Published in final edited form as:
Vaccine. 2023 August 14; 41(36): 5322–5329. doi:10.1016/j.vaccine.2023.07.022.

Social inequalities and the early provision and dispersal of COVID-19 vaccinations in the United States: A population trends study

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Abstract

Background: In December 2020 the U.S. began a massive COVID-19 vaccination campaign, an action that researchers felt could catalyze inequalities in COVID-19 vaccination utilization. While vaccines have the potential to be accessible regardless of social status, the objective of this study was to examine how and when socioeconomic status (SES) and racial/ethnic inequalities would emerge in vaccination distribution.

Methods: Population vaccination rates reported at the county level by the Centers for Disease Control and Prevention across 46 states on 3/30/2021. Correlates included SES, the share of the population who were Black, Hispanic, Female, or aged ≥65 years, and urbanicity (thousands of residents per square mile). Multivariable-adjusted analyses relied on zero-inflated negative binomial regression to estimate the odds of providing any vaccine, and vaccination rate ratios (aVRR) comparing the distribution rate for vaccinations across the U.S.

Results: Across the U.S., 16.3 % of adults and 37.9 % of adults aged 65 and older were vaccinated in lower SES counties, while 20.45 % of all adults and 48.15 % of adults aged 65 and older were vaccinated in higher SES counties. Inequalities emerged after 41 days, when < 2 % of Americans were vaccinated. Multivariable-adjusted analyses revealed that higher SES was associated with improved vaccination distribution (aVRR = 1.127, [1.100–1.155], $p < 1E–06$), while increases in the percent reporting Black or Hispanic race/ethnicity was associated with lower vaccination distribution (aVRR = 0.998, [0.996–0.999], $p = 1.03E–04$).

Conclusions: Social inequalities in COVID-19 vaccines reflect an inefficient and inequitable distribution of these technologies. Future efforts to improve health should recognize the central role of social factors in impacting vaccine delivery.

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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.

Keywords

Vaccine; Social epidemiology; COVID-19; Pandemic response; Social inequalities; Race/ethnicity; Socioeconomic status; Vaccination; Immunization disparities; Social inequality

1. Introduction

Starting at the end of December 2020, Pfizer began delivering its much-anticipated messenger-ribonucleic acid (mRNA)-based COVID-19 vaccine in the United States to a small number of healthcare workers under an Emergency Use Authorization from the Food and Drug Administration [1]. Shortly thereafter, several other vaccines were approved in the United States, Europe, and worldwide. Vaccination effectiveness has been excellent to very good for Pfizer and other vaccines in clinical trials [2], and real-world examples have shown that the vaccination works reliably across several populations, including in the most vulnerable field [3]. Encouraging news about vaccinations was received with global jubilation but also highlighted concerns about the need for an equitable plan for vaccine distribution [4] and the enormous potential for social inequalities to rapidly arise in vaccine uptake globally [5].

Prior work examining the roll-out of medical technologies more broadly suggests that these concerns regarding equitable distribution are likely well-founded [6]. Fundamental cause theory argues that individuals and communities with more resources often use those resources to access life-saving technologies [7]. Expanding on this work, the social history of disease theory clarified that inequalities often emerge rapidly when effective interventions become available [8]. Empirical evidence supports these theories showing, for instance, that following the introduction of Highly Active Antiretroviral Treatments (HAART) for HIV/AIDS in 1996, socioeconomic and racial disparities in HIV/AIDS-related mortality increased in the years post-HAART, even though HIV/AIDS mortality rates decreased at a population level once HAART became available [9]. Additionally, studies have identified social inequalities in Statin usage [10] and cancer screening technologies [11] and behaviors [12]. Specifically examining vaccination, researchers have noted inequalities in uptake for human papilloma virus [13], childhood vaccinations [14], and while specifically examining vaccination for COVID-19, researchers have reported inequalities in intent to vaccinate [15] and in vaccine uptake [16]. This work suggests that socioeconomic factors hasten the distribution of health interventions, such as medications or vaccines, in some communities and among some individuals while delaying in other areas and among different individuals.

Anticipating Federal Drug Administration approval for novel COVID-19 vaccines targeted at preventing infection and reducing the severity of COVID-19, Omer, Benjamin [17] provided recommendations for reducing the potential for lags in COVID-19 vaccine uptake that focused specifically on improving the efficiency of access and avoiding the creation of barriers. Responding to the possibility of inequitable distribution of vaccines, the U.S. Centers for Disease Control and Prevention (CDC) recognized the need to develop programs that would seek to ensure that underrepresented minority, rural and poor populations would receive an equitable share of vaccinations [18]. Yet, there were immediate problems with

COVID-19 vaccination uptake, including that access to the COVID-19 vaccination might differ depending on SES and race/ethnicity [19]. Concurrently, media reports indicated that some communities had problems delivering vaccines equitably because of difficulties with internet access [20], pharmacy deserts [21], and the phenomenon of advantaged groups implementing extraordinary efforts to ferret out shot locations [22] including using vaccination sites designated to serve disadvantaged groups [23]. While often framed as a matter of individual choice, the need for individuals to go to extraordinary measures may suggest that better-resourced communities would be able to jockey to secure vaccines at higher rates for their members. But what seemed to be happening was that better-resourced individuals traveled to other areas to get the vaccinations they wanted, even when their communities could not fulfill that demand. Indeed, in an initial cross-sectional study of vaccine distribution disparities, the CDC COVID-19 response team reported that only 5.4 % of the first 12 million doses went to individuals identifying as Black, with 11.5 % going to people identifying as Hispanic [24]. However, the U.S. Census Bureau [25] reports that 13.4 % of all American residents self-identify as Black, and 18.5 % report Hispanic ethnicity (2019 est.). Since then, a few studies have noted the presence of a socioeconomic gradient in vaccination uptake when studied cross-sectionally at the ecological level across Israel [15], among children in Montreal, Canada [26], in a cross-sectional study in the U.S. [27], and cross-sectionally across the U.S. at month 3 following vaccination provision [28]. Similarly, inequalities have been reported globally when comparing vaccination uptake both within and between countries [29].

Critical questions, then, are 1) whether the COVID-19 vaccine roll-out in the United States has unfolded to achieve an equitable vaccine distribution, and 2) to what extent are community-level resources driving inequalities in vaccine access? To address these questions, this study tested whether county-level SES and racial/ethnic composition measures were associated with COVID-19 vaccination rates in American adults aged 18 and older and in the high-risk group of adults 65 and older. To understand the population uptake of vaccination, we found it helpful to think about two distinct stages including the: 1) timing of the initiation of vaccination into a new area (denoted provision) and 2) the rate of subsequent distribution in that area as vaccines spread through counties (denoted administration). We hypothesized that inequalities in vaccination uptake would arise quickly and would compound with time.

2. Methods

2.1. Setting

The vaccination program in the U.S. was one of the first, globally, and was rolled out in conjunction with state governments and with coordination and supply chain developmental efforts from the Centers for Disease Control and Prevention. At the local level, states were charged with providing aid to county Departments of Health in vaccinating their population. Vaccine campaigns, therefore, differed in structure and requirements for access that varied by state. Thus, most vaccination programs developed by local Departments of Health began by rapidly seeking to vaccinate healthcare workers and vulnerable people living in congregate settings. Once complete, access was then provided to older adults and directed to sets of occupation-based or community-based groups through community-facing distribution points. However, once resources developed and the need for bespoke programs began to wane, vaccination programs were shifted to private sources including pharmacies that provide other approved vaccines to the community.

2.2. Data

Daily vaccination and population counts were downloaded from the *Centers for Disease Control and Prevention's* (CDC) vaccination portal on their COVID-19 data tracker page (covid.cdc.gov) from 1/23/2021 to 12/27/2021. On their portal, the CDC allows researchers to access collated information reported to the CDC directly by local Departments of Health as part of the COVID-19 response. Data from counties in Texas (n = 254) and Hawaii (n = 5) were excluded because those states began reporting vaccination statistics several months after they started distributing vaccinations. In addition, a small number of rural counties (n = 8) lacked information about vaccination dispersion, so these counties were also excluded leaving a final analytic sample of 2,762 counties in 48 states.

2.3. Measures

The outcome in this study is the percent of the population reported as having completed their specific vaccination schedule (e.g., two vaccinations for those injected with using the messenger ribonucleic acid (mRNA) based vaccines made by Pfizer or Moderna, or a single viral deoxyribonucleic acid-based vaccination made by Johnson & Johnson) in their reported county of residence by day from 1/23/2021 to 12/27/2021. This temporal window reduced the degree to which vaccination provision is exclusively focused on healthcare workers and captured most of the main vaccination drive in the U.S. County population counts derived from US census data were used as denominators to calculate county-level vaccination rates. Vaccines began being delivered in late December 2020 across the U.S., and CDC data includes the date on which total vaccination counts were reported for each county. Histograms were used to examine the administration of vaccinations across counties in the U.S. to assess distributional assumptions (results not shown).

County-level socioeconomic and demographic information was assessed using the five-year estimates provided by the American Community Survey [30]. SES was operationalized using a validated method that integrated the information into an index based on the county-level percent of residents with less than a high school diploma, the percent of adults with a four-year college degree, the unemployment rate, the median household income, and the percent living below the federal poverty line [31]. The index was determined to have good overall consistency (mean inter-item correlation = 0.46, Cronbach's α = 0.81). While analyses revealed strong associations with this composite SES measure, sensitivity analyses examining subcomponents of the SES index revealed consistent associations across all specific indicators of SES supporting the use of the overall index. We also created high (above median) and low (below median) SES categories for descriptive purposes.

Demographic variables, including the percent aged 65 and older, Black, Hispanic, and female, were merged with data on vaccination at the county level. Urbanicity was measured as the number of people residing in a county divided by the county's total area (thousands/

square mile) and log-transformed for these analyses. Additionally, because there has been a reported partisan difference in the acceptability of vaccines [32], we accounted for the Republican vote share in the 2020 presidential elections.

2.4. Statistical analyses

We begin by describing analytic variables using means and standard deviations, or percentages. To show regions where SES was tracked with COVID-19 vaccination rates, we provided maps that show correspondence between vaccination and SES by alternatively highlighting higher SES areas where vaccinations were exceptionally high or (in a different color) low SES areas where vaccination rates were meager.

We relied on multivariable-adjusted zero-inflated negative binomial regression to model processes of the initial provision and then the overall distribution of vaccination uptake. “Provision” refers to the initiation of vaccination efforts in any single county, which we felt would likely be determined by state-level actions when vaccination was first released for use in healthcare workers. In contrast, “administration” refers to the subsequent rate of administration of vaccines in any one specific county as it moves towards completing the vaccination of the overall population. Because there are multiple outcomes, this dual process requires a zero-inflated model in which an exogenous variable is needed to predict the presence of zeros—instances in which a county has not yet begun to provide vaccination. We chose urbanicity, SES, and race/ethnicity to predict provision because proximity to urban centers might reasonably affect initial access to vaccines but might not strongly influence how rapidly they would be distributed within counties. In keeping with this reasoning, urbanicity was used with the leading independent variables of interest (SES and percent Black) to model the odds of vaccination provision. Population counts were used to model the underlying number of vaccines provided since more vaccinations must be provided to a larger, more significant number of people to achieve the same coverage percentage in places with larger populations. Models of vaccination administration examined SES and the share of the Black, Hispanic, Female, or 65 years and older population.

2.5. Sensitivity analyses

In this study, we used an SES index relying on a summation of standardized items however, since readers may be interested in understanding how specific items behaved, we performed sensitivity analyses to examine whether associations between outcome variables and subcomponents of the SES index were consistent across all specific indicators of SES. To examine bias resulting from missing data in states that did not include data for the counties in those states, we used logistic regression to determine whether demographic and socioeconomic indicators were associated with the odds of counties being formed. Coefficients were compared between models using t-tests.

All statistical analyses were completed using State 17/MP [StataCorp].

2.6. Ethics

Analyses in this study reflect secondary data analyses of de-identified counts of vaccinated individuals and are not considered human subjects’ research.

3. Results

3.1. County-level SES, racial, and ethnic disparities

Descriptive characteristics of the counties included in the analysis (Table 1) showed significant demographic and vaccination differences between counties with varying levels of SES across the U.S.

The median county had vaccinated 17.6 % of its adult population on the date shown in Fig. 1 (3/30/2021). This map showed counties color-ranked by vaccination rates above and below the median vaccination rates. Notable pockets of low vaccination were evident at the state level in southern states including Georgia and the counties of other states neighboring it, within significant parts of West Virginia, and throughout the midwestern states. Groups of counties with higher vaccination rates were found in the Northeastern corridor, midwestern counties near the great lakes, and parts the West coast and Florida.

Fig. 2 shows rates of completed vaccinations at the county level, with different lines for SES tertiles, and compares them to the national average. These results show that inequalities by SES had emerged by 3/15/2021, approximately 79 days after the date vaccination rollout began in earnest. Fig. 3 shows rates of completed vaccinations at the county level, stratified by racial composition. Fig. 3 clarifies that racial gaps opened earlier than SES gaps in the U.S., with inequalities widening between counties with high versus low percentages of minorities emerging within 41 days of the initial provision of vaccinations. Together, figures show that lower-SES counties and those with proportionally larger Black and Hispanic populations showed a slower uptake of completed vaccination than higher-SES counties and those with smaller Black or Hispanic people.

3.2. Vaccine provision and administration characteristics

Next, we jointly examined the overall pattern of vaccine provision alongside changes in administration over time using zero-inflated negative binomial regression [Table 2]. In unadjusted analyses, SES was strongly associated with the provision and administration of vaccinations. In multivariable analyses, however, results showed that more urbanized populations had early commencement of vaccination campaigns. Concurrently, counties with higher rates of Black or Hispanic people exhibited later commencement of vaccination programs. County-level SES was not associated with sizable changes in vaccination provision after adjusting for urbanicity and racial/ethnic makeup. Instead, the impact of SES was observed specifically on vaccination administration over time. After adjusting for covariates, we found that each SD increase in SES was associated with a 3.8 % [1.1–6.5] increase in the daily vaccination rate over time. These results suggested that those areas with higher SES showed higher rates of vaccination administration following the initial provision and that the widening of the gap accelerated slowly but consistently away from the average over time.

3.3. Vast socioeconomic inequalities in vaccination

Table 3 shows a multilevel longitudinal analysis focusing specifically on the potential for SES predicting growth in vaccination administration among those initially eligible for vaccination. As Table 3 shows, we found that higher SES was not associated with initial vaccination administration after adjusting county-level intercepts (Table 3). Instead, we found that each unit increase in SES was associated with a 0.064 % (SD = 0.001 %) more rapid increase in vaccination uptake each week after multivariable adjustment. We also found that counties with higher percentages of Black residents ($B = -0.113$, $P < 0.001$) or Hispanic residents ($B = -0.133$, $P < 0.001$) also had lower vaccination administration rates at baseline. When examining weekly change, however, we found that these inequalities grew among Black Americans ($B = -0.006$, $P < 0.001$) but that they tapered in areas with more Hispanic Americans ($B = 0.003$, $P < 0.001$) as compared to White Americans.

3.4. Sensitivity analyses

We conducted analyses to examine whether analytic decisions may have changed our results. Inclusion in the study was not possible for any counties in Texas, which did not report vaccination information reliably. Logistic regression analyses revealed that counties in states that were included did not differ in terms of SES ($p = 0.149$) or percent Black ($p = 0.604$) but had lower overall percent reporting Hispanic ethnicity (aOR = 0.90 [0.89–0.91] $p < 0.001$), higher percent female (aOR = 1.07 [1.01–1.13] $p = 0.025$), and higher levels of urbanicity (aOR = 1.03 [1.01–1.06] $p = 0.014$) as compared to counties in Texas and Hawaii that were excluded from analyses.

4. Discussion

Social inequalities are often present when individuals proactively seek out healthcare and adopt healthy lifestyles. In the present study, we hypothesized that residents in counties with greater access to resources would have greater access to COVID-19 vaccination than counties with fewer resources. The current paper produces evidence consistent with this proposition and clarifies that such inequalities compounded over time. Additionally, we hypothesized that higher share of minoritized groups including higher proportion of Black or Hispanic Americans as compared to White Americans, would be associated with reduced vaccination provision and administration over time. In the case of newly released medical treatments, like the COVID-19 vaccines, this study suggests that the timely action of states is needed to facilitate peoples' capacity to access to these beneficial health interventions [6].

Using population data representing >90 % of all Americans, we found that, upon adjusting for demographics and urbanicity, a one standard deviation unit change in county-level SES was associated with a 3.8 % higher vaccination rate on any given day of observation. Counties with higher percentages of minority populations saw vaccination rate decreases of 0.3 % and 0.2 % for each percentage point increase in the share of Blacks and Hispanics, respectively, in those counties. Together, these results are consistent with the possibility that resources are being actively used to improve public health in some communities and are being provided less rapidly in others.

The spatial dynamics of the COVID-19 pandemic and its transmission through global social networks have been identified as the epidemic has unfolded [33], and recent work has shown that socioeconomic [34,35] and racial/ethnic disparities in incidence and mortality have been evident as multiple waves of infection have rolled across the U.S. [36,37]. Mechanistic reports have proposed that these inequalities may have arisen from differences in behaviors such as masking and the ability to avoid infection by working from home [38]. However, inequalities in access to clinical trials and expensive antibody cocktails may also have contributed [1]. The present work suggests that inequalities may be amplified by the unequal ways in which vaccines are being distributed.

This study supports a range of prior studies showing that health inequalities emerged or were exacerbated when new health-enhancing knowledge or technology was developed but unequally distributed in the population [39]. Concerning vaccination uptake, researchers have shown explicitly that inequalities arise at the point of distribution for childhood vaccines both in high-income countries [40] and when vaccinations are optional such as in the case of adolescent vaccination for human papillomavirus [13]. Previous work in COVID-19 vaccination has reported that intent to vaccinate [15] and vaccine uptake early in the vaccination program [16] were inversely associated with disadvantaged racial/ethnic status and SES in Israel. Similar results have been reported in France, though vaccination inequalities appear muted in comparison to those reported in this study [41]. Since vaccination plays a central role in efforts to protect against more severe COVID-19 outcomes, these studies imply that vaccinations are one method through which social inequalities in COVID-19 might amplify inequalities in COVID-19 mortality. However, since infection in those who are unvaccinated or medically vulnerable are primary predictors of poorer COVID-related outcomes, results signify the potential for sizable social inequalities in COVID-19 outcomes, including the impacts of parental death [42] and difficulties with post-COVID syndrome [43].

Our results showed that communities with more Hispanic residents had lower overall vaccination rates than Whites, but this crossed over with Whites rapidly near the end of 2021. While it is obvious that vaccine outreach and vaccine hesitancy are complex subjects [44], we did not anticipate this result. We believe that it may imply the delay in vaccination outreach that occurred with COVID-19 when national media implied that vaccinations delivered within the US system early on may not be for foreigners living in the US. Coupled with that, many state outlets seeking to facilitate access in disadvantaged groups often required access to the internet, control over work schedules, and that patients fill out forms in English where they were asked to detail their health insurance details. Individuals, such as foreign nationals who distrust governmental resources for any reason, including their legal status, see such requests as a reason to avoid accessing healthcare resources [45]. Perhaps Hispanic groups were, therefore, disadvantaged because governmental efforts to distribute the vaccine did not recognize the importance of these barriers early on.

4.1. Limitations and strengths

Though being the first longitudinal study of socioeconomic inequalities in COVID-19 vaccination, the current study has several limitations to consider when interpreting results. Our analyses relied on county-level information, and we could not, therefore, examine individual-level behaviors impacting access to vaccination. However, individual-level data do not exist at this juncture and, because of the rapidity of vaccination uptake in many parts of the country, likely will not have the temporal resolution to determine inequalities in the middle of the vaccination campaign as we were able to do here. Despite this limitation, we believe that since county-level data are regularly used by policymakers to examine the effectiveness of efforts to deploy medical interventions, these data are particularly important.

Discussions about racism during the COVID-19 pandemic have highlighted ways that racism disadvantages racialized populations, often to the benefit of white populations. Adjustment for percent-Black or -Hispanic revealed significant inequalities but did not explain socioeconomic inequalities. Local structural and interpersonal factors, including structural racism or stigma, may not be completely captured in this study. The measures included in this study certainly do not capture the full potential for racism in minority outcomes since poorer individuals and minorities are often concentrated in the same zip codes and communities with fewer resources, even within the richest and the most impoverished counties. This indicates that larger inequalities may be more definitively identified by examining zip-code or individual-level information.

Finally, while this study is representative of the U.S. experience, there are clearly sizable differences in vaccine distribution programs globally both in terms of the timing of the commencement of each program and in the number and types of vaccines available to residents within different countries. On the one hand, there are a number of countries that have distributed vaccines more rapidly and efficiently than the U.S. as seems likely in the case of France as noted above [41]. Yet, concurrently there are many countries that still lack reliable access to COVID-19 vaccines while other areas are struck by anti-vaccine messaging, and have had trouble providing them broadly as a result. Thus, the generalizability of the patterns shown here likely vary sizably cross-nationally and may be worth further study to determine how inequalities might be proactively shrunk based on programmatic decisions.

5. Conclusions

Social inequalities in health often result from inequalities in the distribution of medical interventions, reflecting the inefficient distribution of these technologies and delayed health improvements [46]. COVID-19 vaccinations used advanced immunization technologies and were developed in record time, which may fundamentally change how public health and medicine are managed. Policymakers and researchers often attribute inequalities to the victims by focusing on the characteristics of those with fewer resources [47]. Sociomedical researchers have made efforts to shift focus toward the ways that elites play by capturing advantageous circumstances for themselves [6]. However, the newfound ability that such vaccinations provide to avoid COVID-19 is embedded within our existing society and appears highly sensitive to its particularities [48]. The U.S. created an incredible vaccination program in a short period. Still, Americans with more resources skipped the lines such that outcomes favoring communities with more resources arose within weeks of the first vaccine provision. These inequalities may help to cause sizable inequalities in COVID-related outcomes including hospitalization and death but also the prevalence of post-acute COVID syndrome and increased risk of post-COVID cardiovascular and metabolic disease outcomes. Worse still, these inequalities were allowed to proliferate globally with poorer countries facing more severe vaccine shortfalls for much longer [49]. We, therefore, support efforts to anticipate and address social inequalities in life-saving technologies by integrated federal, state-led, community-focused actions before these inequalities emerge.

Acknowledgements

Support was provided by the National Institute on Aging (NIH/NIA RF1 AG058595).

Data availability

Data will be made available on request.

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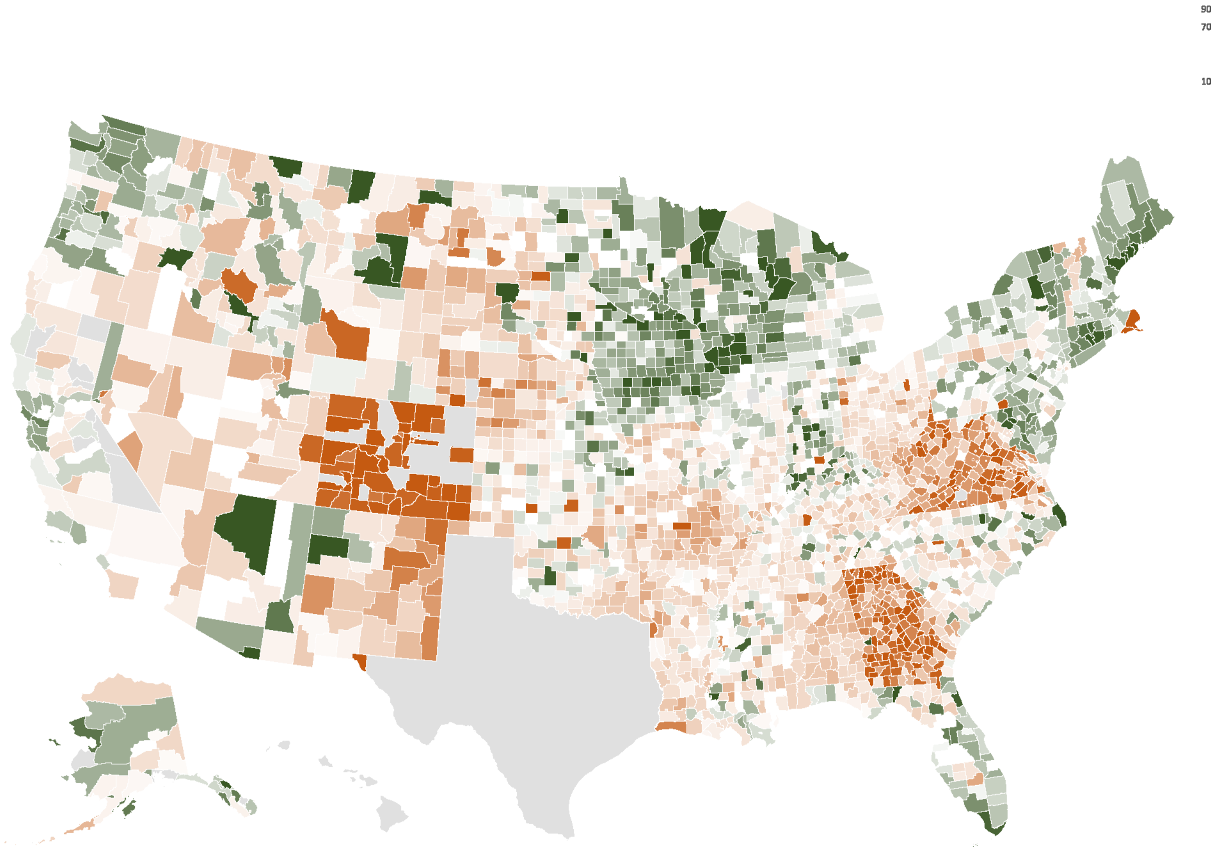

Fig. 1.

Geographic Distribution of Vaccination among individuals aged ≥65 stratified by U.S. County. Darker green show areas with coverage further above 70 % coverage. Darker orange shows counties with coverage under 70 %. Areas that appear whiter show regions where coverage is close to 70 %, the U.S. average on the date shown. Data from 3/30/2021 shown for comparison purposes. Gray areas lacked information about vaccination.

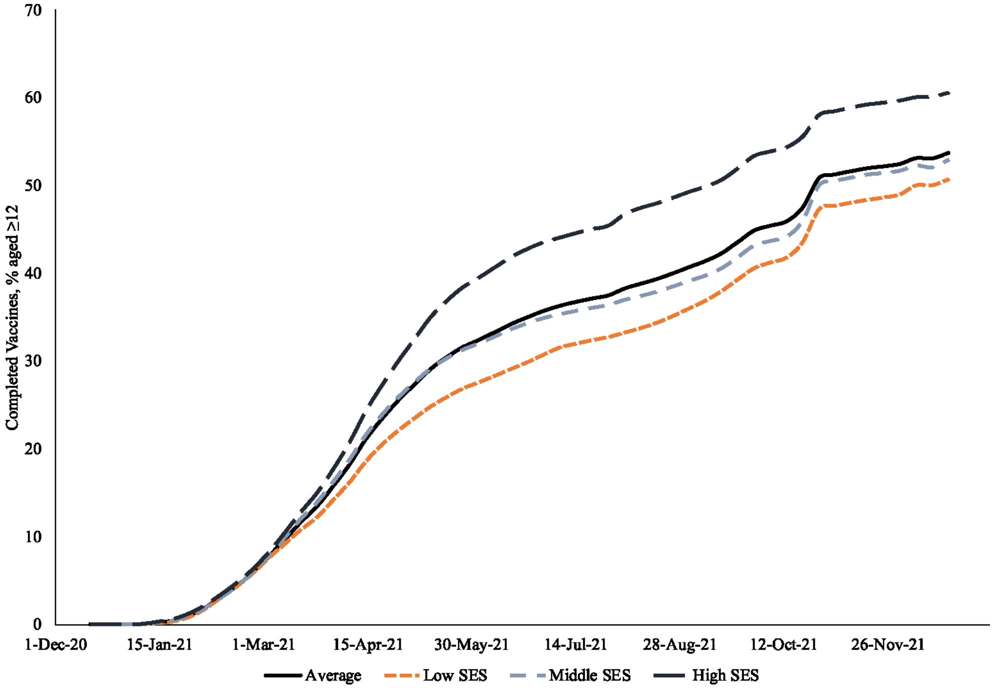

Fig. 2.

Trends showing average vaccination uptake among U.S. residents aged 12 and older throughout the U.S. (black solid line). Additional lines show trends stratified by socioeconomic tertile (the lowest SES tertile: short dashes with orange coloring, the average SES tertile is gray-blue lines with medium dashes, and the highest SES tertile is long dashes with black line).

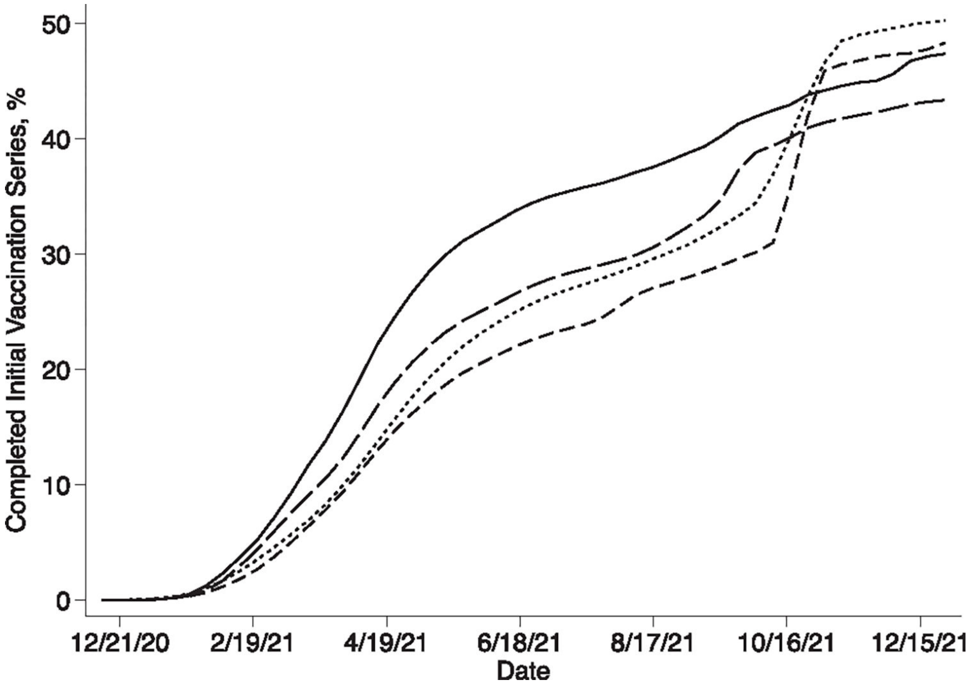

Fig. 3.

Trends showing vaccination uptake in U.S. counties, separated by racial/ethnic composition: White (solid), %Black > 10 % (long dashes), % Hispanic > 10 % (short dashes), both % Black and %Hispanic > 10 % (dots).

Table 1

Characteristics of the U.S. population in 48 states included in this study.

Characteristics	U.S. Population	Lowest Socioeconomic Status	Medium Socioeconomic Status	Highest Socioeconomic Status
Socioeconomic Status, Mean (SD)	0.03 (0.74)	0.78 (0.46)	0.04 (0.17)	−0.78 (0.40)
Black, Percent of Population, Mean (SD)	10.13 (15.13)	5.72 (8.42)	6.67 (10.16)	18.21 (20.56)
Hispanic, Percent of Population, Mean (SD)	6.69 (9.62)	8.41 (9.05)	5.93 (8.64)	5.63 (10.79)
Aged 65 and older, Percent ofPopulation, Mean (SD)	8.64 (2.13)	7.95 (2.06)	9.15 (2.12)	8.85 (2.02)
Female, Percent of Population, Mean (SD)	50.01 (2.14)	50.02 (1.71)	50.05 (1.83)	49.97 (2.76)
Republican Presidential Vote Share, %	64.21 (15.93)	66.97 (15.92)	67.46 (12.44)	58.50 (17.28)
Urbanicity, thousands/square-mile, Mean (SD)	−0.04 (1.72)	0.38 (2.02)	−0.21 (1.71)	−0.30 (1.25)
Vaccination Completion	N (%)	N (%)	N (%)	N (%)
All Ages, N (%)	34201.5 (27.00)	70448.4 (30.83)	21021.8 (26.87)	9253.4(23.11)
Ages 12 and older, N (%)	34483.7 (31.43)	71701.6 (36.02)	21308.6 (31.31)	9257.5 (26.85)
Ages 65 and older, N (%)	9661.2 (49.83)	18559.2 (54.53)	6873.7 (50.52)	3090.3 (44.20)

Note: SD: standard deviation; Lowest SES indicates those counties whose SES index fell in the lowest 33 %, medium SES indicates counties that fell in the central 33 %, while highest SES are counties with SES at or above the highest 33 %ile grouping. Urbanicity measured in thousands/square-mile. Analyses do not include Texas or Hawaii due to lack of data.

Table 2

Multivariable-adjusted associations between socioeconomic status and both provision and distribution of vaccinations modeled using zero-inflated negative binomial regression across the U.S. population and adjusting for county-level random effects.

Initial Distribution	**Unadjusted Model**			**Multivariable Adjusted Model**		
	aRR	**95 % C.I.**	**P**	**aRR**	**95 % C.I.**	**P**
Socioeconomic Status	1.048	1.018–1.078	<1E-06	1.036	1.008–1.065	<1E-06
% Black				0.990	0.989–0.992	<1E-06
% Hispanic				0.991	0.990–0.993	<1E-06
% Aged 65 and older				1.037	1.029–1.046	<1E-06
% Female				0.996	0.981–1.012	0.624
Urbanicity				0.896	0.885–0.906	<1E-06
Republican Vote Share				0.989	0.987–0.990	<1E-06
Distributional Growth	aRR	95 % C.I.	P	aRR	95 % C.I.	P
Socioeconomic Status	1.202	1.168–1.237	<1E-06	1.038	1.011–1.065	0.005
% Black				1.002	1.000–1.003	0.010
% Hispanic				1.010	1.008–1.012	<1E-06
% Aged 65 and older				0.979	0.971–0.986	<1E-06
% Female				0.991	0.984–0.998	0.008
Urbanicity				1.180	1.166–1.193	<1E-06
Republican Vote Share				0.996	0.995–0.998	<1E-06
Vaccine Provision	aRR	95 % C.I.	P	aRR	95 % C.I.	P
Socioeconomic Status	0.930	0.901–0.959	3.48E-06	1.007	0.967–1.048	0.741
Urbanicity				0.879	0.857–0.901	<1E-06
% Black				1.003	1.001–1.005	0.001
% Hispanic				1.003	1.001–1.005	0.009

Note: aRR: Multivariable-adjusted risk ratio; 95 % C.I.: 95 % confidence interval; SD: standard deviations from random effects component. Urbanicity measured in thousands/square-mile. P-values are estimated to the sixth decimal place. Analyses do not include Texas or Hawaii due to lack of data.

Table 3

Multivariable-adjusted associations between socioeconomic status and change in vaccination for the U.S. population aged 12 and older and aged 65 and older adjusting for state and county-level random intercepts.

Baseline Differences	**Aged 12 and older**			**Aged 65 and older**		
	B	**SE**	**P**	**B**	**SE**	**P**
Socioeconomic Status, SD	0.351	0.331	0.289	−0.388	0.488	0.427
Black, %	0.005	0.020	0.815	0.000	0.030	0.992
Hispanic, %	−0.083	0.023	3.7E-04	−0.146	0.034	1.4E-05
Older than 65 years, %	−0.085	0.101	0.397	−0.467	0.149	0.002
Female, %	0.104	0.086	0.229	0.261	0.130	0.044
Urbanicity	−0.303	0.172	0.077	0.050	0.248	0.839
Republican Vote Share, %	0.018	0.019	0.320	−0.017	0.027	0.538
Change over time	B	SE	P	B	SE	P
Socioeconomic Status, SD	0.207	0.025	<1.0E-06	0.308	0.041	<1.0E-06
Black, %	−0.026	0.001	<1.0E-06	−0.020	0.002	<1.0E-06
Hispanic, %	0.014	0.002	<1.0E-06	0.009	0.003	3.3E-04
Older than 65 years, %	0.056	0.008	<1.0E-06	0.009	0.013	0.518
Female, %	−0.011	0.007	0.132	−0.009	0.012	0.465
Urbanicity	0.013	0.011	0.227	0.003	0.018	0.852
Republican Vote Share, %	−0.055	0.001	<1.0E-06	−0.034	0.002	<1.0E-06

Note: B: regression coefficient; SE: standard error; P, p-value. Urbanicity measured in thousands/square-mile. P-values are estimated to the sixth decimal place. Analyses do not include Texas or Hawaii due to lack of data. Models adjust for variables shown here along with nonlinear rates of change over time using quadratic and cubic transformations for time, and for both random state and county effects.