COVID

Communication

An Exploratory Ecological Study between COVID-19 Vaccination Rate and Racial/Ethnic and Socioeconomic Status Neighborhood Conditions in Michigan

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Abstract: COVID-19 vaccination rate disparities continue to persist in the U.S., despite their wide availability. A multidimensional host of sociodemographic, economic, political, and cultural factors have resulted in differences in vaccine coverage rates across the U.S. The present study descriptively explores one component of the complex relationship among what drives COVID-19 vaccination rate differences—specifically, the relationship between neighborhood sociodemographic characteristics and vaccination rates in Michigan. Data from the 2019 5-Year American Community Survey are merged with vaccine coverage rate data at the census tract level for the 18-years-and-older population for Michigan from 15 December 2020 to 19 November 2021. On the one hand, the results reveal that a neighborhood's racial and ethnic composition and socioeconomic status characteristics are part of the complex bundle of characteristics affecting neighborhood vaccination coverage rates across Michigan. On the other hand, the findings also reveal a set of surprising patterns as they relate to the racial and ethnic composition of neighborhoods in Michigan. Future studies should further explore the extent to which race/ethnicity and class-related neighborhood characteristics are statistically relevant in examining the broader community effects on vaccine coverage rates in Michigan.

Keywords: COVID-19; race/ethnicity; socioeconomic status; neighborhoods; Michigan

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1. Introduction

COVID-19 vaccination rate disparities continue to persist in the U.S., despite their wide availability. In addition to resulting in over 1,000,000 deaths [1], the COVID-19 pandemic has affected every facet of our sociodemographic, economic, political, and health realms, such as, to name a few, in education, employment, and mental health [2–4]. Moreover, Black Americans have experienced disproportionately higher infection, hospitalization, and mortality rates due to COVID-19 [5]. In addition to social distancing and personal protective equipment (PPE), the development and distribution of vaccines in late 2020 represented one of the best medical solutions to minimize the caseload, hospitalization, and mortality rates due to the virus and its variants [6–8]. Nevertheless, a multidimensional host of sociodemographic, economic, political, and cultural factors, such as household income, education, and political ideology, have resulted in differences in vaccine coverage rates across the U.S. [9–12]. The present ecological study examines one component of the complex relationship among what drives COVID-19 vaccination rate differences—specifically, the relationship between neighborhood sociodemographic characteristics and vaccination rates in Michigan.

Evidence suggests an association between neighborhood socioeconomic status (SES) characteristics and vaccination rates [13–15]. For example, neighborhoods with lower

educational attainment and income levels, high unemployment, and high poverty levels have, on average, lower vaccination rates than their higher-SES counterparts [16]. Such geographic disparities are further compounded when differentiating neighborhoods by other demographic variables, such as racial and ethnic group composition and nativity status [17]. At the descriptive level of analysis, vaccination rates in Michigan reveal a pattern in which places, i.e., counties with higher educational levels, have higher vaccination rates than their counterparts with lower educational attainment or income levels [18]. However, the present paper aims to investigate the relationship between neighborhood SES characteristics, racial/ethnic composition, and vaccination coverage rates within a multivariable framework at the state level. Therefore, a state-level analysis of the relationship mentioned above will provide a more nuanced picture of the neighborhood-level sociodemographic factors affecting COVID-19 vaccination rates. In addition to Michigan having a diverse population in terms of race/ethnicity, SES, and demographic composition, the state also has a lower share of its population vaccinated compared to the U.S. as a whole [19]. In brief, the results revealed that the neighborhood SES level and racial and ethnic composition affect COVID-19 vaccination rates, net of the remaining predictors.

2. Data and Methodology

2.1. Dataset

Two datasets were used to examine the relationship between neighborhood SES and COVID-19 vaccination rates. The first dataset, acquired via a Freedom of Information Act (FOIA) request from the Michigan Department of Health and Human Services (MDHHS), lists the proportion of the 18-years-and-older population with vaccine coverage for the state of Michigan from 12/15/2020 to 11/19/2021. According to MDHHS, vaccine coverage refers to those who have received both doses of the two-dose series of the Pfizer or Moderna vaccine or the single-dose Johnson and Johnson vaccine [20]. Michigan allocated vaccine distribution in line with the Centers for Disease Control and Prevention's phases, emphasizing protecting those at increased risk for severe COVID-19 illness and complications [21].

A unique geospatial characteristic of the MDHHS dataset is that vaccination coverage data are at the census tract level. Census tracts are statistical units, i.e., subdivisions within a county, established by the Census Bureau, which allow for a more detailed analysis of the population composition at the neighborhood level since they are smaller in population size, i.e., between 2500 and 8000 persons, relatively permanent, and more homogenous concerning the SES characteristics and living conditions than those at the county or zip code level [22,23]. Less than one percent of census tracts for the state were excluded, i.e., 28 tracts from the MDHHS dataset, due to a lack of available coverage information, suppressed to protect privacy, unavailable census tract population size, no county name given, or unidentifiable census tracts.

The second dataset comes from the 2019 5-Year American Community Survey (ACS) extracted from the Census Bureau's data extraction website. A series of neighborhood-level characteristics at the census tract level, which constitutes the independent variables, are merged with the MDHHS data file. The merged dataset makes up the final file used for the analyses. Unmatched census tracts and tracts with zero population were omitted from the final file. Moreover, the researchers also excluded tracts with a group quarter population exceeding 50%. Group quarters are places such as college dorms, nursing homes, correctional facilities, and other group living arrangements, as defined by the U.S. Census Bureau [24], which may be guided by a different set of vaccination policies than those targeting the general population [25]. Overall, 3.2% of the original ACS file census tracts were excluded, corresponding to 0.67% of the state's total population. Following previous research, census tracts were used as proxies for neighborhoods [26]. The final census tract sample of 2772 has a total population of 9,898,502, corresponding to 98.5% of all census tracts in Michigan.

2.2. Dependent and Independent Variables

This MDHHS file was used to calculate the dependent variable "vaccine full coverage," referring to the proportion of those who have received both doses of the two-dose series of the Pfizer or Moderna vaccine or the single-dose Johnson and Johnson vaccine. The dependent variable was not statistically transformed since its distribution follows a normal distribution pattern. Moreover, skewness and kurtosis values, along with a visual inspection of the normal probability plot of the dependent variable, meet all the requirements of a normal distribution.

Following previous research, proxy variables are extracted from the ACS data to measure neighborhood racial/ethnic composition, SES, and family/household characteristics [27,28]. See Table 1 for a list of all the predictors. The proportion of non-Latinx White, non-Latinx Black, non-Latinx Asian, other non-Latinx White groups, and Latinx in each census tract relative to the tract's total population taps into the measurement of race and ethnicity, hereafter referred to as White, Black, Asian, and Latinx, unless otherwise noted. Due to small cell sizes, the categories of non-Latinx American Indian/Alaska Native, non-Latinx Native Hawaiian, other Pacific Islander, some other non-Latinx race, and two or more non-Latinx races were combined into the 'non-Latinx other non-White group' category. While not perfect, the racial and ethnic groups of interest are identified following the classifications set by the Office of Management and Budget (OMB), which differentiates groups by race and ethnicity, the latter being Latinx or not origin [29,30].

Table 1. Descriptive summary of variables.

	Mean *	Std. Deviation	Minimum	Maximum
% Vaccine full coverage	56.7	0.15	9.4	100.0
% White non-Latinx	71.5	0.30	0.0	100.0
% Black non-Latinx	17.6	0.29	0.0	100.0
% Asian non-Latinx	2.7	0.06	0.0	79.0
% Latinx	5.0	0.08	0.0	82.8
% Other non-White non-Latinx	3.1	0.03	0.0	40.5
% College degree and more	27.4	0.18	0.0	95.2
% Below poverty	16.2	0.14	0.0	82.9
% Foreign-born	6.3	0.09	0.0	71.6
% 65 and over years old	17.3	0.07	0.0	56.0
% Does not have internet	16.1	0.10	0.0	67.8
N	2772			

* Represents averages across all census tracts. Source: MDHHS and 2019 5-Year American Community Survey.

It should be noted that race and ethnicity should, at most, be considered a proxy measure of structural racism and discrimination, especially in a health outcome analysis. The remaining variables that tap into the measurement of neighborhood SES and family/household characteristics are education, measured as the percentage of those with a bachelor's degree or higher for the 25-years-and-older population, the poverty rate, and the share of foreign-born in each tract. Finally, we also included variables that measure the percentage of the 65-years-and-older population and those who own a computer and have an internet subscription, both of which can influence a neighborhood's vaccination rate [31–33]. All variables were tested for the presence of multicollinearity. The test result for residual autocorrelation (Durbin–Watson) is 2.3, which is within acceptable limits to satisfy the independence of errors [34].

2.3. Statistical Analysis

The first part of the data analysis includes a series of exploratory summary descriptive statistics using means, standard deviations, and minimum and maximum values. The final section of the data analysis consists of ordinary least squares regression (OLS) in order to evaluate the relationship between neighborhood conditions and vaccination coverage rates

in Michigan. Given that the distribution of vaccination rates was found to be normal, OLS regression was employed. The OLS equation is as follows:

$$Y = X\beta + \varepsilon \quad (1)$$

where Y is the dependent variable, β is the coefficient on the vector of predictors (X), as shown in Table 1, and ε is the error. Unstandardized regression coefficients are presented in Table 2. All analyses are conducted using SPSS version 27.

Table 2. Multiple regression results predicting COVID-19 vaccination coverage rate.

	Coefficient	Std. Error	Sig.	95% Confidence Interval for B	
				Lower Bound	Upper Bound
Race/Ethnicity (Ref = Non-Latinx White)					
Non-Latinx Black	−0.075	0.064	0.239	−0.201	0.050
Non-Latinx Asian	0.387 *	0.156	0.014	0.079	0.695
Latinx	0.263 *	0.119	0.028	0.028	0.497
Non-Latinx Other	0.075	0.313	0.811	−0.542	0.692
College Plus	0.121 *	0.053	0.023	0.017	0.226
Poverty	−0.674 *	0.066	0.000	−0.804	−0.545
Foreign-Born	−0.343 *	0.132	0.010	−0.603	−0.084
65 and Years Old and Over	0.627 *	0.163	0.000	0.306	0.948
No Internet	−0.596 *	0.176	0.001	−0.942	−0.249
Constant	0.639 *	0.040	0.000	0.559	0.718
R Square	0.637 *				
N	2772				

* $p < 0.05$. Source: MDHHS and 2019 5-Year American Community Survey.

3. Results

Table 1 shows a descriptive summary of all predictors and the outcome. Nearly six out of ten, precisely 57%, of Michigan residents received either the single-dose Johnson and Johnson vaccine or both doses of the two-dose series of the Pfizer or Moderna vaccine between 12/15/2020 and 11/19/2021. Concerning race and ethnicity, Whites, Blacks, Asians, Latinx, and other non-Latinx non-White groups make up 72%, 18%, 3%, 5%, and 3%, respectively, of the total share in all Michigan census tracts. In terms of SES, the share of those with a college degree or higher and poverty stands at 27% and 16%, respectively. Lastly, the share of the 65-year-old-and-older population and not having internet access is 17% and 16%, respectively.

Table 2 presents the results from the multiple linear regression, which reveal a series of interesting findings regarding the relationship between the COVID-19 vaccination coverage in Michigan and the full range of predictors. Looking first at the effect of race and ethnicity, the coefficients for Asians and Latinx are positive and statistically significant compared to Whites, meaning that the direction of the impact on the vaccination rate is such that it increases in neighborhoods with higher shares of Asian and Latinx, independent of the effect of the other predictors. Meanwhile, the share of the Black and non-Latinx other populations in neighborhoods does not influence the vaccination rate. Since the inception of the COVID-19 vaccine, Blacks and Latinx have been less likely than White people to receive the COVID-19 vaccine, though there is increasing equity in vaccination rates [35]. The magnitude of the effect of race and ethnicity is such that neighborhoods with higher Asian group concentration register the highest impact on vaccination rates, followed by those with Latinx groups. We also included a different version of the race/ethnicity variable, such that it differentiated between non-Latinx Whites and non-Whites (including both non-White non-Latinx and Latinx). The results reveal that the latter category's relationship with the vaccination rate was negative, relative to non-Latinx Whites (results not shown, but available upon request). In other words, as the census tract share of non-Whites (including both non-White non-Latinx and Latinx) increased, the vaccination rate decreased.

Education and poverty have the opposite relationship with vaccination rates. Specifically, as a neighborhood's share of those with a college degree or higher increases, the vaccination rates also increase, holding all the other predictors constant. Meanwhile, the opposite holds for the effect of poverty. In other words, for every one-unit increase in a neighborhood's poverty rate, the vaccination rate decreases by approximately 0.7 percentage points, net of all the remaining predictor variables. To the extent that poverty and educational attainment are used as a proxy for SES, the results reveal that poverty has a stronger influence on COVID-19 vaccination rates than education.

Nativity status and age are inversely related to the vaccination rate with respect to each other. Specifically, the vaccination rate decreases with an increasing share of the foreign-born population in a neighborhood. Moreover, higher shares of the 65-years-and-over population in a neighborhood are related to increasing vaccination rates. According to Table 2, the age variable has a stronger relationship than foreign-born status, as revealed by the coefficients. Lastly, a lack of access to the internet or not having an internet subscription service is negatively related to a neighborhood's vaccination rate. Interestingly, the neighborhood poverty rate has a stronger impact on vaccination rates than a lack of access to the internet.

4. Discussion and Conclusions

This paper examined the relationship between neighborhood characteristics and COVID-19 vaccine coverage rates in Michigan. Selected sociodemographic characteristics from the 2015–2019 ACS were merged to the census tract vaccine coverage rate data between 12/15/2020 and 11/19/2021, as provided by MDHHS. Overall, the study revealed three main findings concerning the relationship between a neighborhood's sociodemographic characteristics, such as race/ethnicity and SES, and vaccine coverage rates.

The first finding relates to race and ethnicity. A neighborhood's racial and ethnic composition is associated with the vaccination rate, albeit with mixed and surprising results. Except for Blacks, the neighborhood shares of Asian and Latinx groups in a neighborhood has a positive effect on vaccination rates relative to Whites, even when holding SES and other selected neighborhood characteristics constant. Future studies should further explore this finding as it pertains to Michigan. The second main finding pertaining to the SES characteristics' effect is a set of findings. A neighborhood's vaccine coverage rate increases with increasing shares of those with a college degree or higher, but it is negatively related to the poverty rate. This finding supports previous research on a national level in that socioeconomically disadvantaged neighborhoods have lower vaccination rates [36,37]. Moreover, the positive association with older age is expected, given that the older groups were the main targets of vaccination policies. The final main finding speaks to the level of magnitude of change of each predictor variable's relationship in the outcome. Among the variables having a negative relationship with the vaccination rates, poverty exhibits the largest impact, followed by the lack of access to the internet or not having an internet subscription. Lack of internet access can be a barrier to COVID-19 vaccination since many vaccine providers require people to schedule their vaccine appointments online [36]. Meanwhile, the over-65-year-old population has the largest effect on the COVID-19 vaccination rate, followed by the Asian neighborhood population share, relative to all the remaining predictors.

Race, ethnicity, and SES are part of the complex bundle of characteristics affecting neighborhood vaccination rates across Michigan. Racial and ethnic differences in COVID-19 vaccination rates also exist in Michigan, following national-level trends [38–41]. To the extent that such descriptive-level differences in racial and ethnic group vaccination rates reflect the broader community structure that reside in, the present study results reveal a mixed picture of effects involving both variables included in the models and those not included. Nevertheless, race and ethnicity, and class-related neighborhood characteristics, are statistically important in examining the broader community effects on vaccine coverage

rates. COVID-19 vaccination efforts can concentrate on areas with low SES to assist in increasing equity in vaccination rates.

Factors that present challenges to COVID-19 vaccine equity that affect racial and ethnic minority groups include education, income, and wealth gaps; job access and working conditions; racism and other types of discrimination; gaps in access to healthcare; transportation, and neighborhood conditions [38]. Furthermore, a lack of trust resulting from past medical racism and experimentation and vaccine hesitancy can also contribute to lower vaccination rates among non-White groups, especially among the Black population [42,43]. This can present challenges for individuals pertaining to locating providers and services and seeking preventative care [44]. Future studies should look into the above factors contributing to vaccine coverage inequalities as they pertain to Michigan relative to other states.

Concerning the time reflection of the current dataset (through November 2021), we believe that the findings would change following the submission of the manuscript if we collect data to the present day. In addition to receiving federal funding support, such as from the CDC, state and local initiatives have also aimed to reduce racial and ethnic disparities in vaccination rates [45,46]. Moreover, despite expanded vaccine approval and recommendations, vaccine hesitancy still exists for various reasons, including but not limited to concerns regarding the safety and side effects of vaccines and other legacy issues with healthcare providers, including mistrust, fear, and a lack of information [47–49]. Additionally, current data show that Michigan has lower COVID-19 vaccination rates compared to the U.S. overall, i.e., currently, 60.8% of people in Michigan are fully vaccinated, compared to 67.2% in the U.S. [19]. However, since the submission of our manuscript, COVID-19 vaccine recommendations have expanded to include younger individuals, boosters for specific age groups, and another COVID-19 vaccine option (Novavax), which can affect such a prediction. Perhaps we still need time to see the full effects of this.

As with every study, the present study is also not free from limitations. Five main limitations pertain to (1) the limited time range of vaccination coverage data, (2) the single-state case study, (3) the findings related to one specific virus, (4) incorporating more SES-related neighborhood variables, including but not limited to the CDC's Social Vulnerability Index, and (5) its ecological nature and the possible introduction of ecological bias. Incorporating vaccination coverage data beyond the time range used in the present study and comparing the results with other states will undoubtedly further strengthen the findings. Taking into consideration all of the above limitations, along with adding and comparing the results with other non-COVID-19 vaccination rates, will provide a robust context for disentangling the idiosyncrasies related to neighborhood effects. Nevertheless, we believe that the findings provide an initial step into further exploring the relationship between neighborhood SES characteristics and COVID-19 vaccination rates as they pertain to Michigan.

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References

1. Centers for Disease Control and Prevention_a. COVID Data Tracker. 2023. Available online: https://covid.cdc.gov/covid-data-tracker/#datatracker-home (accessed on 22 January 2023).
2. Haleem, A.; Javaid, M.; Vaishya, R. Effects of COVID-19 pandemic in daily life. *Curr. Med. Res. Pract.* **2020**, *10*, 78–79. [CrossRef] [PubMed]
3. Hall, L.R.; Sanchez, K.; da Graca, B.; Bennett, M.M.; Powers, M.; Warren, A.M. Income Differences and COVID-19: Impact on Daily Life and Mental Health. *Popul. Health Manag.* **2022**, *25*, 384–391. [CrossRef] [PubMed]
4. Kantamneni, N. The Impact of the COVID-19 Pandemic on Marginalized Populations in the United States: A Research Agenda. *J. Vocat. Behav.* **2020**, *119*, 103439. [CrossRef] [PubMed]
5. Mackey, K.; Ayers, M.C.K.; Kondo, K.K.; Saha, S.; Advani, S.M.; Young, M.S.; Spencer, D.H.; Rusek, M.; Anderson, M.J.; Veazie, M.S.; et al. Racial and Ethnic Disparities in COVID-19–Related Infections, Hospitalizations, and Deaths. *Ann. Intern. Med.* **2021**, *174*, 362–373. [CrossRef] [PubMed]
6. Christie, A.; Henley, S.J.; Mattocks, L.; Fernando, R.; Lansky, A.; Ahmad, F.B.; Adjemian, J.; Anderson, R.N.; Binder, A.M.; Carey, K.; et al. Decreases in COVID-19 Cases, Emergency Department Visits, Hospital Admissions, and Deaths Among Older Adults Following the Introduction of COVID-19 Vaccine—United States, September 6, 2020–May 1. *MMWR. Morb. Mortal. Wkly. Rep.* **2021**, *70*, 858–864. [CrossRef]
7. Patel, M.K.; Bergeri, I.; Bresee, J.S.; Cowling, B.J.; Crowcroft, N.S.; Fahmy, K.; Hirve, S.; Kang, G.; Katz, M.A.; Lanata, C.F.; et al. Evaluation of post-introduction COVID-19 vaccine effectiveness: Summary of interim guidance of the World Health Organization. *Vaccine* **2021**, *39*, 4013–4024. [CrossRef]
8. Pilishvili, T.; Gierke, R.; Fleming-Dutra, K.E.; Farrar, J.L.; Mohr, N.M.; Talan, D.A.; Krishnadasan, A.; Harland, K.K.; Smithline, H.A.; Hou, P.C.; et al. Effectiveness of mRNA Covid-19 Vaccine among U.S. Health Care Personnel. *N. Engl. J. Med.* **2021**, *385*, e90. [CrossRef]
9. Agarwal, R.; Dugas, M.; Ramaprasad, J.; Luo, J.; Li, G.; Gao, G. Socioeconomic privilege and political ideology are associated with racial disparity in COVID-19 vaccination. *Proc. Natl. Acad. Sci. USA* **2021**, *118*, e2107873118. [CrossRef]
10. El-Mohandes, A.; White, T.M.; Wyka, K.; Rauh, L.; Rabin, K.; Kimball, S.H.; Ratzan, S.C.; Lazarus, J.V. COVID-19 vaccine acceptance among adults in four major US metropoli-tan areas and nationwide. *Sci. Rep.* **2021**, *11*, 21844. [CrossRef]
11. Killgore, W.; Cloonan, S.; Taylor, E.; Dailey, N. The COVID-19 Vaccine Is Here—Now Who Is Willing to Get It? *Vaccines* **2021**, *9*, 339. [CrossRef]
12. Latkin, C.; Dayton, L.A.; Yi, G.; Konstantopoulos, A.; Park, J.; Maulsby, C.; Kong, X. COVID-19 Vaccine Intentions in the United States, a Social-Ecological Framework. *Vaccine* **2021**, *39*, 2288–2294. [CrossRef] [PubMed]
13. Hughes, M.M.; Wang, A.; Grossman, M.K.; Pun, E.; Whiteman, A.; Deng, L.; Hallisey, E.; Sharpe, J.D.; Ussery, E.N.; Stokley, S.; et al. County-Level COVID-19 Vaccination Coverage and Social Vulnerability—United States, December 14, 2020–March 1, 2021. *MMWR. Morb. Mortal. Wkly. Rep.* **2021**, *70*, 431–436. [CrossRef] [PubMed]
14. Sacarny, A.; Daw, J.R. Inequities in COVID-19 Vaccination Rates in the 9 Largest US Cities. *JAMA Health Forum* **2021**, *2*, e212415. [CrossRef]
15. Baker, E.H. Socioeconomic Status, Definition. In *The Wiley Blackwell Encyclopedia of Health, Illness, Behavior, and Society*; Cockerham, W.C., Dingwall, R., Quah, S., Eds.; Wiley Blackwell: Chicester, UK, 2014. [CrossRef]
16. Crane, M.A.; Faden, R.R.; Romley, J.A. Disparities in County COVID-19 Vaccination Rates Linked to Disadvantage and Hesitancy. *Health Aff.* **2021**, *40*, 1792–1796. [CrossRef] [PubMed]
17. Siegel, M.; Critchfield-Jain, I.; Boykin, M.; Owens, A.; Muratore, R.; Nunn, T.; Oh, J. Racial/Ethnic Disparities in State-Level COVID-19 Vaccination Rates and Their Association with Structural Racism. *J. Racial Ethn. Health Disparities* **2021**, *9*, 2361–2374. [CrossRef]
18. Wilkinson, M. Education Levels Drive Michigan Vaccines. What's Rate in Your Neighborhood? Bridge Michigan. 2021. Available online: https://www.bridgemi.com/michigan-health-watch/education-levels-drive-michigan-vaccines-whats-rate-your-neighborhood (accessed on 7 February 2022).
19. Centers for Disease Control and Prevention_b. COVID-19 Vaccinations in the United States. 2022. Available online: https://covid.cdc.gov/covid-data-tracker/#vaccinations_vacc-people-fully-percent-total (accessed on 2 August 2022).
20. Michigan Department of Health and Human Services_b. COVID-19 Vaccine Dashboard: COVID-19 Vaccine Cover-Age. 2022. Available online: https://www.michigan.gov/coronavirus/resources/covid-19-vaccine/covid-19-dashboard (accessed on 7 February 2022).
21. Michigan Department of Health and Human Services (MDHHS)_a. Michigan COVID-19 Vaccination Prioritization Guid-Ance of 2021. Available online: https://www.michigan.gov/-/media/Project/Websites/coronavirus/Folder38/MI_COVID-19_Vaccination_Prioritization_Guidance_2152021.pdf?rev=693f705f3588442aa17f506ab2b792cc (accessed on 2 August 2022).
22. Census Bureau. *Geographic Areas Reference Manual, Chapter 10: Census Tracts and Block Numbering Areas*; Census Bureau: Suitland, MD, USA, 1994. Available online: https://www.census.gov/programs-surveys/geography/guidance/geographic-areas-reference-manual.html (accessed on 3 August 2022).

23. Grubesic, T.H. ZIP Codes and spatial analysis: Problems and prospects. *Socio-Economic Plan. Sci.* **2008**, *42*, 129–149. [CrossRef]
24. Census Bureau. Group Quarters and Housing Units Estimates Terms and Definitions. Available online: https://www.census.gov/programs-surveys/popest/about/glossary/housing.html (accessed on 22 January 2023).
25. Ochieng, N.; Chidambaram, P.; Garfield, R.; Neuman, T. Factors Associated with COVID-19 Cases and Deaths in Long-Term Care Facilities: Findings from a Literature Review. 2021. Available online: https://www.kff.org/coronavirus-covid-19/issue-brief/factors-associated-with-covid-19-cases-and-deaths-in-long-term-care-facilities-findings-from-a-literature-review/view/footnotes/ (accessed on 3 August 2022).
26. Nguyen, K.H.; Rubinsky, A.D.; DeRouen, M.C.; Kemper, K.E.; Bibbins-Domingo, K.; Lyles, C.R. Impacts of Individual Patient Language and Neighborhood Ethnic Enclave on COVID-19 Test Positivity among Hispanic/Latinx Patients in San Francisco. *Med. Care* **2023**, *61*, 67–74. [CrossRef]
27. DiRago, N.V.; Li, M.; Tom, T.; Schupmann, W.; Carrillo, Y.; Carey, C.M.; Gaddis, S.M. COVID-19 vaccine rollouts and the reproduction of urban spatial inequality: Disparities within large US cities in March and April 2021 by racial/ethnic and socioeconomic composition. *J. Urban Health* **2022**, *99*, 191–207. [CrossRef]
28. van Holm, E.J.; Wyczalkowski, C.K.; Dantzler, A.P. Neighborhood conditions and the initial outbreak of COVID-19: The case of Louisiana. *J. Public Health* **2020**, *43*, 219–224. [CrossRef]
29. National Institutes of Health; US Office of Budget and Management. Revisions to the Standards for the Classification of Fed-Eral Data on Race and Ethnicity. 2020. Available online: https://orwh.od.nih.gov/toolkit/other-relevant-federal-policies/OMB-standards (accessed on 2 August 2022).
30. Office of Management and Budget. Revisions to the standards for the classification of federal data on race and ethnicity. *Fed. Regist.* **1997**, *62*, 58782–58790.
31. Michaels, I.H.; Pirani, S.J.; Carrascal, A. Disparities in Internet Access and COVID-19 Vaccination in New York City. *Prev. Chronic Dis.* **2021**, *18*, 210143. [CrossRef] [PubMed]
32. Freed, M.; Orgera, K.; Cubanski, J.; Tolbert, J.; Neuman, T. Vaccination Rates Are Relatively High for Older Adults, but Lag in Counties in the South, in Counties with Higher Poverty Rates and in Counties that Voted for Trump. 2021. Available online: https://www.kff.org/coronavirus-covid-19/issue-brief/vaccination-rates-are-relatively-high-for-older-adults-but-lag-in-counties-in-the-south-in-counties-with-higher-poverty-rates-and-in-counties-that-voted-for-trump/ (accessed on 31 August 2022).
33. Moy, L.; Cannon, Y. How to Build More Equitable Vaccine Distribution Technology. 2021. Available online: https://www.brookings.edu/techstream/how-to-build-more-equitable-vaccine-distribution-technology/ (accessed on 23 August 2022).
34. Stevens, J.P. *Applied Multivariate Statistics for the Social Sciences*, 5th ed.; Taylor & Francis: New York, NY, USA, 2009.
35. Nduggan, N.; Hill, L.; Artiga, S.; Haldar, S. Latest Data on COVID-19 Vaccinations by Race/Ethnicity. Kaiser Family Foundation. 2022. Available online: https://www.kff.org/coronavirus-covid-19/issue-brief/latest-data-on-covid-19-vaccinations-by-race-ethnicity/ (accessed on 5 February 2022).
36. Barry, V.; Dasgupta, S.; Weller, D.L.; Kriss, J.L.; Cadwell, B.L.; Rose, C.; Pingali, C.; Musial, T.; Sharpe, J.D.; Flores, S.A.; et al. Patterns in COVID-19 Vaccination Coverage, by Social Vulnerability and Urbanicity—United States, December 14, 2020–May 1, 2021. *MMWR. Morb. Mortal. Wkly. Rep.* **2021**, *70*, 818–824. [CrossRef] [PubMed]
37. Diesel, J.; Sterrett, N.; Dasgupta, S.; Kriss, J.L.; Barry, V.; Esschert, K.V.; Whiteman, A.; Cadwell, B.L.; Weller, D.; Qualters, J.R.; et al. COVID-19 Vaccination Coverage Among Adults—United States, December 14, 2020-May 22, 2021. *MMWR. Morb. Mortal. Wkly. Rep.* **2021**, *70*, 922–927. [CrossRef] [PubMed]
38. Centers for Disease Control and Prevention_c. COVID-19 Vaccine Equity for Racial and Ethnic Minority Groups. 2021. Available online: https://www.cdc.gov/coronavirus/2019-ncov/community/health-equity/vaccine-equity.html (accessed on 5 February 2022).
39. Khubchandani, J.; Macias, Y. COVID-19 vaccination hesitancy in Hispanics and African-Americans: A review and recommendations for practice. *Brain Behav. Immun. Health* **2021**, *15*, 100277. [CrossRef] [PubMed]
40. Smith, A.C.; Woerner, J.; Perera, R.; Haeny, A.M.; Cox, J.M. An Investigation of Associations between Race, Ethnicity, and Past Experiences of Discrimination with Medical Mistrust and COVID-19 Protective Strategies. *J. Racial Ethn. Health Disparities* **2021**, *9*, 1430–1442. [CrossRef]
41. White, N.D.; Grimm, H. Vaccine Equity: Lessons Learned from the COVID-19 Pandemic. *Am. J. Lifestyle Med.* **2022**, *16*, 443–446. [CrossRef]
42. Warren, R.C.; Forrow, L.; Hodge, D.A.; Truog, R.D. Trustworthiness before Trust—Covid-19 Vaccine Trials and the Black Community. *N. Engl. J. Med.* **2020**, *383*, e121. [CrossRef]
43. Willis, D.E.; Andersen, J.A.; Montgomery, B.E.E.; Selig, J.P.; Shah, S.K.; Zaller, N.; Bryant-Moore, K.; Scott, A.J.; Williams, M.; McElfish, P.A. COVID-19 Vaccine Hesitancy and Experiences of Discrimination among Black Adults. *J. Racial Ethn. Health Disparities* **2022**. [CrossRef]
44. Health Resources & Services Administration. Health Literacy. 2019. Available online: https://www.hrsa.gov/about/organization/bureaus/ohe/health-literacy/index.html (accessed on 2 February 2022).
45. Bartkowiak, D., Jr. CDC Awards Michigan $90 million to Expand COVID Vaccine Programs, Focus on Underserved Populations. 2021. Available online: https://www.clickondetroit.com/health/2021/04/06/cdc-awards-michigan-90-million-to-expand-covid-vaccine-programs/#// (accessed on 23 October 2022).

46. Michigan Department of Health & Human Services_c. Michigan Coronavirus Task Force on Racial Disparities. 2021. Available online: https://www.michigan.gov/mdhhs/0,5885,7-339-71551_5460_99929---,00.html (accessed on 23 October 2022).
47. Abba-Aji, M.; Stuckler, D.; Galea, S.; McKee, M. Ethnic/racial minorities' and migrants' access to COVID-19 vaccines: A systematic review of barriers and facilitators. *J. Migr. Health* **2022**, *5*, 100086. [CrossRef]
48. Bajaj, S.S.; Stanford, F.C. Beyond Tuskegee—Vaccine Distrust and Everyday Racism. *N. Engl. J. Med.* **2021**, *384*, e12. [CrossRef]
49. Hildreth, J.E.; Alcendor, D.J. Targeting COVID-19 vaccine hesitancy in minority populations in the US: Implications for herd immunity. *Vaccines* **2021**, *9*, 489. [CrossRef] [PubMed]