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Medical mistrust and COVID-19 vaccine attitudes and behavior: Findings from a population-based cohort study in Michigan

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ABSTRACT

Background: Uptake of COVID-19 vaccines has stalled in the U.S. Some studies suggest that medical mistrust may be a barrier, but evidence is limited due to cross-sectional designs or convenience sampling.
Methods: We examined associations of medical mistrust with COVID-19 vaccine attitudes at baseline and vaccination uptake at follow-up using a population-based sample of Michigan adults with PCR-confirmed SARS-CoV-2 infection. We summed ratings for three items of the Medical Mistrust Index (MMI) to measure trust in healthcare providers. For vaccine attitudes, we averaged ratings for two items on importance of getting the COVID-19 vaccine. For vaccination uptake as ever receiving at least one dose of a COVID-19 vaccine. We conducted (1) linear regression models to examine cross-sectional associations between MMI and vaccine attitudes ($n = 3865$), (2) modified Poisson regression with robust standard errors to estimate prospective associations between MMI and vaccination uptake ($n = 3741$), and (3) effect modification and stratified analyses by race and ethnicity.
Results: The mean MMI score was 1.89. The mean of positive vaccine attitudes measure at baseline was 3.45 and the prevalence of receiving a vaccine at follow-up was 75.3 %. Higher MMI was associated with worse vaccine attitudes at baseline (coefficient = −0.64, 95 % confidence interval [CI]: −0.71, −0.56), and lower vaccine uptake at follow-up (adjusted risk ratio: 0.83, 95 % CI: 0.80, 0.86). Both associations were pronounced among non-Hispanic White and another non-Hispanic race and ethnicity individuals.
Conclusions: Understanding drivers of medical mistrust may help rebuild public trust in healthcare systems to promote vaccine uptake and improve public health.

1. Introduction

The high morbidity and mortality of the coronavirus disease 2019 (COVID-19) pandemic led to considerable global efforts toward vaccine development [1]. The first COVID-19 vaccine in the United States (U.S.) became available to priority populations at highest risk for exposure—such as healthcare workers, first responders, and long-term care residents—in December 2020 and for populations aged 16 years and above in April 2021 [2,3]. According to the most recent data from the Centers for Disease Control and Prevention, as of May 10, 2023, 81 % of U.S. population aged 18 and over have had at least one COVID-19 vaccine dose, while only 70 % have completed the primary vaccine series (2 doses of the Pfizer-BioNtech vaccine or 2 doses of the Moderna vaccine or 2 doses of the Novavax vaccine or 1 dose of the Johnson & Johnson's Janssen vaccine) [4]. Moreover, only 34 % have received an updated booster dose as of October 19, 2022 [4]. COVID-19 vaccination

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reduces the risk of SARS-CoV-2 infection, acute symptoms of COVID-19 illness, long COVID, and hospitalization and deaths due to COVID-19 [5,6].

Despite a high vaccination coverage, growing research has documented that medical mistrust is a barrier to COVID-19 vaccination for many populations in the U.S. [2,7,8] Medical mistrust is a multifaceted concept, defined as a lack of trust in healthcare providers (interpersonal level) and healthcare systems (institutional level) [2,9–11]. Due to long-standing racism and historical atrocities, medical mistrust has been historically prevalent in the U.S., particularly among Black Americans and American Indians [2,11]. For example, in the Tuskegee Syphilis Study conducted between 1932 and 1972, researchers knowingly deceived Black American men about the purpose of the study and withheld effective treatment for syphilis, which increased medical mistrust among these populations [2,11]. Many non-Hispanic [NH] Whites also have a high level of medical mistrust because of their mistrust in the healthcare industry and the U.S. government [2,12] and their negative experiences of politics or policies [12–15].

The COVID-19 pandemic may have exacerbated medical mistrust in the U.S. as discrimination against minoritized populations escalated, health recommendations changed over time, and overall trust in governments largely declined when the response to COVID-19 became highly political [16–19]. It has been well documented that medical mistrust is associated with adverse health behaviors, such as low medication adherence [20], low rates of health screening behaviors [21], low participation in care-seeking behaviors [22], and low vaccination rates [23], which ultimately contribute to poorer health outcomes [2]. Due to decreased trust in medical institutions and governments during the pandemic [16,17], medical mistrust may be worsened, leading to negative health attitudes or behaviors and contributing to severe COVID-19 illness. Therefore, understanding the role of medical mistrust in health attitudes and behaviors is essential in the context of the COVID-19 pandemic.

Several recent studies have examined the relationship between medical mistrust and COVID-19 vaccine-related behaviors in the U.S. Greater medical mistrust was associated with COVID-19 vaccine hesitancy among U.S. populations [2,7], including Black Americans [22,24]. Some studies also highlighted that medical mistrust mediated the association between race and ethnicity and COVID-19 vaccine hesitancy or rejection of COVID-19 vaccine trial participation [25,26]. However, these previous studies used cross-sectional research designs [2,7,8,24,25] or non-random convenience sampling [8,24–26], which limits an understanding of the relationship between medical mistrust and vaccination behaviors during the pandemic.

To address the literature gaps, we examined associations of medical mistrust with COVID-19 vaccine attitudes at baseline and uptake of vaccination at follow-up using a population-based sample of adults in Michigan with PCR-confirmed SARS-CoV-2 infection between March 2020 and May 2022. We also tested race and ethnicity as potential effect modifiers for the associations of medical mistrust with COVID-19 vaccine attitudes and vaccine uptake given that racial and ethnic minoritized populations are more likely to have greater medical mistrust and vaccine hesitancy due to historical and contemporary racism than NH White populations [2,11]. First, we hypothesized that a higher level of medical mistrust would be associated with poor attitudes toward the COVID-19 vaccine at baseline. Second, we hypothesized that a higher level of medical mistrust would be associated with lower vaccine uptake at follow-up. Finally, we hypothesized that associations of medical mistrust with COVID-19 vaccine attitudes and vaccine uptake would be more pronounced among racial and ethnic minoritized individuals compared to NH White individuals.

2. Material and methods

2.1. Data

We used baseline and follow-up data from the Michigan COVID-19 Recovery Surveillance Study (MI CReSS), a statewide representative survey of adults 18 years and older with a polymerase chain reaction (PCR)-confirmed SARS-CoV-2 test. Eligibility criteria for participation in the study included: (1) noninstitutionalized adults aged 18 or older, (2) PCR-confirmed SARS-CoV-2 infection recorded in the Michigan Disease Surveillance System (MDSS) between March 2020 and May 2022, (3) valid phone number and geographic information (county/zip code), and (4) alive at the time of the surveys. All respondents were invited to participate in the study via mailed letters and completed the survey over the phone with a trained interviewer in English, Spanish, or Arabic, or online in English.

Inclusion of subjects in MI CReSS was based on a stratified probability sample of eligible adults, which was selected from 13 geographic strata, including six public health emergency preparedness regions (1, 3, 5, 6, 7, and 8) [27], six counties in southeast Michigan (Macomb, Oakland, Saint Clair, Monroe, Washtenaw, and Wayne [except Detroit]), and one city (Detroit). Sixteen sequential cross-sectional samples were drawn over time with a base number of 50–70 individuals from each geographic region, while the remainders of the samples were drawn proportionally based on overall reported case counts within each area. Respondents completed baseline surveys between June 2020 and December 2022, and follow-up surveys between January 2022 and November 2023. To account for nonresponse, we applied sampling weights to match the weighted distribution of our sample to the age and sex distribution of the sampling frame in each geographic area. We used longitudinal weighting for cohort data analysis, which accounted for attrition and nonresponse [28]. To account for missingness in income, we used the weighted sequential hot-deck method [29] and hot deck propensity score imputation at baseline and weighted sequential hot-deck method at follow-up under a missing at random assumption [30]. The median time from COVID-19 illness onset to baseline survey was 4.4 months (IQR = 3.4–5.7 months) and the median time from COVID-19 illness onset to cohort survey was 18.4 months (IQR = 14.9–21.4 months). The response rate was 32.1 % for baseline survey and 80.7 % for follow-up survey (American Association for Public Opinion Research response rate #6) [31]. All respondents provided consent to participate. The University of Michigan institutional review board deemed this study exempt due to the use of secondary de-identified data.

2.2. Analytic samples

We have separate analytic samples for each outcome variable because we asked questions for vaccination attitudes only at baseline. For the vaccine attitudes outcome, the questions were only asked at baseline after data collection had already started. Of the 5521 surveys completed at baseline, we excluded surveys that did not ask questions about vaccine attitudes (n = 1348), had missing information about exposure or covariates (n = 293), or were completed by proxy respondents because of mental capacity concerns (n = 7) or other reasons (n = 8). Thus, the first analytic sample for the vaccine attitudes analysis was n = 3865. For the vaccination uptake outcome, we used MI CReSS follow-up data. Of the 4100 follow-up surveys completed, we excluded surveys missing information about outcome, exposure, or covariates (n = 346) or completed by proxy respondents due to mental capacity concerns (n = 8) or other reasons (n = 5), leading to an analytic sample of n = 3741.

2.3. Exposure variable

We measured medical mistrust at baseline using three items adapted from the Medical Mistrust Index (MMI) [32,33]. The three items

comprised of declarative statements regarding trust in healthcare providers: "I trust that healthcare providers are giving the best treatment available," "I trust that healthcare providers have my best interest in mind when treating me," and "I trust that healthcare providers will tell me if a mistake is made about my medical treatment." Each item was answered on a 4-point Likert-type scale (1 = "strongly disagree," 2 = "disagree," 3 = "agree," and 4 = "strongly agree"). We reverse coded the responses and averaged the items (Cronbach's α = 0.84) to create a MMI score ranging from 1 to 4 where a higher score indicated a higher level of medical mistrust [33,34].

2.4. Outcome variables

We assessed (1) positive attitudes toward COVID-19 vaccines at baseline and (2) uptake of COVID-19 vaccination at follow-up. To evaluate positive vaccine attitudes at baseline, we used two questions: "How important is it for individuals who have never had coronavirus to get a government-approved COVID-19 vaccine?" and "How important is it for individuals who have had coronavirus to get a government-approved COVID-19 vaccine?" Both questions were answered using a 5-point Likert-type scale (1= "not important at all," 2= "of little importance," 3= "of average importance," 4 = "very important," and 5 = "absolutely essential"). Since the two items were highly correlated with high reliability (Cronbach's α = 0.95), we averaged them into a single continuous variable for positive vaccine attitudes, where scores ranged from 1 to 5 and a higher score indicated a higher level of positive vaccine attitudes [35,36]. For a sensitivity analysis, we also created binary variables for each item (0 = not important at all, of little importance, of average importance; 1 = very important, absolute essential). For COVID-19 vaccination uptake, we coded a binary variable (0 = "no", 1 = "yes") using the question, "Have you ever had the COVID-19 vaccine?" that was asked at follow-up [2]. As the proportion of individuals who were partially vaccinated was only 1.4 %, we did not disaggregate vaccination uptake further.

2.5. Potential effect modifiers

We used race and ethnicity as potential effect modifiers for the associations between medical mistrust and vaccine attitudes and behaviors. We used a 4-categorical race and ethnicity variable (Hispanic, NH White, NH Black, another NH race and ethnicity). Another NH race and ethnicity included Middle Eastern/North African, Asian, American Indian/Alaska Native, and multiracial. We tested race and ethnicity as potential effect modifiers because the negative effect of medical mistrust on COVID-19 vaccine attitudes or vaccination uptake could be pronounced among racial and ethnic minoritized individuals given that (1) they are more likely to have greater medical mistrust and vaccine hesitancy due to historical and contemporary racism than NH White individuals and (2) discrimination against minoritized populations escalated during the pandemic [16–19].

2.6. Covariates

We included several sociodemographic and clinical factors and survey variables as covariates: age group (18–34, 35–54, 55–64, ≥65 years), sex at birth (male, female), race and ethnicity, marital status (married/cohabitating, not currently married/cohabitating), educational attainment (high school or less, some college, college graduate), household income in 2019 (<$35,000, $35,000 − 74,999, ≥$75,000), health insurance (private insurance, Medicare/Medicaid/another type, none), a binary indicator for any pre-existing diagnosed comorbidities (presence of chronic obstructive pulmonary disease, asthma, diabetes, cardiovascular disease, hypertension, liver disease, kidney disease, cerebrovascular disease, cancer, immunosuppressive condition, autoimmune condition, physical disability, psychological or psychiatric condition), self-reported COVID-19 symptom severity (asymptomatic/mild, moderate, severe, very severe), survey mode (phone or online), and pandemic phase (January 2020–September 2020, October 2020–May 2021, June 2021–May 2022).

2.7. Statistical analyses

First, we calculated weighted descriptive statistics to characterize each analytic sample. Next, we calculated weighted prevalence estimates of medical mistrust overall and by sociodemographic and clinical covariates. Then, we conducted unadjusted and adjusted linear regression models to examine the cross-sectional association between medical mistrust and positive attitudes toward the COVID-19 vaccine. We also conducted unadjusted and adjusted modified Poisson regression models with robust standard errors to estimate risk ratios (RR) for the prospective association between medical mistrust and COVID-19 vaccination uptake [37–39]. As some respondents received COVID-19 vaccines before the baseline survey, we conducted an additional analysis by restricting the analytic sample for vaccination uptake to (1) respondents (n = 943) who were unvaccinated at the baseline when COVID-19 vaccines were unavailable (from June 2020 to April 4, 2021) and (2) respondents (n = 800) who were unvaccinated at the baseline when COVID-19 vaccines were available (from April 5, 2021 to December 2022). Additionally, we tested race and ethnicity as potential effect modifiers using a Wald test for the cross-sectional association between medical mistrust and vaccine attitudes and the prospective association between medical mistrust and vaccine uptake. Based on methodological literature, we included an interaction term between medical mistrust and race and ethnicity for each outcome variable to conduct effect modification analyses [40]. Finally, we conducted a sensitivity analyses using two binary variables for positive vaccine attitudes as outcomes using Poisson regression models with robust standard errors to confirm the robustness of associations between medical mistrust and vaccine attitudes. All statistical analyses were completed using Stata, version 17 and incorporated sampling strata and survey weights.

3. Results

The mean of MMI score at baseline was 1.89 (range: 1–4) with a higher score indicating a higher level of medical mistrust (Table 1). When examining each item of the MMI score, 9.2 % of respondents agreed or strongly agreed that healthcare providers were not giving them the best treatment available, 9.2 % agreed or strongly agreed that healthcare providers did not have their best interest in mind when treating them, and 28.8 % agreed or strongly agreed that healthcare providers would not tell them if a mistake was made in their medical treatment. The mean score of positive vaccine attitudes measure at baseline was 3.45 (range: 1–5) and the prevalence of receiving a COVID-19 vaccine at follow-up was 75.3 %.

In bivariate analyses, the mean MMI was higher among respondents who did not have positive vaccine attitudes than respondents who had positive vaccine attitudes (Table 2). The mean MMI was also higher among respondents who did not receive the COVID-19 vaccine (mean: 2.13, standard error (SE): 0.03) than respondents who received the COVID-19 vaccine (mean: 1.80, SE: 0.01). Compared to respondents who were older, the mean MMI was greater among respondents who were younger. Compared to respondents who were NH White, the mean MMI was higher among respondents who were Hispanic, NH Black, or from another NH race and ethnicity. Additionally, the mean MMI was higher among respondents who had a lower education than respondents who had a higher education.

In the regression models, higher medical mistrust was associated with worse vaccine attitudes: a 1-point higher MMI score was associated with a − 0.71 lower score of positive vaccine attitudes in the unadjusted model (95 % confidence interval [CI]: −0.78, −0.63) (Table 3). After adjusting for covariates, the magnitude of this association was slightly attenuated to −0.64 but remained statistically significant (95 % CI:

Table 1
Characteristics of study participants, Michigan COVID-19 Recovery Surveillance Study, 2020–2023.

	Weighted mean or percentage	
	Baseline (n = 3865)	Follow-Up (n = 3741)
Medical Mistrust Index (range: 1–4), mean (SE, median, IQR)	1.89 (0.01, 2, 1.33–2.33)	
Medical Mistrust Index item, [a] %		
Healthcare providers don't give the best treatment available	9.2	
Healthcare providers don't have my best interest in mind for treatment	9.2	
Healthcare providers will not tell me about mistake in medical treatment	28.8	
Positive vaccine attitudes (range: 1–5) mean (SE, median, IQR)	3.45 (0.02, 4, 2.5–5)	
Vaccination uptake, %		
Yes		75.3
No		24.7
Age, %		
18–34	38.8	33.0
35–54	33.8	36.0
55–64	14.8	16.4
≥65	12.6	14.6
Sex, %		
Male	45.3	45.2
Female	54.7	54.8
Race and ethnicity, %		
Hispanic	6.6	6.6
NH White	73.8	70.8
NH Black	8.2	10.5
Another NH race and ethnicity	11.5	12.1
Marital status, %		
Married/cohabiting	62.4	63.2
Not married/cohabiting	37.6	36.9
Education, %		
High school or less	23.0	23.6
Some college	33.9	32.7
College graduate	43.1	43.8
Household income, %		
<$35,000	29.1	27.3
$35,000–74,999	30.1	29.9
≥$75,000	40.8	42.8
Health insurance, %		
Private insurance	69.8	69.7
Medicare/Medicaid/others	21.6	23.8
None	8.6	6.5
Pre-existing diagnosed comorbidities, %		
Yes	53.7	51.7
No	46.3	48.3
COVID-19 symptom severity, %		
Asymptomatic/mild	32.0	33.9
Moderate	37.4	35.5
Severe	22.1	21.4
Very severe	8.5	9.2

COVID-19 = Coronavirus disease 2019; SE = Standard error; NH = non-Hispanic.
a. This presents the percentage reporting agree and strongly agree for each medical mistrust index item.

Table 2
Weighted mean of Medical Mistrust Index at baseline by sociodemographic and clinical factors at baseline or follow-up, Michigan COVID-19 Recovery Surveillance Study, 2020–2023.

	Medical Mistrust Index (range = 1–4)			
	Baseline (n = 3865)		Follow-Up (n = 3741)	
	Weighted mean (SE)	p-value [a]	Weighted mean (SE)	p-value [a]
Positive vaccine attitudes				
Importance of vaccination for people who have not had COVID-19		<0.001		
Yes	1.74 (0.01)			
No	2.10 (0.02)			
Importance of vaccination for people who have had COVID-19		<0.001		
Yes	1.73 (0.01)			
No	2.07 (0.02)			
Vaccination uptake				<0.001
Yes			1.80 (0.01)	
No			2.13 (0.03)	
Age		<0.001		<0.001
18–34	1.92 (0.02)		1.91 (0.02)	
35–54	1.93 (0.02)		1.92 (0.02)	
55–64	1.86 (0.03)		1.86 (0.03)	
≥65	1.72 (0.02)		1.73 (0.02)	
Sex		0.930		0.339
Male	1.89 (0.02)		1.87 (0.02)	
Female	1.89 (0.01)		1.89 (0.01)	
Race and ethnicity		0.004		0.005
Hispanic	1.94 (0.04)		1.89 (0.05)	
NH White	1.86 (0.01)		1.86 (0.01)	
NH Black	1.95 (0.04)		1.99 (0.04)	
Another NH race and ethnicity	1.97 (0.03)		1.92 (0.03)	
Marital status		0.835		0.969
Married/cohabiting	1.89 (0.01)		1.88 (0.01)	
Not married/cohabiting	1.89 (0.02)		1.88 (0.02)	
Education		<0.001		0.047
High school or less	1.94 (0.02)		1.91 (0.03)	
Some college	1.92 (0.02)		1.90 (0.02)	
College graduate	1.84 (0.02)		1.85 (0.02)	
Household income		<0.001		0.069
<$35,000	1.93 (0.02)		1.87 (0.02)	
$35,000–74,999	1.92 (0.02)		1.92 (0.02)	
≥$75,000	1.83 (0.02)		1.86 (0.02)	
Health insurance		<0.001		0.509
Private insurance	1.86 (0.01)		1.87 (0.01)	
Medicare/Medicaid/others	1.95 (0.02)		1.90 (0.02)	
None	1.97 (0.04)		1.91 (0.04)	
Pre-existing diagnosed comorbidities		0.069		0.035
Yes	1.87 (0.01)		1.85 (0.02)	
No	1.91 (0.02)		1.90 (0.02)	
COVID-19 symptom severity		0.001		0.097
Asymptomatic/mild	1.84 (0.02)		1.85 (0.02)	
Moderate	1.88 (0.02)		1.88 (0.02)	
Severe	1.94 (0.02)		1.93 (0.03)	
Very severe	1.98 (0.04)		1.89 (0.04)	

COVID-19 = Coronavirus disease 2019; SE = Standard error; NH = non-Hispanic.
a. We conducted t-tests to test the null hypothesis that the means of subgroups are equal at baseline or follow-up.

−0.71, −0.56). Higher medical mistrust was also associated with lower COVID-19 vaccination uptake. In the unadjusted model, a 1-point higher MMI score was associated with a 0.81 times lower risk of receiving a COVID-19 vaccine after 1-year follow-up (95 % CI: 0.78, 0.84). In the adjusted model, the magnitude of the association was similar (aRR: 0.83; 95 % CI: 0.80, 0.86).

We conducted an additional analysis on vaccination uptake for respondents who were unvaccinated at the baseline survey (Table 4). For respondents who were surveyed when baseline vaccines were unavailable, a 1-point higher MMI score was associated with a 0.93 times lower risk of receiving a COVID-19 vaccine (95 % CI: 0.87, 0.99), which was attenuated after adjustment for covariates (aRR: 0.94; 95 % CI: 0.89, 1.00). For respondents who were not vaccinated at the baseline survey when COVID-19 vaccines were available, a 1-point higher MMI score was associated with a 0.55 times lower risk of receiving a COVID-19 vaccine (95 % CI: 0.44, 0.70), which remained similar after adjustment for covariates (aRR: 0.52; 95 % CI: 0.41, 0.67).

We also tested race and ethnicity as potential effect modifiers for associations of medical mistrust with vaccine attitudes and uptake, by examining interaction terms between MMI score and race and ethnicity (Supplementary Table S1). Race and ethnicity were statistically

Table 3
Associations of medical mistrust with positive COVID-19 vaccine attitudes and vaccination uptake, Michigan COVID-19 Recovery Surveillance Study, 2020–2023.

	Positive vaccine attitudes [a] (n = 3865)		Vaccination uptake [b] (n = 3741)	
	Unadjusted	Adjusted	Unadjusted	Adjusted
	Coef. (95 % CI)	Coef. (95 % CI)	RR (95 % CI)	RR (95 % CI)
Medical Mistrust Index (range: 1–4)	−0.71***	−0.64***	0.81***	0.83***
	(−0.78, −0.63)	(−0.71, −0.56)	(0.78, 0.84)	(0.80, 0.86)
Age (ref: ≥65)				
18–34		−0.49*** (−0.62, −0.35)		0.83*** (0.78, 0.88)
35–54		−0.57*** (−0.70, −0.44)		0.80*** (0.76, 0.84)
55–64		−0.30** (−0.45, −0.14)		0.90*** (0.85, 0.95)
Sex (ref: male)				
Female		0.14** (0.05, 0.22)		1.02 (0.98, 1.06)
Race and ethnicity (ref: NH White)				
Hispanic		0.41*** (0.23, 0.60)		1.10† (1.00, 1.22)
NH Black		0.28*** (0.12, 0.44)		1.00 (0.93, 1.08)
Another NH race and ethnicity		0.23** (0.09, 0.37)		1.05 (0.98, 1.13)
Marital status (ref: Not married/cohabiting)				
Married/cohabiting		−0.13* (−0.23, −0.03)		0.96 (0.92, 1.01)
Education (ref: college graduate)				
High school or less		−0.54*** (−0.66, −0.42)		0.77*** (0.72, 0.83)
Some college		−0.37*** (−0.47, −0.27)		0.88*** (0.84, 0.92)
Household income (ref: ≥$75,000)				
<$35,000		−0.15* (−0.27, −0.02)		0.93* (0.87, 1.00)
$35,000–74,999		−0.13* (−0.24, −0.03)		0.95† (0.91, 1.00)
Health insurance (ref: private insurance)				
Medicare/Medicaid/ others		−0.24*** (−0.36, −0.13)		0.95 (0.86, 1.06)
None		−0.14 (−0.30, 0.03)		0.85*** (0.80, 0.90)
Pre-existing diagnosed comorbidities				
Yes		0.11* (0.02, 0.20)		1.08*** (1.04, 1.13)
COVID-19 symptom severity (ref: asymptomatic/mild)				
Moderate		0.12* (0.02, 0.22)		1.01 (0.96, 1.05)
Severe		0.09 (−0.03, 0.21)		1.00 (0.95, 1.06)
Very severe		0.14 (−0.03, 0.31)		0.98 (0.91, 1.07)

COVID-19 = Coronavirus disease 2019; Coef. = Coefficient; RR = Risk Ratio; CI = Confidence Interval; NH = non-Hispanic.
a. Vaccine attitudes variable was determined by calculating the average of two items to get a continuous score ranging from 1 to 5, with a higher score indicating a higher level of positive vaccine attitudes.
b. Vaccination uptake variable was determined at follow-up by asking respondents if they had ever had the COVID-19 vaccine (yes or no).
Notes: Coefficients for positive vaccine attitudes are from linear regression models. Adjusted models include survey mode and pandemic phase.
† $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

significant effect modifiers for the association between medical mistrust and vaccine attitudes ($p = 0.027$) or vaccine uptake ($p = 0.004$). The stratified analysis showed that the association between medical mistrust and vaccine attitudes was the most pronounced among another NH race and ethnicity individuals (coefficient = −0.71; 95 % CI: −0.91, −0.51), followed by NH White individuals (coefficient = −0.67; 95 % CI: −0.76, −0.59) (Table 5). Moreover, the magnitude and statistical significance of the association between medical mistrust and vaccination uptake were the most pronounced among NH White individuals (aRR: 0.80; 95 % CI: 0.77, 0.83), followed by another NH race and ethnicity individuals (aRR: 0.88; 95 % CI: 0.79, 0.98).

In the sensitivity analysis, we examined associations between the MMI and two binary variables of vaccine attitudes that asked about the importance of getting vaccination among people who had not had COVID-19 and people who had had COVID-19 (Supplementary Table S2). In the adjusted model, a 1-point higher score in the MMI was associated with a 0.69 times lower prevalence of respondents who reported vaccination was very important or absolutely essential for people who have not had COVID-19 (95 % CI: 0.66, 0.73), while the MMI was associated with a 0.66 times lower prevalence of respondents who reported vaccination was very important or absolutely essential for people who have had COVID-19 (95 % CI: 0.62, 0.70).

4. Discussion

In this paper we examined cross-sectional associations between medical mistrust and COVID-19 vaccine attitudes and prospective associations between medical mistrust and vaccine uptake using a population-based sample of adults in Michigan with PCR-confirmed SARS-CoV-2. We found among those who had COVID-19 infection in Michigan, greater medical mistrust was associated with worse attitudes toward COVID-19 vaccine at baseline and a lower risk of COVID-19 vaccine uptake at follow-up, supporting our first and second hypotheses. We also confirmed the prospective association between medical mistrust and vaccination uptake by restricting the analytic sample to respondents who were not vaccinated at the baseline survey.

These findings are consistent with previous studies that documented an association between higher levels of medical mistrust and COVID-19 vaccine hesitancy among U.S. adults [2,7,8,24]. For example, using a

Table 4
Associations of medical mistrust with vaccination uptake, respondents who were unvaccinated at baseline when vaccines were unavailable and respondents who were unvaccinated at baseline when vaccines were available, Michigan COVID-19 Recovery Surveillance Study, 2020–2023.

	Vaccination uptake			
	Baseline vaccines unavailable (n = 943)		Baseline vaccines available, but unvaccinated at baseline (n = 800)	
	Unadjusted RR (95 % CI)	Adjusted RR (95 % CI)	Unadjusted RR (95 % CI)	Adjusted RR (95 % CI)
Medical Mistrust Index (range: 1–4)	0.93*	0.94†	0.55***	0.52***
	(0.87, 0.99)	(0.89, 1.00)	(0.44, 0.70)	(0.41, 0.67)
Age (ref: ≥65)				
18–34		0.86**		3.13**
		(0.77, 0.96)		(1.50, 6.52)
35–54		0.86**		1.84
		(0.78, 0.94)		(0.88, 3.85)
55–64		0.95		2.21*
		(0.86, 1.03)		(1.02, 4.80)
Sex (ref: male)				
Female		1.02		1.06
		(0.95, 1.10)		(0.77, 1.47)
Race and ethnicity (ref: NH White)				
Hispanic		1.07		1.14
		(0.92, 1.25)		(0.56, 2.31)
NH Black		1.00		1.19
		(0.90, 1.10)		(0.73, 1.92)
Another NH race and ethnicity		1.02		0.96
		(0.91, 1.14)		(0.55, 1.69)
Marital status (ref: Not married/cohabiting)				
Married/cohabiting		0.89**		1.33
		(0.82, 0.96)		(0.93, 1.90)
Education (ref: college graduate)				
High school or less		0.81***		0.49**
		(0.72, 0.91)		(0.32, 0.76)
Some college		0.82***		0.83
		(0.75, 0.89)		(0.58, 1.19)
Household income (ref: ≥$75,000)				
<$35,000		0.88*		0.92
		(0.78, 0.98)		(0.60, 1.42)
$35,000–74,999		1.01		0.69†
		(0.92, 1.09)		(0.46, 1.03)
Health insurance (ref: private insurance)				
Medicare/Medicaid/ others		0.86		0.83
		(0.71, 1.05)		(0.47, 1.47)
None		1.00		0.67*
		(0.91, 1.11)		(0.45, 1.00)
Pre-existing diagnosed comorbidities				
Yes		1.03		1.09
		(0.95, 1.11)		(0.79, 1.51)
COVID-19 symptom severity (ref: asymptomatic/mild)				
Moderate		0.95		1.56*
		(0.86, 1.04)		(1.03, 2.35)
Severe		1.04		1.66*
		(0.95, 1.13)		(1.05, 2.61)
Very severe		0.97		2.07**
		(0.86, 1.08)		(1.20, 3.56)

COVID-19 = Coronavirus disease 2019; RR = Risk Ratio; CI = Confidence Interval; NH = non-Hispanic.
Notes: Adjusted models include survey mode.
† p < 0.1 * p < 0.05, ** p < 0.01, *** p < 0.001.

Table 5
Stratified analyses by race and ethnicity: Associations of medical mistrust with positive COVID-19 vaccine attitudes and vaccination uptake, Michigan COVID-19 Recovery Surveillance Study, 2020–2023.

Stratified analysis	**Positive vaccine attitudes** [a] (n = 3865)			
	Hispanic (*n* = 221) Coef. (95 % CI)	NH White (*n* = 2936) Coef. (95 % CI)	NH Black (*n* = 303) Coef. (95 % CI)	Another NH race and ethnicity (*n* = 405) Coef. (95 % CI)
Medical Mistrust Index	−0.37**	−0.67***	−0.33**	−0.71***
	(−0.65, −0.09)	(−0.76, −0.59)	(−0.58, −0.08)	(−0.91, −0.51)
	Vaccination uptake [b] (n = 3741)			
Stratified analysis	Hispanic (*n* = 184) aRR (95 % CI)	NH White (*n* = 2807) aRR (95 % CI)	NH Black (*n* = 369) aRR (95 % CI)	Another NH race and ethnicity (*n* = 381) aRR (95 % CI)
Medical Mistrust Index	0.95	0.80***	0.99	0.88*
	(0.80, 1.11)	(0.77, 0.83)	(0.89, 1.10)	(0.79, 0.98)

COVID-19 = Coronavirus disease 2019; Coef. = Coefficient; RR = Risk Ratio; CI = Confidence Interval; NH = non-Hispanic.
a. Vaccine attitudes variable was determined by calculating the average of two items to get a continuous score ranging from 1 to 5, with a higher score indicating a higher level of positive vaccine attitudes.
b. Vaccination uptake variable was determined at follow-up by asking respondents if they had ever had the COVID-19 vaccine (yes or no).
Notes: Coefficients for positive vaccine attitudes are from linear regression models. Covariates are age, sex, marital status, education, household income, health insurance, pre-existing diagnosed comorbidities, COVID-19 symptoms severity, survey mode and pandemic phase.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

cross-sectional, nationally representative sample of U.S. adults collected between April and May 2021, Allen and colleagues found that medical mistrust was associated with a 16 % lower odds of COVID-19 vaccination [2]. Lamuda and colleagues also documented that individuals who had high medical mistrust were 24 percentage points less likely to plan to get COVID-19 vaccine compared to individuals with high medical

trust among a cross-sectional nationally representative household survey collected in October 2020 [7]. As previous studies used cross-sectional designs [2,7,8,24] or non-random convenience sampling [8,24], we contribute to the literature by documenting the evidence for medical mistrust and both COVID-19 vaccine attitudes and uptake using a population-based cohort study.

Additionally, we found that race and ethnicity were statistically significant effect modifiers of the association between medical mistrust and COVID-19 vaccine attitudes and vaccination uptake. The stratified analysis suggests that these associations were more pronounced among another NH race and ethnicity and NH White individuals compared to Hispanic or NH Black individuals. The underlying reasons for these differential associations are not clear given that Black Americans have historically reported a higher level of medical mistrust and negative attitudes toward vaccination than other racial and ethnic groups [25,26]. Our results may be because other factors, including political leaning and trust in the scientific community or public health messaging, are also important drivers of COVID-19 vaccine hesitancy in addition to race and ethnicity [41,42]. For example, Tram and colleagues found that political partisanship was an important driver of COVID-19 vaccine hesitancy among White Americans but less so among Black Americans [41]. As the response to COVID-19 has been uniquely politicized, vaccine hesitancy may indicate a political stance or doubt about science-related populism [39]. Moreover, public health recommendations for COVID-19 have been evolving and inconsistent—such as social distancing and mask-mandatory policy— which may lead to mistrust in the scientific community [16–19,41]. Therefore, anti-COVID-19 vaccine attitudes and behaviors may be complex phenomenon and expression of diverse underlying perspectives, including political stance, mistrust in governments, and reduced credibility in science and science-based policy in general [41,43].

Our findings suggest that medical professionals, healthcare workers, and government officers could see improvements in vaccine uptake if there are efforts to reduce medical mistrust and improve trust in other areas of public health. Public health authorities and governments need to acknowledge the problems and develop initiatives to improve communication and build public trust in healthcare systems, public health institutions, and governments. Communication strategies to rebuild public trust should be sensitive to the concerns of different audiences [2]. For example, there is a need to improve communication and credibility in public health messaging, recommendations, and policies for overall populations, while efforts should start from addressing long-standing racism for racial and ethnic minoritized populations [2,44]. Additionally, community engagement and partnerships should be promoted in improving both medical mistrust and vaccine attitudes or behaviors because the involvement of trusted community groups in public health campaigns was found to be important in building public trust [45].

While our study presents novel findings on the association of medical mistrust with COVID-19 vaccine attitudes and uptake in the U.S., there are limitations to highlight. First, our probability-based sample includes only individuals who received a positive PCR test for SARS-CoV-2, were recorded in the MDSS with valid contact and geographic information, and were alive when the survey was conducted. The sample may suffer from selection bias because individuals who had COVID-19 but did not get a PCR test or were not recorded in the MDSS may have different levels of medical mistrust or vaccine attitudes and behaviors. Moreover, the sample does not include individuals who have not been infected with COVID-19, which may limit generalizability of our findings. Second, we used self-reported assessments of COVID-19 vaccination uptake and symptoms of COVID-19 illness. In particular, it is possible that self-reported vaccination uptake was overestimated [46], which may lead to an underestimated association between medical mistrust and COVID-19 vaccination behavior. Finally, although we adjusted for a range of covariates, the possibility of unmeasured confounding exists. For example, ones' social network, political partisanship, or trust in the scientific community may affect both medical mistrust and individuals' vaccine attitudes and uptake, but we were not able to include them as they were not available in our survey tool [17,41,43,47]. Despite these limitations, the main strength of our study is studying differential relationships between medical mistrust and vaccine outcomes by race and ethnicity using MI CReSS data, which is unique, timely, and state-representative population-based cohort data on Michigan adults with COVID-19.

5. Conclusions

This study identified associations of medical mistrust with COVID-19 vaccine attitudes and behaviors using a population-based cohort study. Medical mistrust was associated with less positive attitudes toward COVID-19 vaccine and lower likelihood of getting a COVID-19 vaccine uptake among Michigan adults with SARS-CoV-2 infection. We also found that these associations were more pronounced among another NH race and ethnicity and NH White individuals compared to Hispanic or NH Black individuals. As medical mistrust is associated with negative health attitudes and behaviors, future studies should identify the reasons for mistrust in healthcare providers and healthcare systems for different racial and ethnic groups and provide strategies to reduce medical mistrust and promote preventive health behaviors among U.S. populations. This will improve our responsiveness and resilience for future public health emergencies, beyond the COVID-19 pandemic.

Research Ethical Approval

Ethical approval for this analysis was considered exempt by the University of Michigan Institutional Review Board (HUM00195694) due to the use of a de-identified secondary dataset. Informed consent was obtained from all individual participants included in this study. All research was completed in accordance with the Declaration of Helsinki.

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Disclaimer

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Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jvacx.2024.100600.

Data availability

Although the dataset used in this study is not currently available to others, we are in the process of making a de-identified dataset and data dictionary publicly available.

References

[1] Li Y, Tenchov R, Smoot J, Liu C, Watkins S, Zhou Q. A comprehensive review of the global efforts on COVID-19 vaccine development. ACS Cent Sci 2021;7(4):512–33. https://doi.org/10.1021/acscentsci.1c00120.
[2] Allen JD, Fu Q, Shrestha S, et al. Medical mistrust, discrimination, and COVID-19 vaccine behaviors among a national sample U.S. adults. SSM - Popul Health 2022; 20:101278. https://doi.org/10.1016/j.ssmph.2022.101278.
[3] U.S. Food & Drug Administration. FDA approves first COVID-19 vaccine. Accessed August 21, https://www.fda.gov/news-events/press-announcements/fda-approves-first-covid-19-vaccine; 2023.
[4] U.S. Centers for Disease Control and Prevention. COVID-19 Vaccinations in the United States. Accessed August 20, https://covid.cdc.gov/covid-data-tracker/#vaccinations; 2023.
[5] Jin Zhang J, Dong X, Hui Liu G, Dong Gao Y. Risk and protective factors for COVID-19 morbidity, severity, and mortality. Clin Rev Allergy Immunol 2022;64(1): 90–107. https://doi.org/10.1007/s12016-022-08921-5.
[6] Antonelli M, Penfold RS, Merino J, et al. Risk factors and disease profile of post-vaccination SARS-CoV-2 infection in UK users of the COVID symptom study app: a prospective, community-based, nested, case-control study. Lancet Infect Dis 2022; 22(1):43–55. https://doi.org/10.1016/S1473-3099(21)00460-6.
[7] Lamuda PA, Azar A, Taylor BG, Balawajder EF, Pollack HA, Schneider JA. Latent class analysis of medical mistrust and COVID-19 vaccine hesitancy among adults in the United States just prior to FDA emergency use authorization. Vaccine 2023;41 (16):2671–9. https://doi.org/10.1016/j.vaccine.2023.03.016.
[8] Bogart LM, Dong L, Gandhi P, et al. COVID-19 vaccine intentions and mistrust in a National Sample of black Americans. J Natl Med Assoc 2022;113(6):599–611. https://doi.org/10.1016/j.jnma.2021.05.011.
[9] Ho IK, Sheldon TA, Botelho E. Medical mistrust among women with intersecting marginalized identities: a scoping review. Ethn Health 2022;27(8):1733–51. https://doi.org/10.1080/13557858.2021.1990220.
[10] Thompson HS, Valdimarsdottir HB, Winkel G, Jandorf L, Redd W. The group-based medical mistrust scale: psychometric properties and association with breast cancer screening. Prev Med 2004;38(2):209–18. https://doi.org/10.1016/j.ypmed.2003.09.041.
[11] Benkert R, Cuevas A, Thompson HS, Dove-Medows E, Knuckles D. Ubiquitous yet unclear: a systematic review of medical mistrust. Behav Med 2019;45(2):86–101. https://doi.org/10.1080/08964289.2019.1588220.
[12] Jamison AM, Quinn SC, Freimuth VS. "You don't trust a government vaccine": narratives of institutional trust and influenza vaccination among African American and white adults. Soc Sci Med 2019;221:87–94. https://doi.org/10.1016/j.socscimed.2018.12.020.
[13] Ash MJ, Berkley-Patton J, Christensen K, et al. Predictors of medical mistrust among urban youth of color during the COVID-19 pandemic. Transl Behav Med 2021;11(8):1626–34. https://doi.org/10.1093/tbm/ibab061.
[14] Alang S, McAlpine DD, Hardeman R. Police brutality and mistrust in medical institutions. J Racial Ethn Health Disparities 2020;7(4):760–8. https://doi.org/10.1007/s40615-020-00706-w.
[15] Williamson LD, Smith MA, Bigman CA. Does discrimination breed mistrust? Examining the role of mediated and non-mediated discrimination experiences in medical mistrust. J Health Commun 2019;24(10):791–9. https://doi.org/10.1080/10810730.2019.1669742.
[16] Suhay E, Soni A, Persico C, Marcotte DE. Americans' Trust in government and health behaviors during the COVID-19 pandemic. RSF Russell Sage Found J Soc Sci 2022;8(8):221–44. https://doi.org/10.7758/RSF.2022.8.8.10.
[17] Latkin CA, Dayton L, Yi G, Konstantopoulos A, Boodram B. Trust in a COVID-19 vaccine in the U.S.: a social-ecological perspective. Soc Sci Med 2021;270:113684. https://doi.org/10.1016/j.socscimed.2021.113684.
[18] Bogart LM, Ojikutu BO, Tyagi K, et al. COVID-19 related medical mistrust, health impacts, and potential vaccine hesitancy among black Americans living with HIV. JAIDS J Acquir Immune Defic Syndr 2021;86(2):200–7. https://doi.org/10.1097/QAI.0000000000002570.
[19] Gorman JM, Gorman SE, Sandy W, Gregorian N, Scales DA. Implications of COVID-19 vaccine hesitancy: results of online bulletin board interviews. Front Public Health 2022;9:757283. https://doi.org/10.3389/fpubh.2021.757283.
[20] Dale SK, Bogart LM, Wagner GJ, Galvan FH, Klein DJ. Medical mistrust is related to lower longitudinal medication adherence among African-American males with HIV. J Health Psychol 2016;21(7):1311–21. https://doi.org/10.1177/1359105314551950.
[21] Adams LB, Richmond J, Corbie-Smith G, Powell W. Medical mistrust and colorectal Cancer screening among African Americans. J Community Health 2017;42(5): 1044–61. https://doi.org/10.1007/s10900-017-0339-2.
[22] Earnshaw VA, Bogart LM, Klompas M, Katz IT. Medical mistrust in the context of Ebola: implications for intended care-seeking and quarantine policy support in the United States. J Health Psychol 2019;24(2):219–28. https://doi.org/10.1177/1359105316650507.
[23] Oliver JE, Wood T. Medical conspiracy theories and health behaviors in the United States. JAMA Intern Med 2014;174(5):817. https://doi.org/10.1001/jamainternmed.2014.190.
[24] Nah S, Williamson LD, Kahlor LA, Atkinson L, Upshaw SJ, Ntang-Beb JL. The roles of social media use and medical mistrust in black Americans' COVID-19 vaccine hesitancy: the RISP model perspective. Health Commun Published online August 2023;8:1–14. https://doi.org/10.1080/10410236.2023.2244169.
[25] Thompson HS, Manning M, Mitchell J, et al. Factors Associated With Racial/Ethnic Group–Based Medical Mistrust and Perspectives on COVID-19 Vaccine Trial Participation and Vaccine Uptake in the US. JAMA Netw Open 2021;4(5): e2111629. https://doi.org/10.1001/jamanetworkopen.2021.11629.
[26] Morgan KM, Maglalang DD, Monnig MA, Ahluwalia JS, Avila JC, Sokolovsky AW. Medical mistrust, perceived discrimination, and race: a longitudinal analysis of predictors of COVID-19 vaccine hesitancy in US adults. J Racial Ethn Health Disparities 2023;10(4):1846–55. https://doi.org/10.1007/s40615-022-01368-6.
[27] Michigan department of health and human services. Regional trauma networks 2022. Accessed May 10, 2023, https://www.michigan.gov/mdhhs/doing-business/trauma/regional.
[28] Brown M, Goodman A, Peters A, et al. COVID-19 survey in five National Longitudinal Studies: Waves 1, 2 and 3 user guide (version 3). Lond UCL Cent Longitud Stud MRC Unit Lifelong Health Ageing; 2021. Published online.
[29] Cox B. The weighted sequential hot deck imputation procedure. Am Stat Assoc Published online 1980:721–6.
[30] Mayer B. Hot deck propensity score imputation for missing values. Sci J Med Clin Trials Published online 2013. https://doi.org/10.7237/sjmct/248.
[31] American Association for Public Opinion Research. *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys*. https://aapor.org/wp-content/uploads/2022/11/Standard-Definitions20169theditionfinal.pdf; 2016.
[32] Eaton LA, Driffin DD, Kegler C, et al. The role of stigma and medical mistrust in the routine health care engagement of black men who have sex with men. Am J Public Health 2015;105(2):e75–82. https://doi.org/10.2105/AJPH.2014.302322.
[33] LaVeist TA, Isaac LA, Williams KP. Mistrust of health care organizations is associated with underutilization of health services. Health Serv Res 2009;44(6): 2093–105. https://doi.org/10.1111/j.1475-6773.2009.01017.x.
[34] Wiginton JM, Eaton LA, Watson RJ, Maksut JL, Earnshaw VA, Berman M. Sex-positivity, medical mistrust, and PrEP conspiracy beliefs among HIV-negative cisgender black sexual minority men in Atlanta. Georgia Arch Sex Behav 2022;51 (5):2571–81. https://doi.org/10.1007/s10508-021-02174-7.
[35] Head KJ, Kasting ML, Sturm LA, Hartsock JA, Zimet GD. A National Survey Assessing SARS-CoV-2 vaccination intentions: implications for future public health communication efforts. Sci Commun 2020;42(5):698–723. https://doi.org/10.1177/1075547020960463.
[36] Wagner AL, Sheinfeld Gorin S, Boulton ML, Glover BA, Morenoff JD. Effect of vaccine effectiveness and safety on COVID-19 vaccine acceptance in Detroit, Michigan, July 2020. Hum Vaccin Immunother 2021;17(9):2940–5. https://doi.org/10.1080/21645515.2021.1917233.
[37] Zou G. A modified Poisson regression approach to prospective studies with binary data. Am J Epidemiol 2004;159(7):702–6. https://doi.org/10.1093/aje/kwh090.
[38] Knol MJ, Le Cessie S, Algra A, Vandenbroucke JP, Groenwold RHH. Overestimation of risk ratios by odds ratios in trials and cohort studies: alternatives to logistic regression. CMAJ Can Med Assoc J J Assoc Medicale Can 2012;184(8):895–9. https://doi.org/10.1503/cmaj.101715.
[39] McNutt LA, Wu C, Xue X, Hafner JP. Estimating the relative risk in cohort studies and clinical trials of common outcomes. Am J Epidemiol 2003;157(10):940–3. https://doi.org/10.1093/aje/kwg074.
[40] Szklo M, Nieto FJ. Epidemiology: Beyond the basics. 4th ed. Jones & Bartlett Learning; 2018.
[41] Tram KH, Saeed S, Bradley C, et al. Deliberation, dissent, and distrust: understanding distinct drivers of coronavirus disease 2019 vaccine hesitancy in the United States. Clin Infect Dis 2022;74(8):1429–41. https://doi.org/10.1093/cid/ciab633.
[42] Bagasra AB, Doan S, Allen CT. Racial differences in institutional trust and COVID-19 vaccine hesitancy and refusal. BMC Public Health 2021;21(1):2104. https://doi.org/10.1186/s12889-021-12195-5.

[43] Kreps SE, Kriner DL. Model uncertainty, political contestation, and public trust in science: evidence from the COVID-19 pandemic. Sci Adv 2020;6(43):eabd4563. https://doi.org/10.1126/sciadv.abd4563.
[44] Shen AK, Hughes Iv R, DeWald E, Rosenbaum S, Pisani A, Orenstein W. Ensuring equitable access to COVID-19 vaccines in the US: current system challenges and opportunities: analysis examines ensuring equitable access to COVID-19 vaccines. Health Aff (Millwood) 2021;40(1):62–9. https://doi.org/10.1377/hlthaff.2020.01554.
[45] Hyland-Wood B, Gardner J, Leask J, Ecker UKH. Toward effective government communication strategies in the era of COVID-19. Humanit Soc Sci Commun 2021;8(1):30. https://doi.org/10.1057/s41599-020-00701-w.
[46] Jiménez-García R, Hernandez-Barrera V, Rodríguez-Rieiro C, et al. Comparison of self-report influenza vaccination coverage with data from a population based computerized vaccination registry and factors associated with discordance. Vaccine 2014;32(35):4386–92. https://doi.org/10.1016/j.vaccine.2014.06.074.
[47] Johnson LM, Green HD, Koch B, Harding R, Stockman JK, Wagner KD. Correlates of medical mistrust among minority women at risk for HIV and their networks. Health Educ Behav 2021;48(6):860–72. https://doi.org/10.1177/1090198120986783.