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Hesitancy or Resistance? Differential Changes in COVID-19 Vaccination Intention Between Black and White Americans

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Abstract
The literature on COVID-19 vaccination has rarely taken a macro and longitudinal approach to investigate the nuanced racial and ethnic differences in vaccine hesitancy and refusal. To fill this gap, this study examines the relationships between race, time, and COVID-19 vaccine hesitancy and refusal using state-level data from the US Census Household Pulse Survey, 2020 US Decennial Census, and other sources (i.e., American Community Survey, Human Development Index database, and Centers for Disease Control and Prevention). Four longitudinal Generalized Estimating Equations (GEEs) were estimated to analyze how time-variant and time-invariant measures, and time itself influenced COVID-19 vaccine hesitancy and refusal rates, controlling for the effect of other relevant covariates. The results provide descriptive evidence that COVID-19 vaccine hesitancy had decreased in the USA, but vaccine refusal remained stable between January and October 2021. The GEEs further indicated that the proportion of the Black population was positively associated with both vaccine hesitancy and refusal rates, while the proportion of the White population was positively associated with the vaccine refusal rate but not associated with the vaccine hesitancy rate. In addition, over the 10-month period, COVID-19 vaccine hesitancy and refusal in the Black population declined rapidly, but vaccine refusal in the White population stayed fairly stable. More research and practical efforts are needed to understand and inform the public about these important but overlooked trends.

Keywords Vaccine hesitancy · Vaccine refusal · Race · COVID-19 · Macro approach

Introduction

Since the beginning of 2020, the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), also known as COVID-19, has resulted in a global health crisis. Thus far, successful vaccination is the only key to combating the pandemic [1]. Fortunately, owing to various national and local efforts to promote and distribute COVID-19 vaccines, a large proportion of the US population had been fully vaccinated [2]. However, there are still many Americans who are unsure about COVID-19 vaccination or choose not to be vaccinated [3]. The World Health Organization (WHO) defined vaccine hesitancy as the "delay in acceptance or refusal of vaccination despite the availability of vaccination services" [4]. Currently, vaccine hesitancy is considered one of the ten leading threats to global health, following air population and climate change, HIV, and global influenza pandemic, among others [5].

The racial and ethnic disparities in the health and social impact of COVID-19 are striking. Aside from their higher rate of hospitalization, Black Americans were reported to face a higher mortality rate (23%) [6]. This disproportionate burden for Black communities might be in part attributed to their larger share in the US population with pre-existing conditions [7] and their lower vaccination rate [8]. In fact, prior to the pandemic, Quinn et al. [9] observed that Black participants were more hesitant to accept the influenza vaccine than White participants. Similarly, during COVID-19, Black Americans were found to have a higher vaccine hesitancy rate than White Americans [10–12]. Researchers postulated that America's long history of racism in medical research and inequalities in health care is the fundamental reason for the Black community's mistrust of vaccination [11, 13].

Recent evidence, however, suggests that although the level of hesitancy in Black communities was initially high,

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they became more quick than Whites to accept COVID-19 vaccines. Padamsee et al. [14] collected panel data that tracked participants over a seven-month period from December 2020 to June 2021 in order to compare changes in COVID-19 vaccination intention between Black and White Americans. They found that vaccine hesitancy in Black Americans was higher than that of White Americans initially, but it decreased more rapidly over time [14]. When studying vaccine hesitancy in the context of COVID-19, the fact that the pandemic is a fast-moving health crisis cannot be stressed enough. However, to the best of our knowledge, no studies have systematically examined racial disparities in COVID-19 vaccine hesitancy from a longitudinal perspective at the time this article was written, with the exception of the study conducted by Padamsee et al. [14].

Regrettably, the COVID-19 vaccination literature that follows the WHO's definition often does not differentiate between vaccine hesitancy and refusal [15–19] despite the fact that the two constructs are fundamentally different. Vaccine hesitancy is characterized by feelings of ambivalence about vaccination [20], while vaccine refusal implicates the rejection of receiving vaccines [21]. According to the US Census Bureau, between January and October 2021, the percentage of US adults who were hesitant about being vaccinated against COVID-19 had substantially declined from 12.9 to 5.9%; however, the size of the vaccine-resistant group remained almost unchanged—about 8.8% of US adults refused to accept COVID-19 vaccines in January 2021, compared to 7.8% in October 2021 [22]. The rapidly declining vaccine hesitancy might have overshadowed the fact that a substantial proportion of racial minorities in the US have persistently resisted COVID-19 vaccination. Thus, longitudinal studies are necessary to better understand the changing patterns of COVID-19 vaccine hesitancy versus refusal in the USA.

Nevertheless, vaccine hesitancy and refusal are influenced by the interactions of macro-level forces and processes. For instance, political influences are unneglectable forces shaping public attitudes toward vaccination. Before the pandemic, polls and studies found that Republicans were more skeptical about taking influenza vaccines than their Democratic counterparts [23, 24]. Republican states were also found to have lower coverage for adolescent vaccination [25]. During COVID-19, Gollwitzer et al. [26] noted that Republican counties exhibited less physical distancing than Democratic counties. To date, the social and political contexts of COVID-19 vaccination intention, however, remain unclear as most prior studies were conducted at the micro-level [17, 18, 27–29].

This paper contributes to the current literature by distinguishing between vaccine hesitancy and refusal. In our analyses, we defined COVID-19 vaccine hesitancy as the reluctance to be vaccinated against COVID-19, while vaccine refusal as the opposition to COVID-19 vaccination. We noted that previous research on COVID-19 vaccination intention has rarely taken a macro and longitudinal approach to investigate the nuanced racial and ethnic differences. To fill these gaps, we conducted longitudinal statistical analyses to explore the relationships between race, time, and COVID-19 vaccine hesitancy and refusal using state-level data from the Household Pulse Survey (HPS), 2020 US Decennial Census, and other sources (i.e., American Community Survey, Human Development Index database, and Centers for Disease Control and Prevention). We proposed two research questions that guide our data analyses: (1) *How did COVID-19 vaccine hesitancy and refusal vary over time in the US?* (2) *How were COVID-19 vaccine hesitancy and refusal linked to states' racial demographics?*

Data and Methods

Data

We conducted a state-level investigation that includes 50 US states and Washington, DC, across 18 weeks between January and October 2021. Our primary data source came from the publicly available macro data of the 2021 Household Pulse Survey (HPS), conducted by the US Census Bureau in collaboration with other federal agencies. The HPS was launched in April 2020 to quickly and efficiently collect data to measure American household experiences during the pandemic. It was designed to produce state-level estimates. National household probability samples were selected based on the Census Bureau's Master Address File (MAF), which is considered the gold standard for US statistics [30]. The HPS questionnaire includes questions on how education, employment, food security, health, housing, household spending, and transportation have been affected by COVID-19. Starting from Week 22 of the HPS data collection period, new questions regarding vaccination intention were added to the questionnaire. We used available data from Week 22 (January 6–18, 2021) to Week 39 (September 29–October 11, 2021), the most recent weeks at the time this article was written for our data analyses. Independent samples of households were selected for each data collection period from weeks 22–39. The publicly available macro data tables were downloaded from the HPS webpage (https://www.census.gov/programs-surveys/household-pulse-survey/data.html).

In addition, we derived a set of sociodemographic variables from the 2020 US Decennial Census, the 2015–2019 American Community Survey (ACS) estimates at the state level and the Human Development Index (HDI) database of the global data lab. To measure state climate, we used the 2020 presidential election results [31]. Numbers of positive COVID-19 cases by states were obtained from the Centers

for Disease Control and Prevention (CDC) and state-level public health websites.

Outcome Measures

COVID-19 vaccine hesitancy and refusal rates were the two outcome measures of this study. The HPS first asked respondents whether they had received a COVID-19 vaccine. If a respondent had not received a vaccine, the HPS asked a follow-up question about their intention to be vaccinated (1, definitely get a vaccine; 2, probably get a vaccine; 3, unsure about getting a vaccine; 4, probably NOT get a vaccine; 5, definitely NOT get a vaccine). Responses to those questions were aggregated at the state level and reported in macro data tables for every data collection week by the HPS. Based on our definitions of COVID-19 vaccine hesitancy and refusal, we calculated the *hesitancy rate* for each state as the percentage of those who indicated that they were "unsure about getting a vaccine" or would "probably NOT" get a vaccine among all people who had not received a COVID-19 vaccine in their respective state. Similarly, the *refusal rate* was constructed as the percentage of people who reported that they would "definitely NOT" accept a vaccine among all the people who had not received a COVID-19 vaccine in their respective state. Both hesitancy and refusal rates were time-variant variables as they changed across the 18 data collection weeks.

Covariates

We first used the 2020 US Decennial Census to construct relevant variables whenever feasible, since the Decennial Census includes the total population. To create variables that lacked corresponding data in the Decennial Census, we used 5-year estimates from the 2019 American Community Survey (ACS). These data were collected by the US Census Bureau and were based on a sample from the population. Given our main interest in the relationship between race and COVID-19 vaccination intention, we first constructed six race/ethnicity variables derived from the Decennial Census data, including the proportions of state populations identified as Hispanic or Latino (any race), non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, non-Hispanic American Indian/Pacific Islander/Native Hawaiian, and multiracial/other non-Hispanic. Henceforth, we did not add "non-Hispanic" after every mention of the non-Hispanic racial groups (e.g., we used the term "White" instead of "non-Hispanic White").

Besides race/ethnicity, other demographic characteristics might also be associated with COVID-19 vaccine hesitancy and refusal. For example, studies showed that women were less willing to take COVID-19 vaccines than men [27, 28, 32]; younger individuals were more likely to be vaccine-hesitant or to refuse vaccine than older individuals [33]; college degree was also associated with higher odds of refusal and delay compared with those without [33]. Following these aforementioned studies, we included variables to capture state demographic profiles. We used population size from the Decennial Census, sex ratio (the number of males per 100 females), median age from the ACS, and the percentage of the population with a college degree from the ACS. The Human Development Index (HDI) was developed and published yearly by the United Nations Development Program (UNDP). It is considered the most popular index assessing countries' and regions' well-being levels [34]. The HDI includes multiple dimensions, and we focused on the health dimension in this paper, which is most relevant to vaccination intentions. To uncover within-country variations, the UNDP also provided subnational HDI data. Hence, we obtained the scores of the 2019 HDI on health, the most recent data available, for each state from the HDI Database of the Global Data Lab.

With regard to the state-level political context, we calculated the state-level voting gap in the 2020 presidential election by subtracting the state percentage of total votes for Joseph Biden (Democrat presidential candidate) from the state percentage of total votes for Donald Trump (Republican presidential candidate) [26]. A higher value indicates that the state reported higher votes in support of the Republican presidential candidate. To measure the spread of coronavirus, we calculated positive COVID-19 cases per capita for each state. Specifically, we obtained the total number of positive cases for each state during each data collection week from the Centers for Disease Control and Prevention (CDC) or state-level public health websites. Then, to allow valid comparisons across states, we adjusted population size by dividing the number of positive cases by each state's total population. All independent variables are time-invariant except the variable related to the positive COVID-19 cases per capita. Descriptive statistics of all variables in analyses are presented in Table 1.

Statistical Analysis

We first conducted descriptive statistics to address our first research question. To answer our second research question, we used Generalized Estimating Equations (GEEs), an extension of generalized linear models (GLM) that accommodate clustered data [35], to produce estimates of model parameters. In this paper, we defined clusters as temporal, since each state had 18 sets of values for each time-variant measure. GEEs were used to analyze how time-variant and time-invariant measures and time itself influenced COVID-19 vaccine hesitancy and refusal rates, controlling for the effects of other relevant covariates. In sum, we specified four GEEs: *model 1* is the main-effect model predicting

Table 1 Descriptive statistics for analysis variables ($n = 918$)

Variable	*N*	Min	Max	Mean	St. dev
Dependent variables					
Vaccine hesitancy rate	918	1.14%	20.80%	9.19%	3.52%
Vaccine refusal rate	918	1.63%	23.21%	8.32%	3.30%
Independent variables					
Proportion of population that is White	918	23.84%	91.66%	68.15%	15.23%
Proportion of population that is Black	918	0.44%	38.87%	10.37%	9.61%
Proportion of population that is Hispanic	918	1.59%	44.34%	11.03%	9.22%
Proportion of population that is Asian	918	0.78%	39.65%	4.59%	5.77%
Proportion of population that is American Indian/ Pacific Islander/Hawaiian Native	918	0.13%	15.01%	1.68%	2.89%
Proportion of population that is multi-racial or other race	918	2.54%	17.62%	4.18%	2.20%
Total population	918	441,337	30,827,105	5,065,555	5,713,104
Sex ratio	918	90	109	98	3
Median age	918	31	45	38	2
Proportion of population that has a college degree	918	20.61%	58.54%	31.77%	6.37%
Human development index on health	918	84.60	94.30	90.18	2.54
State political leaning	918	-87.60%	43.70%	0.43%	23.93%
Positive COVID-19 cases per capita	918	0.00%	0.52%	0.04%	0.04%
Time (week)	918	1	18	6	5

Vaccine hesitancy rate is measured as the percentage of state population who were hesitant to receive COVID-19 vaccines. Vaccine refusal rate is measured as the percentage of state population who refused to receive COVID-19 vaccines. Sex ratio represents the number of males per 100 females. State political leaning is the state-level voting gap in the 2020 presidential election by subtracting the state percentage of total votes for Joseph Biden from the state percentage of total votes for Donald Trump

COVID-19 vaccine hesitancy rates across 50 states and Washington, DC, over a period of 18 weeks. It included state percentages of White and Black (other racial/ethnic groups served as the reference group) as focal independent variables and adjusted for the effects of other covariates (i.e., sociodemographic variables, state political leaning, positive COVID-19 cases per capital, and time). *Model 2* is the interaction model that included variables from Model 1 and interaction terms between race and time. Two similar models (*Models 3* and *4*) were estimated to predict COVID-19 vaccine refusal rates.

To select the best-fitting models, we estimated a series of GEEs by varying the model specifications. We tested normal, gamma, and inverse Gaussian distributions with logarithmic and identity link functions. The normal distribution with an identity link function was found to be the best fit for the four models. GEEs also require the specification of an intracluster dependency correlation matrix [36, 37]. Three correlation structure specifications were tested and found to be [35] (1) independent, which assumes the nonexistence of dependency, so that all off-diagonal elements of the working correlation matrix are zero; (2) exchangeable, which assumes constant intracluster dependency, so that all the off-diagonal elements of the correlation matrix are equal; and (3) unstructured, which assumes a completely general correlation matrix, which is estimated without constraints. We estimated all GEE models with the three matrices, and the exchangeable specification yielded the lowest quasi-likelihood under the independence criterion (QIC) values for all models, meaning it was the best-fitting specification [35]. Therefore, all reported results used the exchangeable specification.

Finally, we examined possible multicollinearity among the variables in the analysis. Based on the variance inflation factor, tolerance, and condition index criteria, inferences from the GEE models are not affected by multicollinearity. All independent variables were standardized before inclusion in the GEEs in order to make coefficients readily comparable.

Results

How Did COVID-19 Vaccine Hesitancy and Refusal Vary over Time in the USA?

Figures 1 and 2 are box and whisker charts demonstrating overall trends of COVID-19 vaccine hesitancy and refusal across the 18 data collection periods. We noted several important observations. As shown in Fig. 1, the hesitancy rate fluctuated over time—it declined during the first 6 weeks, stayed fairly stable during the second 6 weeks,

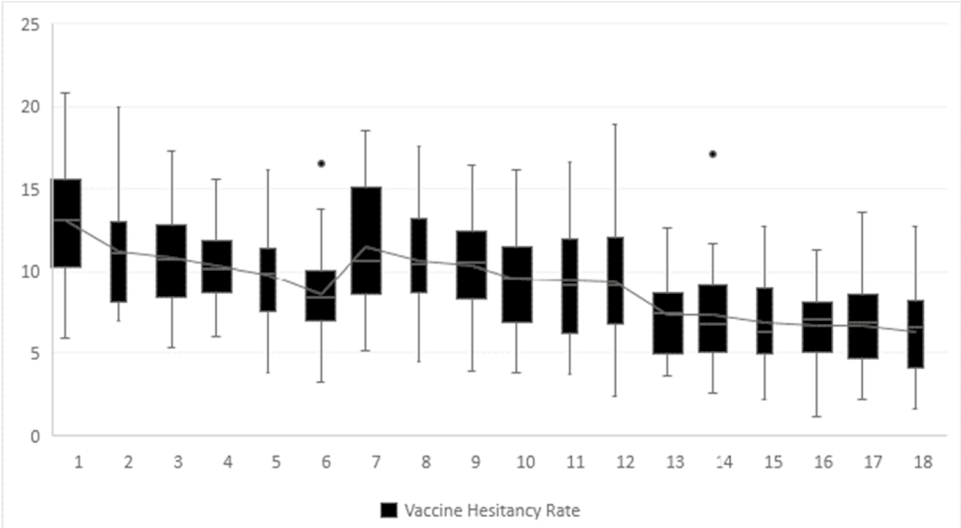

Fig. 1 Vaccine hesitancy rate by HPS collection week: January–October 2021

Notes: Vaccine hesitancy rate is measured as the percentage of state population who were hesitant to receive COVID-19 vaccines.

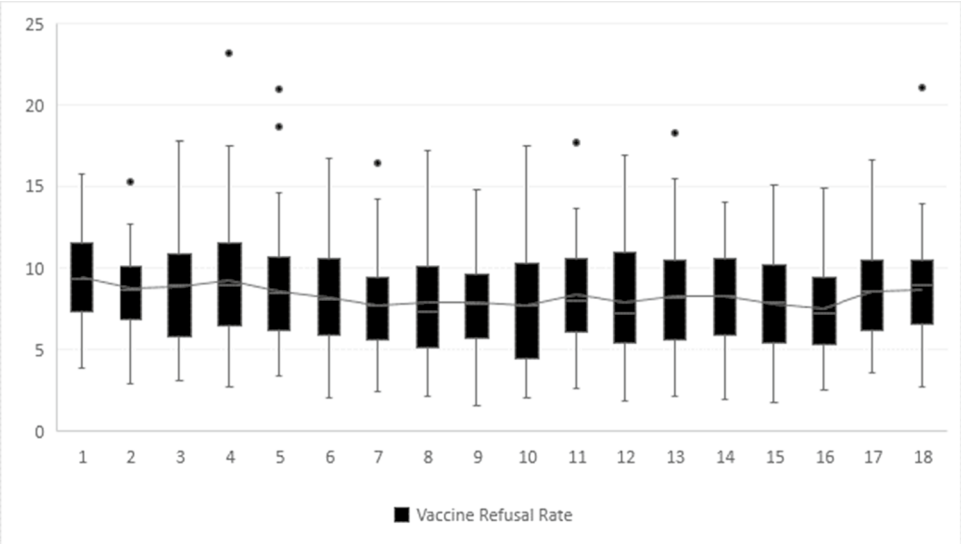

Fig. 2 Vaccine refusal rate by HPS collection week: January–October 2021

Notes: Vaccine refusal rate is measured as the percentage of state population who refused to receive COVID-19 vaccines.

and then slightly declined during the last 6 weeks. Overall, its median value dropped from 13.1 in week 1 to 6.3% in week 18. The standard deviation of the hesitancy rate also decreased slightly (3.4% in week 1, 2.6% in week 18), indicating that the cross-state variation of vaccine hesitancy declined over time. In contrast, Fig. 2 reveals that the refusal rate was relatively stable during the 18 weeks. In week 1, the median value was 9.3%, and it stayed at 8.9% in week 18. Interestingly, the average standard deviation of the vaccine refuse rate increased from 2.9 to 3.4% over the 18 weeks. These findings provide descriptive evidence that COVID-19 vaccine hesitancy had decreased but vaccine refusal stayed constant.

How Were Changes in COVID-19 Vaccine Hesitancy and Refusal Linked to States' Racial Demographics?

We then used longitudinal GEE models to predict vaccine hesitancy and refusal with state-level covariates. Table 2 presents coefficient estimates from models 1 and 2 which predicted the COVID-19 vaccine hesitancy rate. Model 1 shows that as the proportion of the Black population in a

Table 2 Models 1 and 2: results of Generalized Estimating Equations predicting vaccine hesitancy rates for 50 states and Washington DC over 18 data collection weeks ($n = 918$)

	Model 1			Model 2		
	B	SE	*p*	*B*	SE	*p*
Intercept	9.03***	0.122	< 0.0001	9.03***	0.122	< 0.0001
Proportion of population that is *White* (Ref: proportions of other racial groups)	0.15	0.220	0.487	0.15	0.220	0.488
Proportion of population that is *Black* (Ref: proportions of other racial groups)	1.13***	0.237	< 0.0001	1.10***	0.235	< 0.0001
Total population	0.06	0.127	0.654	0.06	0.127	0.654
Sex eatio	0.30	0.333	0.369	0.30	0.332	0.369
Median age	-0.10	0.231	0.670	-0.10	0.231	0.670
Proportion of population that has a college degree	-0.41	0.324	0.207	-0.41	0.324	0.207
Human development index on health	-0.20	0.291	0.486	-0.20	0.291	0.485
State political leaning	1.77***	0.350	< 0.0001	1.78***	0.350	< 0.0001
Positive COVID-19 cases per capita	-0.18**	0.059	0.002	-0.18**	0.056	0.001
Time (week)	-1.84***	0.059	< 0.0001	-1.84***	0.048	< 0.0001
Proportion of population that is *Black* x time	-	-	-	-0.24***	0.051	< 0.0001

Sex ratio represents the number of males per 100 females. State political leaning is the state-level voting gap in the 2020 presidential election by subtracting the state percentage of total votes for Joseph Biden from the state percentage of total votes for Donald Trump. Models used normal distribution with an identity link function with an exchangeable correlation matrix. ***$p < 0.001$, **$p < 0.01$, and *$p < 0.05$

state increased relative to the proportions of other racial/ethnic groups (Hispanic, Asian, American Indian/Pacific Islander/Native Hawaiian, and Multiracial/Other), the increase in vaccine hesitancy rate was statistically significant ($p < 0.0001$), adjusting for the effects of other variables and time. The association between the proportion of Whites and the vaccine hesitancy rate was not statistically significant ($p = 0.487$), but the direction was positive ($B = 0.15$).

Turning to other statistically significant variables, positive COVID-19 cases per capita were negatively associated with vaccine hesitancy rates ($p = 0.002$). States that had more votes for Republicans (those with more votes for Trump relative to votes for Biden) had a higher vaccine hesitancy rate ($p < 0.0001$). Time was also a statistically significant predictor, with the vaccine hesitancy rate declining across the 18 data collection weeks ($p < 0.0001$).

Since the proportion of the Black population was statistically significant in model 1, we included the interaction term "proportion Black x time" in model 2 to further examine the temporal changes in vaccine hesitancy in the Black population. The interaction term was negative and statistically significant ($B = -0.24$, $p < 0.0001$). To help visualize this interaction, we generated predicted values for the dependent variable (vaccine hesitancy rate) at various values of the interaction term (proportion Black*time), while holding all other covariates at their mean values. We then plotted these values, as shown in Fig. 3. In earlier weeks, we see a positive effect of the proportion of the Black population on vaccine hesitancy, as states with higher proportions of the Black population had higher vaccine hesitancy rates. However, in later weeks, the direction of this relationship changed; higher proportions of the Black population were associated with lower vaccine hesitancy rates.

Table 3 reports results for models 3 and 4 which predicted the vaccine refusal rate. As shown in model 3, the proportion of the Black population in a state relative to the proportions of other racial groups was significantly associated with an increased vaccine refusal rate ($p < 0.0001$). Similarly, the proportion of the White population was also significantly associated with an increase in the vaccine refusal rate ($p = 0.019$). In terms of other statistically significant predictors, states that had a larger male versus female population reported higher vaccine refusal rates ($p = 0.006$), and states that were more Republican had higher vaccine refusal rates ($p = 0.002$). Similar to the vaccine hesitancy rate, the vaccine refusal rate also declined over the 18 weeks ($p < 0.0001$).

Because both proportions of Black and White populations were statistically significant in model 3, we included the interaction terms "proportion of Black x time" and "proportion of White x time" in model 4. The interaction between the proportion of the Black population and time was negative and statistically significant ($B = -0.21$, $p < 0.0001$), and the interaction between the proportion of Whites and time was positive but not statistically significant ($B = 0.01$, $p = 0.984$). As before, we calculated the predicted values of the two interaction terms based on model 3 and plotted them in Fig. 4. The first box of Fig. 4 indicates that during earlier data collection weeks, the proportion of the Black population had positive effects on the vaccine refusal rate, but the effect became negative

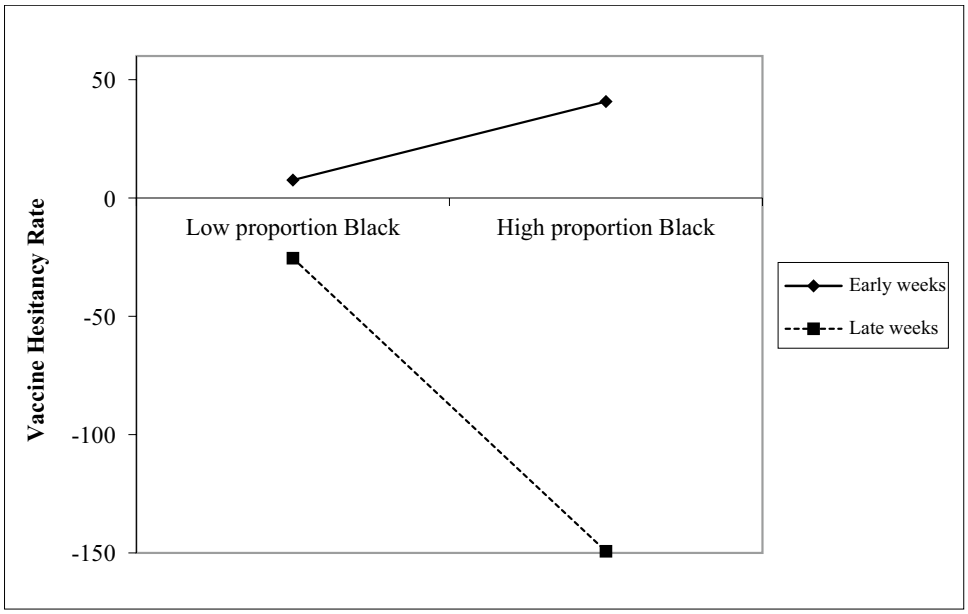

Fig. 3 Interaction between proportion of Black/White and time when predicting vaccine hesitancy

Notes: Vaccine hesitancy rate is measured as the percentage of state population who were hesitant to receive COVID-19 vaccines.

Table 3 Models 3 and 4: results of Generalized Estimating Equations predicting vaccine refusal rates for 50 sand Washington DC over 18 data collection weeks ($n = 918$)

	Model 3			Model 4		
	B	SE	*p*	*B*	SE	*p*
Intercept	8.30***	0.161	< 0.0001	8.30***	0.161	< 0.0001
Proportion of population that is *White* (Ref: proportions of other racial groups)	0.57*	0.244	0.019	0.57*	0.247	0.021
Proportion of population that is *Black* (Ref: proportions of other racial groups)	0.96**	0.280	0.001	0.94**	0.280	0.001
Total population	0.12	0.122	0.324	0.12	0.122	0.324
Sex ratio	1.23**	0.448	0.006	1.23**	0.448	0.006
Median age	0.28	0.339	0.414	0.28	0.339	0.414
Proportion of population that has a college degree	-0.09	0.461	0.849	-0.09	0.461	0.849
Human development index on health	-0.70	0.378	0.063	-0.71	0.378	0.062
State political leaning	1.55**	0.492	0.002	1.55**	0.492	0.002
Positive COVID-19 cases per capita	0.01	0.055	0.936	0.01	0.053	0.972
Time (week)	-0.27***	0.067	< 0.0001	-0.27***	0.061	< 0.0001
Proportion of population that is *White* x time	-	-	-	0.01	0.065	0.984
Proportion of population that is *Black* x time	-	-	-	-0.21	0.057***	< 0.0001

sex ratio represents the number of males per 100 females. State political leaning is the state-level voting gap in the 2020 presidential election by subtracting the state percentage of total votes for Joseph Biden from the state percentage of total votes for Donald Trump. Models used normal distribution with an identity link function with an exchangeable correlation matrix. ***$p < 0.001$, **$p < 0.01$, and *$p < 0.05$

over time, as higher proportions of the Black population were associated with lower vaccine refusal rates during later data collection weeks. The finding is quite different in the "proportion of White x time" (second box of Fig. 4). Higher proportions of Whites were associated with higher vaccine refusal rates, and this effect was time-invariant during the 18 weeks, which explains why the interaction term was statistically insignificant.

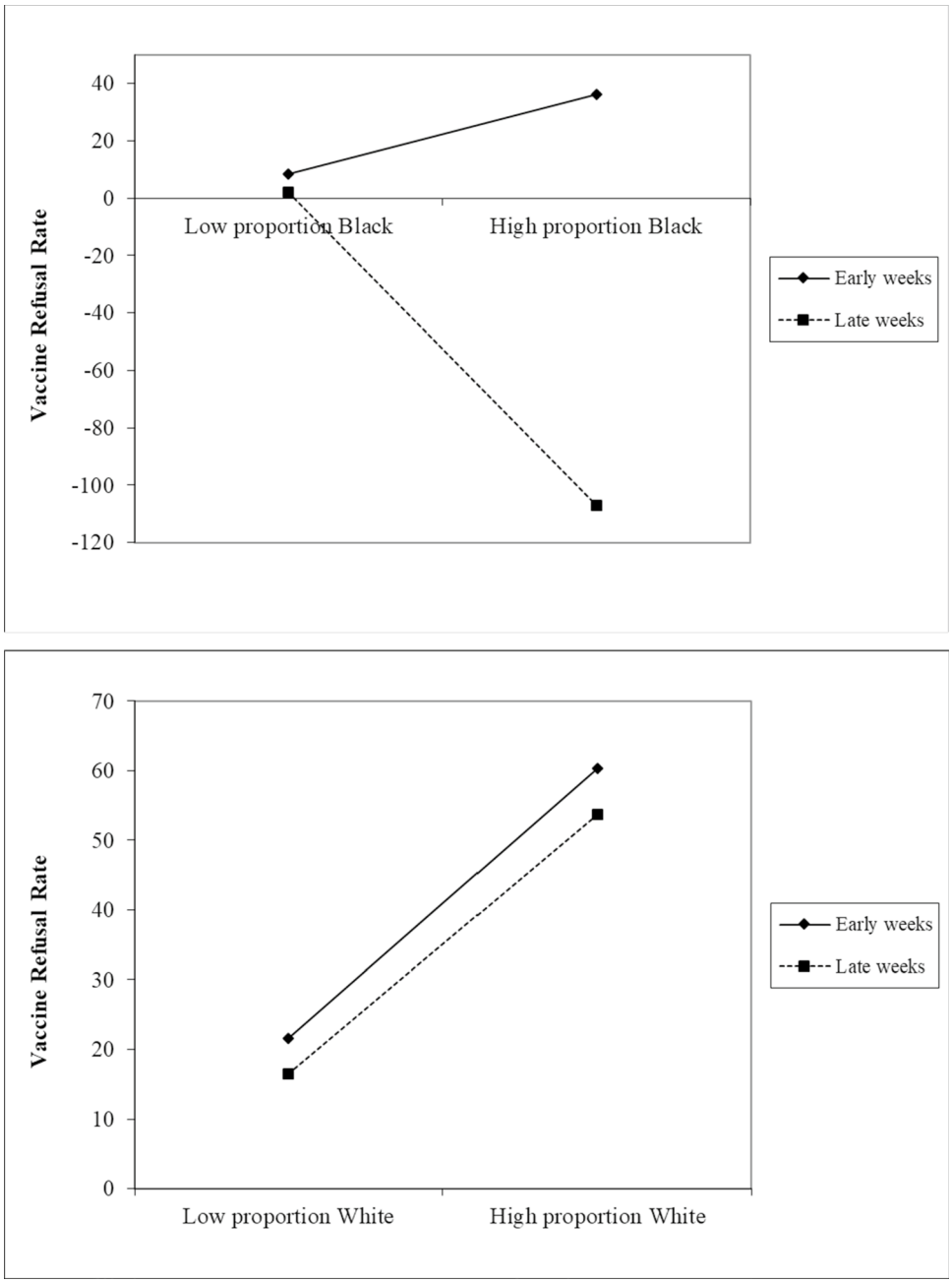

Fig. 4 Interaction between proportion of Black/White and time when predicting vaccine refusal

Notes: Vaccine refusal rate is measured as the percentage of state population who refused to receive COVID-19 vaccines.

Discussion

One of the most consistent sociodemographic predictors of vaccine intention and uptake in the USA is race. Rather than focusing on individuals, we employed a macro and longitudinal approach to examine differential changes in COVID-19 vaccine hesitancy and refusal between Black and White populations. Our results indicated that the proportion of the Black population in a state was positively associated with the state's vaccine hesitancy and refusal rates, which is consistent with evidence found at the individual level [10–12]. However, we also noticed that the positive effect of the Black population on COVID-19 vaccine hesitancy and refusal had declined rapidly over the 10-month period in 2021. This finding is consistent with a recent study conducted at the individual level. Specifically, Padamsee et al. [14] surveyed and followed 1,200 American adults for seven months from 2021 to 2022, and their results showed that "Black individuals more quickly overcame this (COVID-19 vaccine) hesitancy than White individuals" (p. 7).

One of our speculations of the declining vaccine hesitancy and refusal in Black communities might be attributed to the increasing number of Black Americans who were starting to believe that COVID-19 vaccines were necessary to protect themselves, their families, and communities. This dynamic likely also results from the concerted efforts made by Black leaders and organizations to promote COVID-19 vaccination through the dissemination of accurate and culturally sensitive information [38–40] that might resonate more strongly with the Black communities [14]. In other words, Black Americans might become cautious about new medical technologies, such as COVID-19 vaccines at the beginning, but once they are convinced that vaccines are safe and effective, they would accept vaccination more readily. Thus, vaccine mistrust in Black communities, grounded in the collective experiences of racism, could be viewed as "an expression of commitment to protective health behavior," rather than a "resistance to protective health behavior" [14, p. 8]. In fact, there is evidence indicating that to avoid being sick or spreading the virus to others, Black Americans were more willing than Whites to wear masks or practice social distancing during the pandemic [41–43]. Our population-based analyses and Padamsee et al.'s [14] results at the individual level both underscore the importance of understanding vaccine hesitancy and refusal in the Black population from a longitudinal perspective.

In addition to utilizing a longitudinal study design, our ability to differentiate vaccine hesitancy versus vaccine refusal in analyses was an added novel element among contemporary studies on COVID-19 vaccination. We noted that although the proportion of the White population was not associated with the state's COVID-19 vaccine hesitancy, it was positively associated with vaccine refusal. The extant literature on COVID-19 vaccination has paid limited attention to Whites, as they were often used as the reference group for other racial/ethnic groups [15–19]. By further investigating the nuanced intersection between race and time, we highlighted that while vaccine refusal in the Black population quickly declined in 2021, the resistance to COVID-19 vaccination among the proportion of Whites stayed fairly consistent.

Then, how do we make sense of anti-vaccination attitudes among Whites and explain the differential changes in COVID-19 vaccine refusal between Black and White Americans? Several explanations were plausible. For example, researchers in the past have noted that religious and political conservatism are prominent factors predicting vaccine refusal because they often reflect a skepticism toward science and are in favor of more conspiratorial, individualist, and hierarchical thinking [44–47]. As Whitehead and Perry [48] pointed out, anti-vaccination sentiment in the USA was highly associated with Christian nationalism, which was found to be related to White racial identity [49–53]. However, we should not overlook that some older Black Americans, especially those living in the Southern states, are also deeply religious and Christian. Besides religious and political conservatism, other underlying factors could also contribute to vaccine refusal in the White population. For example, Alcendor found that among White population living in the Southern USA, especially in rural communities, poor health literacy and distrust of government and medical establishments were related to their COVID-19 vaccine refusal [54]. Interestingly, in some earlier studies on other types of vaccination, researchers attributed racial differences in vaccine choice to White privilege [55, 56]. As they argued, the ability to choose not to be vaccinated ("opt-out") is itself an act of privilege [55, 56].

Although there is no simple way to fully explain these racial differences, there seem to be two distinct mechanisms that shaped anti-vaccination among Black versus White Americans. On the one hand, COVID-19 vaccine refusal in the White population might more likely to be associated with their deeply held values and identities [57] and thus are more resistant to change. On the other hand, vaccine refusal in the Black population is rooted in systemic racism in medical research and medical care. Therefore, as compared to White Americans, Black Americans might be more likely to have vaccine-specific concerns and more receptive to receiving information on COVID-19 vaccines.

By focusing on state-level data instead of individuals, our study helps contribute to a better understanding of the social and political contexts of COVID-19 vaccine hesitancy and refusal. Our findings revealed that Republican states had higher hesitancy and refusal rates than Democratic states, which aligns with the previous findings suggesting that Democrats are more eager to receive the COVID-19 vaccines [15, 58, 59]. We also found that vaccine hesitancy decreased when the number of positive COVID-19 cases increased. Indeed, perceived heightened risk has been shown to lead people to hold a more favorable attitude toward vaccination, especially when the threat of disease is perceived to be imminent [58]. Findings from the prior research on gender and COVID-19 vaccination are mixed. While many studies reported that women were less willing to take COVID-19 vaccines than men [11, 27, 28, 32, 60–63], other researchers did not find gender differences [15] or found that women had greater intentions to obtain a COVID-19 vaccine than men [64]. At the state level, our analyses show a positive association between the male population and vaccine refusal.

Recently, the macro-level approach has been more widely used in the studies of COVID-19 vaccination, especially at the county level. Several studies, for example, showed that the vaccination rate was negatively associated with the county's social vulnerability [65–67]. Alcendor examined all counties in Tennessee and found that Black and White populations had the lowest COVID-19 vaccination rates,

which aligns with our findings [68]. In addition, Lee and Huang used census-tract-level data in a Texas county, and their regression analysis results indicated that vaccine hesitancy among residents in one community could spread to its nearby communities [69]. These macro-level analyses, along with ours, attest to the importance for public health practitioners to design and develop targeted vaccination interventions for "at-risk" states, counties, or neighborhoods.

Thus far, our study was able to provide in-depth analyses of the relationship between race and vaccine hesitancy and refusal; some limitations presented in this paper can be further addressed in future studies. First, our study only focused on Black and White populations. Future research may consider examining COVID-19 vaccine hesitancy and refusal among other racial/ethnic groups. Second, researchers can also investigate other state-level predictors of vaccine hesitancy and refusal (e.g., religions) that were not included in this study due to issues related to data limitations. Third, future studies could also connect the state-level findings we identified in this paper to vaccination behaviors at the individual level through a multilevel modeling approach. Fourth, in seeking to identify patterns of COVID-19 vaccine hesitancy and refusal in Black and White populations, we did not directly observe the micro-level processes that result in these changes in behavior. Instead, we speculated several explanations based on previous evidence, which need to be directly tested in future research. Fifth, we calculated positive COVID-19 cases per capita to measure the spread of coronavirus within each state. Although valid, this measure is limited, as it did not take into consideration different levels of testing across states. A higher number of positive cases per capita might reflect more widespread testing in the state. We also did not have information on home testing. Further research could consider using other measures such as the percentage of COVID-19-positive testing results, hospital capacity, or deaths. Sixth, in this paper, we focused on racial differences in vaccine hesitancy and refusal. Future research should continue exploring the intersectionality between race, gender, and social class and how it affects people's vaccination intentions.

Conclusions

In the USA, racial minorities, especially Black Americans, have suffered disproportionately from the COVID-19 pandemic [13]. Yet, Black communities exhibited high levels of vaccine hesitancy and refusal. Researchers have argued that vaccine mistrust was used as self-protective reactions by Black Americans in response to their historical oppression, contemporary maltreatment, and sociopolitical climate [70–72], and Black people's skepticism of COVID-19 vaccines was "totally justified" [13, p. 544]. Our findings further demonstrate that more and more Black Americans have overcome their vaccine hesitancy or refusal and become more willing to be vaccinated against COVID-19. However, at the national level, the overall COVID-19 vaccine uptake rate in the Black population is still lower than in the White population [73], implying that Black communities may be facing other systemic and structural challenges relating to vaccination access barriers. If this is the case, more research and practical efforts are needed to address those barriers.

On the other hand, the high and persistent COVID-19 vaccine refusal among Whites could have the negative consequence of delaying the nation's development of herd immunity and prolonging the existential threat of the virus. For instance, some states have reported an increase in vaccine refusal (i.e., Kansas, Lowa, Missouri, Oklahoma, South Dakota, and Wyoming) in 2021, and all of these states had a higher proportion of Whites. Among them, the most extreme case was Wyoming, where 12.7% of the population reported refusing COVID-19 vaccines in January, and the percentage increased to 21.1% in October 2021 [22]. In those states, more proactive and effective communication strategies are urgently needed to address, rather than dismiss, people's concerns about COVID-19 vaccines. For example, besides life scientists and health care professionals, COVID-19 information campaigns may consider involving more social scientists and experts in public policies and communication in content development, education, and raising awareness [74]. Public health messengers that are trusted by local communities and social media can also help address vaccine refusal and combat misinformation [75–77]. Overall, our paper has provided valuable preliminary findings about the differential changes in COVID-19 vaccination intention between Black and White Americans; our paper calls for more research on COVID-19 vaccination to adopt a longitudinal and macro approach in investigating the nuanced differences between vaccine hesitancy and refusal and their relationships with race.

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References

1. Randolph HE, Barreiro LB. Herd immunity: understanding COVID-19. Immunity. 2020;52(5):737–41.
2. CDC. Centers for Disease Control and Prevention. COVID Data Tracker. https://covid.cdc.gov/covid-data-tracker/#vaccinations_vacc-total-admin-rate-total. Accessed 14 April 2022.
3. The New York Times. See how vaccinations are going in your county and state. 2021. https://www.nytimes.com/interactive/2020/us/covid-19-vaccine-doses.html. Accessed 28 December 2021.
4. MacDonald NE. Vaccine hesitancy: definition, scope and determinants. Vaccine. 2015;33(34):4161–4.
5. Friedrich MJ. WHO's top health threats for 2019. JAMA. 2019;321(11):1041–1041.
6. USAFacts. Black Americans make up 13% of the US population. They make up 23% of COVID-19 deaths. 2020. https://usafacts.org/articles/covid-deaths-race-state-age-black-hispanic-white/. Accessed 14 April 2022.
7. Centers for Disease Control and Prevention. CDC. African American health: Creating equal opportunities for health. 2017. https://www.cdc.gov/vitalsigns/aahealth/index.html. Accessed 14 April 2022.
8. Kricorian K, Turner K. COVID-19 vaccine acceptance and beliefs among black and Hispanic Americans. PLoS ONE. 2021;16(8):e0256122. https://doi.org/10.1371/journal.pone.0256122.
9. Quinn S, Jamison A, Musa D, Hilyard K, Freimuth V. Exploring the continuum of vaccine hesitancy between African American and white adults: results of a qualitative study. PLoS currents. 2016;8(29). https://doi.org/10.1371/currents.outbreaks.3e4a5ea39d8620494e2a2c874a3c4201.
10. Gramlich, J, Funk, G. Black Americans face higher COVID-19 risks, are more hesitant to trust medical scientists, get vaccinated. Pew Research Center. 2020. https://www.pewresearch.org/fact-tank/2020/06/04/black-americans-face-higher-covid-19-risks-are-more-hesitant-to-trust-medical-scientists-get-vaccinated/. Accessed 23 April 2022.
11. Malik AA, McFadden SM, Elharake J, Omer SB. Determinants of COVID-19 vaccine acceptance in the US. EClinicalMedicine. 2020;26:1–8.
12. Walsh, B. Axios-Ipsos poll: The racial gap on coronavirus vaccine. Axios. 2020. https://www.axios.com/axios-ipsos-poll-coronavirus-index-vaccine-racial-trust-gap-28629c26-ef99-416c-ad60-03a43d725e67.html. Accessed 23 April 2022.
13. Laurencin CT. Addressing justified vaccine hesitancy in the black community. J Racial Ethn Health Disparities. 2021;8(3):543–6.
14. Padamsee TJ, Bond RM, Dixon GN, Hovick SR, Na K, Nisbet EC, Wegener DT, Garrett RK. Changes in COVID-19 vaccine hesitancy among Black and White individuals in the US. JAMA Netw Open. 2022;5(1):e2144470–e2144470.
15 Khubchandani J, Sharma S, Price JH, Wiblishauser MJ, Sharma M, Webb FJ. COVID-19 vaccination hesitancy in the United States: a rapid national assessment. J Commun Health. 2021;46(2):270–7.
16. Liu R, Li GM. Hesitancy in the time of coronavirus: Temporal, spatial, and sociodemographic variations in COVID-19 vaccine hesitancy. SSM-population health. 2021;15(100896):1–17.
17. Nguyen KH, Nguyen K, Corlin L, Allen JD, Chung M. Changes in COVID-19 vaccination receipt and intention to vaccinate by socioeconomic characteristics and geographic area, United States, January 6–March 29, 2021. Ann Med. 2021;53(1):1419–28.
18. Savoia E, Piltch-Loeb R, Goldberg B, Miller-Idriss C, Hughes B, Montrond A, Kayyem J, Testa MA. Predictors of COVID-19 vaccine hesitancy: socio-demographics, co-morbidity, and past experience of racial discrimination. Vaccines. 2021;9(7):767.
19. Willis DE, Andersen JA, Bryant-Moore K, Selig JP, Long CR, Felix HC, Curran GM, McElfish PA. COVID-19 vaccine hesitancy: race/ethnicity, trust, and fear. Clin Transl Sci. 2021;14(6):2200–7.
20. Dubé E, MacDonald, NE. Chapter 26 - vaccine acceptance: barriers, perceived risks, benefits, and irrational beliefs. In: Bloom BR, Lambert P, editors. The vaccine book (2nd ed.). Academic Press; 2016. pp. 507–528. https://doi.org/10.1016/B978-0-12-802174-3.00026-6.
21. Reich JA. Vaccine refusal and pharmaceutical acquiescence: parental control and ambivalence in managing children's health. Am Sociol Rev. 2020;85(1):106–27. https://doi.org/10.1177/0003122419899604.
22. Census Bureau. Household Pulse Survey COVID-19 Vaccination Tracker. 2021. https://www.census.gov/library/visualizations/interactive/household-pulse-survey-covid-19-vaccination-tracker.html. Accessed 14 April 2022.
23. Baum MA. Red state, blue state, flu state: media self-selection and partisan gaps in swine flu vaccinations. J Health Polit Policy Law. 2011;36(6):1021–59.
24. Mesch GS, Schwirian KP. Confidence in government and vaccination willingness in the USA. Health Promot Int. 2015;30(2):213–21.
25. Bernstein S, North A, Schwartz J, Niccolai LM. State-level voting patterns and adolescent vaccination coverage in the United States, 2014. Am J Public Health. 2016;106(10):1879–81.
26. Gollwitzer A, Martel C, Brady WJ, Pärnamets P, Freedman IG, Knowles ED, Van Bavel JJ. Partisan differences in physical distancing are linked to health outcomes during the COVID-19 pandemic. Nat Hum Behav. 2020;4(11):1186–97.
27. Callaghan T, Moghtaderi A, Lueck JA, Hotez P, Strych U, Dor A, Fowler EF, Motta M. Correlates and disparities of intention to vaccinate against COVID-19. Soc Sci Med. 2021;272(113638):1–5.
28. Latkin CA, Dayton L, Yi G, Colon B, Kong X. Mask usage, social distancing, racial, and gender correlates of COVID-19 vaccine intentions among adults in the US. PLoS ONE. 2021;16(2):e0246970. https://doi.org/10.1371/journal.pone.0246970.
29. Murphy J, Vallières F, Bentall RP, Shevlin M, McBride O, Hartman TK, McKay R, Bennett K, Mason L, Gibson-Miller J, Levita L. Psychological characteristics associated with COVID-19 vaccine hesitancy and resistance in Ireland and the United Kingdom. Nat Commun. 2021;12(1):1–5.
30. Fields JF, Hunter-Childs, J, Tersine, A, Sisson, J, Parker, E, Velkoff, V, Logan, C, Shin, H. Design and Operation of the 2020 Household Pulse Survey, 2020. U.S. Census Bureau. 2020. Accessed 14 April 2022.
31. CNN Politics. Presidential Results. 2020. https://www.cnn.com/election/2020/results/president.
32. Lazarus JV, Ratzan SC, Palayew A, Gostin LO, Larson HJ, Rabin K, Kimball S, El-Mohandes A. A global survey of potential acceptance of a COVID-19 vaccine. Nat Med. 2021;27(2):225–8.
33. Soares P, Rocha JV, Moniz M, Gama A, Laires PA, Pedro AR, Dias S, Leite A, Nunes C. Factors associated with COVID-19 vaccine hesitancy. Vaccines. 2021;9(3):300. https://doi.org/10.3390/vaccines9030300.
34. Smits J, Permanyer I. The subnational human development database. Scientific Data. 2019;6(1):1–5.
35. Garson G. Generalized Linear Models and Generalized Estimating Equations. Asheboro, NC: Statistical Associates Publishing; 2012.

36. Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. Biometrika. 1986;73:13–22. https://doi.org/10.1093/biomet/73.1.13.
37. Zeger S, Liang K. Longitudinal Data Analysis for Discrete and Continuous Outcomes. Biometrics. 1986;42:121–30. https://doi.org/10.2307/2531248.
38. African American Leadership Forum. COVID-19. https://web.archive.org/web/20210507164215/https://tcaalf.com/covid-19/. Accessed 14 July 2021
39. American Public Health Association. COVID-19 and equity. https://apha.org/topicsand-issues/communicable-disease/coronavirus/equity. Accessed 14 July 2021.
40. Jones M. The COVID-19 vaccine in the Black community: let's take care of each other. Raleigh News & Observer. March 16, 2021. https://www.newsobserver.com/opinion/article249951699.html. Accessed 14 July 2021.
41. Franz B, Milner A, Braddock II. Do Black Lives Matter in the American Public's Mitigation Responses to the COVID-19 Pandemic? An Analysis of Mask Wearing and Racial/Ethnic Disparities in Deaths from COVID-19. J Racial Ethn Health Disparities. 2022;9(4):1577–83.
42. Gibbons J. Distancing the socially distanced: racial/ethnic composition's association with physical distancing in response to COVID-19 in the US. PLoS ONE. 2021;16(5):e0251960.
43. Pew Research Center. Republicans, Democrats move even further apart in coronavirus concerns [Internet]. Pew Research. 2020; [cited 2022 July 12]. Available from: https://www.pewresearch.org/politics/2020/06/25/republicans-democrats-move-even-further-apart-in-coronavirus-concerns/.
44. Buckman C, Liu IC, Cortright L, Tumin D, Syed S. The influence of local political trends on childhood vaccine completion in North Carolina. Soc Sci Med. 2020;260:113187. https://doi.org/10.1016/j.socscimed.2020.113187.
45. Callaghan T, Motta M, Sylvester S, Trujillo KL, Blackburn CC. Parent psychology and the decision to delay childhood vaccination. Soc Sci Med. 2019;238:112407. https://doi.org/10.1016/j.socscimed.2019.112407.
46. Hornsey MJ, Harris EA, Fielding KS. The psychological roots of anti-vaccination attitudes: A 24-nation investigation. Health Psychol. 2018;37(4):307.
47. Jochman JC, Swendener A, McQuillan J, Novack L. Are Biological Science Knowledge, Interests, and Science Identity Framed by Religious and Political Perspectives in the United States? Sociol Q. 2018;59(4):584–602.
48. Whitehead AL, Perry SL. How culture wars delay herd immunity: Christian nationalism and anti-vaccine attitudes. Socius. 2020;6:1–12.
49. Davis JT. Funding God's policies, defending whiteness: Christian nationalism and whites' attitudes towards racially-coded government spending. Ethn Racial Stud. 2019;42(12):2123–42.
50. Perry SL, Whitehead AL, Davis JT. God's country in black and blue: how Christian nationalism shapes Americans' views about police (mis) treatment of blacks. Sociol Race Ethn. 2019;5(1):130–46.
51. Sherkat DE, Lehman D. Bad Samaritans: religion and anti-immigrant and anti-Muslim sentiment in the United States. Soc Sci Q. 2018;99(5):1791–804.
52. Shortle AF, Gaddie RK. Religious nationalism and perceptions of Muslims and Islam. Polit Relig. 2015;8(3):435–57.
53. Whitehead AL, Perry SL. Is a "Christian America" a more patriarchal America? Religion, politics, and traditionalist gender ideology. Can Rev Sociol/Revue canadienne de sociologie. 2019;56(2):151–77.
54. Alcendor DJ. Targeting COVID vaccine hesitancy in rural communities in Tennessee: implications for extending the COVID-19 pandemic in the South. Vaccines. 2021;9(11):1279.
55. Jamison AM, Quinn SC, Freimuth VS. "You don't trust a government vaccine": narratives of institutional trust and influenza vaccination among African American and white adults. Soc Sci Med. 2019;221:87–94.
56. Reich JA. Neoliberal mothering and vaccine refusal: imagined gated communities and the privilege of choice. Gend Soc. 2014;28(5):679–704.
57. Motta M, Callaghan T, Sylvester S, Lunz-Trujillo K. Identifying the prevalence, correlates, and policy consequences of anti-vaccine social identity. Politics Groups and Identities; 2021. p. 1–5. https://doi.org/10.1080/21565503.2021.1932528.
58. Fridman A, Gershon R, Gneezy A. COVID-19 and vaccine hesitancy: a longitudinal study. PLoS ONE. 2021;16(4):e0250123. https://doi.org/10.1371/journal.pone.0250123.
59. Gerretsen P, Kim J, Caravaggio F, Quilty L, Sanches M, Wells S, Brown EE, Agic B, Pollock BG, Graff-Guerrero A. Individual determinants of COVID-19 vaccine hesitancy. PLoS ONE. 2021;16(11):e0258462. https://doi.org/10.1371/journal.pone.0258462.
60. Fisher KA, Bloomstone SJ, Walder J, Crawford S, Fouayzi H, Mazor KM. Attitudes toward a potential SARS-CoV-2 vaccine: a survey of US adults. Ann Intern Med. 2020;173(12):964–73.
61. Morales DX, Beltran TF, Morales SA. Gender, socioeconomic status, and COVID-19 vaccine hesitancy in the US: an intersectionality approach. Sociol Health Illn. 2022. Published Online. https://doi.org/10.1111/1467-9566.13474.
62. Sallam M. COVID-19 vaccine hesitancy worldwide: a concise systematic review of vaccine acceptance rates. Vaccines. 2021;9(1600, 1–14.
63. Troiano G, Nardi A. Vaccine hesitancy in the era of COVID-19. Public Health. 2021;194:245–51.
64. Latkin C, Dayton LA, 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(16):2288–94. https://doi.org/10.1016/j.vaccine.2021.02.058.
65. Brown CC, Young SG, Pro GC. COVID-19 vaccination rates vary by community vulnerability: a county-level analysis. Vaccine. 2021;39(31):4245–9.
66. Crane MA, Faden RR, Romley JA. Disparities in county COVID-19 vaccination rates linked to disadvantage and hesitancy: study examines disparities in county COVID-19 vaccination rates. Health Aff. 2021;40(11):1792–6.
67. Mollalo A, Tatar M. Spatial modeling of COVID-19 vaccine hesitancy in the United States. Int J Environ Res Public Health. 2021;18(18):9488.
68 Alcendor DJ. Targeting COVID vaccine hesitancy in rural communities in Tennessee: implications for extending the COVID-19 pandemic in the South. Vaccines. 2021;9(11):1279.
69. Lee J, Huang Y. COVID-19 Vaccine hesitancy: the role of socioeconomic factors and spatial effects. Vaccines. 2022;10(3):352.
70. Bogart LM., Dong L, Gandhi, P, Ryan, S, Smith, TL, Klein, DJ, Ojikutu, BO. What contributes to COVID-19 vaccine hesitancy in black communities, and how can it be addressed? RAND Corporation. 2021. https://doi.org/10.7249/RRA1110-1. Accessed 14 April 2022.
71. Bogart LM, Ojikutu BO, Tyagi K, Klein DJ, Mutchler MG, Dong L, Lawrence SJ, Thomas DR, Kellman S. COVID-19 related medical mistrust, health impacts, and potential vaccine hesitancy among Black Americans living with HIV. J Acquir Immune Defic Syndr. 2021;86(2):200–7. https://doi.org/10.1097/QAI.0000000000002570.
72. Razai MS, Osama T, McKechnie DG, Majeed A. Covid-19 vaccine hesitancy among ethnic minority groups. Bmj. 2021;372(513). https://doi.org/10.1136/bmj.n513.
73. Ndugga N, Pham O, Hill L, Artiga S, Mengistu S. Latest data on COVID-19 vaccinations race/ethnicity. Kaiser Family

Foundation (KFF). 2021. https://www.kff.org/coronavirus-covid-19/issuebrief/latest-data-on-covid-19-vaccinations-race-ethnicity/ Accessed 14 April 2022.
74. Bolsen T, Palm R. Politicization and COVID-19 vaccine resistance in the US. Prog Mol Biol Transl Sci. 2022;188(1):81–100.
75. Barnabas RV, Wald A. A public health COVID-19 vaccination strategy to maximize the health gains for every single vaccine dose. Ann Intern Med. 2021;174(4):552–3.
76. Cardenas NC. 'Europe and United States vaccine hesitancy': leveraging strategic policy for 'Infodemic'on COVID-19 vaccines. J Public Health. 2022;44(2):e315–6.
77. Laine C, Cotton D, Moyer DV. COVID-19 vaccine: promoting vaccine acceptance. Ann Intern Med. 2021;174(2):252–3.