s10995-021-03158-8

12. Preis H, Mahaffey B, Heiselman C, Lobel M. Vulnerability and resilience to pandemic-related stress among U.S. women pregnant at the start of the COVID-19 pandemic. *Social Science and Medicine*. 2020;266:113348. doi:10.1016/j.socscimed.2020.113348

13. Preis H, Mahaffey B, Pati S, Heiselman C, Lobel M. Adverse Perinatal Outcomes Predicted by Prenatal Maternal Stress among U.S. Women at the COVID-19 Pandemic Onset. *Annals of Behavioral Medicine*. 2021;55(3):179-191. doi:10.1093/abm/kaab005

14. Duane AM, Stokes KL, DeAngelis CL, Bocknek EL. Collective Trauma and Community Support: Lessons From Detroit. *Psychological Trauma: Theory, Research, Practice, and Policy*. Published online 2020. doi:10.1037/tra0000791

15. Boelig RC, Aagaard KM, Debbink MP, Shamshirsaz AA. Society for Maternal-Fetal Medicine Special Statement: COVID-19 research in pregnancy: progress and potential. *American Journal of Obstetrics & Gynecology*. 2021;225(6):B19-B31. doi:10.1016/J.AJOG.2021.08.039

16. Molenaar NM, Rommel AS, Witte L de, et al. Seroprevalence of SARS-CoV-2 during pregnancy and associated outcomes: results from an ongoing prospective cohort study, New York City. *medRxiv*. Published online February 3, 2021:2021.02.01.21250943. doi:10.1101/2021.02.01.21250943

17. Carrión D, Colicino E, Pedretti NF, et al. Neighborhood-level disparities and subway utilization during the COVID-19 pandemic in New York City. *Nature Communications*. 2021;12(1):3692. doi:10.1038/s41467-021-24088-7

18. Open NY | The State of New York. Accessed June 10, 2021. https://www.ny.gov/programs/open-ny

19. Massey DS, Denton NA. The Dimensions of Residential Segregation. *Social Forces*. 1988;67(2):281. doi:10.2307/2579183

20. Huynh M, Spasojevic J, Li W, et al. Spatial social polarization and birth outcomes: preterm birth and infant mortality – New York City, 2010–14. *Scandinavian Journal of Public Health*. 2018;46(1):157-166. doi:10.1177/1403494817701566

21. Chambers BD, Baer RJ, McLemore MR, Jelliffe-Pawlowski LL. Using Index of Concentration at the Extremes as Indicators of Structural Racism to Evaluate the Association with Preterm Birth and Infant Mortality—California, 2011–2012. *Journal of Urban Health*. 2019;96(2):159-170. doi:10.1007/s11524-018-0272-4

22. Janevic T, Zeitlin J, Egorova N, Hebert PL, Balbierz A, Howell EA. Neighborhood racial and economic polarization, hospital of delivery, and severe maternal morbidity. *Health Affairs*. 2020;39(5):768-776. doi:10.1377/hlthaff.2019.00735

23. COVID-19 Resources | The Public Health Disparities Geocoding Project Monograph | Harvard T.H. Chan School of Public Health. Accessed June 17, 2021. https://www.hsph.harvard.edu/thegeocodingproject/covid-19-resources/

24. DEEP-MAPS | Catalist. Accessed June 20, 2021. https://catalist.us/deep-maps/

25. HUD USPS ZIP Code Crosswalk Files | HUD USER. Accessed June 20, 2021. https://www.huduser.gov/portal/datasets/usps_crosswalk.html

26. Stadlbauer D, Tan J, Jiang K, et al. Repeated cross-sectional sero-monitoring of SARS-CoV-2 in New York City. *Nature*. Published online November 3, 2020. doi:10.1038/s41586-020-2912-6

27. Bianco A, Buckley AB, Overbey J, et al. Testing of patients and support persons for coronavirus disease 2019 (COVID-19) infection before scheduled deliveries. *Obstetrics and Gynecology*. 2020;136(2):283-287. doi:10.1097/AOG.0000000000003985

28. Aris IM, Kleinman KP, Belfort MB, Kaimal A, Oken E. A 2017 US reference for singleton birth weight percentiles using obstetric estimates of gestation. *Pediatrics*. 2019;144(1):2021. doi:10.1542/peds.2019-0076

29. Griffith DA. Some robustness assessments of Moran eigenvector spatial filtering. *Spatial Statistics*. 2017;22:155-179. doi:10.1016/j.spasta.2017.09.001

30. Testing for spatial error autocorrelation in the presence of endogenous regressors. *International Regional Science Review*. 1997;20(1-2):153-182. doi:10.1177/016001769702000109

31. Weng HY, Hsueh YH, Messam LLM v., Hertz-Picciotto I. Methods of covariate selection: Directed acyclic graphs and the change-in-estimate procedure. *American Journal of Epidemiology*. 2009;169(10):1182-1190. doi:10.1093/aje/kwp035

32. On Racism: A New Standard For Publishing On Racial Health Inequities | Health Affairs. Accessed July 21, 2021. https://www.healthaffairs.org/do/10.1377/hblog20200630.939347/full/

33. Brown KM, Lewis JY, Davis SK. An ecological study of the association between neighborhood racial and economic residential segregation with COVID-19 vulnerability in the United States' capital city. *Annals of Epidemiology*. 2021;59:33-36. doi:10.1016/j.annepidem.2021.04.003

34. Finch BK, Thomas K, Beck AN. The Great Recession and adverse birth outcomes: Evidence from California, USA. *SSM - Population Health*. 2019;9:100470. doi:10.1016/j.ssmph.2019.100470

35. Margerison CE, Luo Z, Li Y. Economic conditions during pregnancy and preterm birth: A maternal fixed-effects analysis. *Paediatric and Perinatal Epidemiology*. 2019;33(2):154-161. doi:10.1111/ppe.12534

36. Laid Off More, Hired Less: Black Workers in the COVID-19 Recession | RAND. Accessed June 23, 2021. https://www.rand.org/blog/2020/09/laid-off-more-hired-less-black-workers-in-the-covid.html

37. Wei SQ, Bilodeau-Bertrand M, Liu S, Auger N. The impact of COVID-19 on pregnancy outcomes: A systematic review and meta-analysis. *CMAJ*. 2021;193(16):E540-E548. doi:10.1503/cmaj.202604

38. Acabchuk RL, Kamath J, Salamone JD, Johnson BT. Stress and chronic illness: The inflammatory pathway. *Social Science and Medicine*. 2017;185:166-170. doi:10.1016/j.socscimed.2017.04.039

39. Joseph Davey D, Bekker LG, Coates TJ, Myer L. Contracting HIV or Contracting SAR-CoV-2 (COVID- 19) in Pregnancy? Balancing the Risks and Benefits. *AIDS and Behavior*. 2020;24(8):2229-2231. doi:10.1007/s10461-020-02861-x

40. Berghella V, Boelig R, Roman A, Burd J, Anderson K. Decreased incidence of preterm birth during coronavirus disease 2019 pandemic. *Am J Obstet Gynecol MFM*. 2020;2(4):100258. doi:10.1016/j.ajogmf.2020.100258

41. Janevic T, Stein CR, Savitz DA, Kaufman JS, Mason SM, Herring AH. Neighborhood deprivation and adverse birth outcomes among diverse ethnic groups. *Annals of Epidemiology*. 2010;20(6):445-451. doi:10.1016/j.annepidem.2010.02.010

42. Karasek D, Baer RJ, Bell AJ, et al. *Title: The Association of COVID-19 Infection in Pregnancy with Preterm Birth: A Retrospective Cohort Study in California*. Accessed June 15, 2021. https://ssrn.com/abstract=3857659

43. Gregory ECW, Osterman MJK, Valenzuela CP. Vital Statistics Rapid Release Changes in Births to New York City Residents Occurring Outside New York City, by Race and Hispanic Origin of the. Published online 2018. Accessed August 17, 2021. https://www.cdc.gov/nchs/products/index.htm.

Table 1. Characteristics of participating pregnant persons by structural disadvantage, New York City, April-December 2020 (n=967)

Participant Characteristic	Total n=967	COVID-19 Disadvantage Index in quartiles (CDI) Q1 (High) n (%)	Q2 n (%)	Q3 n (%)	Q4 (Low) n (%)	P-value
Maternal age in years						<.0001
18-24	74	29 (15)	16 (10)	20 (8)	9 (3)	
25-34	502	108 (57)	88 (55)	126 (49)	180 (50)	
35+	391	53 (28)	56 (35)	111 (43)	171 (48)	
Race/ethnicity						<.0001
White, non-Latina	367	11 (6)	45 (28)	91 (35)	220 (61)	
Black/African American, non-Latina	169	55 (29)	37 (23)	49 (19)	28 (8)	
Latina	293	107 (56)	60 (38)	85 (33)	41 (11)	
Asian, non-Latina	87	10 (5)	6 (4)	18 (7)	53 (15)	
Other, non-Latina	41	6 (3)	10 (6)	12 (5)	13 (4)	
Unknown race, non-Latina	10	1 (1)	2 (1)	2 (1)	5 (1)	
Insurance						<.0001
Private/self-pay	657	95 (50)	98 (61)	166 (65)	298 (83)	
Public	310	95 (50)	62 (39)	91 (35)	62 (17)	
Pre-pregnancy BMI						<.0001
Underweight	27	4 (2)	3 (2)	5 (2)	15 (4)	

(<18.5)					
Normal (18.5-24.9)	380	48 (25)	49 (31)	90 (35)	193 (54)	
Overweight (25.0-29.9)	290	61 (32)	48 (30)	83 (32)	98 (27)	
Obese (>30)	270	77 (41)	60 (38)	79 (31)	54 (15)	
Nulliparous	450	109 (57)	78 (49)	125 (49)	138 (38)	0.0002

Abbreviations: BMI= body mass index.

Table 2. Associations between neighborhood structural racism and pandemic stress with SARS-CoV-2 seropositivity during pregnancy, overall and by race/ethnicity, New York City, April-December 2020, n=967

	Overall					BIPOC			Non-Latina White		
	Ab+ n (%)	**RR**	**95% CI**	**aRR[a]**	**95% CI**	**Ab+ n(%)**	**aRR[a]**	**95% CI**	**Ab+ n (%)**	**aRR[a]**	**95% CI**
<u>Structural racism measures in quartiles</u>											
Structural disadvantage (CDI)											
Q1 (High)	60 (32)	3.6	2.5, 5.2	2.6	1.7, 3.9	59 (33)	2.2	1.2, 3.8	1 (9)	1.4	0.2, 10.3
Q2	44 (28)	3.1	2.1, 4.5	2.5	1.7, 3.7	37 (32)	2.2	1.3, 3.9	7 (16)	2.2	1.1, 4.6
Q3	57 (22)	2.5	1.7, 3.6	2.1	1.4, 3.1	41 (25)	1.8	1.0, 3.1	16 (18)	2.8	1.6, 5.1
Q4 (Low)	32 (9)	1.0	ref	1.0	ref	18 (13)	1.0	ref	14 (6)	1.0	ref
Racial-economic segregation (ICE)											
Q1 (Black, low-income)	86 (28)	2.7	1.9, 3.8	1.9	1.3, 2.8	83 (30)	1.7	0.9, 3.1	3 (1)	1.3	0.4, 4.4
Q2	46 (24)	2.4	1.6, 3.6	1.9	1.2, 2.9	40 (30)	1.8	0.9, 3.4	6 (11)	1.4	0.6, 3.2
Q3	29 (18)	1.7	1.1, 2.7	1.5	0.9, 2.4	16 (21)	1.4	0.7, 2.8	13 (15)	1.9	1.0, 3.3
Q4 (White, high-income)	32 (10)	1.0	ref	1.0	ref	16 (14)	1.0	ref	16 (8)	1.0	ref
<u>Pandemic stress measures in quartiles</u>											
COVID-19 mortality rate											
Q1 (High)	68 (26)	2.3	1.6, 3.4	1.8	1.2, 2.6	65 (30)	1.7	1.0, 2.7	3 (7)	0.7	0.2, 2.3
Q2	48 (26)	2.3	1.6, 3.5	1.8	1.2, 2.7	44 (30)	1.7	1.0, 2.8	4 (11)	1.2	0.5, 3.0
Q3	40 (21)	1.8	1.1, 3.0	1.6	1.0, 2.5	27 (23)	1.3	0.7, 2.4	13 (17)	1.9	1.0, 3.4

Q4 (Low)	37 (11)	1.0	ref	1.0	ref	19 (16)	1.0	ref	18 (9)	1.0	ref
COVID-19 unemployment rate increase											
Q1 (High)	56 (28)	2.6	1.8, 3.7	1.7	1.2, 2.5	55 (29)	1.6	0.9, 2.6	1 (9)	0.8	0.1, 7.2
Q2	29 (26)	2.4	1.5, 4.0	2.3	1.5, 3.5	25 (37)	2.5	1.5, 4.4	4 (9)	1.2	0.4, 3.1
Q3	71 (23)	2.1	1.5, 3.1	1.7	1.2, 2.4	55 (27)	1.6	0.9, 2.6	16 (15)	1.9	1.1, 3.4
Q4 (Low)	37 (1)	1.0	ref	1.0	ref	20 (15)	1.0	ref	17 (8)	1.0	ref

Abbreviations: Ab+=SARS-CoV-2 antibody positive; aRR=adjusted risk ratio; BIPOC=Black, Indigenous, and people of color; CDI=COVID-19 Disadvantage Index; ICE=Index of Concentration at the Extremes; RR=risk ratio; ref=reference group.

[a]Adjusted for maternal age, insurance type, parity, pre-pregnancy BMI.

Table 3. Associations between neighborhood structural racism and pandemic stress with preterm birth (<37 weeks), overall and by race/ethnicity, New York City, April-December 2020, n=967

	Overall					**BIPOC**			**Non-Latina White**		
	Preterm n (%)	**RR**	**95% CI**	**aRR[a]**	**95% CI**	**Preterm n (%)**	**aRR[a]**	**95% CI**	**Preterm n (%)**	**aRR[a]**	**95% CI**
<u>Structural racism measures in quartiles</u>											
Structural disadvantage (CDI)											
Q1 (High)	21 (11)	1.8	1.1, 3.0	1.7	1.0, 2.9	21 (12)	1.5	0.8, 2.8	0 (0)	Insufficient data	
Q2	18 (11)	1.8	1.2, 2.9	1.7	1.1, 2.6	16 (14)	1.7	1.0, 3.0	2 (4)		
Q3	20 (8)	1.3	0.8, 2.1	1.2	0.7, 1.9	16 (10)	1.2	0.7, 2.1	4 (4)		
Q4 (Low)	22 (6)	1.0	ref	1.0	ref	12 (9)	1.0	ref	10 (5)		
Racial-economic segregation (ICE)											
Q1 (Black, low-income)	37 (12)	2.2	1.4, 3.4	2.0	1.3, 3.2	36 (13)	2.0	1.0, 4.0	1 (4)	Insufficient data	
Q2	13 (7)	1.3	0.7, 2.2	1.1	0.6, 2.0	13 (10)	1.4	0.7, 3.0	0 (0)		
Q3	14 (9)	1.6	0.9, 2.8	1.5	0.9, 2.7	8 (11)	1.7	0.7, 3.8	6 (7)		
Q4 (White, high-income)	17 (6)	1.0	ref	1.0	ref	8 (7)	1.0	ref	9 (5)		
<u>Pandemic stress measures in quartiles</u>											

COVID-19 mortality rate										
Q1 (High)	25 (10)	1.7	1.0, 2.8	1.6	0.9, 2.6	23 (11)	1.4	0.7, 2.7	2 (5)	Insufficient data
Q2	18 (10)	1.7	1.1, 2.7	1.6	0.9, 2.6	17 (12)	1.5	0.8, 2.8	1 (3)	
Q3	19 (10)	1.7	1.0, 2.9	1.6	0.9, 2.7	15 (13)	1.7	0.8, 3.3	4 (5)	
Q4 (Low)	19 (6)	1.0	ref	1.0	ref	10 (8)	1.0	ref	9 (4)	
COVID-19 unemployment rate increase										
Q1 (High)	22 (12)	1.8	1.1, 2.9	1.6	1.0, 2.8	22 (11)	1.5	0.8, 2.7	0 (0)	Insufficient data
Q2	9 (6)	1.3	0.7, 2.5	1.2	0.7, 2.3	7 (10)	1.3	0.6, 2.8	2 (5)	
Q3	29 (11)	1.5	1.0, 2.4	1.4	0.9, 2.2	24 (12)	1.4	0.8, 2.4	5 (5)	
Q4 (Low)	35 (10)	1.0	ref	1.0	ref	12 (9)	1.0	ref	9 (4)	

Abbreviations: aRR=adjusted risk ratio; BIPOC=Black, Indigenous, and people of color; CDI=COVID-19 Disadvantage Index; ICE=Index of Concentration at the Extremes; RR=risk ratio; ref=reference group.
[a]Adjusted for maternal age, insurance type, parity, pre-pregnancy BMI, SARS-CoV-2 antibody status.

Table 4. Associations between neighborhood structural racism and pandemic stress with small for gestational age (SGA), overall and by race/ethnicity, New York City, April–December 2020, n=967

	Overall					**BIPOC**			**Non-Latina White**		
	SGA n (%)	**RR**	**95% CI**	**aRR[a]**	**95% CI**	**SGA n (%)**	**aRR[a]**	**95% CI**	**SGA n (%)**	**aRR[a]**	**95% CI**
<u>Structural racism measures in quartiles</u>											
Structural disadvantage (CDI)											
Q1 (High)	22 (12)	1.2	0.8, 1.9	1.3	0.8, 2.2	21 (12)	1.3	0.6, 2.5	1 (9)	1.0	0.1, 6.6
Q2	9 (6)	0.6	0.2, 1.4	0.6	0.3, 1.5	5 (4)	0.5	0.2, 1.2	4 (9)	1.1	0.4, 3.3
Q3	29 (11)	1.2	0.7, 1.8	1.2	0.8, 2.0	22 (13)	1.4	0.7, 2.6	7 (8)	0.8	0.4, 1.9
Q4 (Low)	35 (10)	1.0	ref	1.0	ref	15 (11)	1.0	ref	20 (9)	1.0	
Racial-economic segregation (ICE)											
Q1 (Black, low-income)	35 (11)	1.2	0.8, 1.8	1.4	0.8, 2.3	31 (11)	1.3	0.6, 2.8	4 (14)	1.5	0.5, 4.1
Q2	17 (9)	1.0	0.5, 1.7	1.1	0.6, 1.8	15 (11)	1.3	0.6, 3.0	2 (4)	0.4	0.1, 1.7
Q3	14 (9)	0.9	0.5, 1.7	1.0	0.5, 1.8	6 (8)	0.9	0.4, 2.1	8 (9)	1.0	0.5, 2.0
Q4 (White, high-income)	29 (9)	1.0	ref	1.0	ref	11 (10)	1.0	ref	18 (9)	1.0	

Pandemic stress measures in quartiles											
COVID-19 mortality rate											
Q1 (High)	28 (11)	1.0	0.7, 1.6	1.1	0.7, 1.9	22 (10)	0.8	0.4, 1.5	6 (14)	1.8	0.7, 4.6
Q2	17 (9)	0.9	0.5, 1.6	1.0	0.5, 1.9	13 (9)	0.7	0.3, 1.4	4 (11)	1.5	0.4, 5.0
Q3	16 (8)	0.8	0.5, 1.3	0.8	0.5, 1.4	11 (9)	0.7	0.3, 1.4	5 (6)	0.8	0.4, 1.9
Q4 (Low)	34 (10)	1.0	ref	1.0	ref	17 (14)	1.0	ref	17 (8)	1.0	
COVID-19 unemployment rate increase											
Q1 (High)	21 (10)	1.0	0.6, 1.6	1.1	0.6, 2.0	19 (10)	0.9	0.4, 1.9	2 (18)	1.8	0.5, 6.3
Q2	13 (12)	1.1	0.7, 1.8	1.1	0.7, 1.9	11 (16)	1.4	0.7, 3.0	2 (5)	0.5	0.1, 1.9
Q3	25 (8)	0.8	0.5, 1.3	0.8	0.5, 1.4	16 (8)	0.7	0.3, 1.4	9 (9)	0.9	0.4, 1.9
Q4 (Low)	36 (11)	1.0	ref	1.0	ref	17 (13)	1.0	ref	19 (9)	1.0	

Abbreviations: aRR=adjusted risk ratio; BIPOC=Black, Indigenous, and people of color; CDI=COVID-19 Disadvantage Index; ICE=Index of Concentration at the Extremes; RR=risk ratio; ref=reference group.
[a]Adjusted for maternal age, insurance type, parity, pre-pregnancy BMI, SARS-CoV-2 antibody status.

Figure 1. Joint effects of structural racism and pandemic stress, SARS-CoV-2 infection during pregnancy, and adverse birth outcomes, New York City, April-December 2020, n=967