Short communication

COVID-19 vaccination rates vary by community vulnerability: A county-level analysis

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ABSTRACT

We used the COVID-19 Community Vulnerability Index and 7 theme scores to assess associations between vulnerability and county-level COVID-19 vaccination (n = 2415 counties) through May 25th, 2021. When comparing vaccination rates among quintiles of CCVI scores, Theme 3 (housing type, transportation, household composition, and disability) was associated with the largest disparity, with the least vulnerable counties (Q1) having 33% higher rates of vaccination among individuals aged 18+ (53.5% vs 40.2%) compared to counties with the highest vulnerability (Q5). Using generalized linear models with binomial distributions and log links, we found that a 10-point increase in the CCVI index, socioeconomic vulnerability, housing type and composition, and epidemiological factors were associated with at least a 1.0 percentage point decline in county-level vaccination. The association between community vulnerability and lower vaccination rates suggests the need for continued efforts for equitable COVID-19 vaccination across marginalized communities.

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1. Introduction

Public health and clinical research and commentaries have highlighted that increased rates of adverse COVID-19 outcomes among marginalized communities are founded in individual-level and community-level factors that increase risk of exposure (e.g., multifamily or multigenerational homes, employment in conditions with reduced protection from the virus) as well as factors associated with increased risk of severe COVID-19 outcomes (e.g., reduced access to healthcare, lower health insurance rates, higher rates of chronic comorbidities) [1–4].

Since COVID-19 vaccines were introduced in the market, public health officials have been focused on ensuring equitable distribution and uptake of the vaccine. As of May 25th, 2021, nearly 124 million individuals in the US, representing around 40% of the population, are fully vaccinated against COVID-19 [5]. Vaccination rates at the state level vary nearly two-fold, with 53% of residents in Vermont being fully vaccinated compared to 27% of residents in

Mississippi [6]. A report by the Centers for Disease Control and Prevention (CDC) highlighted disparities in COVID-19 vaccination through March 1st, 2021, among communities with higher social vulnerability using the CDC's Social Vulnerability Index (SVI) [7]. We add to this literature that evaluates county-level COVID-19 vaccination by capitalizing on three additional months of data and by utilizing the COVID-19 Community Vulnerability Index (CCVI), which additionally includes domains related to epidemiological, public health system, and high risk environment factors [8]. Continued evaluation of COVID-19 vaccination and county-level characteristics is necessary in order to ensure equitable and efficient administration of COVID-19 vaccination across the United States.

2. Methods

County-level rates of COVID-19 vaccination were sourced from the CDC COVID Data Tracker [5]. Our study evaluated county-level rates of fully vaccinated (i.e., having received both doses of a two-dose vaccination series or a single dose of a one-dose series) populations aged 18+ and aged 65+. Population denominators were sourced from the 2019 Vintage Census Estimates to align with

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the denominators utilized by the CDC COVID tracking data. The CDC provides information regarding the percent of vaccination records with a valid place of residence, noting that states with less than 80% information should be evaluated with caution. Among the 2864 counties in the CDC vaccination data, we removed 449 counties from 6 states that had less than the 80% threshold for valid residential information, resulting in a final study sample of 2415 counties.

County-level vulnerability was assessed using the U.S. COVID-19 Community Vulnerability Index (CCVI) by the Surgo Foundation (https://precisionforcovid.org/ccvi). The CCVI is computed using 40 measures within 7 themes: socioeconomic status (SES); minority status and language; housing type, transportation, household composition, and disability ("housing type/composition" hereafter); epidemiological factors; healthcare system factors; high risk environments; and population density [8]. The CCVI overall score as well as the 7 theme indices range from 0 to 1, with 1 representing the most vulnerable area. To improve interpretability, we multiplied the CCVI scores by 100 in our analysis, so that the CCVI scores ranged from 0 to 100.

Descriptive statistics included tests for trends to test for differences in vaccination rates among populations within counties that fall into quintiles of the CCVI and 7 CCVI themes. Vaccination rates for each quintile were based on the overall number of vaccinations and total population for all counties in the given quintile (for the respective age group) to account for differences in county populations. To further assess the association with vulnerability and vaccination rates, generalized linear models (GLM) with a binomial distributions and log links were calculated for the CCVI overall score and the 7 themes (continuous from 0 to 100) and county-level vaccination rates. GLM models were weighted based on county population denominators for the respective age group.

Analyses and figures were completed in Stata v16 and Tableau 2020.3. This study was designated as non-human subjects research by the University of Arkansas for Medical Sciences Institutional Review Board (#262558).

3. Results

The vaccination rate among individuals aged 18+ was 48.2%. County-level vaccination (n = 2415) ranged from 1.0% to 84.7%, with the 10th-to-90th percentile ranging from 33.6% to 48.2%. Among states with at least 10 represented counties, county-level rates ranged from 42.9% to 55.9% in New Hampshire to 1.0% to 63.7% in Massachusetts when considering relative differences in vaccination percentages between counties. In all but five states, the county with the highest rate of vaccination had more than twice the vaccination rate than that of the county with the lowest rate.

Table 1 provides vaccination rates based on quintiles of community vulnerability scores. Counties with lower levels of community vulnerability (Q1) had 7% higher vaccination rates compared to counties with the highest level of vulnerability (Q5) for individuals aged 18+ (47.9% vs 44.6%; p < 0.001). Among the 7 themes, we found a significant difference in vaccination for all themes for both age groups. The theme with the largest relative difference for vaccination among those age 18+ was the housing type/composition theme (Theme 3), with counties that had the least vulnerability (Q1) having 33% higher rates of vaccination among individuals aged 18+ (53.5% vs 40.2%) compared to counties with the highest vulnerability (Q5). Of note is that there were positive tests for trends related to Theme 2 (minority status and language) as well as Theme 7 (population density) for both age groups.

A map was constructed to depict counties based on high (i.e., quintile 5 or 4) or low (i.e., quintile 1, 2, or 3) vaccination and over-

all CCVI score for populations aged 18+ (Fig. 1) and aged 65+ (Supplemental Fig. 1). Counties shaded in green have high vaccination rates, and counties shaded in red have low vaccination rates, with darker shading representing increased vulnerability (i.e., higher CCVI). There was a concentration of high vulnerability, low vaccination counties in the South, with over half the counties in Alabama (92.5%) , Mississippi (82.9%), Louisiana (81.3%), Tennessee (80.0%), South Caroline (71.7%), Florida (59.7%), North Carolina (69.0%), Oklahoma (61.0%), Arkansas (58.7%), and Kentucky (51.7%) having high vulnerability and low vaccination.

We fit GLM models to test for associations between the CCVI overall and each of the 7 themes with vaccination among individuals aged 18+ (Fig. 2) and aged 65+ (Supplemental Fig. 2). Marginal effects in Table 2 are multiplied by 10 to provide the absolute change in county-level COVID-19 vaccination rates with a 10-point increase in a given CCVI score. We found that a 10-point increase in the CCVI index score (more vulnerable) was associated with a 1.2 percentage point decline in vaccination among those age 18+ as well as among those aged 65+. Among populations aged 18+ we found that a 10-point increase (more vulnerable) in socioeconomic, housing type/composition, and epidemiological theme scores were all associated with at least a 1 percentage point decline in vaccination rates. We found a positive association between vaccination and population density for both age groups, and additionally a positive association between minority status/language for those aged 18+.

4. Discussion

This study evaluated the association between measures of county-level vulnerability and COVID-19 vaccination and found lower vaccination rates in more vulnerable areas. We found significant reductions in vaccination with increases in the CCVI index as well as five of the seven theme scores.

Our findings largely align with a previous evaluation that used data through March 1st, 2021 along with the four CDC SVI themes of social vulnerability [7]. Our finding of lower vaccination in areas with increased housing type/composition vulnerability is not directly comparable to the findings from the previous CDC SVI evaluation [7]. Specifically, the CCVI constructs the housing type/-composition theme by combining two themes from the SVI (household composition & disability and housing type & transportation) and additionally adds a metric of indoor plumbing [8]. The previous CDC evaluation found household composition and disability status to be negatively associated with vaccination and housing type and transportation to be moderately positively associated with vaccination [7].

Our finding of a negative association between socioeconomic vulnerability and vaccination rates aligns with the socioeconomic disparities in COVID-19 outcomes that have been apparent throughout the pandemic [9–11]. The SES index from the CCVI algorithm includes measures of poverty, unemployment, income, educational attainment, and uninsurance rates [8]. Each of these components are likely to be associated with unique and compounding oppressors that may hinder vaccination. For example, individuals who are uninsured or with low income may be less likely to have regular contact with primary care, may have a misunderstanding about the potential out-of-pocket costs associated with vaccination, or may have reduced access to technology needed to learn about vaccinations, to gather information about vaccination eligibility and administrating facilities, and to make an appointment. Unemployment may be a barrier to vaccination as many individuals receive directly through their employers, such as individuals in educational professions as well as front-line clinical workers. Continued efforts to provide outreach to marginalized

Table 1
Percent of the Population with COVID-19 Vaccination, by COVID-19 Community Vulnerability Index and Theme Quintiles (n = 2415 counties).[a]

	Percent of 18+ Population Vaccinated, by CCVI Quintile						Percent of 65+ Population Vaccinated, by CCVI Quintile					
	Q1	Q2	Q3	Q4	Q5	Test for trend	Q1	Q2	Q3	Q4	Q5	Test for trend
COVID-19 Community Vulnerability Index	47.9	53.0	50.3	48.8	44.6	–	72.4	75.8	73.9	71.7	67.9	–
Theme 1: Socioeconomic status	53.8	53.0	48.3	44.6	45.2	–	76.7	76.0	72.7	69.0	66.9	–
Theme 2: Minority status and language	40.9	44.4	44.4	45.6	50.3	+	67.4	70.5	71.1	71.3	72.0	+
Theme 3: Housing type, transportation, household composition, and disability	53.5	51.6	48.0	44.9	40.2	–	75.9	73.7	71.1	69.0	65.2	–
Theme 4: Epidemiological factors	51.3	48.2	42.6	40.3	41.5	–	73.0	72.8	69.0	67.2	67.7	–
Theme 5: Healthcare system factors	52.2	49.8	48.1	47.3	46.5	–	75.7	73.6	72.3	71.2	68.1	–
Theme 6: High risk environments	50.9	49.8	48.1	46.6	44.7	–	72.0	72.6	70.5	70.8	71.6	–
Theme 7: Population density	42.6	39.5	40.5	41.6	50.4	+	65.6	64.4	66.6	68.6	73.0	+

"–" and "+" tests for trends are all statistically significant at p < 0.001 using tests for trends between quintile rates, weighted for county population size.

[a] Vaccination data include fully-vaccinated populations through May 25th, 2021 from https://covid.cdc.gov/covid-data-tracker/#vaccinations. Population denominators align with numbers utilized by the Centers for Disease Control based on Vintage 2019 Census Tables found at https://www.census.gov/programs-surveys/popest/data/tables.2019.html. COVID-19 Community Vulnerability Indices come from precisionforcovid.org/ccvi.
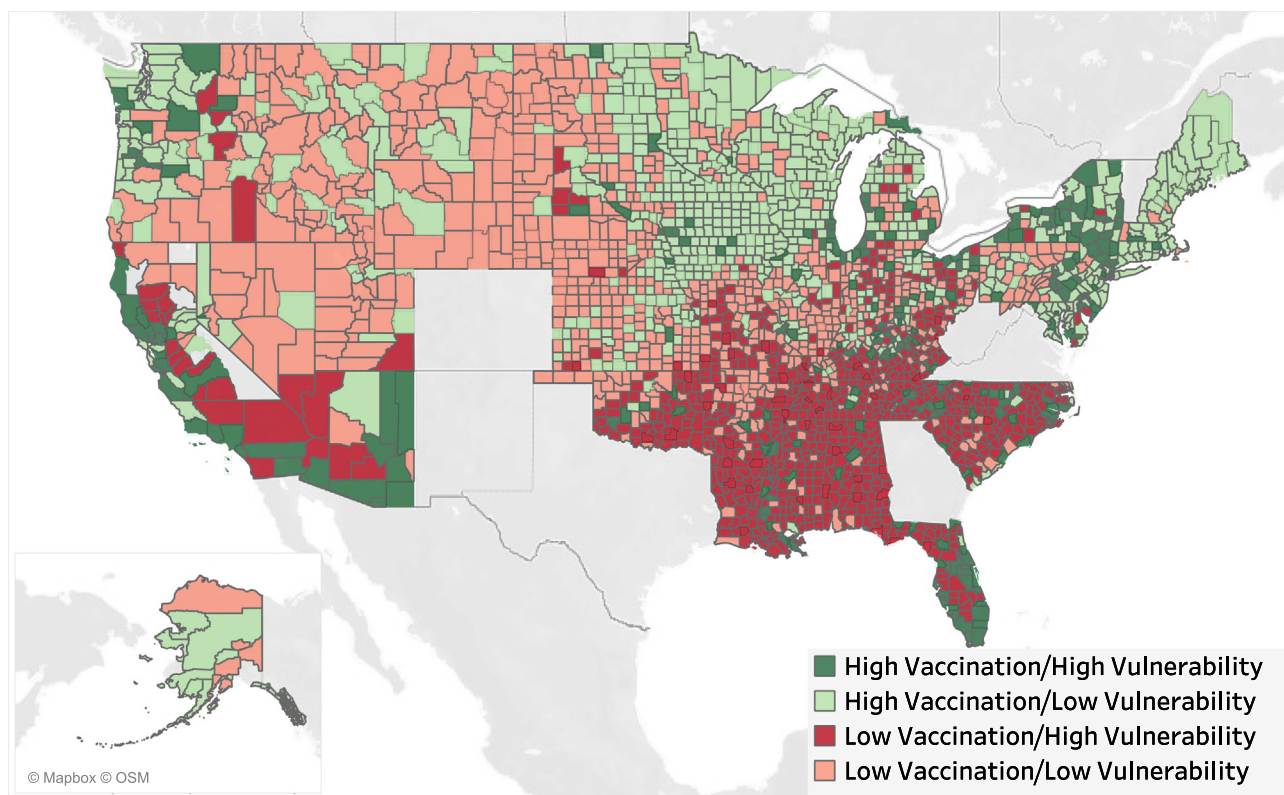

Fig. 1. County-level map depicting COVID community vulternability index scores and COVID-19 vaccination rates among populations aged 18+ (n = 2415 counties) Caption: Vaccination data include fully-vaccinated populations through May 25th, 2021 from https://covid.cdc.gov/covid-data-tracker/#vaccinations. Population denominators align with numbers utilized by the Centers for Disease Control based on Vintage 2019 Census Tables found at https://www.census.gov/programs-surveys/popest/data/tables.2019.html. COVID-19 Community Vulnerability Indices come from precisionforcovid.org/ccvi. "High" indicates quintile 4 or 5, and "Low" indicates quintile 1, 2, or 3.

communities, including mobile vaccination clinics and scheduling and educational resources using multiple modalities, may improve equity in vaccination.

A previous study utilized the CDC SVI to suggest an approach for prioritizing vaccination distribution based on vulnerability and observed rates of COVID-19 outcomes [12]. Our study adds to this literature by highlighting that vaccination has largely been negatively associated with various measures of vulnerability, suggesting a lack of such prioritization. A prioritization approach should be considered to increase vaccine allocation and educational outreach among areas with higher levels of vulnerability.

Our study found higher vaccination rates associated with increased minority race/ethnicity and population density scores. Our finding of increased rates in areas with higher density aligns with previous evaluations, including a recent report by the CDC that found that higher vaccination in urban relative to rural areas [13]. Of note is that the study identified that populations in rural areas were more likely to travel outside of their county to receive vaccination.

Given our finding related to the minority race/ethnicity theme and the pattern of high vulnerability, low vaccination counties in the South, we conducted post hoc assessments (results available
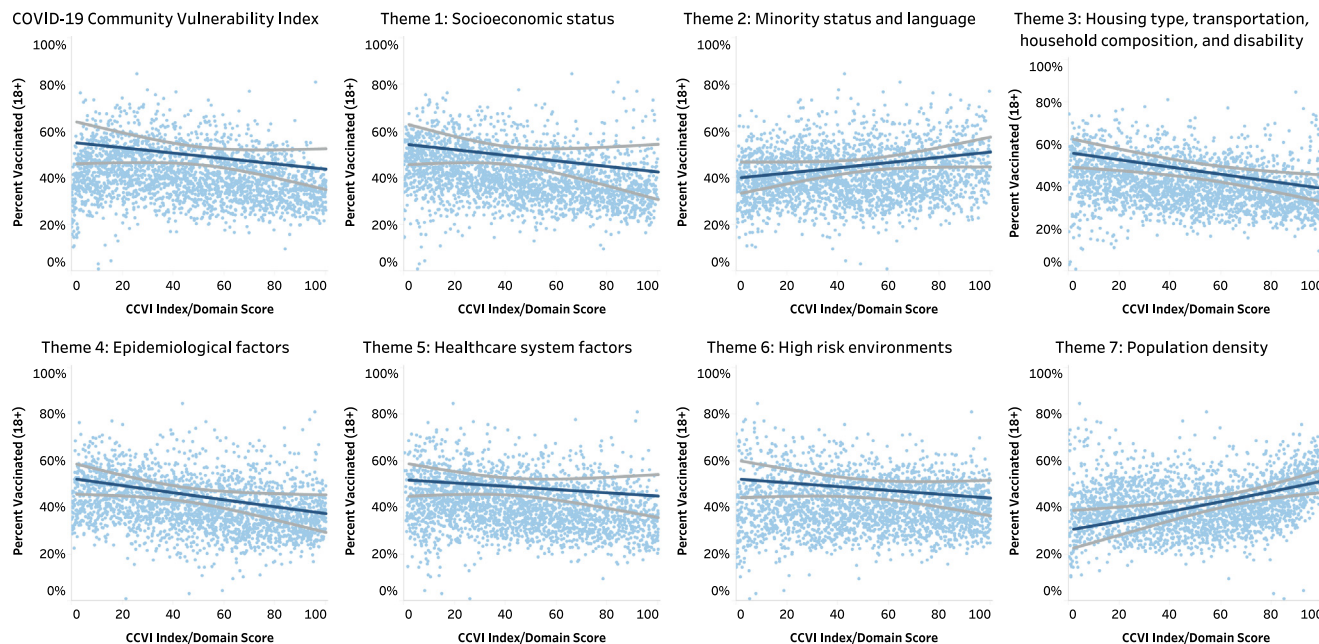
Fig. 2. County-level associations between COVID-19 Community Vulnerability Index and Vaccination Rates Among Populations Aged 18+ (n = 2415 counties). Caption: Vaccination data include fully-vaccinated populations through May 25th, 2021 from https://covid.cdc.gov/covid-data-tracker/#vaccinations. Population denominators align with numbers utilized by the Centers for Disease Control based on Vintage 2019 Census Tables found at https://www.census.gov/programs-surveys/popest/data/tables.2019. html. COVID-19 Community Vulnerability Indices come from precisionforcovid.org/ccvi. Lines indicate fitted Generalized Linear Models with binomial distribution and log link, and associated 95% Confidence Intervals.

Table 2

Marginal Effects from Generalized Linear Models Assessing the Association between COVID-19 Community Vulnerability Indices and COVID-19 Vaccination Rates (n = 2,415 counties).[a]

	Percent of 18+ Population Vaccinated			Percent of 65+ Population Vaccinated		
	Marginal Effect[b]	95 %CI	p	Marginal Effect[b]	95 %CI	p
COVID-19 Community Vulnerability Index	−1.2	(−1.6,−0.7)	<0.001	−1.2	(−1.5,−0.9)	<0.001
Theme 1: Socioeconomic status	−1.2	(−1.7,−0.7)	<0.001	−1.4	(−1.7,−1.1)	<0.001
Theme 2: Minority status and language	1.1	(0.8,1.4)	<0.001	0.2	(−0.1,0.5)	0.166
Theme 3: Housing type, transportation, household composition, and disability	−1.7	(−2.0,−1.4)	<0.001	−1.3	(−1.6,−1.1)	<0.001
Theme 4: Epidemiological factors	−1.5	(−1.9,−1.2)	<0.001	−0.8	(−1.1,−0.5)	<0.001
Theme 5: Healthcare system factors	−0.7	(−1.1,−0.3)	<0.001	−1.0	(−1.3,−0.7)	<0.001
Theme 6: High risk environments	−0.8	(−1.2,−0.5)	<0.001	−0.1	(−0.5,0.2)	0.451
Theme 7: Population density	2.2	(1.9,2.5)	<0.001	1.2	(0.9,1.5)	<0.001

[a] Vaccination data include fully-vaccinated populations through May 25th, 2021 from https://covid.cdc.gov/covid-data-tracker/#vaccinations. Population denominators align with numbers utilized by the Centers for Disease Control based on Vintage 2019 Census Tables found at https://www.census.gov/programs-surveys/popest/data/tables. 2019.html. COVID-19 Community Vulnerability Indices come from precisionforcovid.org/ccvi.

[b] Marginal effects were multiplied by 10 to improve interpretability by showing the absolute change in vaccination for a 10 point increase in the given index.

upon request) to assess vaccination based on the non-White racial/ethnic group with the highest percentage among those counties that had high racial/ethnic vulnerability (Q4 or Q5). We found high vaccination rates (i.e., Q4 or Q5) among 89% (n = 24/27), 52% (n = 242/469), and 44% (n = 32/72) of counties in which non-Hispanic Asian, Hispanic, and non-Hispanic American Indian and Alaska Native (AIAN) populations were the highest minority population, respectively, compared to only 32% (n = 129/397) of counties in which Black populations were the highest minority population. Despite higher vaccination rates among counties with increased racial/ethnic vulnerability, our post hoc analyses suggest that the increased vaccination may be concentrated among Asian, Hispanic, and AIAN populations rather than communities with higher concentrations of Black populations.

This study has some limitations. While states are reporting a breakdown of vaccination by race to the CDC, racial data is not available in the CDC vaccination data at any geographic level other than nationally [5]. Until county-level data regarding aggregate vaccination rates by race/ethnicity are available, evaluations

should consider utilizing area-level measures of racial/ethnic concentration and measures of social vulnerability to ensure evaluations are focused on equitable vaccination distribution and uptake. Relatedly, additionally analyses, should consider using smaller levels of geographic units when available, such as census tracts, in order to identify differences that may exist within counties. Finally, the CCVI themes are each constructed of multiple indicators from a variety of sources that are not directly available from the Surgo Foundation CCVI source. Evaluations of each indicator individually may be useful in identifying more specific aspects of vulnerability that may be most strongly related to vaccination rates.

5. Conclusions

This study evaluated the association between community vulnerability and COVID-19 vaccination and found that increases in measures of community vulnerability were largely associated with

lower vaccination rates. Given that the CCVI was specifically constructed to identify communities that may be at increased risk for COVID-19, efforts should be focused on increasing vaccination among communities designated as highly vulnerable according to the CCVI in order to reduce inequitable vaccination rollout and uptake among at-risk populations

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2021.06.038.

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