Racial/Ethnic Segregation and Access to COVID-19 Testing: Spatial Distribution of COVID-19 Testing Sites in the Four Largest Highly Segregated Cities in the United States

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See also Yang, p. 369.

Objectives. To quantify the relationship between the segregation of Black, Indigenous, and Latinx communities and COVID-19 testing sites in populous US cities.

Methods. We mapped testing sites as of June 2020 in New York City; Chicago, Illinois; Los Angeles, California; and Houston, Texas; we applied Bayesian methods to estimate the association between testing site location and the proportion of the population that is Black, Latinx, or Indigenous per block group, the smallest unit for which the US Census collects sociodemographic data.

Results. In New York City, Chicago, and Houston, the expected number of testing sites decreased by 1.29%, 3.05%, and 1.06%, respectively, for each percentage point increase in the Black population. In Chicago, Houston, and Los Angeles, testing sites decreased by 5.64%, 1.95%, and 1.69%, respectively, for each percentage point increase in the Latinx population.

Conclusions. In the largest highly segregated US cities, neighborhoods with more Black and Latinx residents had fewer COVID-19 testing sites, likely limiting these communities' participation in the early response to COVID-19.

Public Health Implications. In light of conversations on the ethics of racial vaccine prioritization, authorities should consider structural barriers to COVID-19 control efforts. (*Am J Public Health*. 2022;112(3):518–526. https://doi.org/10.2105/AJPH.2021.306558)

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Black, Indigenous, and Latinx communities in the United States have experienced disproportionate rates of COVID-19 infection, hospitalization, and mortality.[1] They will likely also take longer to recover as individuals and communities from the social and economic ramifications of the pandemic.[2] Observers outside public health predicted this epidemiological landscape in the absence of coordinated federal data collection. Lay Black people, Indigenous people, and other people of color (BIPOC) have identified structural racism—the historical, economic, political, and interpersonal factors resulting in poor outcomes for racial minorities—as the underlying mechanism for racial inequity during the pandemic.[3] Structural racism precedes the health inequity observed during the pandemic through myriad pathways.[4] Racial inequity in employment, housing, and wealth impede BIPOC communities' practice of social and physical distancing.[5,6] Racial and ethnic discrimination in clinical settings and inequity in access to healthy food and clean air contribute to disproportionate rates of comorbidities that complicate COVID-19 among BIPOC.[1] We quantified the contribution of segregation, a geographic manifestation of structural racism, to health inequity among Black, Indigenous, and Latinx communities during the COVID-19 pandemic.

There is limited academic work on the impact of structural racism on access to the early public health response to the pandemic, which largely consisted of the establishment of diagnostic testing sites. A previous study on access to testing in the United States focused on the relationship between testing locations and the percentage of counties that are "non-White" in addition to median income and the percentage uninsured.[7] However, large geographic units (e.g., counties) may obscure the more local, neighborhood-level dynamics of structural racism.[8] Furthermore, it is critical to be specific about the particular minority communities in question, as racism often manifests differently depending on the ethnoracial group.[9]

Racial segregation is the systematic geographic separation of racial and ethnic minorities from White neighborhoods through deliberate policies and practices and the resultant experience of social and economic marginality for separated racial and ethnic minorities.[10] This geographic manifestation of structural racism long preceded the COVID-19 pandemic. In the United States, the most extreme patterns of segregation occur between Black and White Americans.[11] However, other groups, including Indigenous and Latinx communities, are also segregated from White communities.[10] Although some literature points to the potential benefits of having neighbors of the same race, the process of segregation is distinct from the willful creation of enclaves for the preservation of ethnoracial vibrancy.[12]

Sociologist and legal scholar Monica Bell elucidates the complex, multilevel, and intentional process of segregation. Segregation consists of separation, concentration, subordination, and domination.[8] First, there is uneven geographic distribution of racial or ethnic groups across a coherent geographic area (separation). Next, there is movement of marginalized ethnic groups into identifiable and stigmatized enclaves (concentration). Concentration highlights neighborhood effects—the influence of clusters of marginalized communities that leads to compounded deprivation. This process of concentration establishes and reproduces hegemonic racial hierarchy (subordination). Subordination goes beyond the observable consequences of concentration and articulates the subjective experience of segregation for racial minorities. The stigmatizing experience of subordination facilitates the social control and economic exploitation of disadvantaged groups by White people, who then hoard political opportunity and power (domination). Although the costs of domination are disproportionately experienced by marginalized people, domination also harms White people by hampering interracial social and political coalition building. Segregation is an intentional process that creates and rearticulates social order.

We characterize the spatial distribution of COVID-19 testing sites in the 4 most populous, highly segregated US cities using the dissimilarity index.[13,14] We report on the relationship between the distribution of the early COVID-19 response and the segregation of Black, Indigenous, and Latinx communities.

METHODS

We used a complete list of testing sites made publicly available by GISCorps (Urban and Regional Information Systems Association, Des Plaines, IL) through June 2020. Testing sites included drive-through locations, preexisting hospital centers and clinics, commercial pharmacies, and pop-up testing sites. We then generated a list of the 20 most segregated US cities as measured by the dissimilarity index.[15] The dissimilarity index is the most commonly used measure of segregation between 2 groups and reflects their relative distributions across neighborhoods in the same city.[14] The index ranges between 0 and 100 and quantifies the percentage of 1 group that would have to move across neighborhoods to be distributed the same way as the second group. The higher the number, the more segregated the area.[14] We then selected the 4 most populous cities on this list (i.e., New York City; Los Angeles, CA; Chicago, IL; and Houston, TX) to facilitate a focused analysis.[16]

Covariates

Our outcome was the number of testing sites in each census block group as of June 2020. Covariates of interest included the percentage of the population that was non-Hispanic Black or African American, the percentage of the population that was Hispanic or Latino, and the percentage of the population that was non-Hispanic American Indian or Alaska Native at the census block group level. With the exception of the Methods and Results sections, where we refer to covariates, we use the term "Black" interchangeably with the "Black or African American" census category, "Indigenous" interchangeably with the "American Indian or Alaska Native" category, and "Latinx" interchangeably with the "Hispanic or Latino" category. We used 2020 ethnoracial estimates provided by SimplyAnalytics (New York, NY), a demographic analytics company.

These 2020 estimates are generated using a combination of US Census Bureau data, including from the 2015 through 2019 5-year American Community Survey, the 2019 Public Use Microdata Sample, and the 2010 Decennial Census.

We used the percentage of a census block group that is non-Hispanic Black or African American, Hispanic or Latino, or non-Hispanic American Indian or Alaska Native to measure ethnoracial separation, as it is a critical component of segregation.[8] Because segregation is structural and distinct from willful separation, these proportions capture the results of decades of racist policies and structures.[17] Racial and ethnic separation serves as a marker of racially driven spatial discrimination and captures the impact of structural racism, as manifested by segregation. These particular ethnoracial groups were selected because of the COVID-19 inequities already demonstrated in the literature.[1,10] The census block group is the smallest geographic unit for which the US Census Bureau publishes data on race and ethnicity. It is an administrative unit that is more detailed than a census tract and, therefore, more closely approximates neighborhood demographic dynamics than do aggregated tract-, county-, or state-level estimates.

Cartography

We performed geospatial analysis of the distribution of COVID-19 testing sites in Chicago, New York City, Houston, and Los Angeles. Because the dissimilarity index allows comparison of only 2 racial or ethnic groups at once, we chose Black–White separation. This dichotomy represents the most extreme segregation patterns in the United States.[11] We geocoded testing site addresses using a Google geocoding application programming interface (API) to arrive at latitude and longitude coordinates. We then generated corresponding census block group spatial identification numbers for testing site coordinates using a Census.gov geolocator API. Finally, we mapped the percentage of the city population that is non-Hispanic Black or African American and the percentage of the population that is non-Hispanic White using dot densities. We generated our maps in ArcGIS Pro version 2.6 (Esri, West Redlands, CA).

Statistical Model and Analysis

We performed a population-adjusted hierarchical Bayesian Poisson regression analysis using the S.CARleroux function in the CARBayes package.[18] This model accounts for spatial correlation that may be present in the outcome by including block group–specific random effects that are correlated based on the geography of a city. Because we used the Leroux version of the conditional autoregressive model,[19] random effects from neighboring block groups (i.e., those with a shared border) were more similar a priori. We allowed the data to determine the appropriate amount of spatial correlation and variability in the data by specifying weakly informative previous distributions on the model parameters. We included all ethnoracial groups in the same model but created separate models for each city. We tested zero-inflated Poisson models, but they were outperformed by our chosen model (see the supplemental tables for additional model fit details [available as a supplement to the online version of this article at http://www.ajph.org]).

Our model adjusted for population size using an offset term in the Poisson regression. We also performed a sensitivity analysis using population density as a covariate and present those results in the supplementary tables. Because income and race are along the causal pathway of racism, we did not adjust for employment, income, or other socioeconomic measures as covariates.[20] We made this choice to avoid adjusting away the economic or employment dimensions of structural racism and thereby underreporting the effect of racism on health care access.[21,22] Because structural racism is an organizing system of oppression, structural racism includes the impact of income inequality, employment inequity, microaggressions, and internalized racism on racial minorities.[4] Our use of racial covariates as proxies for structural racism, then, includes the impact of these and other unobservable mediators of structural racism on racial minorities. Our inclusion of race and ethnicity covariates does not presume there is an innate quality of the selected groups that can be separated or isolated from the economic, educational, and political context in which these groups live.[23] We report relative risks or incidence rate ratios, posterior SDs, and 95% quantile-based credible intervals. We performed our analysis in R version 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Chicago has a dissimilarity index of 82.50 and is the most racially segregated city in the United States by this measure (Table 1). Chicago is also the third most populous city in the United

TABLE 1— Ethnoracial Composition Based on 2019 Estimates and Testing Sites per City as of June 2020: 4 US Cities

City	No. Testing Sites	Population	Population by Block Group, Mean % (IQR): Non-Hispanic Black or African American	Population by Block Group, Mean % (IQR): Hispanic or Latino	Population by Block Group, Mean % (IQR): Non-Hispanic American Indian or Alaska Native	Dissimilarity Index	Block Groups, No.: Total	Block Groups, No.: No Testing Sites	Block Groups, No.: At Least 1 Testing Site
Chicago, IL	30	2 693 099	36.21 (89.43)	26.78 (41.56)	0.38 (0.51)	82.50	2185	2155	30
New York City	166	8 328 998	22.40 (32.93)	27.13 (34.83)	0.29 (0.41)	81.40	6492[a]	6338	154
Houston, TX	80	3 729 748	23.03 (30.56)	42.40 (46.66)	0.35 (0.41)	68.60	1668[b]	1600	76
Los Angeles, CA	68	3 876 741	10.12 (6.88)	47.14 (55.20)	0.58 (0.75)	66.90	2510	2451	59

Note. IQR = interquartile range.

[a]We removed 1 New York City block group because it was a complete island with no neighboring block groups and thus was necessarily excluded from the neighborhood matrix for spatial autocorrelation.

[b]We excluded 8 Houston block groups that are islands among other Texas municipalities because they lack spatial neighbors within Houston city limits.

States. There were 30 testing sites in Chicago as of June 2020 (Figure 1). With every percentage point increase in the proportion of the block group population that was non-Hispanic Black or African American, there was a 3.05% population-adjusted reduction in the expected number of testing sites in that block group (Table 2). With every percentage point increase in the proportion of the block group that was Hispanic or Latino, there was a 5.64% population-adjusted reduction in the expected number of testing sites in that block group. Results for the percentage of the block group that was non-Hispanic American Indian or Alaska Native were not significant in Chicago.

New York City has a dissimilarity index of 81.40 and is the second most racially segregated city in the United States by this measure (Table 1). New York is also the most populous city in the United States. There were 166 testing sites in New York City as of June 2020 (Figure 1). With every percentage point increase in the proportion of the block group population that was non-Hispanic Black or African American, there was a 1.29% population-adjusted reduction in the expected number of testing sites in that block group (Table 2). Results for the percentage of the block group that was either Hispanic or Latino or non-Hispanic American Indian or Alaska Native were not significant in New York.

Houston has a dissimilarity index of 68.60 and is the 14th most segregated city in the United States by this measure (Table 1). Houston is also the fourth most populous city in the United States. There were 80 testing sites in Houston as of June 2020 (Figure 1). With every percentage point increase in the proportion of the block group population that was non-Hispanic Black or

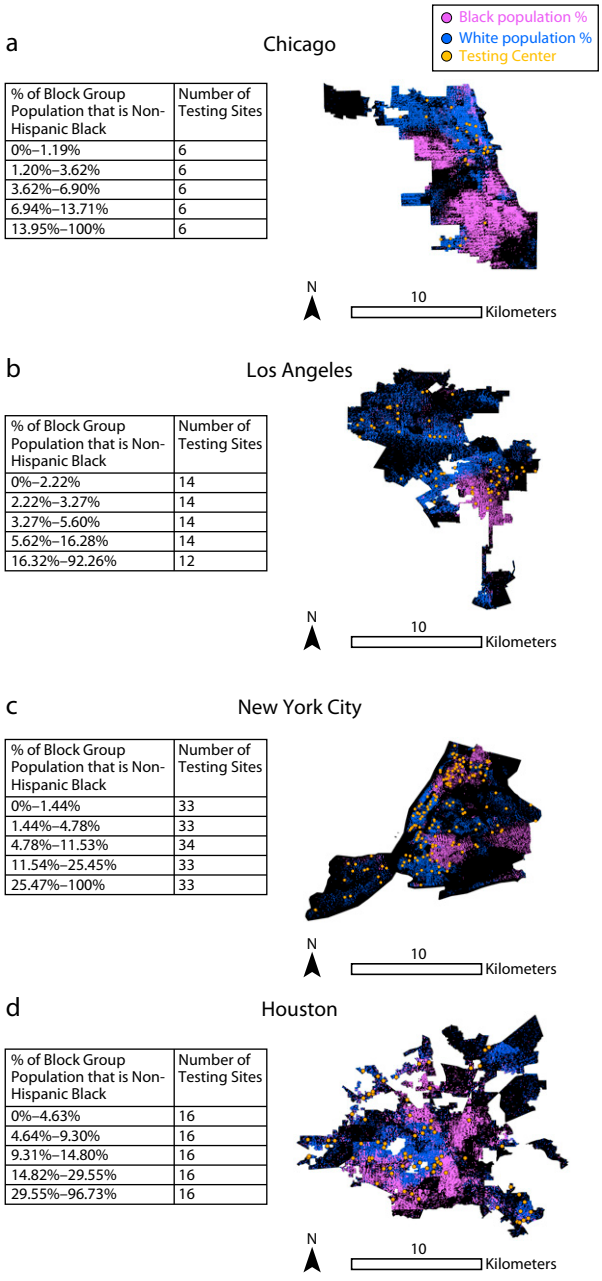

FIGURE 1— COVID-19 Testing Site Locations and the Proportion of Census Block Groups That Are Black or White in (a) Chicago, IL; (b) Los Angeles, CA; (c) New York City; and (d) Houston, TX: June 2020

African American, there was a 1.06% population-adjusted reduction in the expected number of testing sites in that block group (Table 2). With every percentage point increase in the proportion of the block group population that was Hispanic or Latino, there was a 1.95% population-adjusted decrease in the expected number of testing sites in that block group. Results for the percentage of the block group that was non-Hispanic American Indian or Alaska Native were not significant in Houston.

Los Angeles has a dissimilarity index of 66.90 and is the 18th most segregated city in the United States by this measure (Table 1). Los Angeles is also the second most populous city in the United States. There were 68 testing sites in Los Angeles as of June 2020 (Figure 1). With every percentage point increase in the proportion of the block group population that was Hispanic or Latino, there was a 1.69% population-adjusted decrease in the expected number of testing sites in that block group. Results for the percentage of the block group that was either non-Hispanic Black or African American or non-Hispanic American Indian or Alaska Native were not significant in Los Angeles.

DISCUSSION

By quantifying the association between the number of COVID-19 testing sites and the proportion of the population that is Black, Latinx, and Indigenous at the census block group level, we revealed the impact of historical and contemporary patterns of racial segregation on the public health response to the COVID-19 pandemic. Our primary findings are that even after adjusting for population, the expected number of testing sites decreases between 1.06% and 3.05% for each percentage point increase in the proportion of a census block group that is Black and between 1.69 and 5.64 for each percentage point increase in the proportion of a census block group that is Latinx. We demonstrate that the patterns of racial segregation that preceded the pandemic influenced the public health infrastructure established to address COVID-19 in the most populous US cities. Our study extends previous work by demonstrating racial and ethnic

TABLE 2— Estimated Relative Risk of COVID-19 Testing Site for a 1% Population-Adjusted Increase in Block Group Population That Is Non-Hispanic Black, Hispanic or Latino, or Non-Hispanic American Indian or Alaska Native: 4 US Cities, June 2020

	RR (SD; 95% CI)
New York, NY	
Non-Hispanic Black or African American	0.99 (0.004; 0.98, 0.99)
Hispanic or Latino	1.01 (0.003; 1.00, 1.01)
Non-Hispanic American Indian or Alaska Native	0.94 (0.22; 0.55, 1.43)
Chicago, IL	
Non-Hispanic Black or African American	0.97 (0.01; 0.95, 0.98)
Hispanic or Latino	0.94 (0.02; 0.91, 0.97)
Non-Hispanic American Indian or Alaska Native	1.82 (1.11; 0.41, 4.63)
Houston, TX	
Non- Hispanic Black or African American	0.99 (0.01; 0.98, 1.00)
Hispanic or Latino	0.98 (0.01; 0.97, 0.99)
Non-Hispanic American Indian or Alaska Native	0.86 (0.40; 0.31, 1.85)
Los Angeles, CA	
Non-Hispanic Black or African American	1.01 (0.01; 0.99, 1.02)
Hispanic or Latino	0.98 (0.01; 0.97, 0.99)
Non-Hispanic American Indian or Alaska Native	1.02 (0.29; 0.55, 1.70)

Note. CI = credible interval; RR = relative risk.

inequity at the neighborhood level, where residential segregation dynamics are manifest.[8] Our suggestion of segregation as the specific instance of structural racism that underlies the demonstrated disparity uniquely contributes to the literature. Furthermore, our identification of the particular minority communities affected lends specificity to the literature in this area. Finally, this study is novel in accounting for spatial correlation in our statistical model.

There is a wealth of literature that elucidates how racial discrimination and geography lead to inequity in health and other social outcomes.[24] Redlining, for example, is a historical example of segregation with persistent health implications.[17] Redlining occurred in cities across the United States, including Chicago, New York, Los Angeles, and Houston. This historical policy continues to have implications for contemporary public health in these cities. A 2019 Urban Institute study showed that contemporary access to capital in Chicago is directed more toward White neighborhoods than toward Black neighborhoods by a factor of 3 to 1. This disparate rate of investment already reflects adjustments made for mission-driven economic development initiatives that specifically target poor and minority communities for special investment.[25] Lack of commercial investment in marginalized communities has implications for health equity.

The early federal response to the pandemic was to establish testing centers via public–private partnership between the federal government, commercial pharmacies, and other businesses in addition to health centers. However, any partnership based on the preexisting distribution of businesses risks underserving BIPOC owing to historical and contemporary practices of investment on the basis of race and geography. For example, a community with fewer commercial pharmacies may not adequately benefit from a federal response predicated on partnerships with local businesses. The public health response to COVID-19 was superimposed on racist policy and structures. Thus, a race-blind approach to testing, coupled with preexisting health inequity, rendered BIPOC particularly vulnerable. Spatial discrimination and the way that structural racism mediates the differential geographic distribution of health system resources are critical to understanding the impact of structural racism on the response to the pandemic.

Monica Bell's theory of segregation helps us recognize how segregation creates and reinforces racial inequities during the pandemic.[8] The systematic separation of racial groups that long predated the pandemic has led to the concentration of ethnoracial minorities. The concentration of comorbidities that complicate COVID-19 in minority communities is a key example of a neighborhood effect. Concentration establishes and reproduces hegemonic racial hierarchy, which results in subordination. Subordination articulates the subjective dimensions of segregation for marginalized people. An example of subordination is the former US surgeon general's degrading call to Black "big mamas" and Latina "*abuelas*" to change their individual behaviors while ignoring the structural factors shaping increased COVID-19 risk in these communities. The stigmatizing experience of subordination facilitates the social control and economic exploitation of disadvantaged groups by White people, who then hoard political opportunity and power (domination).

Our results demonstrate domination in action: the sequestration of testing resources in White communities even as minority communities suffered so disproportionately.

The juxtaposition of disproportionately increased risk and disproportionately limited access to testing resources is not incidental. For example, in Chicago, more than 70% of early COVID-19 deaths were among Black people.[26] Latinx neighborhoods in the city were also among the hardest hit across Illinois.[26] This disease burden among BIPOC in Chicago was the combined result of preexisting health inequity as well as new challenges that arose during the pandemic. For both cultural reasons and economic inequality, 26% of Black Americans and 27% of Latinxs live in multigenerational households, compared with 16% of White Americans.[27] Additionally, because of employment inequity, BIPOC are more likely to have employment that does not accommodate remote work.[5,28]

These longstanding factors prevent hidden frontline and essential workers and their household members from social distancing. Furthermore, the incidence of homelessness and state detention are also increased in Black, Indigenous, and Latinx populations: research has demonstrated high rates of COVID-19 in prisons and immigration detention centers.[29,30] Residence and community in crowded, congregated settings confers an increased risk of respiratory disease and results in disease distribution along clear racial fault lines. Finally, the exclusion of undocumented immigrants and migrants, who are often Black and Latinx, from safety net health care protections renders them especially vulnerable to COVID-19.[6,31]

Because of this, social determinants of health as articulated in Public Health 3.0 may not go far enough for Black, Latinx, and Indigenous communities. The present moment necessitates a shift to an appreciation of the "social–structural" determinants of health: Public Health 3.0×. The study of social determinants of health might suggest individual or behavioral solutions to racial health inequity. A perspective that considers social determinants of health alone locates the burden of overcoming health inequity in supposedly "hard-to-reach" communities. However, investing in a shared language of structure accounts for histories and contemporary realities of oppression such as residential segregation. A shift to consideration of the "social–structural determinants of health" locates the burden of ameliorating health inequity in the health system rather than in minoritized individuals and communities. Race is not merely a unique social characteristic of communities that is associated with disease. Rather, the structural oppression faced by racially marginalized groups manifests as a shared experience of increased health vulnerability. A structural perspective suggests institutional solutions.

Limitations

Our study has several limitations. First, we focused on only the most populous racially segregated US cities. Second, the history of settler colonialism in the United States suggests that there may be associations between Indigenous populations and locations of COVID-19 testing sites similar to what we observed for Black and Latinx communities in our model; however, the relatively small proportion of the population comprising Indigenous peoples in the areas studied limited our ability to assess this effect. Results for the Indigenous population in New York and Houston were not significant, but they do suggest a possible inverse association between the location of testing centers and areas where Indigenous people live. The continued existence of reservations is a glaring example of the legacy of efforts to segregate the Indigenous population in the United States.[32]

Third, we focused only on locations of testing sites, but the manner in which location relates to access may not be straightforward. For example, some sites may be located in overpoliced areas or otherwise unsafe locations, have inconvenient hours, or not be easily accessible to persons with a disability. Additionally, cross-jurisdictional travel to access testing is a possible attenuating factor. Consequently, our analysis does not directly show that such disparities in location necessarily lead to decreased testing access, but this effect is plausible and deserves further study. One illustration of this limitation is our inability to capture how the protests for racial justice in the summer of 2020 may have affected access to testing sites. Additionally, many academic centers, in particular, exist in proximity to minority communities that still face access issues despite proximity.[33]

Lastly, numerical indices are a useful proxy for segregation by measuring separation. However, they are limited in that they do not necessarily capture the other dimensions of segregation (e.g., concentration, subordination, and domination). A strength of our approach is our articulation of proposed mechanisms for these other dimensions of segregation in the Discussion section.

Public Health Implications

We reveal the unique vulnerability of Black, Indigenous, and Latinx communities in the early response to COVID-19

and identify potential avenues to mitigate this vulnerability. In doing so, our work directly contributes to conversations about the ethics of a race-conscious approach to delivering the COVID-19 vaccine and distributing other health care resources.[34] Our data show that the largely race-blind patchwork testing strategy that did not explicitly account for race led to inequities in testing center placement. Thus, it is important to explicitly consider race in vaccine distribution. This is especially true considering how disproportionately BIPOC have been affected by COVID-19.

Our work may also illuminate paths to meaningfully partnering with BIPOC communities in vaccine delivery and other public health efforts. We should consider nontraditional vaccine dispensation sites in neighborhoods that are primarily Black, Indigenous, or Latinx, including mobile units, barbershops, churches, and community centers.[35] However, vaccine prioritization on the basis of race absent genuine and long-term community partnership is unlikely to be successful. Local health departments may consider ways to cocreate an environment that is conducive to equitable and ethical BIPOC coleadership in COVID-19 control efforts and public health efforts beyond the pandemic. This might include the involvement of community partners in priority setting and the renumeration of local experts for their involvement in community-engaged programming. When we locate the challenge in the health care system rather than burdening members of vulnerable communities with bridging the participation gap based on individual behavioral factors, we make strides against the pandemic and toward health justice, fulfilling the promise of Public Health 3.0. AJPH

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CONTRIBUTORS

E. N. Asabor lead the conceptualization of the study, conducted the analysis, and drafted the article. J. L. Warren supervised the statistical analysis and critically revised the article. T. Cohen conceptualized the study and provided overall project supervision. All authors interpreted the results of the analysis.

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CONFLICTS OF INTEREST

Although unrelated to the current project, J. L. Warren discloses consulting fees from Revelar Inc. The authors otherwise have no conflicts of interest.

HUMAN PARTICIPANT PROTECTION

No protocol approval was necessary because no human participants were involved in this study and the data used were aggregated and are readily available to the public.

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