State specific estimates of vaccine hesitancy among US adults

Uyoyo Omaduvie[1,2], Ghassan Bachuwa[1,2], Olalekan A. Ayo-Yusuf[3], Constantine I. Vardavas[4], Israel Agaku[5]

AFFILIATION
1 College of Human Medicine, Michigan State University, East Lansing, United States
2 Hurley Medical Center, Flint, Michigan, United States
3 Africa Centre for Tobacco Industry Monitoring and Policy Research, Sefako Makgatho Health Sciences University, Pretoria, South Africa
4 School of Medicine, University of Crete, Heraklion, Greece
5 School of Dental Medicine, Harvard University, Boston, United States

CORRESPONDENCE TO
Uyoyo Omaduvie. College of Human Medicine, Michigan State University, East Lansing, United States. E-mail: omaduvie@msu.edu

KEYWORDS
sociodemographic, COVID-19, vaccine hesitancy, pandemic, sociopolitical, state

Received: 12 October 2021
Revised: 18 November 2021
Accepted: 24 November 2021

Popul. Med. 2021;3(December):33 https://doi.org/10.18332/popmed/144224

ABSTRACT

INTRODUCTION Vaccine hesitancy has both individual and population-level consequences. At the individual level, it increases the risk of transmission while posing a barrier to achieving herd immunity at the population level. Studies have examined the sociodemographic characteristics associated with vaccine hesitancy at a national level in the US, but there is a paucity of state-specific data.

METHODS We investigated state-by-state variation in COVID-19 vaccine hesitancy and examined the role of variations in incidence and mortality rates. Self-reported data were obtained from the Household Pulse Survey, a web-based, representative survey of 68348 US adults conducted during 6–18 January 2021. Confirmed COVID-19 incident and mortality cases were obtained from the COVID Tracking Project and standardized as cases per capita based on US census population estimates by state. Adjusted prevalence ratios (APRs) were estimated using Poisson regression in StataV15.1.

RESULTS Nationally, 23.5% reported vaccine hesitancy, ranging from 11.7% in Rhode Island, to 40.2% in Louisiana. Factors associated with increased likelihood of being vaccine hesitant included: being Black as compared to White (APR=1.63; 95% CI: 1.53–1.73), having already tested positive for COVID-19 versus never having tested positive (APR=1.18; 95% CI: 1.12–1.25), being female versus male (APR=1.15; 95% CI: 1.11–1.20), and living in a Republican versus Democratic 'leaning' State (APR=1.26; 95% CI: 1.20–1.32). Conversely, the likelihood of being vaccine hesitant was lower among those in multi-unit dwelling, those with higher education level and income. One in four Americans indicated vaccine hesitancy, especially women, Blacks and those living in Republican 'leaning' States.

CONCLUSIONS Enhanced and sustained efforts are needed to boost trust and confidence in the COVID-19 vaccines. A better understanding of reasons why specific subgroups object to the vaccine may inform targeted efforts to encourage vaccine confidence and uptake.

INTRODUCTION

Vaccines and immunization remain one of the most cost-effective ways of preventing disease and it is estimated to avert 2–3 million deaths annually[1].Vaccines have resulted in the eradication of deadly illnesses, turning once devastating diseases to distant memories. For vaccination campaigns to be successful from a public health perspective, enough people must take them to achieve herd immunity[2,3]. Widespread vaccine hesitancy is therefore a public health crisis and has been listed as one of the top ten threats to global health. Defined by the World Health Organization (WHO) as the reluctance or refusal to vaccinate despite the availability of vaccine, vaccine hesitancy is not necessarily new[4]. The reasons for vaccine hesitancy are complex and not confined to complacency and lack of confidence in vaccines[5]. However, the COVID-19 vaccine hesitancy demands special attention because this is by far the largest, most destructive, and most sustained public health disaster in the past many decades.

COVID-19 was declared a global pandemic on 11 March 2020, allowing the rapid deployment of resources including manpower and necessary non-pharmacological interventions

to prevent further spread. In the US, the urgency of COVID-19 paved way for one of the fastest vaccine development and approval timelines, facilitated in no small part by a dynamic public–private partnership initiated by the US government known as 'Operation WARP Speed'[6]. This speedy process, while facilitating access to vaccines to those in critical need, has also raised skepticism in the general population regarding whether due process was followed and whether the vaccine is safe. In an international study of G7 countries, only 12% of Americans strongly agreed that if the public authorities propose a vaccination against COVID-19, they would be confident that the proposed vaccine will not be dangerous. Furthermore, 22% said they were worried about the safety of COVID-19 vaccines because of the speed with which they are being developed and produced[7].

Studies have been conducted at the national level to examine prevalence and determinants of vaccine hesitancy. For example, Fisher et al.[8] found that vaccine hesitancy was higher among younger adults, females, people with high school education level or less, lower annual household income, people living in rural settings, persons who declined the influenza vaccine in the past year, and those who live in the Southern US[8]. A Pew survey report released on 3 December 2020, showed that with respect to political affiliation, 50% of republican-leaning persons compared with 69% of democratic-leaning persons would accept the COVID-19 vaccine when it became available[9].

Less is, however, known about state-specific variations in vaccine hesitancy; this is important as vaccine rollout in the US is decentralized and at the state level. State-specific data can therefore inform public health planning, programs, and policy. Furthermore, given that wide variations exist in the burden of COVID-19 incidence and mortality rates across states, we were interested in examining whether this variation was associated with vaccine hesitancy. In line with the Health Belief Model which posits that an individual's course of action with regard to health-related behavior is determined by among other factors, the perceived severity of the condition and their perceived susceptibility to it, not only the perceived benefits or harms.

METHODS

Data source

Data came from the Household Pulse Survey (HPS), an ongoing weekly, web-based, anonymous, cross-sectional survey conducted by the U.S. Census Bureau and multiple federal agencies. The analyzed wave of the survey was conducted during 6–18 January 2021. The number of respondents was 68348. We obtained state-specific data for the number of COVID-19 cases and deaths from the start of the pandemic up to 5 January 2021 (the period before and just up to the survey), from the COVID Tracking Project website. Due to differences in state population sizes, we standardized the case burden by estimating incidence and mortality rates by state. As this was analysis of secondary, de-identified, and publicly available data, the study was deemed as non-human subject research, IRB therefore was not sought.

Measurements and variables

Sociodemographic characteristics

States were classified into categories based on US census regions as well as by their political leanings (democratic and republican) using the 2020 electoral college votes[10]. Individual-level sociodemographic characteristics were assessed in the survey including age, gender, race/ethnicity, education level, income, and housing type (important because of concerns about transmission risk in communal dwellings). The latter was assessed as follows: 'Which best describes your house or apartment building?'. Responses were recoded to include: 'detached mobile units such as boat, recreational vehicle, mobile home', 'detached single house', 'attached single house', 'up to 4 apartments in the building', and '≥5 apartments in the building'.

Past COVID-19 diagnosis and receipt of COVID-19 vaccine

Ever diagnosis of COVID-19 was defined as a response of 'Yes' to the question: 'Has a doctor or other health care provider ever told you that you have COVID-19?'. Participants were classified as having received a COVID-19 vaccine if they answered 'Yes' to the question: 'Have you received a COVID-19 vaccine?'. Those answering 'No' were classified as not having received it. Eligible participants were further asked: 'Did you receive (or do you plan to receive) all required doses?'. Categorical response options were 'Yes' or 'No'.

Intent to decline COVID-19 vaccine and associated reasons

The survey asked participants 'Once a vaccine to prevent COVID-19 is available to you, would you …'. Participants could select one of the following response options: 1) 'Definitely get a vaccine', 2) 'Probably get a vaccine', 3) 'Probably not get a vaccine', and 4) 'Definitely not get a vaccine'. We classified response 1 as definite intention to receiving vaccines; responses 2–3 as unsure if to accept or decline the vaccine, and response 4 as definite intention to decline the vaccine. Among the last group, follow-up questions were posed in the survey to assess reasons for showing hesitancy towards vaccines: 'Which of the following, if any, are reasons that you: only probably will/probably won't/definitely won't, get a COVID-19 vaccine/won't receive all required doses of the COVID-19 vaccine? There were 11 possible responses, and respondents could select all that applied: 'I'm concerned about possible side effects of a COVID-19 vaccine'; 'I don't know if the COVID-19 vaccine will work'; 'I don't believe I need a COVID-19 vaccine'; 'I don't like vaccines'; 'My doctor has not recommended it'; 'I plan to wait and see if it is safe and may get it later'; 'I think other people need it more than I do right now'; 'I am concerned about the cost of the COVID-19 vaccine'; 'I don't trust COVID-19 vaccines'; 'I

don't trust the government'; or 'Other reasons'. A follow-up question was posed to the group who did not believe in the vaccine: 'Why do you believe that you don't need a COVID-19 vaccine?' Categorical response options were: 'I already had COVID-19'; 'I am not a member of high-risk group'; 'I plan to use masks or other precautions instead'; 'I don't believe COVID-19 is a serious illness'; 'I don't think vaccines are beneficial'; or 'Other reasons'.

Statistical analysis

Data processing and analyses were conducted using StataV15.1. Data were weighted to yield representative results at the national and state level. Prevalence of vaccine hesitancy was calculated overall and by state. Of the population who reported vaccine hesitancy, we analyzed the reasons for their hesitancy. Using pooled national data, we examined correlates of vaccine hesitancy using a multivariable Poisson regression model. Probabilistic model selection was done using the Akaike and Bayesian information criterion. Independent variables included in the final regression model were age, gender, race/ethnicity, education level, annual household income, marital status, type of housing, US region, political leaning of state, and previous diagnosis of COVID-19. Statistical significance was assessed at $p<0.05$, and all tests of significance were two-tailed.

RESULTS

Population characteristics

Within the pooled sample, mean age was 47.2 years (46.9–47.5). By age categories, 10.5%, 35.3%, 34.2%, 2% were 18–24, 25–44, 45–64, and ≥ 65 years, respectively. Overall, 48.4% were male, and 51.6% were female. By race/ethnicity, 62.6%, 11.3%, 5.3%, 17.2%, and 3.8%, were non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, Hispanic, and non-Hispanic other race. Most (55.1%) were married, while 18.3% were either widowed, divorced, or separated, and 26.7% identified as never married. Only 8.5% had less than high school education, 30.6% graduated from high school, 21.3% had some college education, 26.7% had a college degree, and 12.9% had a professional degree. Furthermore, 14.4%, 24.4%, 31.1%, 22.1%, and 8.0%, had annual household income (US$) less than 25000, 25000–50000, 50000–100000, 100000–200000 and >200000, respectively (Table 1).

Past COVID-19 diagnosis and receipt of COVID-19 vaccine

Overall, 14.6% reported they had ever been diagnosed with COVID-19 (range: 0.04% in Vermont to 14.8% in California) and 7.7% reported that they had ever received a COVID-19 vaccine (range: 0.2% Wyoming to 11.8% in Texas). Consistent patterns (or reverse patterns as the case might be) were seen in the groups most likely to be diagnosed with COVID-19 versus those most likely to have received a vaccine. The top 10 states in terms of self-reported COVID-19 diagnosis were: California 14.8%, Texas 9.5%, Florida 5.8%,

Table 1. Demographic characteristics of the population

Sociodemographic characteristics	%
Age (years)	
18–24	10.5
25–44	35.3
45–64	34.2
≥65	2
Gender	
Male	48.4
Female	51.6
Race/ethnicity	
Non-Hispanic White	62.6
Non-Hispanic Black	11.3
Non-Hispanic Asian	5.3
Hispanic	17.2
Non-Hispanic other race	3.8
Income (US$)	
<25000	14.4
25000–50000	24.4
50000–100000	31.1
100000–200000	22.1
>200000	8.0
Education level	
Less than high school	8.5
High school	30.6
Some college	21.3
College graduate	26.7
Professional degree	12.9
Marital status	
Married	55.1
Divorced/separated/widowed	18.3
Single	26.7
Ever diagnosed with COVID-19	
Yes	14.6
No	85.4
Plan to get COVID-19 vaccine	
Yes	51.0
Unsure	39.5
No	9.5
Type of housing	
Detached mobile units	5.1
Detached single house	69.1
Attached single house	7.9
Up to 4 apartment building	6.5
≥5 apartment building	11.4
Political Party affiliation	
Republican	42.5
Democratic	57.5

New York 5.7%, Illinois 4.4%, Ohio 4.4%, Georgia 3.8%, Pennsylvania 3.4%, Indiana 2.6%, and Arizona 2.4%. The top 10 states in terms of receipt of a COVID-19 vaccine were: Texas 11.8%, California 8.4%, Florida 6.1%, New York 6.0%, Pennsylvania 3.6%, Illinois 3.4%, Ohio 3.3%, Georgia 3.0%, North Carolina 2.9%, Michigan 2.9% (Table 2).

Table 2. Percentage of the population that reported previous COVID-19 diagnosis, and receiving the COVID-19 vaccine by state

State	Previous COVID-19 diagnosis %	Received COVID-19 vaccine %
Alabama	1.8	1.4
Alaska	0.1	0.4
Arizona	2.4	2.1
Arkansas	1.0	1
California	14.8	8.4
Colorado	1.5	2
Connecticut	0.8	1.4
Delaware	0.2	0.3
District of Columbia	0.07	0.2
Florida	5.8	6.1
Georgia	3.8	3
Hawaii	0.1	0.8
Idaho	0.6	0.6
Illinois	4.4	3.4
Indiana	2.6	2
Iowa	1.1	1.2
Kansas	0.9	1
Kentucky	1.2	1.5
Louisiana	1.7	1.5
Maine	0.2	0.5
Maryland	1.9	1.8
Massachusetts	1.5	2.3
Michigan	2.1	2.9
Minnesota	1.5	1.7
Mississippi	0.8	0.9
Missouri	2.1	1.8
Montana	0.4	0.5
Nebraska	0.7	0.7
Nevada	1.1	0.8
New Hampshire	0.3	0.5
New jersey	2.4	2.8
New Mexico	0.6	0.8
New York	5.7	6
North Carolina	2.4	2.9
North Dakota	0.3	0.3
Ohio	4.4	3.3
Oklahoma	1.3	1.7
Oregon	0.6	1.5
Pennsylvania	3.4	3.6
Rhode Island	0.5	0.4
South Carolina	1.7	1.2
South Dakota	0.4	0.5
Tennessee	2.3	2.3
Texas	9.5	11.8
Utah	1.1	1
Vermont	0.04	0.3
Virginia	2.0	2.7
Washington	1.3	2.2
West Virginia	0.4	0.6
Wisconsin	2.2	1.7
Wyoming	0.2	0.2

Intent to decline COVID-19 vaccine and associated reasons

Of those who had not received any COVID-19 vaccine, 50.95% would receive the COVID-19 vaccine when it is available, 39.52% said they were unsure if they would or would not get the vaccine, and 9.53% said they would not get the vaccine. By state, the percentage who indicated intent to decline the vaccine was lowest in the following 10 states: Rhode Island 11.7%, Massachusetts 13.9%, California 16.2%, Connecticut 17.0%, District of Columbia 17.3%, Washington 17.5%, Delaware 17.6%, New Hampshire 18.0%, New Jersey 18.1%, and Virginia 18.4%. Conversely, this percentage was highest in the following 10 states: Louisiana 40.2%, Mississippi 35.9%, Idaho 34.8%, Alabama 34.7%, Wyoming 34.1%, Montana 33.5%, South Carolina 32.1%, Arizona 30.8%, Indiana 30.7%, and Oklahoma 30.7% (Table 3).

Within the pooled national sample, the 3 most common reasons for vaccine hesitancy were: 'I plan to wait and see. If it is safe, I will get it later' (22.1%); 'I think others need it more than me' (17.8%), and 'I do not trust the government' (18.0%). Only about 9.3% in the pooled national were concerned about the side effect of the vaccine, and 2.4% did not believe they needed a vaccine at all. The most common reasons cited for not believing the vaccine was needed were: 'I plan to use masks and other precautions' (25.9%),

Table 3. Percentage intent to decline COVID-19 vaccination, political leaning of state, total number of COVID-19 cases, and COVID-19 related mortality, by state in ascending order

State	% (95% CI)	Electoral vote	Total cases	Total deaths
Rhode Island	11.7 (7.7–15.7)[a]	DEM	93852	1870
Massachusetts	13.9 (10.9–16.9)	DEM	397202	12734
California	16.2 (13.5–19.0)	DEM	2452334[b]	27003
Connecticut	17.0 (13.4–20.6)	DEM	196968	6192
District of Columbia	17.3 (12.0–22.6)	DEM	30166	801
Washington	17.5 (14.8–20.1)	DEM	256435	3482
Delaware	17.6 (13.2–21.9)	DEM	61100	947
New Hampshire	18.0 (12.7–23.4)	DEM	47992	792
New jersey	18.1 (14.3–21.8)	DEM	551419	19382
Virginia	18.4 (14.5–22.2)	DEM	371913	5191
New Mexico	18.8 (15.0–22.6)	DEM	148499	2594
Colorado	18.9 (15.0–22.8)	DEM	346893	4991
Hawaii	19.8 (13.6–26.0)	DEM	22650	289
Maine	20.6 (14.9–26.3)	DEM	26565	369
Illinois	21.0 (17.5–24.4)	DEM	991719	18562
Utah	21.1 (18.1 – 24.2)	REP	288951	1312
Vermont	21.2 (14.6–27.7)	DEM	8038	149
Nebraska	21.7 (17.1–26.3)	REP	169585	1682
New York	21.8 (17.3–26.3)	DEM	1041028	30802[c]
Maryland	21.9 (18.0–25.7)	DEM	289758	6082
Minnesota	22.9 (19.2–26.7)	DEM	425261	5461
Texas	22.9 (19.5–26.2)	REP	1843153	28219
Pennsylvania	23.2 (19.3–27.0)	DEM	673915	16546
Nevada	23.4 (19.3–27.4)	DEM	235455	3235
Oregon	23.4 (20.1–26.7)	DEM	118453	1506
Iowa	23.6 (19.3–27.9)	REP	243829	3999
Wisconsin	23.6 (19.4–27.8)	DEM	531890	5366
Kansas	24.5 (20.6–28.5)	REP	231317	2897
Florida	25.0 (21.1–28.9)	REP	1367778	22515
Michigan	25.6 (22.1–29.1)	DEM	546642	13608
Arizona	25.7 (22.4–29.1)	DEM	567474	9317
Kentucky	26.6 (22.0–31.2)	REP	280836	2772
South Dakota	27.0 (21.4–32.6)	REP	101076	1513
Tennessee	27.3 (23.0–31.6)	REP	617649	7267
Georgia	28.0 (23.3–32.6)	DEM	706154	11072
Ohio	29.0 (24.5–33.4)	REP	735003	9247
West Virginia	29.3 (23.6–34.9)	REP	93162	1442
North Carolina	29.4 (24.5–34.3)	REP	575396	6996
Alaska	30.1 (25.6–34.6)	REP	47006	218
North Dakota	30.3 (24.4–36.1)	REP	93494	1336

Continued

Table 3. Continued

State	% (95% CI)	Electoral vote	Total cases	Total deaths
Missouri	30.4 (25.3–35.4)	REP	405589	5825
Oklahoma	30.7 (26.0–35.4)	REP	308268	2571
Indiana	30.7 (26.5–34.9)	REP	533083	8663
Arkansas	30.8 (25.5–36.1)	REP	238888	3836
South Carolina	32.1 (27.3–36.8)	REP	328073	5498
Montana	33.5 (27.7–39.3)	REP	83378	1005
Wyoming	34.1 (26.5–41.7)	REP	45569	464
Alabama	34.7 (28.5–40.9)	REP	379593	4886
Idaho	34.8 (30.2–39.4)	REP	143305	1459
Mississippi	35.9 (29.5–42.3)	REP	225444	4975
Louisiana	40.2 (34.1–46.2)[d]	REP	326648	7635

a Rhode Island has lowest mean intent to decline COVID-19 vaccine. b California has the highest COVID-19 cases. c New York has the highest COVID-19 related mortality. d Louisiana has the highest mean intent to decline the COVID-19 vaccine. DEM: Democratic-leaning states. REP: Republican-leaning states.

'COVID-19 is not a serious illness' (25.4%), and 'I am not a member of high-risk group' (23.8%). Within republican and democratic-leaning states, the top 3 reasons cited for vaccine hesitancy were identical, and reflective of the general population: 'I plan to wait and see. If it is safe, I will get it later' (22.8% democratic vs 21.4% republican), 'I think others need it more than me' (18.0% democratic vs 17.5% republican), and 'I do not trust the government' (16.8% democratic vs 17.1% republican) (Table 4).

Sociodemographic characteristics associated with vaccine hesitancy

Within the pooled national sample, factors associated with increased likelihood of being vaccine hesitant included: being Black than White (APR=1.63; 95% CI: 1.53–1.73); having already tested positive for COVID-19 versus never having tested positive (APR=1.18; 95% CI: 1.12–1.25); being female versus male (APR=1.15; 95% CI: 1.11–1.20); and living in a republican versus democratic-leaning state (APR=1.26; 95% CI: 1.20–1.32). Conversely, the likelihood of vaccine hesitancy was lower among people aged 45–65 years (APR=0.85; 95% CI: 0.76–0.95), and ≥65 years (APR=0.35; 95% CI: 0.31–0.40), compared to those 18–24 years; living in a multi-unit dwelling ≥5 apartment building (APR=0.63; 95% CI: 0.57–0.69), compared to those in detached mobile unit (APR=0.78; 95% CI: 0.72–0.84); those with a professional degree (APR=0.51; 95% CI: 0.45–0.58) versus less than a high school education; and annual household income more than $200000 (APR=0.44; 95% CI: 0.39–0.50) compared with less than $25000. Persons living in the South (APR=1.12; 95% CI: 1.04–1.21), Midwest (APR=1.16; 95% CI: 1.07–1.25), and West (APR=1.18; 95% CI: 1.09–1.26), compared to the Northeast (all $p<0.05$) (Table 5). For details on vaccine hesitancy among people who have not received any COVID-19 vaccine by age, gender, race/ethnicity, see Supplementary file.

Table 4. Reasons for COVID-19 vaccine hesitancy

I do not plan to get the COVID-19 vaccine because	%
I plan to wait and see. If it is safe, I will get it later	22.14
I think others need it more than me	17.76
I do not trust the government	16.96
Other reasons	10.24
I do not trust the COVID-19 vaccine	9.37
Side effects	9.31
I am concerned about cost	5.77
I do not believe I need a vaccine	2.42
I do not like vaccines	2.34
I do not know if a COVID-19 vaccine will work	1.99
My doctor has not recommended it	1.69
I do not believe I need the COVID-19 vaccine because	
I plan to use masks and NPI	25.85
COVID-19 is not a serious illness	25.35
I am not a member of high-risk group	23.75
Other reasons	9.05
I already had COVID-19 infection	8.48
Vaccines are not beneficial	7.51

Table 5. Poisson regression for vaccine hesitancy

Intent to vaccinate	APR (95% CI)
Age (years)	
18–24 (Ref.)	1
25–44	1.24 (1.12–1.38)
45–64	0.85 (0.76–0.95)
≥65	0.35 (0.31–0.40)
Gender	
Male (Ref.)	1
Female	1.15 (1.11–1.20)
Race/ethnicity	
Non-Hispanic White (Ref.)	1
Non-Hispanic Black	1.63 (1.53–1.73)
Non-Hispanic Asian	0.49 (0.41–0.58)
Hispanic	0.85 (0.79–0.91)
Non-Hispanic other race	1.33 (1.22–1.44)
Education level	
Less than Highschool (Ref.)	1
Highschool graduate	1.10 (0.98–1.24)
Some college	0.96 (0.86–1.08)
College graduate	0.74 (0.66–0.83)
Professional degree	0.51 (0.45–0.58)
Income (US$)	
<25000 (Ref.)	1
25000–50000	0.90 (0.85–0.96)
50000–100000	0.80 (0.75–0.85)
100000–200000	0.61 (0.57–0.66)
> 200000	0.44 (0.39–0.50)
Marital status	
Single (Ref.)	1
Married	1.14 (1.09–1.20)
Divorced/widowed/separated	0.84 (0.80–0.89)
Type of housing	
Detached mobile unit (Ref.)	1
Detached single house	0.78 (0.72–0.84)
Attached single house	0.67 (0.60–0.74)
Up to 4 apartment building	0.71 (0.64–0.79)
≥5 apartment building	0.63 (0.57–0.69)
Region	
Northeast (Ref.)	1
South	1.12 (1.04–1.21)
Midwest	1.16 (1.07–1.25)
West	1.18 (1.09–1.26)
Political party	
Democratic (Ref.)	1
Republican	1.26 (1.20–1.32)
Ever diagnosed with COVID	
No (Ref.)	1
Yes	1.18 (1.12–1.25)

APR: adjusted prevalence ratio.

DISCUSSION

This study examined variations across states in the percentage showing COVID-19 vaccine hesitancy. We found that vaccine hesitancy varied widely with a difference of close to 30 percentage points between the state with lowest prevalence (Rhode Island, 11.7%), and that with the highest prevalence (Louisiana, 40.2%). This state-specific variation is a novel finding from our study that state programs can use to plan for their vaccine campaigns. Our study also confirmed findings from other studies, including key sociodemographic factors that directly impact intent to decline the COVID-19 vaccination. For example, Black race and female gender were strongly associated with vaccine hesitancy, consistent with other studies[11,12]. A possible explanation for the higher likelihood of vaccine hesitancy among females is perception of reduced risk, since some studies have shown that females have less risk of acquiring the infection and experiencing COVID-19 related mortality[13]. Another factor that may be contributing to vaccine hesitancy among females is the unknown effects of COVID-19 vaccine on reproductive capability, fetus in pregnant females, and breastfeeding children in lactating women. However, it must be noted that despite female gender being a seemingly protective factor, individual-based risk factors such as the presence of lower socioeconomic status, inability to physical distance due to housing conditions, chronic medical conditions including obesity, and asthma, are associated with increased risk of acquiring COVID-19 infection and developing severe disease. Identifying as Black, was the strongest determinant of vaccine hesitancy, a finding that aligns with well documented mistrust in government and research[14-16]. That one in four of the general population reported hesitancy is likely attributable to the widespread climate of mistrust about the origins of COVID-19, mistrust in government, and for some, mistrust in vaccines in general, all of which have dovetailed to engender conspiracy theories with resultant higher levels of vaccine skepticism, and hesitancy especially among racial minorities. Research studies have also shown that people who believe conspiracies about COVID-19 report that they will be less likely to access a COVID-19 vaccine once one becomes available, they are also more likely to indicate less support for COVID-19 public health policies[17,18]. Data show that Blacks are more likely to get infected and experience severe COVID-19 disease and mortality when compared with other races[19,20]. However, our study shows that they are also the group with the highest odds of declining the vaccine. Interventions to address this multifaceted distrust must first acknowledge and address issues of social inequity and promote transparent partnerships to vaccine confidence and acceptance.

Education level can influence the ability of an individual to comprehend scientific information[21], and this plays a pivotal role in vaccine acceptance and uptake. In our study, having a high school education or less was also associated with vaccine hesitancy. The ability to comprehend scientific

information such as what vaccines are, how they work, and what efficacy of the vaccine means, for example, is directly impacted by literacy. Lack of access to internet and internet connectible devices can also negatively impact vaccine attitudes. While information about the vaccines is present on the websites of public health agencies such as the Centers for Disease Control and Prevention, and the Food and Drug Administration, the style and language of information can also be a barrier if it is difficult to understand. Anti-vaccination contents are readily available and accessible on social media platforms[22,23], to increase vaccine acceptance, information about vaccines need to be just as easily accessible and understandable by lay audience.

Our results showed a bipartisan distinction in attitudes towards vaccines. Republican-leaning states had higher likelihood of vaccine hesitancy, while states with democratic-leaning showed more vaccine receptivity. This can be partly explained by the politicization of public health measures including facemask wearing, policies on state shutdowns, and physical distancing measures. These attitudes have carried over into public sentiments about the COVID-19 vaccine. Our study did not highlight systematic differences between democratic-leaning versus republic-leaning states in reasons for vaccine hesitancy.

Our study, like other, has shown that vaccine acceptance is higher in populations who perceive that they are at higher risk of contracting the infection and having more severe disease[24]. Our study also highlighted that person who reside in larger apartment buildings are less vaccine hesitant; one possible explanation may be perception of higher risk due to less ability to physical distance since they are constantly exposed to their co-tenants while sharing common high-contact areas such as mail, laundry, and exercise rooms. We also noted that vaccine hesitancy was higher among those with a previous diagnosis of COVID-19. Vaccine hesitancy in this subpopulation may be due to perception of reduced risk of reinfection. However, this may be an incorrect assumption since case reports have highlighted serologically confirmed reinfection in an individual with previous diagnosis of COVID-19[25,26]. Knowledge about the longevity of natural COVID-19 immunity is still evolving. The perception of reduced risk due to innate immunity also has public health significance since some individuals may become less compliant with non-pharmacological interventions such as facemask wearing and physical distancing.

Limitations

This study has several limitations. First, the nature of the survey is designed to be a short-turnaround instrument that provides valuable data to aid in the pandemic recovery, as such data products may not meet some of the Census Bureau's statistical quality standards. Data are subject to suppression based on overall response and disclosure avoidance thresholds. Second, data were self-reported and subject to bias. Third, at the time of data collection vaccines were available to only persons at high-risk such as healthcare workers and elderly persons, and this may have negatively skewed vaccine acceptance responses. Despite these limitations, this study fills an important knowledge gap in state variations in vaccine hesitancy. These data are important for public health practice and has potential to inform vaccine campaign efforts.

CONCLUSIONS

One in four Americans indicated vaccine hesitancy, especially women, Blacks and those living in republican-leaning states. Enhanced and sustained efforts are needed to boost trust and confidence in the COVID-19 vaccines. Knowledge of state-specific information can have significant impact on how clinicians, frontline workers, public health professionals, state departments of health, and overseeing agencies tailor specific campaigns to promote vaccine confidence and uptake, while also encouraging non-pharmacological interventions[27].

REFERENCES

1. Vaccines and immunization. World Health Organization. Accessed November 18, 2021. https://www.who.int/health-topics/vaccines-and-immunization#tab=tab_1
2. Metcalf CJE, Ferrari M, Graham AL, Grenfell BT. Understanding Herd Immunity. Trends Immunol. 2015;36(12):753-755. doi:10.1016/j.it.2015.10.004
3. Randolph HE, Barreiro LB. Herd Immunity: Understanding COVID-19. Immunity. 2020;52(5):737-741. doi:10.1016/j.immuni.2020.04.012
4. Ten threats to global health in 2019. World Health Organization. Accessed November 18, 2021. https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019
5. McAteer J, Yildirim I, Chahroudi A. The VACCINES Act: Deciphering Vaccine Hesitancy in the Time of COVID-19. Clin Infect Dis. 2020;71(15):703-705. doi:10.1093/cid/ciaa433
6. Coronavirus: DOD Response. U.S. Department of Defense. Accessed November 18, 2021. https://www.defense.gov/Spotlights/Coronavirus-DOD-Response/
7. Rivière E. COVID-19 vaccine faces an increasingly hesitant public. Kantar. November 23, 2020. Accessed November 18, 2021. https://www.kantar.com/inspiration/coronavirus/covid-19-vaccine-faces-an-increasingly-hesitant-public
8. Fisher KA, Bloomstone SJ, Walder J, Crawford S, Fouayzi H, Mazor KM. Attitudes Toward a Potential SARS-CoV-2 Vaccine: A Survey of U.S. Adults. Ann Intern Med. 2020;173(12):964-973. doi:10.7326/M20-3569
9. Funk C, Tyson A. Intent to Get a COVID-19 Vaccine Rises to 60% as Confidence in Research and Development Process Increases. Pew Research Center. December 3, 2020. Accessed November 18, 2021. https://www.pewresearch.org/science/2020/12/03/intent-to-get-a-covid-19-vaccine-rises-to-60-as-confidence-in-research-and-development-process-increases/

10. 2020 Electoral College Results. National Archives and Records Administration. Updated April 16, 2021. Accessed November 18, 2021. https://www.archives.gov/electoral-college/2020
11. 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 Community Health. 2021;46(2):270-277. doi:10.1007/s10900-020-00958-x
12. Malik AA, McFadden SM, Elharake J, Omer SB. Determinants of COVID-19 vaccine acceptance in the US. EClinicalMedicine. 2020;26:100495. doi:10.1016/j.eclinm.2020.100495
13. Conti P, Younes A. CORONAVIRUS COV-19/SARS-CoV-2 AFFECTS WOMEN LESS THAN MEN:CLINICAL RESPONSE TO VIRAL INFECTION. J Biol Regul Homeost Agents. 2020;34(2):339-343. doi:10.23812/Editorial-Conti-3
14. Gamble VN. Under the Shadow of Tuskegee: African Americans and Health Care. Am J Public Health. 1997;87(11):1773-1778. doi:10.2105/ajph.87.11.1773
15. Jaiswal J, Halkitis PN. Towards a More Inclusive and Dynamic Understanding of Medical Mistrust Informed by Science. Behav Med. 2019;45(2):79-85. doi:10.1080/08964289.2019.1619511
16. Bogart LM, Ojikutu BO, Tyagi K, et al. 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):200-207. doi:10.1097/QAI.0000000000002570
17. Earnshaw VA, Eaton LA, Kalichman SC, Brousseau NM, Hill EC, Fox AB. COVID-19 conspiracy beliefs, health behaviors, and policy support. Transl Behav Med. 2020;10(4):850-856. doi:10.1093/tbm/ibaa090
18. Romer D, Jamieson KH. Conspiracy theories as barriers to controlling the spread of COVID-19 in the U.S. Soc Sci Med. 2020;263:113356. doi:10.1016/j.socscimed.2020.113356
19. Price-Haywood EG, Burton J, Fort D, Seoane L. Hospitalization and Mortality among Black Patients and White Patients with Covid-19. N Engl J Med. 2020;382(26):2534-2543. doi:10.1056/NEJMsa2011686
20. Laurencin CT, McClinton A. The COVID-19 Pandemic: a Call to Action to Identify and Address Racial and Ethnic Disparities. J Racial Ethn Health Disparities. 2020;7(3):398-402. doi:10.1007/s40615-020-00756-0
21. Berkman ND, Sheridan SL, Donahue KE, Halpern DJ, Crotty K. Low health literacy and health outcomes: an updated systematic review. Ann Intern Med. 2011;155(2):97-107. doi:10.7326/0003-4819-155-2-201107190-00005
22. Lahouati M, De Coucy A, Sarlangue J, Cazanave C. Spread of vaccine hesitancy in France: What about YouTube™? Vaccine. 2020;38(36):5779-5782. doi:10.1016/j.vaccine.2020.07.002
23. Wilson SL, Wiysonge C. Social media and vaccine hesitancy. BMJ Glob Health. 2020;5(10):e004206. doi:10.1136/bmjgh-2020-004206
24. Detoc M, Bruel S, Frappe P, Tardy B, Botelho-Nevers E, Gagneux-Brunon A. Intention to participate in a COVID-19 vaccine clinical trial and to get vaccinated against COVID-19 in France during the pandemic. Vaccine. 2020;38(45):7002-7006. doi:10.1016/j.vaccine.2020.09.041
25. Tillett RL, Sevinsky JR, Hartley PD, et al. Genomic evidence for reinfection with SARS-CoV-2: a case study. Lancet Infect Dis. 2021;21(1):52-58. doi:10.1016/S1473-3099(20)30764-7
26. Nonaka CKV, Franco MM, Gräf T, et al. Genomic Evidence of SARS-CoV-2 Reinfection Involving E484K Spike Mutation, Brazil. Emerg Infect Dis. 2021;27(5):1522-1524. doi:10.3201/eid2705.210191
27. French J, Deshpande S, Evans W, Obregon R. Key Guidelines in Developing a Pre-Emptive COVID-19 Vaccination Uptake Promotion Strategy. Int J Environ Res Public Health. 2020;17(16):5893. doi:10.3390/ijerph17165893

CONFLICTS OF INTEREST
The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none was reported.

FUNDING
There was no source of funding for this research.

ETHICAL APPROVAL AND INFORMED CONSENT
Ethical approval and informed consent were not required for this study, as data used are secondary, de-identified, and publicly available data.

DATA AVAILABILITY
Data supporting this research are available from the following sources: https://www.census.gov/data/tables/2021/demo/hhp/hhp22.html and https://www.census.gov/programs-surveys/household-pulse-survey/datasets.html

PROVENANCE AND PEER REVIEW
Not commissioned; externally peer reviewed.