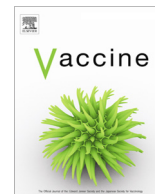




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Trusted information sources in the early months of the COVID-19 pandemic predict vaccination uptake over one year later



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ARTICLE INFO

Article history:

Received 18 February 2022

Received in revised form 28 September 2022

Accepted 30 November 2022

Available online 6 December 2022

Keywords:

Covid-19

SARS-CoV-2

Vaccine

Trust

Information Sources

Health Behaviors

ABSTRACT

Introduction: COVID-19 vaccine uptake has been a major barrier to stopping the pandemic in many countries with vaccine access. This longitudinal study examined the capability to predict vaccine uptake from data collected early in the pandemic before vaccines were available.

Methods: 493 US respondents completed online surveys both at baseline (March 2020) and wave 6 (June 2021), while 390 respondents completed baseline and wave 7 (November 2021) surveys. The baseline survey assessed trust in sources of COVID-19 information, social norms, perceived risk of COVID-19, skepticism about the pandemic, prevention behaviors, and conspiracy beliefs. Multivariable logistic models examined factors associated with the receipt of at least one COVID-19 vaccine dose at the two follow-ups. **Results:** In the adjusted model of vaccination uptake at wave 6, older age (aOR = 1.02, 95 %CI = 1.00–1.04) and greater income (aOR = 1.69, 95 %CI = 1.04–2.73) was associated with positive vaccination status. High trust in state health departments and mainstream news outlets at baseline were positively associated with vaccination at wave 6, while high trust in the Whitehouse (aOR = 0.42, 95 %CI = 0.24–0.74) and belief that China purposely spread the virus (aOR = 0.66, 95 %CI = 0.46–0.96) at baseline reduced the odds of vaccination. In the adjusted model of vaccination uptake at wave 7, increased age was associated with positive vaccination status, and Black race (compared to white) was associated with negative vaccination status. High trust in the CDC and mainstream news outlets at baseline were both associated with being vaccinated at wave 7, while high trust in the Whitehouse (aOR = 0.24, 95 %CI = 0.11–0.51) and belief that the virus was spread purposefully by China (aOR = 0.60, 95 %CI = 0.39–0.93) were negatively associated with vaccination.

Conclusions: These findings indicated that vaccine uptake could be predicted over a year earlier. Trust in specific sources of COVID-19 information were strong predictors, suggesting that future pandemic preparedness plans should include forums for news media, public health officials, and diverse political leaders to meet and develop coherent plans to communicate to the public early in a pandemic so that antivaccine attitudes do not flourish and become reinforced.

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1. Introduction

Vaccination uptake remains a critical issue. The WHO Working Group on Vaccine Hesitancy and other research has identified confidence and complacency as two key domains of vaccine uptake [1]. Vaccine complacency is viewed as the perceived risk of

vaccine-preventable diseases, and confidence is defined as trust in 1) vaccine effectiveness and safety, 2) vaccine delivery system, and 3) policymakers who recommend the vaccines [2,3]. Other research has identified domains such as perceived risk of vaccination, vaccine effectiveness, and social norms as predictors of COVID-19 vaccine hesitancy [4–10]. These domains align with theoretical models of vaccine uptake that show that vaccination decisions are based on an evaluation of risk and benefit information as well as being shaped by individuals' social network norms [11–15]. These identified domains and theoretical models have an underlying

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ing assumption that people are using current information to drive their decision on vaccination uptake. However, there may be factors present before the vaccine was tested that predict uptake. The current study was guided by the question: Can we predict vaccine uptake using information collected before the vaccine was even available? Using longitudinal data, we assessed if sources of trusted information, as well as COVID-19-related social norms and beliefs, predict vaccine uptake approximately a year later.

Prior research suggests that trust is linked to vaccine hesitancy and may be important for COVID-19 vaccine uptake [7,8]. Several reviews and multi-country studies have documented that medical mistrust related to COVID-19 and/or mistrust in vaccines are negatively associated with vaccine intentions, as is distrust in the health care system [16–20]. Larson et al., in a review of vaccine acceptance, conceptualize key domains of trust to include trust in policymakers, the health system, government, as well as trust in public health researchers and officials involved in approving and certifying vaccines as safe and effective [21]. Trust in COVID-19 information, however, may also be viewed as even more distal in the process and may have been established, in part, prior to the pandemic. These perceptions of trust earlier in the pandemic may guide the choice of sources of information and attention paid to these sources. Cross-sectional studies have found a negative association between greater trust in mainstream sources of COVID-19 vaccine information and vaccine hesitancy [12]. Prior research also suggests that early in the pandemic, there was a precipitous decline in perceived trust in sources of COVID-19 vaccine information [22]. In their review highlighting the importance of trust in vaccine decisions, Larson et al. also note that there is little longitudinal data on trust and vaccine uptake [21].

Sources of trusted information may drive different vaccination uptake decisions, instill confidence or confusion, and influence the level of trust in other sources of information. For example, the Trump administration's pronouncements promoting unproven and potentially dangerous treatments for COVID-19 were at times at odds with scientific agencies such as the U.S. Food and Drug Administration (FDA) and Centers for Disease Control and Prevention (CDC), which may have led to distrusting the Trump administration and/or FDA and CDC. Additionally, a study conducted by Ananyev and colleagues found that increased exposure to Fox News led to reduced compliance with social distancing during the pandemic, suggesting that sources of news influenced COVID-19 behaviors [23]. Information sources also did not always stay consistent in their messaging; for example, the Whitehouse COVID-19 Response Team ran the program to develop and disseminate COVID-19 vaccines, and Dr. Fauci consistently emphasized the severity of the pandemic. Yet many in the Trump Whitehouse downplayed the severity of the pandemic, which may have led to reduced vaccine uptake [24,25]. Altogether, these contradictory dynamics may have also reduced trust in governmental public health agencies and may have led individuals to be unsure about which news media sources to trust about the pandemic. This, in turn, could have also led to accessing other news sources, especially social media, that have provided misinformation about the COVID-19 pandemic and vaccinations [26].

One factor that may be correlated with trust is beliefs in conspiracy theories. Often conspiracy beliefs implicitly or explicitly indicate that mainstream sources of information cannot be trusted. Conspiracy beliefs have also been found to be linked to vaccine hesitancy [27,28]. Early endorsements of conspiracy theories may lead to lower vaccine uptake. When people make public proclamations for or against an issue, they are less likely to change their attitudes [29]. Hence, individuals who may have promoted the idea early in the pandemic that it was not serious or was a hoax may have had difficulty changing their attitudes to viewing COVID-19 as sufficiently serious to require vaccination.

Vaccination uptake may also be influenced by social identity [30,31]. Attitudes about the COVID-19 pandemic and the COVID-19 vaccines can also be viewed as a source of social identity. Participating in early COVID-19 prevention behaviors, such as social distancing, may foster a social identity of engaging in COVID-19 prevention behaviors; these individuals may then be more likely to get vaccinated as it aligns with their identity of participating in behaviors that aim to mitigate COVID-19. Social norms can also influence an individual's social identity [32]. For example, having peers who support COVID-19 prevention behaviors early in the pandemic can foster an individual's identity of engaging in behaviors that prevent COVID-19 and thus be associated with later vaccination uptake decisions. Political orientation is an additional factor that may shape an individual's social identity of engaging, or not, in COVID-19 prevention behaviors. As the response to the pandemic became politically polarized, individuals may have viewed their COVID-19 prevention behaviors such as mask-wearing and later vaccines as a public indicator of their political identity. One experimental study found that after the vaccines became available, COVID-19 vaccine messages from politically liberal sources led conservatives to be less likely to encourage other people to become vaccinated [33].

In this study, we used a longitudinal sample of US residents, which allows us the unique opportunity to use measures of these factors collected in March 2020 (i.e., prior to vaccine availability). In March 2020, the COVID-19 clinical vaccine trials were in the early phases, with the initial enrollment of the first participants in mRNA clinical trials. At this time, Moderna was launching its first COVID-19 vaccine clinical trials in the US. Soon after, in May 2020, Pfizer began its US clinical trials. There was no information in March 2020 on potential side effects or vaccine effectiveness, nor was there clear information on when the outcomes of the clinical trials, let alone the vaccines themselves, would be available. We then assessed if this data collected in March 2020 could predict vaccine uptake by June and November 2021, when vaccines were widely available to US residents. We anticipated that trust in news sources, conservatism, behavioral prevention measures, conspiracy beliefs, skepticism, and social norms about the pandemic would be correlated, and these factors would predict COVID-19 vaccine uptake. Identifying such predictors may help identify factors that may be antecedents to vaccine hesitancy and improve methods to improve vaccine uptake.

2. Methods

2.1. Study population

Study participants were drawn from the online longitudinal COVID-19 and Well-Being Study that began in March 2020. This study aimed to examine individual, social, and societal-level fluctuations amid the rapidly changing landscape of the pandemic. Study participants were recruited through Amazon's Mechanical Turk (MTurk). This platform is regularly used by health researchers, as it allows for a diverse sample to be collected in a rapid and timely fashion [34]. Study populations recruited through MTurk are not nationally representative but have been documented to outperform other opinion samples on several dimensions [35]. Studies using MTurk have also demonstrated good reliability [36]. The study protocols followed MTurk's best practices, including ensuring participant confidentiality, protecting study integrity, generating unique completion codes, integrating attention and validity checks throughout the survey, repeating study-specific qualification questions, and removing ineligible participants [37–39]. Moreover, despite COVID-19, the demographic characteristics of MTurk appear to be stable [40]. Eligibility was

determined by the following criteria: being age 18 or older, living in the United States, being able to speak and read English, having heard of the coronavirus or COVID-19, and providing written informed consent. Additionally, to enhance reliability, eligible participants had to pass attention and validity checks embedded in the survey [41]. Following recommendations by Rouse, we embedded checks to mitigate inattentive and random responding [41]. These checks included survey questions with exceedingly low probabilities, such as deep-sea fishing in Alaska and having appendages removed. We also repeated questions to ensure consistency. Finally, we examined the time participants took to complete the survey and verified the completeness of the data. Participants were compensated \$2.50 for the first wave (March 24th–27th, 2020) and \$4.25 for the sixth wave (June 14th–23rd, 2021), and \$4.25 for the seventh wave data (November 16th–29th, 2021), which was equivalent to approximately \$12 per hour. The study protocols were approved by the Johns Hopkins Bloomberg School of Public Health Institutional Review Board.

The first survey was administered beginning on March 24th, 2020, which was a week after 4 individuals started the Phase I clinical trial of the Moderna mRNA-1273. At this time, there was no information on the vaccine's safety or efficacy. By the time of the sixth and seventh survey in June and November 2021, respectively, vaccines were readily available for US adults. All eligible participants from wave 1 were invited to participate in subsequent waves. In total, 809 people participated in wave 1, with 493 respondents completing both waves 1 and 6, and due to attrition, 390 respondents completed both waves 1 and 7.

2.2. Measures

The primary outcome question was the response to the question, "How many doses of the coronavirus vaccine have you received?" To assess trust in sources of information, a set of questions asked participants, "How much do you trust information from [...] about coronavirus?" The following were the five sources of information: (1) the CDC, (2) the Whitehouse, (3) Johns Hopkins University, (4) major news outlets such as CNN, (5) your State Health Department. Response options were "(1) A great deal," "(2) Quite a bit," "(3) Some," "(4) Very little or none." These sources were chosen based on popularity, prestige, and information sources anticipated to provide accurate information. Johns Hopkins University was chosen due to its major role in disseminating COVID-19 data on case rates and deaths. As the first two response categories indicated high trust ratings, responses to trust in information sources were dichotomized as high (a great deal or quite a bit) versus low (some, very little, or none).

Two variables, which were added together, assessed social norms, "My friends would laugh at me if I wore a mask to protect myself from the coronavirus" and "My friends would think it was rude if I didn't hang out with them because of the coronavirus" The response categories were "Strongly agree," "Agree," "Neither agree nor disagree," "Disagree," and "Strongly disagree" (range 2–10). Prevention behavior was assessed with the item, "Are you trying to spend less time around other people to prevent getting the coronavirus?" (yes/no). The item "I am very worried about getting the coronavirus" was used to assess perceived risk/vaccine complacency, and the item "China purposely spread the coronavirus" was used to assess a conspiracy belief. All these items had response categories of a Likert scale with response categories were "Strongly agree," "Agree," "Neither agree nor disagree," "Disagree," and "Strongly disagree." Based on the distribution, the item worried about getting the coronavirus was dichotomized (Strongly agree or Agree vs other responses), and the item China purposely spread the coronavirus was trichotomized (strongly agree/agree, neither agree or disagree, and disagree/strongly disagree).

Skepticism of the COVID-19 pandemic was assessed by the three items, "The health risks from coronavirus has been exaggerated," "The coronavirus is a hoax," and "The coronavirus isn't any worse than the flu." The response categories were "Strongly agree," "Agree," "Neither agree nor disagree," "Disagree," and "Strongly disagree." These three items were summed as a scale and had a Cronbach's alpha of 0.76, (range 3–15), with lower scores indicating greater skepticism.

Political ideology was assessed with the question, "Where would you place yourself on a scale running from "Very liberal" to "Very conservative?" The response categories were (1) "Very liberal," (2) "Liberal," (3) "Slightly liberal," (4) "Moderate," (5) "Slightly conservative," (6) "Conservative," (7) "Very conservative," and (8) "Not applicable." There were six respondents who reported "not applicable" and were recoded to the median. The categories for race/ethnicity were White, Non-Hispanic Black, Hispanic, Asian, Mixed, and Other. Due to small sample sizes, mixed-race and "other" categories were collapsed into one category. Gender, education, and income were also assessed. Level of education was collapsed to reflect some college or less, associate or technical degree or less versus bachelor's degree or higher. Income was dichotomized at the median of \$60,000 or below.

2.3. Analysis

The goal of this study was to assess whether information collected on trust in COVID-19 information sources, social norms, social identity, COVID-19 beliefs, and demographics collected in March 2020 (wave 1) predicted receiving at least one dose of a COVID-19 vaccine uptake by June 2021 (wave 6) and November 2021 (wave 7). The sample was restricted to participants who completed wave 1 and waves 6 and/or 7. Descriptive statistics were assessed for the 493 adults who completed both waves 1 and 6 and the 390 adults who completed waves 1 and 7. Unadjusted and adjusted logistic regression was used to model wave 1 predictors with vaccination uptake in June and November 2021. Only wave 1 measures with p-values less than 0.20 in the bivariate models were included in the fully adjusted models. In the adjusted models, all the variables were adjusted for the other variables to assess the independent contribution of each variable. For both waves, this cutoff was met by all wave 1 measures. A Spearman correlation matrix (N = 493) modeled the correlation coefficients between the predictor variables.

3. Results

At wave 6, approximately-two-thirds of the respondents had received at least one dose of a COVID-19 vaccine (68.4%), and by wave 7, slightly over three-quarters had received at least one dose (76.9%). The study population at wave 1 was predominately White with a bachelor's or higher level of education (Table 1). The mean age was 40.5 years. There were high levels of trust in COVID-19 information from the CDC (81.9%), state health departments (76.7%), and Johns Hopkins University (JHU) (85.4%); moderate levels from major news outlets (48.9%); and low levels from the Whitehouse (28.2%). Approximately half of the respondents identified as liberal (50.5%), 21.9% as moderate, and 26.4% as conservative. A small portion of respondents reported feeling pressure not to adhere to preventative measures (16.8%), and most of the sample reported attempting to spend less time around others (96.4%). Roughly half of the respondents were worried about becoming infected at baseline (54.6%), and a small portion of the sample believed that the coronavirus was spread purposely by China (8.7%).

Table 1
Baseline characteristics among participants of waves 6 and 7.

Variable	Wave 6 (N = 493) n (%)	Wave 7 (N = 390) n (%)
Received at least one COVID-19 vaccine dose	337 (68.4)	300 (76.9)
Age M (SD)	40.5 (12.0)	41.9 (11.9)
Female	274 (55.6)	214 (54.9)
Household income > \$60,000	223 (45.2)	184 (47.2)
Completed bachelor's degree or higher	286 (58.1)	223 (59.7)
Trusted COVID-19 information source		
CDC	404 (81.9)	324 (83.1)
Whitehouse	339 (28.2)	111 (28.5)
Johns Hopkins University	421 (85.4)	338 (86.7)
State Health Department	378 (76.7)	304 (77.9)
Major news outlets	241 (48.9)	195 (50.0)
Social norms for mask wearing or social distancing M (SD) (range 2–10).	83 (16.8)	67 (17.2)
Political affiliation*		
Liberal	249 (50.5)	197 (50.5)
Moderate	108 (21.9)	87 (22.3)
Conservative	130 (26.4)	103 (26.4)
Spending less time around people	475 (96.4)	376 (96.4)
Worried about becoming infected with COVID-19	269 (54.6)	211 (54.1)
Believes that China purposely spread COVID-19	43 (8.7)	35 (8.9)
COVID-19 skepticism scale M (SD) (range 3–15)	65 (13.2)	54 (13.9)
Race		
White	396 (80.3)	321 (82.3)
Black	32 (6.5)	23 (5.9)
Hispanic	13 (3.1)	10 (2.6)
Asian	34 (6.9)	24 (6.2)
Other/Mixed	16 (3.3)	12 (3.1)

* six respondents answered “not applicable”.

For wave 6 bivariate models (Table 2), neither age nor sex was related to vaccination status. Black race (compared to white) was associated with negative vaccination status (OR = 0.46, 95 % CI = 0.22–0.94), but other race categories were not related to vaccination status. High trust in different sources of information was associated significantly with vaccination. High trust in the CDC, state health departments, JHU, and news outlets were positively associated with having received at least 1 vaccine dose, while high trust in the Whitehouse was negatively associated with vaccination status (OR = 0.41, 95 % CI = 0.27–0.62). Conservatism was significantly associated with a negative vaccine status (OR = 0.76, 95 % CI = 0.68–0.85), while social distancing (OR = 3.58, 95 % CI = 1.36–9.41), worry about becoming infected (OR = 1.64, 95 % CI = 1.12–2.40), and not having skepticism about COVID-19 (OR = 1.23, 95 % CI = 1.12–1.34) were associated with positive vaccine status.

In the fully adjusted models, increased age was associated with positive vaccination status (aOR = 1.02, 95 % CI = 1.00–1.04), as was greater income (aOR = 1.69, 95 % CI = 1.04–2.73). High trust in state health departments and mainstream news outlets were positively associated with having at least one vaccination dose, while high trust in the Whitehouse reduced odds of vaccination (aOR = 0.42,

Table 2
Bivariate and adjusted logistic regression models for having at least one COVID-19 vaccine dose by wave 6 (N = 493).

Variable	OR (95 % CI)	aOR (95 % CI)
Age in years	1.01 (0.99, 1.03)	1.02 (1.00, 1.04)
Sex assigned at birth (ref: male)	0.93 (0.70, 1.25)	1.08 (0.68, 1.71)
Income > \$60,000 in last year	1.83 (1.23, 2.70)	1.69 (1.04, 2.73)
Bachelor's degree completed	2.11 (1.44, 3.10)	1.29 (0.81, 2.06)
Trusted COVID-19 information sources		
CDC	4.05 (2.52, 6.53)	1.76 (0.91, 3.40)
Whitehouse	0.41 (0.27, 0.62)	0.42 (0.24, 0.74)
Johns Hopkins University	4.34 (2.58, 7.30)	1.60 (0.80, 3.20)
State Health Departments	3.53 (2.29, 5.46)	2.41 (1.37, 4.25)
Major news outlets	3.43 (2.28, 5.16)	2.03 (1.26, 3.27)
Social norms: social distance or mask usage	1.12 (0.99, 1.25)	1.11 (0.97, 1.28)
Political ideology (liberal to conservative)	0.76 (0.68, 0.85)	0.88 (0.76, 1.03)
Spending less time around people to prevent COVID-19	3.58 (1.36, 9.41)	1.73 (0.52, 5.76)
Worried about getting COVID-19	1.64 (1.12, 2.40)	1.07 (0.65, 1.73)
Believes that China purposely spread COVID-19	0.41 (0.30, 0.56)	0.66 (0.46, 0.96)
COVID-19 skepticism scale	1.23 (1.12, 1.34)	0.96 (0.85, 1.09)
Race (ref: White)		
Non-Hispanic Black	0.46 (0.22, 0.94)	0.48 (0.20, 1.14)
Hispanic	0.91 (0.31, 2.72)	1.26 (0.34, 4.70)
Asian	1.48 (0.65, 3.37)	1.47 (0.58, 3.74)
Other/Mixed	1.98 (0.55, 7.06)	3.68 (0.83, 16.38)

95 % CI = 0.24–0.74). Most COVID-19-related beliefs or behaviors were not significantly associated with vaccination status at wave 6, but the belief that China purposely spread the virus was associated with negative vaccination status (aOR = 0.66, 95 % CI = 0.46–0.96).

Results from bivariate models in wave 7 (Table 3) demonstrate that increased age (OR = 1.03, 95 % CI = 1.01–1.05) and having received a bachelor's degree (OR = 2.25, 95 % CI = 1.40–3.64) are associated with positive vaccination status. High trust in the CDC, JHU, state health departments, and news outlets at baseline were associated with positive vaccination status at wave 7, while high trust in the Whitehouse was associated with not having received a vaccination (OR = 0.28, 95 % CI = 0.17–0.47). Black race (compared to white) was associated with a decreased likelihood of being vaccinated (OR = 0.38, 95 % CI = 0.16–0.89). Social distancing, worry about becoming infected with COVID-19, and not having skepticism about COVID-19 were all positively associated with positive vaccination status, while conservatism (OR = 0.72, 95 % CI = 0.63–0.83) and belief that the virus was spread purposely by China (OR = 0.36, 95 % CI = 0.25–0.51) were associated with negative vaccination status.

In the fully adjusted models, increased age was associated with positive vaccination status, and Black race (compared to white) was associated with negative vaccination status, but other demographic variables were not significantly associated. High trust in the CDC and news outlets at baseline were both associated with

Table 3
Bivariate and adjusted logistic regression models for having at least one COVID-19 vaccine dose by wave 7 (N = 390).

Variable	OR (95 % CI)	aOR (95 % CI)
Age in years	1.03 (1.01, 1.05)	1.04 (1.02, 1.07)
Sex assigned at birth (ref: male)	0.91 (0.57, 1.46)	0.72 (0.39, 1.33)
Income > \$60,000 in last year	1.46 (0.91, 2.36)	1.16 (0.61, 2.19)
Bachelor's degree completed	2.25 (1.40, 3.64)	1.70 (0.92, 3.18)
Trusted COVID-19 information sources		
CDC	4.32 (2.47, 7.56)	2.69 (1.12, 6.49)
Whitehouse	0.28 (0.17, 0.47)	0.24 (0.11, 0.51)
Johns Hopkins University	5.19 (2.81, 9.57)	1.85 (0.78, 4.35)
State Health Departments	3.11 (1.85, 5.23)	1.52 (0.71, 3.26)
Major news outlets	5.76 (3.27, 10.13)	3.54 (1.82, 6.92)
Social norms: social distance or mask usage	1.11 (0.96, 1.27)	1.06 (0.88, 1.28)
Political ideology (liberal to conservative)	0.72 (0.63, 0.83)	0.93 (0.75, 1.15)
Spending less time around people to prevent COVID-19	4.78 (1.61, 14.17)	2.87 (0.71, 2.97)
Worried about getting COVID-19	2.10 (1.30, 3.39)	1.56 (0.82, 2.97)
Believes that China purposely spread COVID-19	0.36 (0.25, 0.51)	0.60 (0.39, 0.93)
COVID-19 skepticism scale	1.30 (1.16, 1.44)	0.97 (0.83, 1.13)
Race (ref: White)		
Non-Hispanic Black	0.38 (0.16, 0.89)	0.29 (0.09, 0.92)
Hispanic	0.67 (0.17, 2.68)	0.90 (0.15, 5.51)
Asian	2.02 (0.59, 6.98)	2.09 (0.50, 8.72)
Other / Mixed	1.45 (0.31, 6.75)	3.29 (0.39, 27.44)

being vaccinated at least once at wave 7, while high trust in the Whitehouse was associated with negative vaccination status (aOR = 0.24, 95 % CI = 0.11–0.51). The belief that the virus was spread purposefully by China at baseline was also negatively associated with vaccination at wave 7 (aOR = 0.60, 95 % CI = 0.39–0.93). Sex, income, and social norms were not significantly associated with vaccine status in bivariate or multivariate models.

In a final analysis, we examined the association between the key covariates, excluding the demographic factors, using Spearman's correlation coefficients. As seen in Table 4, with the exception of the social norms, the majority of other variables were correlated. High trust in the Whitehouse was positively correlated with only one variable (trust in COVID-19 information from state health departments) and negatively associated with trust in major news outlets.

4. Discussion

With data collected before there were results or data about side effects from human vaccines trials for COVID-19, we predicted vaccine uptake over a year later among a sample of US residents. Some of the strongest predictors of vaccine uptake one year later were sources of trusted information about COVID-19 in the early months of the pandemic. Study findings identified that individuals who have low trust in state health departments, low trust in mainstream news media, and high trust in the Whitehouse had lower

odds of being vaccinated over a year later. The findings are consistent the WHO Working Group on Vaccine Hesitancy and with Pew Research Center findings. The Pew Research Center initially surveyed respondents in April 2020 about their COVID-19 information sources as part of the American Trends survey. Those who reported relying on “Public health organizations and officials” and “National news outlets” most for news about the COVID-19 outbreak had the highest vaccination rates when assessed in August 2021 [42]. In comparison, those who reported relying most on “Donald Trump and his coronavirus task force” for news about the pandemic were more than 20 % less likely to have had at least one dose of a COVID-19 vaccine.

It is interesting that high trust in the Trump administration, as assessed by trust in the Trump Whitehouse, was negatively associated with vaccine uptake. Those respondents who had low trust in the Trump Whitehouse had four times greater odds of being vaccinated by late November 2021, compared to those with high trust. There are a few possible explanations for this relationship between trust in the Trump Whitehouse and reduced vaccination uptake. First, it may be believed that the Trump Whitehouse did not support vaccinations. Although the Trump administration funded and supported the COVID-19 vaccine development, public health leaders in the administration who were encouraging vaccination, such as Dr. Anthony Fauci, were often seen as at odds with Trump's pronouncements about the pandemic. Additionally, the conservative media and leaders frequently pilloried public health officials for their encouragement of behavioral COVID-19 prevention efforts, support for lockdowns, and vaccine mandates. These factors may have led some people to believe that the Trump Whitehouse did not support vaccination. Another explanation of the relationship between trust in the Trump Whitehouse and lower levels of vaccine uptake is social identity, with high trust in the Trump Whitehouse indicating a stronger social identity of a Trump supporter, which may include a lower likelihood of viewing the pandemic as a serious threat or vaccine complacency and conflating individual rights with vaccination refusal. Not being vaccinated can also be viewed as behaviorally consistent with high COVID-19 skepticism, which was significantly correlated with trust in COVID-19 information from the Trump Whitehouse in the current study. It is likely that sources of information and a range of beliefs about COVID-19, science literacy, public health, and conspiracies are mutually reinforcing. These beliefs can comprise a barrier that excludes or distorts critical public health information about the pandemic. These findings suggest the important role of conservative leaders and conservative media in promoting vaccine uptake. They have a greater responsibility as many of their followers may not trust scientific sources of COVID-19 information.

We also found that the belief that Chinapurposefully spread COVID-19 was strongly associated with lower vaccine uptake. At face value, it makes little sense that if one believes that China was purposefully spreading COVID-19, one would be less likely to become vaccinated. However, it may be that this belief is a marker of a constellation of beliefs, attitudes, values associated with vaccine behaviors. The survey items of trust in the Trump Whitehouse, China purposefully spreading COVID-19, and COVID-19 skepticism were all highly positively correlated. Except for trust in the Trump Whitehouse, these items were also associated with trying to spend less time around others to prevent COVID-19 and worried about becoming infected with the virus. Trust in all the other sources of COVID-19 information, except the Trump Whitehouse, was negatively correlated with the belief that China purposefully spread COVID-19 and COVID-19 skepticism.

Social norms of support for COVID-19 prevention behaviors early in the pandemic was not found to be an independent predictor of vaccine uptake a year later. In this study, we used an injunctive social norms measure that assessed perceptions of potential

Table 4
Spearman's correlation matrix of covariates.

	High trust for COVID-19 information: CDC	High trust for COVID-19 information: Whitehouse	High trust for COVID-19 information: Johns Hopkins University	High trust for COVID-19 information: Health Departments	High trust for COVID-19 information: Major news outlets	Political conservatism	Spending less time around people	Worried about getting COVID-19	Belief China purposely spread COVID-19	High COVID-19 skepticism	Social norms
High trust for COVID-19 information: CDC	1.00	0.118**	0.463**	0.439**	0.259**	-0.034	0.190**	0.130**	-0.200**	-0.164**	0.036
High trust for COVID-19 information: Whitehouse		1.00	0.017	0.111*	-0.099*	0.491**	-0.002	-0.051	-0.318**	0.230**	-0.004
High trust for COVID-19 information: JHU			1.00	0.424**	0.267**	-0.119**	0.164**	0.188**	-0.171**	-0.251**	0.037
High trust for COVID-19 information: Health Department				1.00	0.280**	-0.073	0.148**	-0.099*	-0.117**	-0.144**	-0.055
High trust for COVID-19 information: major news outlets					1.00	-0.203**	0.147**	0.161**	-0.236**	-0.207**	0.022
Political conservatism						1.00	0.073	-0.221**	0.425**	0.309**	-0.017
Spending less time around other people							1.00	0.199**	0.025	-0.194**	-0.123**
Worried about getting COVID-19								1.00	-0.162**	-0.407**	0.022
Belief China purposely spread COVID-19									1.00	0.394**	0.124**
High COVID-19 skepticism										1.00	0.257**
Social norms											1.00

negative reactions by friends to COVID-19 prevention behaviors. This variable tended not to be strongly associated with the other independent variables. There are several plausible explanations for this finding. First, we did not ask directly about the friends' attitudes or behaviors (descriptive social norms) regarding either the pandemic or prevention behaviors, which may have had more predictive power than the injunctive social norms. Second, as the pandemic was in the early phase, people may not have interacted with their friends sufficiently to gauge their friends' attitudes and behaviors. However, the significant association between perceived reactions by friends to COVID-19 prevention behaviors and COVID-19 skepticism suggests an association between one's beliefs about the pandemic and anticipated reactions by friends for engaging in COVID-19 prevention behaviors. Furthermore, the social norms of COVID-19 prevention behaviors may not have been as strongly established in March 2020, as they were only variably beginning to be supported by laws and policies (e.g., mask mandates) and other prevention-oriented measures (e.g., stickers denoting six feet apart placed on the ground for queueing, plexiglass screens in front of cashiers).

It could be argued that conservative ideologies with an emphasis on individual freedom and distrust of government would lead to low vaccine uptake. Yet, prior to COVID-19, vaccination decisions were not often discussed in the context of individuals' freedoms. Vaccination debates before COVID-19 were much more focused on vaccination exemptions based on religious views. Study findings on the relationship between political ideology and anti-vaccination beliefs prior to COVID-19 were mixed, with no clear indication that vaccine uptake was viewed as a political act [43,44]. One explanation for the finding of the bivariate association between greater political conservatism and lower vaccination uptake, which was attenuated in the multivariate model, is that conservatism fostered higher trust in information on COVID-19 from the Trump Whitehouse, which provided ambiguous messages about vaccination, and led to decreased trust in COVID-19 information from public health entities that encouraged vaccination.

We also found that age and income were associated with vaccination status, which has also been found in prior studies [9]. COVID-19 skepticism was statistically significant in bivariate models but not the multivariable model. COVID-19 skepticism was strongly associated with trust in the Whitehouse, being more conservative, and belief that China purposely spread COVID-19 and strongly negatively associated with concern about COVID-19 infection and trust in COVID-19 information from the CDC, state health departments, mainstream news media, and JHU. COVID-19 skepticism, which assessed denial of the pandemic severity, is consistent with some conservative leaders' downplaying of the pandemic. A longitudinal study in the US prior to vaccine availability found that conservative news media attracted individuals susceptible to conspiratorial thinking, and those with conservative political views were less exposed to mainstream news. Continued exposure to conservative news media reduced support for vaccination and decreased trust in the CDC [45].

The findings from this study, especially the correlation matrix in Table 4, fit well with Young and Bleakley's (2020) ideological health spirals model (IHSM) [31]. In their model, political orientation, demographic, cultural, and individual factors lead to social identities that motivate media and social network exposures, which, in turn, influences attitudes toward COVID-19 behaviors, subjective norms regarding COVID-19, and self-efficacy surrounding COVID-19 behaviors. The IHSM model hypothesizes that attitudes and norms influence media exposure and interpersonal discussions that include a feedback loop, which makes it difficult to alter attitudes and behaviors. The IHSM highlights the role of social identity, which guides and is reinforced by media exposure.

Study limitations should be noted. This was a longitudinal study with attrition. Moreover, the sample was not random, which limits generalizability. We also did not assess all sources of COVID-19 information and how much information about the pandemic was gathered through social media and informal social networks. The measure of trust did not differentiate between less conservative news outlets such as CNN and more conservative news sources such as Fox News. The numerous waves of the pandemic, effects of non-pharmaceutical interventions, changes in recommendations for boosters, availability of vaccinations for children, emerging real-world evidence on vaccine effectiveness and safety, and other factors are all likely to influence vaccine attitudes and behaviors, making it more remarkable that baseline information could predict later vaccination uptake. These findings do not negate the importance of access to vaccines to facilitate uptake [46,47]. The results also do not address the role of vaccine hesitancy based on the perceived safety and efficacy of the COVID-19 vaccines. We did not assess these domains at the baseline as there was no information about them before the vaccines were tested in rigorous randomized control trials. There are also likely bidirectional associations among news sources, trust in news sources, and political orientation, with each mutually reinforcing the other.

The results suggest that political leaders and news outlets have a critical role in shaping their followers' attitudes about vaccines and trust in sources of information about the pandemic. However, once attitudes about the pandemic and vaccines are established, conservative leaders may believe that promoting social distancing and vaccines may lead to a loss of support among their base. Emphasizing the role of altruism in vaccination among conservatives might allow them to encourage vaccines while not contradicting the sentiments of their supporters. An experimental study on vaccine intentions conducted in March of 2021 found that when Republicans were exposed to vaccine endorsements by prominent Republicans, including Trump, vaccine intentions increased by 7 % compared to endorsements by prominent Democrats [33]. Moreover, Republicans who viewed the Democratic endorsements were significantly less likely to encourage others to become vaccinated and had more negative attitudes toward the vaccine than those who viewed the Republican elite endorsement. These findings provide direction for increasing vaccine uptake among Republicans but require conservative news sources to provide a platform for conservative leaders to disseminate messages to encourage vaccine uptake. Conservative leaders should also highlight accurate sources of scientific information and encourage followers to utilize these sources. The influence of social identity, especially identities linked to political orientation, in COVID-19 vaccine uptake suggests that it is essential to utilize media and public figures that are seen as trustworthy and credible among a range of individuals with diverse social identities to promote vaccine uptake.

Future pandemic preparedness plans should include forums for news media, public health officials, and political leaders to meet and develop coherent plans to communicate to the public early in a pandemic so that antivaccine attitudes do not flourish and become reinforced. Given that level of trust and sources of news information differ based on social identity resulting from political ideology and party affiliation, individuals may not trust information from sources of information about COVID-19 vaccinations outside their own political party. Consequently, groups that provide public health recommendations should consider including prominent political and media figures with scientific literacy. Often health advisory groups strive to be apolitical. However, this approach may not be effective in a highly polarized political climate. Therefore, it may be advisable that advisory groups include members who are viewed as credible across the political spectrum.

Funding sources

R01 DA040488, Alliance for a Healthier World.

Data availability

Data will be made available on request.

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.

Acknowledgment

Study participants.

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