



COVID-19 vaccine hesitancy and racial discrimination among US adults

Don E. Willis^a, Brooke E.E. Montgomery^b, James P. Selig^c, Jennifer A. Andersen^a,
Sumit K. Shah^d, Ji Li^c, Sharon Reece^a, Derek Alik^a, Pearl A. McElfish^{a,*}

^a College of Medicine, University of Arkansas for Medical Sciences Northwest, 1125 N. College Ave., Fayetteville, AR 72703, USA

^b Fay W. Boozman College of Public Health, University of Arkansas for Medical Sciences, 4301 W. Markham St., Little Rock, AR 72205, USA

^c Fay W. Boozman College of Public Health, University of Arkansas for Medical Sciences Northwest, 1125 N. College Ave., Fayetteville, AR 72703, USA

^d Office of Community Health and Research, University of Arkansas for Medical Sciences Northwest, 1125 N. College Ave., Fayetteville, AR 72703, USA

ARTICLE INFO

Keywords:

COVID-19
Vaccine hesitancy
Racial discrimination
Racism

ABSTRACT

Vaccination is a critical preventive measure to reduce COVID-19 health risks. We utilize full information maximum likelihood (FIML) logistic regression to analyze COVID-19 vaccine hesitancy in a national sample of United States (US) adults (N = 2,022). Online survey data was collected between September 7th and October 3rd, 2021. Before weighting, the racial composition of the sample was as follows: Asian American (15.0 %), Black/African American (20.0 %), Hispanic/Latino (20.0 %), American Indian or Alaska Native (12.6 %), Native Hawaiian or Pacific Islander (12.5 %), and White (20.0 %). Informed by the Increasing Vaccination Model (IVM), we assessed the relationship between COVID-19 vaccine hesitancy and experiences of racial discrimination (Krieger's 9-item measure). Odds of COVID-19 vaccine hesitancy were greater for most younger age groups, women (OR = 1.96; 95 % CI[1.54, 2.49]), Black/African American respondents (OR = 1.68; 95 % CI[1.18, 2.39]), those with a high school education or less (OR = 1.46; 95 % CI[1.08, 1.98]), Independent (OR = 1.77; 95 % CI[1.34, 2.35]) or Republican political affiliation (OR = 2.69; 95 % CI[1.92, 3.79]), and prior COVID-19 infection (OR = 1.78; 95 % CI[1.29, 2.45]). Odds of COVID-19 vaccine hesitancy were 1.04 greater for every one unit increase in lifetime experiences of racial discrimination (95 % CI[1.02, 1.05]). Odds of COVID-19 vaccine hesitancy were lower for Asian American respondents (OR = 0.682; 95 % CI[0.480, 0.969]), and those who had a primary care doctor had reduced odds of COVID-19 vaccine hesitancy (OR = 0.735; 95 % CI [0.542, 0.998]). Our primary finding provides support for a link between experiences of racial discrimination and hesitancy towards a COVID-19 vaccine among US adults. We discuss implications for public health officials and future research.

1. Introduction

COVID-19 has become a leading cause of death in the United States (US) (Ahmad and Anderson, 2021; Woolf et al., 2021), with some estimates calculating a global death toll of 18 million by the end of 2021 (COVID-19 Excess Mortality Collaborators, 2022). COVID-19 deaths have been disproportionately experienced by people of color and Black individuals in particular (McLaren, 2020). The pandemic reduced life expectancy by more than two years for Black individuals in the US, resulting in the elimination of over a decade of progress in narrowing the Black-White gap in life expectancy (Andrasfay and Goldman, 2021).

Vaccination against COVID-19 prevented an estimated 1.1 million US deaths by November of 2021 (Schneider et al., 2021). However, 15 % of US residents remained unvaccinated as of December 2021 (Monte,

2021), racial disparities in vaccination rates persist (Reitsma et al., 2021; Ndugga et al., 2022), and vaccine hesitancy presents a significant challenge to increasing COVID-19 vaccine uptake. Racial disparities in hesitancy towards COVID-19 vaccination may be a pathway through which racial health disparities are reproduced or exacerbated. Racial disparities in COVID-19 vaccine hesitancy vary by age (King et al., 2021) and have narrowed over time, with the largest reductions among Black and Hispanic adults (Daly et al., 2021); however, research has consistently shown high rates of hesitancy among Black adults (Aw et al., 2021; Daly et al., 2021; Malik et al., 2020; Willis et al., 2021). There have been mixed findings among studies documenting hesitancy among other people of color in the US such as Asian Americans, American Indian or Alaska Natives, and Native Hawaiian or Pacific Islanders, possibly due to data aggregation that often occurs for these groups.

* Corresponding author.

E-mail address: pamcelfish@uams.edu (P.A. McElfish).

<https://doi.org/10.1016/j.pmedr.2022.102074>

Received 13 May 2022; Received in revised form 22 November 2022; Accepted 24 November 2022

Available online 28 November 2022

2211-3355/© 2022 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Studies which combine across racial/ethnic groups due to low representation have found both lower odds of COVID-19 hesitancy among these groups compared to White individuals (Willis et al., 2021) or no difference (McElfish et al., 2021). Research which specifically combined Asian American and Native Hawaiian or Pacific Islander respondents found them to have lower levels of vaccine hesitancy than White respondents (Niño et al., 2021), but others that disaggregated found Native Hawaiian or Pacific Islanders had higher COVID-19 vaccine hesitancy than Asian Americans (Ta Park et al., 2021).

Although many studies have documented racial disparities in vaccine hesitancy, influential reviews and models of vaccine hesitancy noticeably omit discussion of racism and experiences with discrimination (Brewer et al., 2017; WHO, 2014). Reporting of racial health disparities without discussion of the social conditions (e.g., structural and interpersonal racism) from which they emerge can perpetuate myths of biological race (Chowkwanyun and Reed, 2020; Willis and McElfish, 2021). The Increasing Vaccination Model (IVM) is an influential theoretical model of vaccine hesitancy and vaccination that includes two key domains that influence vaccine hesitancy, including thoughts and feelings and social processes (Brewer et al., 2017; Measuring Behavioural, 2020). The IVM does not specifically identify racism as an important social process to consider; however, the IVM does posit social processes as influencing vaccine hesitancy, which then influences vaccination behaviors (Brewer et al., 2017; Measuring Behavioural, 2020). Social processes such as norms, equity, relationships, and interactions are important because “vaccination is inherently a social activity” and “takes place in the context of human interactions.” (Brewer et al., 2017) (p167). Experiences of racial discrimination are an important social process to consider, as they indicate unfair and differential treatment by institutions and individuals based on socially constructed categories of race.

Experiences of racial discrimination are associated with decreased likelihood of receiving preventive health services, but there are mixed findings when it comes to vaccination (Trivedi and Ayanian, 2006; Hausmann et al., 2008). To date, very few empirical analyses have examined racism as a predictor of vaccine hesitancy (Bleser et al., 2016; Quinn et al., 2017), and only two known studies have examined experiences of racial discrimination as a predictor of hesitancy towards COVID-19 vaccination (Savoia et al., 2021; Willis et al., 2022). The first study to document an association between racial discrimination and COVID-19 vaccine hesitancy (Savoia et al., 2021) was conducted prior to the approval of vaccines, and attitudes about the vaccine have shifted substantially as the pandemic has progressed (Daly et al., 2021). The second study found greater odds of COVID-19 hesitancy among Black adults in Arkansas who experienced discrimination from police or in courts compared to those who had not (Willis et al., 2022 2021). Missing from the literature on COVID-19 vaccine hesitancy has been an empirical examination of the role of racism or experiences of racial discrimination among US adults since the vaccine has become available.

We begin to fill this gap in the literature by examining the relationship between COVID-19 vaccine hesitancy and one form of interpersonal racism—experiences of racial discrimination (Krieger et al., 2005). We ask: Are experiences of racial discrimination associated with COVID-19 vaccine hesitancy among US adults? This is the primary research question of our study; however, we extend prior research which has shown important sociodemographic differences in vaccine hesitancy by examining associations with age, gender, race/ethnicity, and education (Aw et al., 2021; McElfish et al., 2021; Willis et al., 2021). We also extend work which demonstrated growing political division over COVID-19 vaccination by assessing the relationship between COVID-19 vaccine hesitancy and political affiliation (Cowan et al., 2021; Agarwal et al., 2021). Finally, given mixed results of past research assessing the role of prior COVID-19 infection (Troiano and Nardi, 2021) and findings suggesting a key role for primary care doctors in addressing vaccine hesitancy, (Shen and Dubey, 2019) we included these variables in our analyses. Although this study is informed by the IVM, we are not fully

testing this model; rather, we primarily aimed to assess one variable—experiences of racial discrimination—which we argue falls within the social processes outlined as important in the IVM (Brewer et al., 2017; WHO, 2014).

2. Methods

2.1. Procedures

We used online survey data collected from 2,022 US adults. Participants were recruited between September 7, 2021 and October 3, 2021 from an online opt-in panel of individuals across the US housed and managed by Atomik Research. The survey was available to participants in English and Spanish. Inclusion criteria included being age 18 or older and living in the US. Recruitment involved providing the following information about the study: (1) the estimated study duration (10 min); (2) potential risks and benefits; (3) the voluntary nature of participation; and (4) confidentiality of responses. Participants indicated consent by selecting that they agreed to participate in the online survey. An Institutional Review Board for the protection of human subjects at the University of Arkansas for Medical Sciences (IRB #263020) approved the study procedures.

We oversampled Asian American, Black/African American, Hispanic/Latino, American Indian or Alaska Native, and Native Hawaiian or Pacific Islander individuals. This oversampling was necessary to avoid aggregation of racial and ethnic groups which often obscures diverse groups, experiences, and attitudes (Quint et al., 2021; Chang et al., 2021). The random iterative method (Mercer et al., 2018) was used to weight the data to be representative of the US population across key demographic variables including gender (men, women, non-binary), race/ethnicity (Asian American, Black/African American, Hispanic/Latino, American Indian or Alaska Native, Native Hawaiian or Pacific Islander, and White), and age (18–24, 25–34, 35–44, 45–54, 55–64, 65+).

2.2. Measures

2.2.1. COVID-19 vaccine hesitancy

The dependent variable in this study was COVID-19 vaccine hesitancy. To measure COVID-19 vaccine hesitancy, respondents were asked, “Thinking specifically about the COVID-19 vaccines, how hesitant were/are you about getting vaccinated?” Response options included “not at all hesitant,” “a little hesitant,” “somewhat hesitant,” and “very hesitant.” This measure is a modified version of a general vaccine hesitancy question developed by Quinn and colleagues (Quinn et al., 2019). This measure was dichotomized to indicate whether individuals were hesitant (a little, somewhat, or very) or not at all hesitant.

2.2.2. Sociodemographic characteristics

We collected sociodemographic information including age, gender, race/ethnicity, and education. Respondents reported their age in years and their gender as man, woman, non-binary, or self-described. Only eight respondents selected a non-binary gender or self-described, so our analytical sample includes only self-identified men and women. Race and ethnicity were measured using the standard two-item questions (CDC, 2020). Responses from the two items were combined to categorize individuals into the following mutually exclusive groups: Asian American, Black/African American, Hispanic/Latino, American Indian or Alaska Native, Native Hawaiian or Pacific Islander, and White. The Hispanic/Latino group includes persons of all races, including individuals who selected multiple races but who listed their ethnicity as Hispanic; all other groups are non-Hispanic. All 27 persons who selected multiple racial identities were Hispanic/Latino, so no multiracial category is included in our analysis. Education was measured by asking respondents their highest degree or level of school completed. Individuals with less than a high school degree were combined with high school

graduates, as were those with a four-year degree or higher, due to low frequency of responses at those levels.

2.2.3. Political affiliation

Political affiliation was measured by asking, “Generally speaking, do you think of yourself as a...?” Response options included Democrat, Republican, Independent, and Other, providing a nominal variable. Independent and Other responses were combined.

2.2.4. COVID-19 infection

Prior infection with COVID-19 was measured by asking, “Have you tested positive, or suspect that you have had, COVID-19?” Response options included “Yes—I tested positive for COVID-19,” “Yes—I suspect that I had COVID-19,” and “No, I do not believe I had COVID-19.” We dichotomized this measure by combining the affirmative responses.

2.2.5. Primary care doctor

To assess whether respondents had a primary care doctor or not, we asked, “Do you have one person you think of as your personal doctor or health care provider?” Response options included “yes, only one,” “more than one,” and “no.” We dichotomized this variable by combining the two affirmative responses.

2.2.6. Racial discrimination

Lifetime experiences of racial discrimination was measured using Krieger’s validated 9-item measure (Krieger et al., 2005). This measure assesses whether someone has ever experienced racial discrimination across nine different situations: school, getting hired or getting a job, at work, getting housing, getting medical care, getting service in a store or restaurant, getting credit/bank loans/a mortgage, on the street or in a public setting, from the police or in the courts. Respondents could indicate whether they had “never,” “once,” “two or three times,” or “four or more times” experienced discrimination because of their race, ethnicity, or skin color in each of these situations. We utilized the frequency (total occurrences) of experiences of racism, and responses were coded 0 for “never,” 1 for “once,” 2.5 for “2–3 times,” and 5 for “4 or more times.” (Krieger et al., 2005). The 9 items were summed to create a scale ranging from 0 to 45 (alpha = 0.919).

2.3. Statistical analyses

We analyzed the data using STATA 15.1 SE to produce the descriptive and bivariate statistics, including Pearson χ (Woolf et al., 2021) statistics with Rao and Scott second-order correction (Rao and Scott, 1981; Rao and Scott, 1984), and adjusted Wald tests for testing associations between COVID-19 vaccine hesitancy and experiences of racial discrimination. All except three variables (gender, political affiliation, and COVID-19 infection) in our analyses had no missing data. There was missing data for gender (0.40 %), political affiliation (9.45 %), and prior COVID-19 infection (3.41 %). We minimized the limitations of the missing data by utilizing full information maximum likelihood (FIML) in a multivariate logistic regression analyses in Mplus version 7.8 (Enders, 2001; Enders, 2010). FIML logistic regression uses all non-missing values to estimate model parameters, providing results comparable to other modern missing data methods (e.g., multiple imputation) (Enders, 2001; Enders, 2010). In unreported analyses, we tested for interaction effects between age and race—the results were not statistically significant. Sensitivity analysis provided as Supplemental Table 1 reveals similar results when using a FIML ordinal logistic regression, with the outcome maintained at the ordinal level.

3. Results

A total of 8,067 individuals entered the online survey, and 25.1 % (N = 2,022) were eligible and completed the survey. Of those who were eligible, 62.0 % completed the survey. The conversion rate (completed

surveys divided by total number who entered the survey site) was highest among Black/African American (84.0 %), Asian American (77.0 %), and Hispanic/Latino (62.0%) respondents, followed by White (55 %), American Indian or Alaska Native (46.0 %), and Pacific Islander (44.0 %) respondents. We present the unweighted and weighted descriptive statistics (percentage, mean, SD, range) for the samples in Table 1. Each age group is well-represented in our sample. Men and women both comprise roughly half the sample. Due to the oversampling of minoritized racial groups, there is substantial representation across each racial and ethnic group, with over 250 responses from each. Respondents with a four-year or graduate degree (37.0 %) made up the largest proportion of the sample across educational attainment. The sample includes Democrats (46.0 %), Independents or other (34.2 %), and Republicans (19.8 %). The majority did not report having tested positive for COVID-19 or suspecting they had been infected (81.4 %). Most reported having a primary care doctor (78.8 %). The average weighted score of experiences of racial discrimination was 6.4—this is similar to the average (6.5) for the study that validated the measure (Krieger et al., 2005). Average experiences of racial discrimination were highest among Black/African American respondents (11.8), followed by American Indian or Alaska Natives (11.0), Native Hawaiian or Pacific Islanders (9.3), Hispanic/Latino respondents (7.2), and Asian Americans (5.7). Experiences of racial discrimination were lowest among White

Table 1
Descriptive Statistics of US Adults.

	Unweighted % (Freq)	Weighted % or \bar{x}	SD	Range
Age (N = 2,022)			-	-
18-24	9.6 (194)	12.0		
25-34	20.6 (417)	18.0		
35-44	23.0 (465)	16.0		
45-54	18.8 (380)	16.0		
55-64	11.5 (233)	17.0		
65+	16.5 (333)	21.0		
Gender (N = 2,014)			-	-
Women	52.7 (1,062)	50.0		
Men	47.3 (952)	50.0		
Race/Ethnicity (N = 2,022)			-	-
Asian American	15.0 (304)	10.0		
Black/African American	20.0 (404)	20.0		
Hispanic/Latino	20.0 (404)	20.0		
American Indian or Alaska Native	12.6 (254)	5.0		
Native Hawaiian or Pacific Islander	12.5 (252)	5.0		
White	20.0 (404)	40.0		
Education (N = 2,022)			-	-
High school or less	28.7 (581)	28.2		
Some college, no degree	22.3 (450)	21.4		
Associate degree	12.0 (242)	12.6		
Four-year or graduate degree	37.0 (749)	37.8		
Political Affiliation (N = 1,831)			-	-
Democrat	46.0 (842)	44.6		
Independent or other	34.2 (626)	32.4		
Republican	19.8 (363)	23.1		
COVID-19 Infection (N = 1,953)			-	-
Yes	18.6 (363)	18.1		
No	81.4 (1,590)	81.9		
Primary Care Doctor (N = 2,022)			-	-
Yes	78.8 (1,594)	81.3		
No	21.2 (428)	18.7		
Discrimination (N = 2,022)				
Lifetime experiences (mean)	2022	6.4	9.8	0-45
COVID-19 Vaccine Hesitant (N = 2,022)			-	-
Yes	63.6 (1,286)	60.5		
No	36.4 (736)	39.5		

respondents (2.7). Although the majority of respondents were hesitant towards the COVID-19 vaccine, over a third (36.4 %) of the sample reported no vaccine hesitancy.

We present weighted bivariate analyses in Table 2. COVID-19 vaccine hesitancy was significantly associated with age ($F_{4,9892} = 17.0; p < .001$), gender ($F_{1,2013} = 8.0; p = .005$), race/ethnicity ($F_{4,8562} = 12.9; p < .001$), education ($F_{3,6060} = 7.4; p < .001$), political affiliation ($F_{2,3640} = 14.0; p < .001$), COVID-19 infection ($F_{4,9892} = 28.1; p < .001$), whether or not they have a primary care doctor ($F_{4,9892} = 15.7; p < .001$), and experiences of racial discrimination ($F_{1,2021} = 60.1; p < .001$). The highest prevalence of vaccine hesitancy was among younger age groups, and the lowest prevalence was among those age 65 or older (41.9 %). The prevalence of vaccine hesitancy was higher among women (64.2 %) than men (57.0 %). Across race/ethnicity, the prevalence of vaccine hesitancy was highest among American Indian or Alaska Native (78.1 %) and Black/African American respondents (70.6 %), followed by Native Hawaiian or Pacific Islander (68.6 %) and Hispanic/Latino respondents (61.0 %). The prevalence of vaccine hesitancy was lowest among Asian American (46.6 %) and White respondents (55.5 %). Across education, the highest prevalence of vaccine hesitancy was among those with a high school degree or less (67.3 %), followed by those with an associate degree (65.5 %) and those with some college but no degree (61.6 %). The prevalence of vaccine hesitancy was lowest among those with a four-

Table 2
Bivariate Analysis of COVID-19 Vaccine Hesitancy in US Adults.

	Hesitant	Not Hesitant	F	p-value
	Freq. (Row %)	Freq. (Row %)	statistic	
Age (N = 2,022)			17.0	<0.001
18-24	140 (69.7)	54 (30.3)	–	–
25-34	308 (74.0)	109 (26.0)	–	–
35-44	328 (68.0)	137 (32.0)	–	–
45-54	247 (63.7)	133 (36.3)	–	–
55-64	123 (52.8)	110 (47.2)	–	–
65+	140 (41.9)	193 (58.1)	–	–
Gender (N = 2,014)			8.0	0.005
Women	715 (64.2)	347 (35.8)	–	–
Men	567 (57.0)	385 (43.0)	–	–
Race/Ethnicity (N = 2,022)			12.9	<0.001
Asian American	150 (46.6)	154 (53.4)	–	–
Black/African American	283 (70.6)	121 (29.4)	–	–
Hispanic/Latino	252 (61.0)	152 (39.0)	–	–
American Indian or Alaska Native	198 (78.1)	56 (21.9)	–	–
Native Hawaiian or Pacific Islander	177 (68.6)	75 (31.4)	–	–
White	226 (55.5)	178 (44.5)	–	–
Education (N = 2,022)			7.4	<0.001
High school or less	412 (67.3)	169 (32.7)	–	–
Some college, no degree	299 (61.6)	151 (38.4)	–	–
Associate degree	163 (65.5)	79 (34.5)	–	–
Four-year or graduate degree	412 (53.2)	337 (46.8)	–	–
Political Affiliation (N = 1,831)			14.0	<0.001
Democrat	459 (52.1)	383 (47.9)	–	–
Independent or other	434 (65.6)	192 (34.4)	–	–
Republican	259 (67.8)	104 (32.2)	–	–
COVID-19 Infection (N = 1,953)			28.1	<0.001
Yes	285 (75.1)	78 (24.9)	–	–
No	953 (57.1)	637 (42.9)	–	–
Primary Care Doctor (N = 2,022)			15.7	<0.001
Yes	966 (58.1)	628 (41.9)	–	–
No	320 (70.9)	108 (29.1)	–	–
Discrimination (N = 2,022)			60.1	<0.001
Lifetime experiences (mean)	7.8	4.3	–	–

Note: Frequencies are unweighted, row %'s are weighted.

year or graduate degree (53.2 %). The average reported lifetime experiences of racial discrimination were higher among individuals who were hesitant (7.8) than those who were not hesitant (4.3) about COVID-19 vaccination.

We present adjusted odds ratios from the FIML logistic regression of COVID-19 vaccine hesitancy in Table 3. Odds of vaccine hesitancy were greater for those age 18–24 (OR = 2.66; 95 % CI[1.67, 4.26]), age 25–34 (OR = 3.40; 95 % CI[2.30, 5.03]), age 35–44 (OR = 3.08 95 % CI[2.08, 4.58]), and age 45–54 (OR = 2.58; 95 % CI[1.78, 3.74]) compared to those age 65 or older. No statistically significant differences were found between respondents age 55–64 and those age 65 or older. Odds of vaccine hesitancy were greater for women (OR = 1.96; 95 % CI[1.54, 2.49]) compared to men. Odds of vaccine hesitancy were lower for Asian American respondents (OR = 0.682; 95 % CI[0.480, 0.969]) and higher for Black/African American respondents (OR = 1.68; 95 % CI[1.18,

Table 3
FIML Logistic Regression of COVID-19 Vaccine Hesitancy in US Adults.

	B	SE	p	^a OR (95 %CI)
Age				
18-24	0.980	0.239	<0.001	2.66 (1.67, 4.26)
25-34	1.22	0.200	<0.001	3.40 (2.30, 5.03)
35-44	1.13	0.202	<0.001	3.08 (2.08, 4.58)
45-54	0.946	0.190	<0.001	2.58 (1.78, 3.74)
55-64	0.315	0.196	0.109	1.37 (0.932, 2.01)
65+	–	–	–	–
Gender				
Women	0.672	0.122	<0.001	1.96 (1.54, 2.49)
Men	–	–	–	–
Race/Ethnicity				
Asian American	-0.383	0.179	0.033	0.682 (0.480, 0.969)
Black/African American	0.519	0.179	0.004	1.68 (1.18, 2.39)
Hispanic/Latino	-0.110	0.168	0.510	0.896 (0.645, 1.24)
American Indian or Alaska Native	0.378	0.222	0.088	1.46 (0.945, 2.25)
Native Hawaiian or Pacific Islander	0.007	0.214	0.974	1.01 (0.662, 1.53)
White	–	–	–	–
Education				
High school or less	0.380	0.155	0.014	1.46 (1.08, 1.98)
Some college, no degree	0.127	0.159	0.423	1.14 (0.832, 1.55)
Associate degree	0.385	0.200	0.055	1.47 (0.992, 2.18)
Four-year or graduate degree	–	–	–	–
Political Affiliation				
Democrat	–	–	–	–
Independent or other	0.571	0.144	<0.001	1.77 (1.34, 2.35)
Republican	0.991	0.174	<0.001	2.69 (1.92, 3.79)
COVID-19 Infection				
Yes	0.576	0.164	<0.001	1.78 (1.29, 2.45)
No	–	–	–	–
Primary Care Doctor				
Yes	-0.307	0.156	0.048	0.735 (0.542, 0.998)
No	–	–	–	–
Discrimination				
Lifetime experiences (mean)	0.035	0.007	<0.001	1.04 (1.02, 1.05)

^a OR = adjusted odds ratios.

2.39]) compared to White respondents; however, it was not significant for the other racial/ethnic groups. Respondents with a high school education or less had 1.46 greater odds of vaccine hesitancy than those with a four-year or graduate degree (95 % CI[1.08, 1.98]). Respondents who reported a political affiliation of Independent or other had 1.77 greater odds of vaccine hesitancy compared to Democrats (95 % CI [1.34, 2.35]). Republicans had odds of vaccine hesitancy more than double those of Democrats (OR = 2.69; 95 % CI[1.92, 3.79]). Respondents who reported having had a COVID-19 infection had 1.78 greater odds of vaccine hesitancy (95 % CI[1.29, 2.45]). Respondents who had a primary care doctor had reduced odds of vaccine hesitancy (OR = 0.735; 95 % CI[0.542, 0.998]). Odds of vaccine hesitancy were 1.04 greater for every-one unit increase in the score of lifetime experiences of racial discrimination (95 % CI[1.02, 1.05]).

4. Discussion

This study fills an important gap in the literature by examining the relationship between COVID-19 vaccine hesitancy and experiences of racial discrimination. We found experiences of racial discrimination are associated with greater odds of COVID-19 vaccine hesitancy even after adjusting for sociodemographic characteristics, political affiliation, prior COVID-19 infection, and having a primary care doctor. For every-one unit increase in racial discrimination across one's lifetime, we found a 4 % increase in the odds of COVID-19 vaccine hesitancy. The total increase in odds could be substantially higher depending on the lifetime frequency of experiences of racial discrimination. These findings are consistent with the limited body of research examining racial discrimination and COVID-19 vaccine hesitancy (Savoia et al., 2021), as well as the limited work linking racial disparities in vaccination rates with structural racism (Siegel et al., 2022). We add new insights as this is the first study to examine the association of racial discrimination with COVID-19 vaccine hesitancy among US adults since the approval and release of the vaccine.

We extend research on sociodemographic differences in vaccine hesitancy by examining associations with age, gender, race/ethnicity, and education. Our findings are consistent with research demonstrating a general trend of less COVID-19 vaccine hesitancy among older age groups (Aw et al., 2021; Malik et al., 2020; McElfish et al., 2021; Willis et al., 2021). Consistent with prior research, we found women had higher odds of COVID-19 vaccine hesitancy than men (Aw et al., 2021; Malik et al., 2020; Willis et al., 2022, 2021). Researchers do not know what drives gendered attitudes towards the COVID-19 vaccine; however, some scholars have found the gendered pressures women with children face as managers of family health decisions promote opposition to risks they perceive as uncontrollable (Calarco and Anderson, 2021). Alternatively, age and gender differences in vaccine hesitancy may be driven by awareness of older age and being male as risk factors for COVID-19-related morbidity and mortality (Yanez et al., 2020). Our findings of higher odds of COVID-19 vaccine hesitancy among those with lower education levels is consistent with other studies; however, like others, we note that this relationship is often non-linear (King et al., 2021).

Our findings provide further support for the growing body of literature on racial disparities in COVID-19 vaccine hesitancy (Aw et al., 2021; Malik et al., 2020; Willis et al., 2021.) Specifically, we found that Black/African American adults have higher odds of COVID-19 vaccine hesitancy compared to White adults; however, Asian American adults had lower odds compared to White adults. Notably, respondents who identified as Hispanic/Latino, American Indian or Alaska Native, or Native Hawaiian or Pacific Islander did not have significantly different odds of COVID-19 vaccine hesitancy compared to White adults when controlling for other independent variables. If not for efforts to oversample these racial/ethnic groups and avoidance of traditional clumping of racialized groups, they would have been aggregated, and distinctions between the results for each group would have been obscured (Quint et al., 2021; Chang et al., 2021).

Building on work which has demonstrated growing political division over COVID-19 vaccination (Cowan et al., 2021; Agarwal et al., 2021), we found odds of COVID-19 vaccine hesitancy were higher among Independents and Republicans compared to Democrats. This finding is consistent with research demonstrating the division over vaccination falls increasingly across political party lines (Cowan et al., 2021). Republicans are more likely to endorse anti-vaccine misinformation and are less willing to be vaccinated—a partisan divide which has widened over time (Cowan et al., 2021; Motta, 2021; Suran, 2022). Scholars suggest political division over vaccination may be related to emerging evidence demonstrating political affiliation has become a source of personal identity (Mason, 2018). Public health officials may need to consider messaging which is not perceived as threatening to political party affiliation or other characteristics deeply connected to personal identity.

We find individuals who report COVID-19 infection have higher odds of COVID-19 vaccine hesitancy. This finding should be interpreted with some caution, given it runs counter to some earlier studies (Aw et al., 2021). However, this finding does raise important questions about how experiences of COVID-19 infection may inform attitudes about vaccination. Do previously infected individuals perceive it as unnecessary due to an assumption of natural immunity? Does the experience of infection increase concerns about reactions to the vaccine given misinformation about whether COVID-19 vaccines contain the virus? We found the odds of COVID-19 vaccine hesitancy were lower among adults who reported having a primary care doctor. This is consistent with research which identified doctors as important actors in addressing COVID-19 vaccine hesitancy, as they are often among the most trusted sources of information (Purvis et al., 2021; Shen and Dubey, 2019).

4.1. Limitations

We have relied on cross-sectional data and cannot make any causal claims. The measures are self-reported. We utilized an online survey, which may not have been accessible to those without regular internet access and a device that can access internet. Given our conversion rate of 62 %, there is a possibility of response bias. Although we use an established measure of experiences of racial discrimination, we have not examined associations between sources of structural racism and COVID-19 vaccine hesitancy. We have utilized a large national sample of US adults and weighted the data to account for the substantial oversampling of racial/ethnic groups. However, the sample does not match the US population on all characteristics (e.g. political affiliation), which may indicate some partisan nonresponse bias. Furthermore, a larger sample size could have provided more precise estimates.

These limitations are balanced by the strengths provided by substantial oversampling of groups which are typically aggregated in similar analyses. For example, due to our oversampling, we were able to disaggregate racial/ethnic groups such as Asian Americans and Native Hawaiian or Pacific Islanders who tend to be combined. This is important in the literature on COVID-19 vaccine hesitancy because what is known about vaccine hesitancy among Native Hawaiian or Pacific Islanders is often contradictory. Mixed results are likely due to differences in aggregation by researchers. Studies which combine Native Hawaiian or Pacific Islanders with Asian Americans report their hesitancy as lower than other racial/ethnic groups (Niño et al., 2021), whereas those which separate them find their hesitancy to be higher (Ta Park et al., 2021). Our results provide further support for disaggregation of data between Asian Americans and Native Hawaiian or Pacific Islanders and future studies oversampling and disaggregating data from the diverse ethnic groups within each of these racial groups (Chang et al., 2021).

5. Conclusions

The IVM highlights the importance of social processes in shaping vaccine hesitancy (Brewer et al., 2017; WHO, 2014). We argue racism and experiences of racial discrimination should be included in the

domain of social processes outlined in the IVM, and our findings provide support for a link between experiences of racial discrimination and hesitancy towards a COVID-19 vaccine among US adults. Although this study is informed by the IVM, we are not fully testing this model. Future research should continue to examine questions of historical, structural, interpersonal, and even internalized racism and discrimination when attempting to understand why hesitancy is not evenly distributed across racial/ethnic groups in the US. If research on vaccine hesitancy is to serve people and improve health outcomes rather than be a scapegoat for racism (Corbie-Smith, 2021), hesitancy among minoritized racial groups must be recognized as reasonable and justified given historical and ongoing structural and interpersonal racism (Washington, 2006; Institute of Medicine, 2003). Such recognition must include more than a nod to the possibility that racism may play a role and should include theoretically-based empirical analysis into how racism and discrimination informs vaccination motivations and behavior. Future research should assess how structural racism relates to COVID-19 vaccine hesitancy among minoritized racial groups, as well as ways in which these structural forces may relate to willingness to be vaccinated among White adults. The lack of attention to the health advantages experienced by White individuals in racial health disparities literature leaves this group unmarked in the social processes and actions of advantaged groups that generate health inequalities (Link and García, 2021).

Funding

The community engagement related to this research is supported by University of Arkansas for Medical Sciences Translational Research Institute funding awarded through the National Center for Research Resources and National Center for Advancing Translational Sciences of the National Institutes of Health (NIH) (UL1 TR003107); Rapid Acceleration of Diagnostics (RADx) (NIH 3 R01MD013852-02S3 and NIH 3 R01MD013852-03S2); and Community Engagement Alliance (CEAL) Against COVID-19 Disparities (NIH 10T2HL156812-01). The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

CRediT authorship contribution statement

Don E. Willis: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration. **Brooke E.E. Montgomery:** Conceptualization, Writing – review & editing. **James P. Selig:** Conceptualization, Methodology, Formal analysis, Writing – review & editing, Supervision. **Jennifer A. Andersen:** Methodology, Formal analysis, Writing – review & editing. **Sumit K. Shah:** Conceptualization, Writing – review & editing. **Ji Li:** Methodology, Formal analysis, Data curation, Writing – review & editing. **Sharon Reece:** Writing – review & editing. **Derek Alik:** Writing – review & editing. **Pearl A. McElfish:** Conceptualization, Investigation, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

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

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2022.102074>.

References

- Agarwal, R., Dugas, M., Ramaprasad, J., Luo, J., Li, G., Gao, G.G., 2021. Socioeconomic privilege and political ideology are associated with racial disparity in COVID-19 vaccination. *Proc Natl Acad Sci U S A* 118 (33), e2107873118. <https://doi.org/10.1073/pnas.2107873118>.
- Ahmad, F.B., Anderson, R.N., 2021. The Leading Causes of Death in the US for 2020. *J. Am. Med. Assoc.* 325 (18), 1829–1830. <https://doi.org/10.1001/jama.2021.5469>.
- Andrasfay, T., Goldman, N., 2021. Reductions in 2020 US life expectancy due to COVID-19 and the disproportionate impact on the Black and Latino populations. *Proc Natl Acad Sci U S A* 118 (5), e2014746118. <https://doi.org/10.1073/pnas.2014746118>.
- Aw, J., Seng, J.J.B., Seah, S.S.Y., Low, L.L., 2021. COVID-19 Vaccine Hesitancy—A Scoping Review of Literature in High-Income Countries. *Vaccines* 9 (8), 900. <https://doi.org/10.3390/vaccines9089000>.
- Bleser, W.K., Miranda, P.Y., Jean-Jacques, M., 2016. Racial/Ethnic Disparities in Influenza Vaccination of Chronically Ill US Adults: The Mediating Role of Perceived Discrimination in Health Care. *Med. Care* 54 (6), 570–577. <https://doi.org/10.1097/MLR.0000000000000544>.
- Brewer, N.T., Chapman, G.B., Rothman, A.J., Leask, J., Kempe, A., 2017. Increasing Vaccination: Putting Psychological Science Into Action. *Psychol. Sci. Public Interest* 18 (3), 149–207. <https://doi.org/10.1177/1529100618760521>.
- Calarco J.M., Anderson E.M. "I'm Not Gonna Put That On My Kids": Gendered Opposition to New Public Health Initiatives. Published online March 18, 2021. doi: 10.31235/osf.io/tv8zw.
- CDC. BRFSS Prevalence & Trends Data: Explore by Location. Published 2020. Accessed August 20, 2020. <https://nccd.cdc.gov/BRFSSPrevalence/rdPage.aspx>.
- Chang, R.C., Pernaia, C., Thomas, K. Count Native Hawaiian And Pacific Islanders In COVID-19 Data—It's An OMB Mandate | Health Affairs Blog. Published 2020. Accessed December 16, 2021. <https://www.healthaffairs.org/doi/10.1377/hblog20200825.671245/full/>.
- Chowkwanyun, M., Reed, A.L., 2020. Racial health disparities and Covid-19 — caution and context. *N. Engl. J. Med.* 383 (3), 201–203. <https://doi.org/10.1056/NEJMp2012910>.
- Corbie-Smith, G., 2021. Vaccine Hesitancy Is a Scapegoat for Structural Racism. *JAMA Health Forum* 2 (3), e210434. <https://doi.org/10.1001/jamahealthforum.2021.0434>.
- COVID-19 Excess Mortality Collaborators, 2022. Estimating excess mortality due to the COVID-19 pandemic: a systematic analysis of COVID-19-related mortality, 2020–21. *Lancet* 399 (10334), 1513–1536. [https://doi.org/10.1016/S0140-6736\(21\)02796-3](https://doi.org/10.1016/S0140-6736(21)02796-3).
- Cowan, S.K., Mark, N., Reich, J.A., 2021. COVID-19 Vaccine Hesitancy Is the New Terrain for Political Division among Americans. *Socius* 7, 1–3. <https://doi.org/10.1177/237802321211023657>.
- Daly, M., Jones, A., Robinson, E., 2021. Public Trust and Willingness to Vaccinate Against COVID-19 in the US From October 14, 2020, to March 29, 2021. *J. Am. Med. Assoc.* 325 (23), 2397–2399. <https://doi.org/10.1001/jama.2021.8246>.
- Enders, C.K., 2001. The Performance of the Full Information Maximum Likelihood Estimator in Multiple Regression Models with Missing Data. *Educ. Psychol. Meas.* 61 (5), 713–740. <https://doi.org/10.1177/0013164401615001>.
- Enders, C.K., 2010. *Applied Missing Data Analysis*. Guilford Press.
- Hausmann, L.R.M., Jeong, K., Bost, J.E., Ibrahim, S.A., 2008. Perceived Discrimination in Health Care and Use of Preventive Health Services. *J. Gen. Intern. Med.* 23 (10), 1679–1684. <https://doi.org/10.1007/s11606-008-0730-x>.
- Institute of Medicine, 2003. *Unequal Treatment: Confronting Racial and Ethnic Disparities in Health Care*. The National Academies Press.
- King, W.C., Rubinstein, M., Reinhart, A., Mejia, R., 2021. Time trends, factors associated with, and reasons for COVID-19 vaccine hesitancy: A massive online survey of US adults from January–May 2021. *PLOS ONE* 16 (12), e0260731. <https://doi.org/10.1371/journal.pone.0260731>.
- Krieger, N., Smith, K., Naishadham, D., Hartman, C., Barbeau, E.M., 2005. Experiences of discrimination: Validity and reliability of a self-report measure for population health research on racism and health. *Soc. Sci. Med.* 61 (7), 1576–1596. <https://doi.org/10.1016/j.socscimed.2005.03.006>.
- Link, B.G., García, S.J., 2021. Diversions: How the Underrepresentation of Research on Advantaged Groups Leaves Explanations for Health Inequalities Incomplete. *J. Health Soc. Behav.* 62 (3), 334–349. <https://doi.org/10.1177/00221465211028152>.
- Malik, A.A., McFadden, S.M., Elharake, J., Omer, S.B., 2020. Determinants of COVID-19 vaccine acceptance in the US. *EclinicalMedicine* 26, 100495. <https://doi.org/10.1016/j.eclinm.2020.100495>.
- Mason, L., 2018. *Uncivil Agreement: How Politics Became Our Identity*. University of Chicago Press. <https://doi.org/10.7208/chicago/9780226524689.001.0001>.
- McElfish, P.A., Willis, D.E., Shah, S.K., Bryant-Moore, K., Rojo, M.O., Selig, J.P., 2021. Sociodemographic Determinants of COVID-19 Vaccine Hesitancy, Fear of Infection, and Protection Self-Efficacy. *J Prim Care Community Health* 12, 21501327211040744. <https://doi.org/10.1177/21501327211040746>.
- McLaren, J., 2020. Racial Disparity in COVID-19 Deaths: Seeking Economic Roots with Census Data. *Nat. Bureau Econ. Res.*, w27407 <https://doi.org/10.3386/w27407>.
- Mercer, A., Lau, A., Kennedy, C. How different weighting methods work. Pew Research Center Methods. Published January 26, 2018. Accessed January 12, 2022. <https://www.pewresearch.org/methods/2018/01/26/how-different-weighting-methods-work/>.
- Monte, L.M. Household Pulse Survey Shows Many Don't Trust COVID-19 Vaccine, Worry about Side Effects. US Census Bureau. Published December 28, 2021. Accessed March 11, 2022. <https://www.census.gov/library/stories/2021/12/who-are-the-adults-not-vaccinated-against-covid.html>.

- Motta, M., 2021. Republicans, Not Democrats, Are More Likely to Endorse Anti-Vaccine Misinformation. *Am. Politics Res.* 49 (5), 428–438. <https://doi.org/10.1177/1532673X211022639>.
- Ndugga, N., Hill, L., Artiga, S., Haldar, S. Latest Data on COVID-19 Vaccinations by Race/Ethnicity. KFF. Published April 7, 2022. Accessed April 12, 2022. <https://www.kff.org/coronavirus-covid-19/issue-brief/latest-data-on-covid-19-vaccinations-by-race-ethnicity/>.
- Niño, M.D., Hearne, B.N., Cai, T., 2021. Trajectories of COVID-19 vaccine intentions among U.S. adults: The role of race and ethnicity. *SSM - Population Health* 15, 100824. <https://doi.org/10.1016/j.ssmph.2021.100824>.
- Purvis, R.S., Hallgren, E., Moore, R.A., Willis, D.E., Hall, S., Gurel-Headley, M., McElfish, P.A., 2021. Trusted Sources of COVID-19 Vaccine Information among Hesitant Adopters in the United States. *Vaccines*. 9 (12), 1418. <https://doi.org/10.3390/vaccines9121418>.
- Quinn, S.C., Jamison, A., Freimuth, V.S., An, J., Hancock, G.R., Musa, D., 2017. Exploring racial influences on flu vaccine attitudes and behavior: Results of a national survey of White and African American adults. *Vaccine* 35 (8), 1167–1174. <https://doi.org/10.1016/j.vaccine.2016.12.046>.
- Quinn, S.C., Jamison, A.M., An, J., Hancock, G.R., Freimuth, V.S., 2019. Measuring vaccine hesitancy, confidence, trust and flu vaccine uptake: Results of a national survey of White and African American adults. *Vaccine* 37 (9), 1168–1173. <https://doi.org/10.1016/j.vaccine.2019.01.033>.
- Quint, J.J., Van Dyke, M.E., Maeda, H., Worthington, J.K., Dela Cruz, M.R., Kaholokula, J.K., Matagi, C.E., Pirkle, C.M., Roberson, E.K., Sentell, T., Watkins-Victorino, L., Andrews, C.A., Center, K.E., Calanan, R.M., Clarke, K.E.N., Satter, D.E., Penman-Aguilar, A., Parker, E.M., Kemble, S., 2021. Disaggregating Data to Measure Racial Disparities in COVID-19 Outcomes and Guide Community Response — Hawaii, March 1, 2020–February 28, 2021. *MMWR Morb. Mortal. Wkly Rep.* 70 (37), 1267–1273. <https://doi.org/10.15585/mmwr.mm7037a1>.
- Rao, J.N.K., Scott, A.J., 1981. The Analysis of Categorical Data From Complex Sample Surveys: Chi-Squared Tests for Goodness of Fit and Independence in Two-Way Tables. *J. Am. Stat. Assoc.* 76 (374), 221–230. <https://doi.org/10.2307/2287815>.
- Rao, J.N.K., Scott, A.J., 1984. On Chi-Squared Tests for Multiway Contingency Tables with Cell Proportions Estimated from Survey Data. *The Annals of Statistics* 12 (1), 46–60. <https://doi.org/10.1214/aos/1176346391>.
- Reitsma, M.B., Goldhaber-Fiebert, J.D., Salomon, J.A., 2021. Quantifying and Benchmarking Disparities in COVID-19 Vaccination Rates by Race and Ethnicity. *JAMA Netw. Open* 4 (10), e2130343. <https://doi.org/10.1001/jamanetworkopen.2021.30343>.
- Savoia, E., Piltch-Loeb, R., Goldberg, B., Miller-Idriss, C., Hughes, B., Montrond, A.M., Kayyem, J.N., Testa, M.A., 2021. Predictors of COVID-19 Vaccine Hesitancy: Socio-Demographics, Co-Morbidity and Past Experience of Racial Discrimination. *medRxiv*. <https://doi.org/10.1101/2021.01.12.21249152>.
- Schneider, E.C., Shah, A., Sah, P., Moghadas, S.M., Vilches, T., Galvani, A., 2021. The U.S. COVID-19 Vaccination Program at One Year: How Many Deaths and Hospitalizations Were Averted? *Commonwealth Fund*. <https://doi.org/10.26099/3542-5n54>.
- Shen, S.C., Dubey, V., 2019. Addressing vaccine hesitancy. *Can Fam Physician* 65 (3), 175–181.
- Siegel, M., Critchfield-Jain, I., Boykin, M., Owens, A., Muratore, R., Nunn, T., Oh, J., 2022. Racial/Ethnic Disparities in State-Level COVID-19 Vaccination Rates and Their Association with Structural Racism. *J. Racial and Ethnic Health Disparities* 9 (6), 2361–2374. <https://doi.org/10.1007/s40615-021-01173-7>.
- Suran, M., 2022. Why Parents Still Hesitate to Vaccinate Their Children Against COVID-19. *J. Am. Med. Assoc.* 327 (1), 23–25. <https://doi.org/10.1001/jama.2021.21625>.
- Ta Park, V.M., Dougan, M., Meyer, O.L., Nam, B., Tzuang, M., Park, L.G., Vuong, Q., Tsoh, J.Y., 2021. Vaccine willingness: Findings from the COVID-19 effects on the mental and physical health of Asian Americans & Pacific Islanders survey study (COMPASS). *Prev. Med. Rep.* 23, 101480. <https://doi.org/10.1016/j.pmedr.2021.101480>.
- Trivedi, A.N., Ayanian, J.Z., 2006. Perceived discrimination and use of preventive health services. *J. Gen. Intern. Med.* 21 (6), 553–558. <https://doi.org/10.1111/j.1525-1497.2006.00413.x>.
- Troiano, G., Nardi, A., 2021. Vaccine hesitancy in the era of COVID-19. *Public Health* 194, 245–251. <https://doi.org/10.1016/j.puhe.2021.02.025>.
- Washington, H.A., 2006. *Medical Apartheid: The Dark History of Medical Experimentation on Black Americans from Colonial Times to the Present*. Doubleday.
- WHO EURO. Report of the SAGE Working Group on Vaccine Hesitancy. Working Group on Vaccine Communications. Published November 14, 2014. Accessed October 28, 2020. https://www.who.int/immunization/sage/meetings/2014/october/1_Report_WORKING_GROUP_vaccine_hesitancy_final.pdf.
- WHO. Measuring Behavioural and Social Drivers (BeSD) of Vaccination Working Group. World Health Organization. Published 2019. Accessed December 16, 2020. https://www.who.int/immunization/programmes/systems/Meeting_report_May2019.pdf.
- Willis, D.E., Andersen, J.A., Bryant-Moore, K., Selig, J.P., Long, C.R., Felix, H.C., Curran, G.M., McElfish, P.A., 2021. COVID-19 vaccine hesitancy: Race/ethnicity, trust, and fear. *Clin. Transl. Sci.* 14 (6), 2200–2207. <https://doi.org/10.1111/cts.13077>.
- Willis, D.E., Andersen, J.A., Montgomery, B.E.E., Selig, J.P., Shah, S.K., Zaller, N., Bryant-Moore, K., Scott, A.J., Williams, M., McElfish, P.A., 2022. COVID-19 Vaccine Hesitancy and Experiences of Discrimination Among Black Adults. *J. Racial and Ethnic Health Disparities*. 1–10. <https://doi.org/10.1007/s40615-022-01290-x>.
- Willis, D.E., McElfish, P.A., 2021. Racial disparities in the COVID-19 response affecting the Marshall Islands diaspora, United States of America. *Bull. World Health Organ.* 99 (9), 680–681. <https://doi.org/10.2471/BLT.20.277855>.
- Willis, D.E., Selig, J.P., Andersen, J.A., Hall, S., Hallgren, E., Williams, M., Bryant-Moore, K., McElfish, P.A., 2022. Hesitant but vaccinated: assessing COVID-19 vaccine hesitancy among the recently vaccinated. *J Behav Med.* 1-10. <https://doi.org/10.1007/s10865-021-00270-6>.
- Woolf, S.H., Chapman, D.A., Lee, J.H., 2021. COVID-19 as the Leading Cause of Death in the United States. *J. Am. Med. Assoc.* 325 (2), 123–124. <https://doi.org/10.1001/jama.2020.24865>.
- Yanez, N.D., Weiss, N.S., Romand, J.A., Treggiari, M.M., 2020. COVID-19 mortality risk for older men and women. *BMC Public Health.* 20 (1), 1742. <https://doi.org/10.1186/s12889-020-09826-8>.