Factors related to COVID-19 vaccine hesitancy among middle-income and low-income adults in the USA

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ABSTRACT

Background Vaccine hesitancy has been an ongoing challenge in campaigns, especially the rapid development and approval of the COVID-19 vaccines. The goal of this study was to understand the characteristics, perceptions and beliefs of COVID-19 vaccination prior to its widespread rollout among middle-income and low-income US adults.

Methods Using a national sample of 2101 adults who completed an online assessment in 2021, this study examines the association of demographics, attitudes and behaviours related to COVID-19 vaccination intentions. Adaptive least absolute shrinkage and selection operator models were used to select these specific covariate and participant responses. Poststratification weights were generated using raking procedures and applied to improve generalisability.

Results and conclusion Vaccine acceptance was high at 76% with 66.9% reporting intent to receive the COVID-19 vaccine when available. Only 8.8% of vaccine supporters screened positive for COVID-19-related stress compared with 9.3% among the vaccine hesitant. However, there were more people with vaccine hesitancy who screened positive for poor mental health and alcohol and substance misuse. The three main vaccine concerns were side effects (50.4%), safety (29.7%) and mistrust of vaccine distribution (14.8%).
Factors influencing vaccine acceptance included age, education, children, region, mental health and social support, threat perception, opinion of governmental response, risk exposure and prevention activities and rejecting COVID-19 vaccine concerns. The results indicated acceptance was more strongly associated with beliefs and attitudes about the vaccine than sociodemographics, which are noteworthy and may lead to targeted interventions to increase COVID-19 vaccine acceptance among subgroups who are vaccine hesitant.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Early surveys indicated moderately high COVID-19 vaccine acceptance before the vaccine was widely available. However, now widely available, vaccine hesitation has delayed vaccine uptake and could impact effective control of the COVID-19 pandemic.

WHAT THIS STUDY ADDS

⇒ We used adaptive least absolute shrinkage and selection operator models with poststratification weighting and demonstrated that COVID-19 vaccine acceptance was associated with rejection of vaccine concerns such as it being unsafe, having low perceived susceptibility or reluctance from immunity due to a prior infection. Results showed that people with mental health disorders were more likely to be vaccine hesitant; furthermore, hesitancy endured regardless of the higher frequency of knowing a friend or family member who tested positive relative to vaccine supporters.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ An important prevention strategy is targeted interventions based on subgroups of vaccine-hesitant populations; for example, increasing the perceptions about the seriousness of COVID-19 and the importance of vaccination among those with mental illness by discussions with providers during regular clinical visits.

INTRODUCTION

Vaccination has been hailed as one of the greatest public health achievements of the 20th century,[1] which has led to major reductions in vaccine-preventable diseases within the first decade of the 21st century in the USA and globally.[2 3] However, in 2019, prior to the emergence of SARS-CoV-2, WHO had already listed vaccine hesitancy as one of the top 10 threats to global health.[4]

The purposes of this study are to (1) estimate the prevalence of COVID-19 vaccine hesitancy among middle-income and low-income US adults during the initial rollout of the Pfizer vaccine after its emergency use authorisation in December 2020; and (2) examine individual characteristics and beliefs associated with COVID-19 vaccine hesitancy in this sample. We expected individuals with a higher perceived threat of infection and number of protective factors such as lower risk behaviours and better mental health states were more agreeable to COVID-19 vaccine acceptance.

METHODS

The details of the survey design have been previously described in Tsai *et al*'s[5] study. Briefly, participants were recruited through Amazon Mechanical Turk (MTurk), a popular online labour market for conducting surveys and interventions. The full study encompassed three waves of data collection among middle-income and low-income US adults to examine their health and social well-being during the COVID-19 pandemic. Prior to the third wave, the Pfizer-BioNTech vaccine was approved for emergency use authorisation on 11 December 2020.[6] Questions regarding COVID-19-related

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perceptions, beliefs and behaviours were added in the 5-month follow-up assessment, and 2144 individuals participated in the third wave administered in February to March. Our study focused on the 2101 participants who completed all three waves.

To maximise generalisability, sample weights using raking procedures were created to be representative of the US population based on two eligibility criteria: age ≥22 years and an annual gross income of ≤$75 000. Data from 2018 American Community Survey were used to compute poststratification weights such that inferential analyses yielded estimates comparable to the target population with respect to age, sex, race, ethnicity and geographical region.[7] More details on the weighting can be found in Tsai *et al*'s[5] study.

Data collection

Data for this study included age, gender, race/ethnicity, education and modifiable sociodemographic characteristics such as student or employment status, marital status, number of minors in the household, income, geographical region, veteran status and military status. These covariates were adjusted in the analysis, which focused on the characteristics, perceptions and beliefs that subjects reported regarding the COVID-19 pandemic and vaccination. The item in the original survey for gender allowed respondents three options: Male, Female and Other. However, only 25 individuals responded as Other. We elected to combine Female and Other and recategorise this as the Non-Male gender category.

The outcome was based on participant responses of having received or intent to receive the COVID-19 vaccine ('Yes, already received the vaccine' and 'Yes, plan to get the vaccine', respectively) versus those who refused ('No'). The two affirmative responses were combined to dichotomise the outcome. This was done because during the survey period, early vaccinations had a limited rollout so less than 10% of survey respondents had received the vaccine. All participants were also asked about reservations for receiving a COVID-19 vaccine and were provided several response options in addition to 'None' and 'Other' categories. The latter allowed participants to free text specific responses.

The survey queried participants regarding COVID-19 testing results and infection status (eg, have not been tested; tested positive >3 months; tested positive ≤3 months; tested and not positive). Participants were also asked whether anyone close to them (eg, friends, family) had tested positive for COVID-19. Social connectedness was assessed with the Medical Outcomes Study (MOS) Social Support Survey-Short Form[8] and a question about the number of close friends and relatives that participants have.

Physical health and psychiatric history status were assessed by asking participants, respectively, whether they have ever been diagnosed with any of 22 different medical conditions or with any of nine psychiatric or substance use disorders. Mental health and alcohol use were assessed with the Patient Health Questionnaire-2 (Cronbach's α=0.83),[9] the Generalized Anxiety Disorder-2 (Cronbach's α=0.84)[10] and the Alcohol Use Disorders Identification Test-Consumption (Cronbach's α=0.74).[11] Additionally, participants were asked about any illicit drug use in the past month. Recent suicidal ideation (SI) was assessed with an item from the Mini-International Neuropsychiatric Interview[12] asking whether participants had considered 'hurting yourself, felt suicidal, or wish that you were dead' over the last 2 weeks.

To assess COVID-19-related stress (CS), we administered the Post-traumatic Stress Disorder (PTSD) Checklist for DSM-5 (PCL-5; Cronbach's α=0.98).[13] Participants were asked to refer to the COVID-19 pandemic as an index stressor event and rate the degree to which they experienced each symptom over the past month on a scale of 0 (Not at all) to 4 (Extremely). Items rated at 2 (Moderately) or higher indicated positive symptom endorsement.[14]

Data analysis

We conducted descriptive univariate analyses for all variables of interest. We used the Wilcoxon rank-sum test to assess differences between groups for continuous variables and the χ^2 statistic for categorical covariates. Fisher's exact test was also used as needed for unstable small expected cell counts.

Many psychometric instruments included overall score cut-off values to categorise responses for interpretability. Some measures such as the PCL-5 had subscale scores, which were rescaled to make understandable inferences. Since many of these variables were highly correlated, we primarily focused on using categorical variables when they were available as an alternative to a continuous score. There were some categorical variables with small response frequencies that were recategorised. We also rescaled the variable for close friends using a log-based transformation to reduce skewing, and we categorised the number of medical conditions based on natural breaks.

Variable selection for the outcome of 'receiving or planning to receive COVID-19 vaccination' was chosen through modelling. Due to the large number of candidate predictive variables, logistic modelling with regularisation by an adaptive least absolute shrinkage and selection operator (lasso) method was used.[15] The adaptive lasso method conducts variable selection by optimising a penalised likelihood function whose amount of penalty towards a large number of variables is controlled by a tuning parameter, which is then selected in a data-driven way. By penalising large coefficients less than small coefficients through weighting, the adaptive lasso method reduces bias and ensures selection consistency in model selection.[16] The penalty weights were obtained through ridge regression. Tuning parameters in ridge regression and adaptive lasso models were both selected by those whose cross-validated error is within one SE from the minimum[17] in 10-fold cross-validation. Covariates with non-zero coefficients are considered as being selected. Finally, we present the estimated coefficients and the p values by fitting the logistic regression with those selected variables.

For all analyses, we present the results for both the unweighted and weighted versions. In the weighted version, participants are weighted according to the poststratification weights. We assumed a type I error of 0.05. All analyses were conducted in R V.4.1.1.[18] Weighted descriptive analyses were conducted using the *survey* package. The adaptive lasso models were fit using the *glmnet* package.

RESULTS

Descriptive analysis

Table 1 shows raw frequency counts and weighted percentages of respondent's vaccine intentions and the distribution of people who endorsed specific reservations to the COVID-19 vaccine. Vaccine acceptance was high comprising nearly 76% of the sample, including 9.1% reporting having received the vaccine and 66.9% who were planning to vaccinate. Additionally, 38.8% had no concerns regarding COVID-19 vaccination regardless of intent to vaccinate. The top concerns regarding vaccination were side effects (50.4%), safety (29.7%) and mistrust of vaccine distribution (14.8%).

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Table 1 Plans for COVID-19 vaccination and reasons for vaccine hesitancy

	Raw n (weighted %)
Plans for vaccination	
Already received vaccine	185 (9.1)
Plan to get the vaccine	1273 (66.9)
No	643 (24.0)
Concerns about vaccine (regardless of vaccination status/plan)	
Worried vaccine is not safe	750 (29.7)
Worried vaccine may have side effects	941 (50.4)
Feel not at risk so don't need vaccine	175 (6.0)
Already had COVID-19 so don't believe vaccine is necessary	55 (1.7)
Don't trust distribution process of vaccine	346 (14.8)
Don't have any concerns	687 (38.8)
Other*	126 (5.8)

Subjects were allowed to select multiple response options.
*Other concerns reported by participants are detailed in the online supplemental table.

As shown in table 2, subjects who were planning or had received the COVID-19 vaccine (hereafter referred to as vaxxers) were almost one decade older than those who did not plan to vaccinate (hereafter referred to as non-vaxxers). Participants were predominantly non-Hispanic, white, identified as non-male and were less likely to have children residing within their household. Most people were highly educated and just under half of people reported as being married or living with a partner.

A large percentage of vaxxers were not actively employed (44.7%) compared with only 38.1% of non-vaxxers. Vaxxers had a higher median income ($35 986; IQR=$28 000) than non-vaxxers ($30 000; IQR=$34 000), and this was statistically significant (p=0.001). Both groups had a similar number of log-transformed close friends, but in the MOS Social Support Survey, vaxxer's mean score was slightly higher indicating marginally more social support than among non-vaxxers (22.4 and 20.5, respectively).

Overall, people did not test for COVID-19 (70.9%) and 52.1% reported not knowing any close family or friends who tested positive. Less than 1% of vaxxers tested as a recent positive (≤3 months) and 2.3% as a prior positive (>3 months). This contrasts with non-vaxxers who had 1.7% test as recently positive at the wave 3 survey and 3.8% test as a prior positive beyond the 3-month threshold. Overall, the majority reported no one close to them tested positive for COVID-19, but 56.5% of non-vaxxers did report a close family or friend having tested positive compared with only 45.3% among vaxxers.

Non-vaxxers perceived COVID-19 as a 'Slight Threat' (31.4%) compared with over 70% of vaxxers who believed that it is a 'Great Threat'. Likewise, 46.7% of non-vaxxers believed the government's response to the pandemic to be a slight or great over-reaction compared with only 6.4% of vaxxers who similarly endorsed this belief. A large proportion of vaxxers (61.8%) believed the government's response to be a slight or great under-reaction, but only 30% of non-vaxxers shared the same opinion.

However, a higher proportion of non-vaxxers screened positive for poor mental health related to COVID-19 and alcohol and substance misuse. Only 8.8% of vaxxers screened positive for CS compared with 9.3% among non-vaxxers, though the difference was not significant (p=0.60). For major depression and anxiety, 20.4% and 17.3% of non-vaxxers were positive screens relative to 13.9% and 14.4% of vaxxers, respectively. Suicidal ideation was also significantly higher in non-vaxxers (9.9%) than in vaxxers (6.5%). About one-fifth of non-vaxxers screened positive for alcohol use disorder (AUD) and had one and a half times more people who identified illicit drug use within the past month relative to vaxxers.

Model selection

The results of the adaptive lasso models for variable selection on the outcome of intent to vaccinate are summarised in table 3. Generally, sociodemographic descriptors, health indicators, perceptions and behaviours for transmission prevention influenced willingness to accept COVID-19 vaccination. There was a large range between models from covariates for age ≥60 (unweighted: 0.29, p=0.12) to concern for vaccine safety (unweighted: 2.25, p<0.001) and from other race (weighted: 0.08, p=0.68) to the belief vaccination is unnecessary due to prior infection (weighted: 2.35, p<0.001).

Covariates for the reservations to vaccination were the strongest group of indicators in both models, but mainly the response items that did not endorse the hesitations regarding vaccine safety, perception of infection risk, perception of necessity due to a prior infection and other free text reasons. Similarly, having no concerns regarding COVID-19 vaccination was associated with intent to vaccinate in the weighted model (1.10, p<0.001).

All variables in the unweighted model are present in the weighted model except for the covariates for self-reported positive COVID-19 result and endorsing a 'Great Amount' for mental health symptom burden related to COVID-19. Covariates found only in the weighted model include other race, Midwest region, no PTSD, self-reported AUD, no positive test result among family or friends, belief of a poor governmental pandemic response and not having any concerns about COVID-19 vaccination.

The largest estimate in the weighted model was 'No', to the belief that the COVID-19 vaccine is unnecessary due to prior infection (2.35, p<0.001). Second was rejecting the belief that it is unsafe (2.07, p<0.001). 'Other' reasons were the third largest contributor (1.79, p<0.001) with free text responses given in the online supplemental table. These were the top three indicators in the unweighted model, but the poststratification weights shifted the order of importance in the final weighted model.

Due to adjustments based on the US population distribution, poststratification weighting affected the strength of association of the variables selected in the final model. Some covariates became less predictive in the weighted model. Poststratification weighting also affected the change in significance from unweighted to weighted models for the variables representing age (0.29, p=0.12; 0.78, p<0.001, respectively) and the number of minors in a household (0.35, p=0.01; 0.13, p=0.27, respectively) and added seven covariates not originally present in the unweighted model. Of these, only other race was not significant and had the least influence in the model. The weighted model provides additional information regarding the characteristics, beliefs and attitudes among vaxxers and retains good discrimination based on the high estimate for the area under the curve (AUC) in both models.

DISCUSSION

Our study examined individual factors related to vaccine acceptance, and subsequently investigated characteristics and beliefs among people who were hesitant about the COVID-19 vaccine. Our work corroborates previous studies that have found non-vaxxers tended to perceive COVID-19 as less of a threat and were more likely to hold the opinion that the government

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Table 2 Demographic, clinical and psychosocial characteristics

	Overall	Received or planning to vaccinate		Test of difference	
		No	Yes	Weighted	
	Weighted mean (SD) or raw n (weighted %)	Weighted mean (SD) or raw n (weighted %)	Weighted mean (SD) or raw n (weighted %)	X(df)	P value
Age	57.2 (17.5)	50.1 (14.3)	59.5 (17.8)		<0.001**
Median personal income (IQR)	$35 000 ($30 000)	$30 000 ($34 000)	$35 986 ($28 000)		0.001**
Gender				X(1)=12.1	0.001
Not male††	1308 (63.9)	437 (68.4)	871 (62.5)		
Male	793 (36.1)	206 (31.6)	587 (37.5)		
Race				X(3)=31.7	<0.001
White	1697 (83.2)	508 (78.6)	1189 (84.7)		
Black	193 (7.1)	82 (10.6)	111 (6.0)		
Asian	155 (3.0)	33 (2.7)	122 (3.1)		
Other	56 (6.7)	20 (8.1)	36 (6.2)		
Ethnicity				X(1)=3.1	0.08
Not Hispanic	1969 (93.0)	605 (91.8)	1364 (93.4)		
Hispanic	132 (7.0)	38 (8.2)	94 (6.6)		
Education				X(3)=139.3	<0.001
High school or below	201 (7.9)	91 (14.1)	110 (6.0)		
Some college	408 (24.5)	167 (31.2)	241 (22.3)		
Associate's/Bachelor's degree	1099 (48.5)	316 (43.3)	783 (50.2)		
Advanced degree	393 (19.1)	69 (11.5)	324 (21.5)		
Student status				X(2)=18.6	<0.001
Not a student	1854 (93.9)	563 (91.2)	1291 (94.7)		
Part-time	89 (2.3)	26 (2.8)	63 (2.1)		
Full time	158 (3.9)	54 (6.0)	104 (3.2)		
Marital status				X(2)=70.7	<0.001
Single	667 (22.1)	180 (22.5)	487 (22)		
Divorced/single/widowed	306 (32.5)	102 (22.4)	204 (35.7)		
Married/partnered	1128 (45.4)	361 (55.0)	767 (42.3)		
Number of children				X(1)=66.4	<0.001
0	1421 (80.0)	382 (71.1)	1039 (82.7)		
≥1	680 (20.0)	261 (28.9)	419 (17.3)		
Employment				X(2)=21.4	<0.001
Employed (FT or PT)	1386 (45.2)	405 (51.4)	981 (43.3)		
Self-employed	204 (11.7)	72 (10.5)	132 (12.1)		
Not working	511 (43.1)	166 (38.1)	345 (44.7)		
Region				X(3)=18.3	<0.001
Northeast	401 (16.9)	106 (14.5)	295 (17.7)		
Midwest	453 (22.7)	135 (19.8)	318 (23.6)		
South	825 (39.7)	285 (44.7)	540 (38.1)		
West	422 (20.7)	117 (21.0)	305 (20.6)		
Veteran status				X(1)=38.3	<0.001
No	1974 (88.4)	615 (93.7)	1359 (86.7)		
Yes	127 (11.6)	28 (6.3)	99 (13.3)		
Number of close friends	14.4 (36.0)	13.6 (43.3)	14.6 (33.3)		<0.001**
Log_{10} (number of close friends)	1.3 (0.23)	1.2 (0.24)	1.3 (0.22)		<0.001**
Medical Outcomes Study Social Support Survey	22.0 (6.7)	20.5 (7.2)	22.4 (6.5)		0.008**
COVID-19 status in past 3 months				X(3)=41.6	<0.001
Not tested	1385 (70.9)	472 (75.6)	913 (69.4)		
Yes, recent positive	36 (1.0)	12 (1.7)	24 (0.7)		
Yes, past positive	68 (2.7)	27 (3.8)	41 (2.3)		
No, not positive	612 (25.5)	132 (19.0)	480 (27.6)		
Have anyone close tested positive for COVID-19?				X(1)=39.6	<0.001
No	1051 (52.1)	294 (43.5)	757 (54.7)		
Yes	1050 (47.9)	349 (56.5)	701 (45.3)		
How much of a threat?				X(3)=1055.0	<0.001

Continued

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Table 2 Continued

	Overall	Received or planning to vaccinate		Test of difference	
		No	Yes	Weighted	
	Weighted mean (SD) or raw n (weighted %)	Weighted mean (SD) or raw n (weighted %)	Weighted mean (SD) or raw n (weighted %)	X(df)	P value
Not a threat	118 (4.1)	105 (15.9)	13 (0.4)		
Slight threat	321 (13.0)	198 (31.4)	123 (7.2)		
Moderate threat	607 (21.2)	176 (23.7)	431 (20.4)		
Great threat	1055 (61.7)	164 (29.1)	891 (71.9)		
Opinion about government response				X(4)=1060.2	<0.001
Great under-reaction	776 (39.5)	111 (15.9)	665 (46.9)		
Slight under-reaction	430 (14.7)	96 (14.1)	334 (14.9)		
Appropriate reaction	503 (29.8)	147 (23.4)	356 (31.8)		
Slight over-reaction	158 (5.6)	95 (12.4)	63 (3.4)		
Great over-reaction	234 (10.5)	194 (34.3)	40 (3.0)		
Number of medical conditions				X(2)=91.0	<0.001
0	875 (26.1)	286 (35.1)	589 (23.2)		
1–2	799 (34.5)	242 (37.0)	557 (33.7)		
3+	427 (39.4)	115 (27.9)	312 (43.0)		
Positive screen for COVID-19-related stress symptoms	305 (8.9)	88 (9.3)	217 (8.8)	X(1)=0.3	0.60
Positive screen for major depression	425 (15.5)	137 (20.4)	288 (13.9)	X(1)=25.7	<0.001
Positive screen for generalised anxiety disorder	441 (15.1)	133 (17.3)	308 (14.4)	X(1)=5.1	0.02
Past 2-week suicidal ideation	257 (7.3)	84 (9.9)	173 (6.5)	X(1)=13.6	<0.001
Positive screen for alcohol use disorder	498 (18.7)	152 (21.9)	346 (17.7)	X(1)=9.6	0.002
Any illicit drug use in past month	212 (7.3)	66 (9.3)	146 (6.6)	X(1)=8.5	0.004

*Wilcoxon rank-sum test.
†Non-male comprised female and other gender responses.
FT, full time; IQR, interquartile range; PT, part-time; SD, standard deviation.

response was exaggerated compared with vaxxers.[19–22] A unique modelling approach employing adaptive lasso regression identified covariates correlated with likelihood to vaccinate. Based on the magnitude of associations, the variables among the beliefs, perceptions and attitudes with willingness to receive the COVID-19 vaccine were more important contributors than sociodemographic characteristics, such as educational level, having more close friends and geographical area.

The variables most strongly associated with COVID-19 vaccination were beliefs and attitudes about the vaccine. These beliefs include that COVID-19 vaccination is safe; it is necessary regardless of immunity from a previous infection; COVID-19 is a great threat; and the government response was poor.

Our results suggested the decision to vaccinate was also influenced by mental health burden, where positive screens for CS, major depression, generalised anxiety, SI, AUD and illicit drug use were consistently greater among non-vaxxers. Except for CS, the differences were significant compared with vaxxers. Non-vaxxers appeared to experience a greater burden of psychological difficulties, though they generally had fewer diagnosed medical conditions than vaxxers.

The association of mental health on vaccination has been corroborated by studies in populations from the USA, China, India and Europe that have found people with mental illness were more likely to be vaccine hesitant.[23 24] This potential causal association may be particularly pronounced among people with severe mental health conditions such as schizophrenia.[25] In contrast, some studies found no differences in vaccine acceptance among people with psychiatric disorders versus general populations,[26] but these studies were among Belgians and Danish populations, which have high rates of vaccination.[27]

Other studies, particularly one among Israelis[28] and another in Indians,[29] showed negative psychological outcomes after vaccination but a bidirectional association of vaccine hesitancy and mental health among Saudis.[29] In support of the causal direction of vaccine hesitancy on psychiatric outcomes, Zhang *et al* found that vaccine hesitancy mediated the effect of sociodemographics on anxiety and depression among their Chinese study population.[30] This information could be used in public health messaging to endorse vaccination among mentally ill populations and the general population.

However, if mental health has a direct influence on vaccine hesitancy, this has important implications in public health messages advocating for COVID-19 vaccination. Education and interventions must target this population's wide-ranging and multifactorial needs. Effective strategies include increasing access and convenience and tailoring messages to target specific psychological disorders within this population.[31] For example, patients with delusions may believe they are already immune and thus find vaccination inconsequential, or those with depression may lack energy and be unmotivated to adhere to public health vaccine recommendations.[32] Psychiatrists are important conduits to addressing the specific COVID-19 vaccination concerns of such patients; furthermore, they may be seen as trustworthy, which may lead patients to be more accepting of vaccination.[32]

Moreover, testing positive for COVID-19 or knowing a close family member or friend who tested positive was more common among non-vaxxers, yet they generally viewed the SARS-CoV-2 virus as a lower threat than vaxxers. This may be attributed to post-positive reluctance among infected non-vaxxers who become complacent to vaccination or benefit from other's vaccination as it becomes widespread.[24] It has also been shown

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Table 3 Summary of variable selection for unweighted and weighted modelling of having received or planning to receive COVID-19 vaccination using an adaptive lasso approach*

	Unweighted		Weighted	
Covariates	**Estimated coefficient**	**P value**	**Estimated coefficient**	**P value**
Age ≥60	0.29	0.12	0.78	<0.001
Race: Other	–	–	0.08	0.68
What is the highest education you have achieved? *Beyond 4-year college degree*	0.80	<0.001	0.67	<0.001
Number of children/minors under 18 in your household *None*	0.35	0.01	0.13	0.27
Region: Midwest	–	–	0.44	<0.001
Log (number of close friends)	0.98	<0.001	1.35	<0.001
Has a doctor or nurse ever told you that you have post-traumatic stress disorder? *No*	–	–	0.83	<0.001
Has a doctor or nurse ever told you that you have alcohol use disorder? *Yes*	–	–	1.15	<0.001
Has anyone close to you (eg, family, friend) tested positive for COVID-19? *No*	–	–	0.47	<0.001
In the past 3 months (ie, since 1 November 2020), have you tested positive for COVID-19? *Yes, positive test result*	0.81	0.09	–	–
How much of a threat do you view the COVID-19 virus on Americans? *Great threat*	0.95	<0.001	0.93	<0.001
What is your opinion of the government's response to COVID-19? *Great under-reaction*	–	–	0.75	<0.001
In the past 3 months, how often did you wear masks when you were in public? *Always*	1.38	<0.001	1.18	<0.001
How much would you rate that any of the above mental health symptoms you reported are related to COVID-19? *Great amount*	0.52	0.03	–	–
'I'm worried that the COVID-19 vaccine isn't safe.' *No*	2.25	<0.001	2.07	<0.001
'I feel that I'm not at-risk for COVID-19 and so don't need the vaccine.' *No*	1.67	<0.001	1.47	<0.001
'I have already had COVID-19 so I don't believe vaccine is necessary.' *No*	1.42	<0.001	2.35	<0.001
'I don't have any concerns about getting the COVID-19 vaccine.' *Yes*	–	–	1.10	<0.001
'Other reason' *No*	1.59	<0.001	1.79	<0.001
AUC	0.92		0.92	

*P values and estimated coefficients are obtained by refitting the logistic model with variables selected by the adaptive lasso.
AUC, area under the curve; lasso, least absolute shrinkage and selection operator.

that patients with COVID-19, comprising more non-vaxxers than vaxxers in our study, have greater mental distress than the general population.[25 26] This is supported by several studies; however, others have found no discernible differences.[29]

Depending on the degree of vaccine hesitancy, some non-vaxxer subgroups may require more conversion efforts than others.[33] Generally, older Americans have been found to be more receptive than their younger counterparts when it came to public health messaging from an authority such as the Centers for Disease Control and Prevention, particularly regarding concerns of the rapid development and approval process of the COVID-19 vaccines[33]; though in our study, we found vaxxers to be older than non-vaxxers. It has also been suggested that targeting the undervaccinated or undecided rather than staunch antivaccine proponents may yield the most success.[34] Providers may address vaccine hesitancy among patients with mental disorders using motivational interviewing strategies to help individuals make an educated decision regarding COVID-19 vaccination.[34] Such tools may be useful in multipronged and targeted approaches, which have been shown to have the highest effectiveness.[35] For example, the US Department of Veterans Affairs was able to assist seriously mentally ill veterans with logistical barriers through staff outreach via a patient's preferred form of communication, and they provided educational materials through various media to address COVID-19-specific vaccine concerns such as distrust.[36]

Overall, our results show that the vaxxer population has greater motivation compared with non-vaxxers, which would explain why vaccination acceptance is high among individuals who may not know any close family or friends who have tested positive for recent infection and is further supported by the covariates for perceptions of high COVID-19 threat and inadequate governmental response.

Our study has several limitations worth describing. We measured intent to vaccinate, and attitudes may have changed by the time vaccine availability became widespread. This is likely

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given the role of social and news media in informing or misinforming the public regarding the development and distribution of the vaccine.[30–32] Additionally, the wave 3 survey was administered beginning in February, which was about 3 months into the emergency use authorisation of the first available vaccine; consequently, rollout had been limited to frontline essential workers and high-risk individuals such as those ≥75 years or immunocompromised individuals. Regardless, our results are consistent with a study that looked at the media and political influence on vaccination intent.[37] There may be issues of generalisability based on the validity of Amazon MTurk data. However, cross-sample investigations have demonstrated that data obtained from MTurk are the same level of quality or higher than data collected from traditional subject pools such as community samples, college students and professional panels.[38] The population distributions between our study population and the general public regarding age groups were skewed. Our study population tended to be younger, non-Hispanic, white and non-male, but we used raking procedures to create poststratification weights to mimic the proportions of the US population to control for this issue.

Several studies support the variables and trends in our models, namely, age,[19] education,[19 39] threat[40] and masking as a precautionary measure.[19] However, the variables for region, close friends, absence of PTSD and self-reported AUD could merely reflect the characteristics of the study population Further study is required since these may be novel indicators or potential targets for vaccination.

This study has notable strengths including a higher proportion of black and Hispanics than many other studies, and it is among those with the largest sample size. Our innovative adaptive lasso modelling is preferred over linear or logistic regression used by others because standard regression may suffer from collinearity or overfitting. The literature shows a wide-ranging proportion of people with willingness to vaccinate against COVID-19 from as low as 50%[19] to as high as 87%.[20] The results of this study showing 66.9% of those willing to vaccinate are corroborated by many surveys administered at various time points with differing measurement and weighting strategies.[39] Thus, we are confident in our comparable findings and have increased assurance in its generalisability.

In summary, this work is consistent with several studies and adds to the current body of knowledge regarding COVID-19 vaccination beliefs, perceptions and attitudes. We have found that select sociodemographic characteristics and beliefs regarding vaccine safety and immunity contributed to COVID-19 vaccination acceptance during its early period of emergency use authorisation. Reservations regarding vaccination were comparable to other studies and poststratification raking increased the generalisability of our results. Further research is needed to understand the relationship of social networks and mental health states in vaccine acceptance. This information could be useful in targeting interventions to specific groups of the population and increase willingness to vaccinate among the vaccine hesitant.

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