Title: Time trends and factors related to COVID-19 vaccine hesitancy from January-May 2021 among US adults: Findings from a large-scale national survey

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Abstract

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Objective: To understand COVID-19 vaccine hesitancy.

Methods: January 6 through May 31, 2021, 5,121,436 US adults completed an online COVID-19 survey. Weighted data was used to evaluate change in vaccine intent and correlates of May vaccine hesitancy.

Results: COVID-19 vaccine hesitancy decreased by one-third from January to May, with relatively large decreases among participants with Black, Pacific Islander or Hispanic race/ethnicity and ≤high school education. In May, independent hesitancy risk factors included

younger age, non-Asian race, having a PhD or ≤high school education, living in a rural county, living in a county with higher 2020 Trump support, lack of worry about COVID-19, working outside the home, never intentionally avoiding contact with others, and no past-year flu vaccine. Differences in hesitancy by race/ethnicity varied by age. Almost half of vaccine hesitant respondents reported fear of side effects and not trusting the COVID-19 vaccine; over one-third reported not trusting the government, not needing the vaccine, and waiting to see if safe. Reasons differed by degree of vaccine intent and by race/ethnicity.

Conclusion: COVID-19 vaccine hesitancy varied by demographics, geography, beliefs, and behaviors.

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Introduction

The first COVID-19 vaccination was administered in the US on December 14, 2020[1], 3 days following the Federal Drug Administration (FDA)'s first Emergency Use Authorization of a COVID-19 vaccine[2]. By March 2021, 3 COVID-19 vaccines had been authorized in the US[3], and the president announced procurement of enough doses for every adult to be vaccinated by the end of May 2021[4]. By May 2021, vaccine eligibility was expanded to everyone covered under the FDA authorizations (initially ≥16 years old, expanded to ≥12 years old on May 10[5]), and efforts to increase vaccine access to underserved populations (e.g., rural communities, homebound individuals) were underway[6,7]. However, vaccine hesitancy (i.e., a refusal or reluctance to be vaccinated) slowed vaccination uptake, potentially prolonging the pandemic[3].

A longitudinal study of US adults (N=7,420) by Daly et al. reported an overall decrease in COVID-19 vaccine hesitancy from 46.0% in October 2020 to 35.2% in March 2021, with larger decreases in Black and Hispanic versus White race/ethnicity[8], thereby reducing the racial disparity in COVID-19 vaccine hesitancy. However, if and how vaccine hesitancy has changed during the first five months of the US COVID-19 vaccine rollout, overall and among subgroups, is largely unstudied.

Among a massive sample of US adults, we report COVID-19 vaccine uptake and intent by month, January-May, 2021, and evaluate time trends by race/ethnicity, education, US region and political environment. For May, the prevalence of COVID-19 vaccine hesitancy is reported by demographics, geographic factors, political/COVID-19 environment, health status, beliefs

and behaviors, and associations between each potential risk factor with hesitancy is estimated with and without adjustment for potential confounders. Lastly, we identify the most common reasons for COVID-19 vaccine hesitancy by level of COVID-19 vaccine intent and race/ethnicity.

Methods

This analysis used the COVID Trends and Impact Survey (CTIS)[9], created by the Delphi Group at Carnegie Mellon University (CMU) and conducted in collaboration with Facebook Data for Good. Survey sampling is described in the **eMethods**. Survey weights accounting for the sampling design and non-response are post-stratified to match the US general population by age, gender, and state[10]. The study design ensures CMU researchers do not see usernames or profile information and Facebook does not see survey microdata.

Study sample. The analysis sample includes 5,121,436 survey responses from participants who completed the survey at least once January 6 to May 31, 2021; study flow for each month is provided in the **eTable 1**. Data was aggregated by month to evaluate time trends in COVID-19 vaccine receipt and intent. To inform policy and public health efforts we used the most recent month's data (May 2021) to assess how demographics, geographic factors, political/COVID-19 environment, health status, beliefs and behaviors relate to COVID-19 vaccine hesitancy.

Measures.

Participants were asked if they had received the COVID-19 vaccine, and if not, "If a vaccine to prevent COVID-19 (coronavirus) were offered to you today, would you choose to get vaccinated." Participants were categorized as vaccine hesitant if they answered that they probably or definitely would not choose to get vaccinated (versus probably or definitely would

choose to get vaccinated or were vaccinated). Those who had already received the vaccine were coded as not hesitant in order to reduce bias from differential access to a COVID-19 vaccine among subgroups over the time studied.

The survey questions and response sets utilized in this report to measure demographics, geographic factors, political/COVID-19 environment, health status, beliefs and behaviors are provided in the **eAppendix**. The categorization of survey variables and creation of derived variables (US Census region, state governor political party, county Trump to Biden vote share in the 2020 presidential election, and county COVID-19 death rate) are described in the **eMethods**.

Statistical analysis. Weighted percentages of COVID-19 vaccine receipt and intent were calculated by month for the full sample and by categories of race/ethnicity, education, US Census region, and county Trump to Biden vote share. Percentages were plotted by month and first-last month differences were calculated. The race/ethnicity comparison was limited to adults 18-34 years due to an interaction between race/ethnicity and age in relation to COVID-19 vaccine hesitancy (reported below with May data), and because hesitancy is higher among younger versus older adults.

Among the May sample, weighted percentages of COVID-19 vaccine hesitancy were calculated by all covariates (demographics, geographic factors, political/COVID-19 environment, health status, beliefs and behaviors) and a series of weighted Poisson regression models were used to estimate the risk ratios (RR) for vaccine hesitancy for each variable. Adjusted risk ratios (aRR) were estimated from a single weighted Poisson regression model including all covariates and an

interaction term for age group and race/ethnicity. In a second multivariable model, a simplified health conditions variable (none, at least one; described in **eMethods**) was replaced with the version specifying specific conditions to estimate aRR by condition.

Finally, weighted percentages for reasons for hesitancy were calculated by level of COVID-19 vaccine intent, and by race/ethnicity among hesitant respondents. For all parameters, 95% confidence intervals (CI) were calculated using robust standard errors.[8] Analyses were conducted in R (Version 4.0.2, R Core Team, Vienna, Austria).

Results

Participant characteristics. May participants (N= 529,658) had a median age range of 55-64 years, 45.0% identified as male, 52.6% female, 1.1% nonbinary, and 1.4% self-described gender; 16.7% were Hispanic, 68.7 % White, 6.5% Black, 3.6% Asian, 0.9% Native American, 0.2% Pacific Islander, and 3.4% were multi-racial; 22.5% had ≤high school education; 41.2% a four-year college degree or higher. Over half (55.7%) worked for pay; 43.2% worked outside the home. Demographics were similar in January through April (data not shown).

COVID-19 vaccine receipt and intent over time. Hesitancy decreased each month, with a one-third decrease from 25.7% (95%CI 25.6-25.8) in January to 17.1% (95% CI, 17.0-17.2) in May, 2021 (**eFigure 1**). There was a bigger decrease in the response "probably not" (-7.0 percentage points (%) [95% CI -7.1, -6.9]) versus "definitely not" (-1.6 % [95% CI -1.7, -1.4]) (**eTable 2**).

Disparities in COVID-19 vaccine hesitancy over time. Per **Figure 1**, from January to May the gap in percent hesitant between race/ethnicity groups among younger adults (panel A) and education levels among all respondents (panel B) decreased, with the biggest decreases among

two of the three most hesitant race/ethnicity groups (e.g., Black and Pacific Islanders but not Native American) and the two most hesitant education groups (≤high school and some college education) in January. There was not a decrease in hesitancy among those with a professional degree or PhD. Changes in percent hesitant over time were fairly similar across US Census regions (panel C); however, there was less of a decrease in the Midwest and Mountain regions versus the South, Pacific and Northeast. The gap in percent hesitant by county Trump vote share increased slightly from January to May, with the highest quartile, which was the most hesitant group, having the smallest decrease (panel D). Supporting data is provided in **eTable 3**.

Factors related to COVID-19 vaccine hesitancy. Hesitancy in May, 2021 is reported by participant demographics and geographic factors in **Table 1.** Although hesitancy was lower in females versus males (RR=0.79, 95% CI 0.78, 0.81), with adjustment for covariates (i.e., variables reported in **Tables 1** and **2**), female versus male gender was associated with higher hesitancy (aRR=1.12, 95%CI 1.10-1.14). In contrast, non-binary adults had similar hesitancy to males (RR=1.10, 95%CI, 0.97-1.22; aRR=0.99, 95%CI 0.88-1.10).

In general, younger age and non-Asian race (particularly Multi-racial and Native American), were related to greater hesitancy. However, an interaction was observed between age and race/ethnicity categories (**Figure 2**). Differences in hesitancy by age (e.g., 18-24 year-olds versus 65-74 year-olds) were more pronounced in Blacks (RR=7.23 [95%CI, 5.89-8.57]) and less pronounced in Asians (RR=2.39 [95%CI 1.01-3.76]; although hesitancy <5% in all Asian age groups) compared to Whites (RR=2.94 [95%CI 2.79-3.09]). Differences in hesitancy by race/ethnicity were more pronounced in younger adults and adults ≥75 years. Furthermore, for some comparisons, the direction of the difference in hesitancy by race/ethnicity differed by

age. For example, for Blacks versus Whites the RR of hesitancy was 1.28 (95%CI, 1.09-1.47) in 18-24 year olds, and 0.52 (95%CI 0.46-0.59) in 64-75 year olds. RRs for age groups stratified by race/ethnicity groups and for race/ethnicity groups stratified by age groups, with and without adjustment for all covariates, are provided in **eTable 4** and **5**. In general, age and race/ethnicity differences were attenuated in the full multivariable model, but still present.

The association between hesitancy and education level followed a U-shaped curve with the lowest hesitancy among those with a master's degree (RR=0.75 [95% CI 0.72-0.78] and the highest hesitancy among those with a PhD (RR=2.16 [95%CI 2.05-2.28]) or ≤high school education(RR=1.88 [95%CI 1.83-1.93]) versus a bachelor's degree. Additional demographic risk factors for hesitancy included working outside the home (RR=2.48 [95%CI 2.39-2.57]) or not working for pay (RR=1.49 [95% CI: 1.43-1.54]) versus working at home, living in the South (RR=1.59 95%CI 1.55-1.64]), Midwest (RR=1.50 [95%CI 1.46-1.55]) or Mountain (RR=1.49 [95%CI 1.43-1.55]) versus the Pacific US region, and in a less urban county (e.g., RR=2.34 [95 CI, 2.27-2.41] for non-core versus large central metro). Associations were attenuated with adjustment, but remained (**Table 1**).

COVID-19 vaccine hesitancy is reported by indicators of political/COVID-19 environment, health status, beliefs and behaviors in **Table 2**. Risk factors for hesitancy were living in a state with Republican versus Democratic governor (RR= 1.33 [95%CI 1.31-1.36]), living in a county with a relatively higher Trump vote share (e.g., RR= 2.55 [95%CI 2.48-2.62] for highest versus lowest quartile), living in a county with a relatively lower April COVID-19 death rate (e.g. RR=0.70 [95%CI 0.68-0.73] for highest versus lowest quartile), history versus no history of a positive COVID-19 test (RR= 1.24 (95%CI 1.22-1.27]), not having versus having a high-risk health

condition (RR=1.41 [95%CI 1.39-1.43]), being less worried about self or immediate family becoming seriously ill from COVID-19 (e.g., RR=3.82 [3.74-3.91] for not worried at all versus worried), not having had versus having had a past-year flu vaccination (RR=5.06 [95%CI 4.94-5.18]), and not avoiding versus avoiding contact with others (e.g., RR=4.03 [95%CI 3.92-4.15] for none versus all of the time). Political affiliation of state governor was excluded from the multivariable model due to collinearity with county Trump vote share. The adjusted associations were attenuated but in the same direction, except for April 2021 COVID-19 death rate, which was not independently related to hesitancy.

COVID-19 vaccine hesitancy by specific health conditions is provided in **eTable 6.** Compared to participants reporting none of the queried high-risk health conditions, hesitancy was lower among participants with each health condition category except weakened or compromised immune system (RR 1.09, [95%CI 1.00-1.17]; aRR 1.41 [95%CI 1.32-1.51]). Most health condition associations were attenuated with adjustment.

Reasons for COVID-19 vaccine hesitancy. Reasons for hesitancy by level of intent (definitely not - probably yes) are reported in **Table 3**. Concern about side effects was chosen most frequently at 49.2% (95%CI, 48.8-49.7) among all hesitant participants, and similarly common among all levels of intent. In contrast, not trusting the COVID-19 vaccine and not trusting the government were the most frequent reasons for hesitancy among adults who would "definitely not" choose to be vaccinated today (59.6 % [95%CI, 59.0-60.1] and (52.3% [95%CI, 51.7-52.8], respectively), double the prevalence seen among the "probably not" group and almost quadruple the prevalence the "probably yes" group. Conversely, 52.2% (95%CI, 51.5- 53.0) of the "probably not" group said they would wait to see if it was safe, versus only 24.2% (95%CI, 23.7-24.8) of

the "definitely not" group. Compared to most reasons for vaccine hesitancy (i.e., the reasons listed above plus don't need, concerned about allergic reaction, don't know if it will work), not liking vaccines in general was chosen less frequently overall and among subgroups (<20% for all).

Reasons for COVID-19 vaccine hesitancy among hesitant US adults by race/ethnicity are provided in **eTable 7**. Concern about side effects, followed by not trusting the COVID-19 vaccine, were the most common concerns in all race/ethnicity groups, with the ranking reversed among Native Americans. Both were chosen by >40% of each group except Asians (39.3% [95%CI, 32.3, 46.3]) reported not trusting the COVID-19 vaccine). There was more racial/ethnicity variability in not trusting the government, which was highest among Multiracial adults (52.4% [95%CI, 50.2-54.5]), followed by Native Americans (44.0% [95%CI, 39.5-48.5]), Whites (43.7% [95%CI, 43.2-44.3], and Hispanics (41.0% [95%CI, 39.5-42.6]); in waiting to see if safe, which was highest in Hispanics (41.6%, 95%CI, 40.1-43.2), followed by Asians (40.8% [95%CI, 33.8-47.7]) and Blacks (40.7% [95%CI, 38.6-42.8]); and in do not need, which was highest in Multiracial (48.5% [95%CI, 46.3-50.7]), and Whites (42.1% [95%CI, 41.5-42.7]). Other reasons were chosen by <40% of hesitant adults in each race/ethnicity group.

Discussion

In this massive national survey of US adults, COVID-19 vaccine hesitancy decreased by one-third between January and May, 2021. A reduction in hesitancy was observed across all race/ethnicity groups, US regions and county political environments, and most education levels, though subgroups decreased at different rates, with large variations by race/ethnicity and

education groups. The reduction in hesitancy was primarily due to a decrease in the percentage responding they would "probably not" accept the vaccine, as there was minimal change in the percentage "definitely not". May 2021 data indicates that five months into the US COVID-19 vaccine rollout, a wide array of demographic, health, political and COVID-19 environment, beliefs and behavioral factors independently contribute to COVID-19 vaccine hesitancy: age, race/ethnicity, education, county urban classification, county political environment, extent of worry about a serious illness from COVID-19, extent intentionally avoiding contact with others, and past-year flu vaccine history chief among them. Additionally, important differences in reasons for COVID-19 vaccine hesitancy exist both by degree of vaccine intent and racial/ethnic groups.

Large decreases January-May in COVID-19 vaccine hesitancy among Blacks and Pacific Islanders led to these groups joining Asian and Hispanics as having a lower prevalence of hesitancy than Whites (all age groups combined) in May 2021. Racial/ethnic disparities have been observed in all aspects of the COVID-19 pandemic, with communities of color experiencing higher rates of SARS-CoV-2 infection (despite higher positivity rates indicative of lower access to testing[11]), COVID-19-related hospitalizations and mortality[11]. Racial/ethnic disparities in COVID-19 vaccine acceptance at the start of the vaccine rollout threatened to continue this trend. However, many groups from at-risk communities initiated targeted outreach campaigns[12]. Our finding that racial/ethnic disparities in COVID-19 hesitancy are decreasing suggests that messaging and outreach campaigns, combined with the opportunity to observe initial months of the rollout, have had positive effects. However, vaccination rates for Black and Hispanics continued to lag

223 through July 6, 2021[13], indicating that further efforts are needed to overcome barriers to access
224 for at-risk communities.

225 Most previous studies of COVID-19 vaccine hesitancy grouped Asians with American
226 Indian/Alaska Native, Native Hawaiian or other Pacific Islanders[8,14–16] However, our study,
227 which included 12,012 Asian participants, identified a remarkably lower prevalence of hesitancy
228 in this race/ethnicity group versus all others. This study also identified a race/ethnicity by age
229 interaction, yielding greater insight into the gross patterns of each factor, which had previously
230 been identified as key predictors of vaccine hesitancy[8,17]. For example, Blacks have relatively
231 high hesitancy among adults under 35 years while Whites have relatively high hesitancy among
232 adults 45 and older. In contrast, Native Americans and Multi-racial groups have particularly high
233 hesitancy, and Asians low hesitancy, across age groups.

234 The large decrease in COVID-19 vaccine hesitancy January-May among those with ≤high school
235 education went a long way towards narrowing the education gap; still this group has a relatively
236 high hesitancy prevalence. Those with professional degrees (e.g., JD, MBA) and PhDs were the
237 only education groups without a decrease in hesitancy, and by May, those with PhDs had the
238 highest hesitancy. To our knowledge, no other study has evaluated education with this level of
239 granularity, which was possible due to our unusually large sample size (>10,000 participants
240 with PhDs). Further investigation into hesitancy among those with a PhD is warranted.

241 January-May, there was a dose-response relationship between relative degree of local Trump
242 support in the 2020 presidential election and hesitancy, that grew slightly over time such that

by May those living in counties in the top quartile were 42% more at risk for being hesitant, highlighting the politicization of public health recommendations.

Adults who were "not worried at all" about themself or someone in their family becoming seriously ill from COVID-19 or who were not intentionally avoiding contact with others had much higher likelihood of COVID-19 vaccine hesitancy, as did those working outside the home. These latter two findings are particularly concerning as they indicate non-vaccinated (versus vaccinated) individuals may be more likely to engage in activities in which transmission can occur. While prior studies have linked history of past-year flu vaccine with hypothetical COVID-19 vaccine acceptance[14,16], our finding that those who had not received a flu vaccine were 224% more likely to be COVID-19 vaccine hesitant, after controlling for such a wide array of covariates, is striking.

Even prior to COVID-19, vaccine hesitancy was identified as one of the top ten global health threats by the World Health Organization (WHO)[18], This is because incomplete vaccine coverage increases the risk of disease for the entire population[19]. This study's county-level variables raise concerns, as high hesitancy areas could provide reservoirs for the Sars-CoV2 virus, even if national or state level vaccination rates increase.

Five months into the vaccine rollout, concern about side effects was common across levels of COVID-19 vaccine intent (49%) and among all racial groups (range: 42-58%). However, several reasons for COVID-19 vaccine hesitancy varied substantially by groups. For example, those who would definitely not versus probably not choose to be vaccinated were about twice as likely to say they don't trust the COVID-19 vaccine, don't trust the government, and/or don't need the

vaccine. Conversely, those who would probably not versus definitely not choose to be vaccinated were twice as likely to say that they are waiting to see if it will be safe and might take it later.

Limitations and Strengths. The study employs a novel sampling method with a soft ask and low response rate, the effect of which has not yet been fully studied. Survey weights adjust for non-response and coverage bias (i.e., matching the sample to gender, age, and geographic profile of the US). However, a comparison with the American Community Survey[20] shows our sample is more educated with higher vaccine uptake than general population, indicating that vaccine hesitancy is underestimated in this sample. Importantly, these characteristics have been consistent over time. CTIS results follow similar patterns observed by others,[8] and have been helpful for tracking trends, understanding associations and informing policies[21,22]. Demographic questions were asked at the end of the survey and had high unit non-response (e.g., 12% for age), which was treated as a category in analysis. Additionally, we assume the survey was completed in good faith. However, a review of fill-in responses for self-described gender suggest a small percentage of participants used that category to make political statements (e.g., trans-phobic comments). A sensitivity analysis eliminating respondents with self-described gender produced very similar results, though the increase in hesitancy for those age ≥75 years was attenuated (data not shown). A strength of our novel sampling method is that it yielded a large sample with diverse characteristics that enabled detailed subgroup analyses that identified new findings (e.g., non-binary and male genders had similar hesitancy prevalence). Additionally, while a previous study evaluated changes in hesitancy by age, sex, education, or income level, October 2020 through March 2021[8], estimated change by these categories had

large overlapping 95% CI, likely in part reflecting the much smaller sample size. Further, the racial and education categories (White, Hispanic, Black, Other; and Yes/No College Degree) collapsed groups in which we have identified meaningful differences.

In the US, the COVID-19 vaccination campaign has moved from an initial phase of scarcity, where equity concerns guided access, to a phase of abundance, where messaging and attention to barriers to access is essential to equity, and where increasing vaccine acceptance is critical to achieving herd immunity. Better understanding of reasons for hesitancy among subgroups, combined with up-to-date information on hesitancy by demographics, political environment, and individual health, behaviors and beliefs can help policy makers achieve these goals. Particularly hesitant subgroups include Native American and Multi-racial groups of all ages, and White and Blacks adults <35 years; adults with ≤high school education or PhDs; adults living in small metro, micropolitan or non-core urban (rural) counties or counties with high Trump support; adults with a history of a positive COVID-19 test; not worried about serious illness from COVID-19; working outside the home; never intentionally avoiding contact with others; and adults who did not receive a past-year flu vaccination. Among participants who said they probably would not get vaccinated today, messaging about safety and policy interventions to address downstream impacts of vaccine side effects, such as potential lost work, could be impactful. However, among those who definitely would not get vaccinated today, results suggest the existence of a subgroup with entrenched hesitancy and high distrust of government that may be hard to reach.

Table 1. COVID-19 vaccine hesitancy in May 2021 by demographics among US adults (N=529,658)

	Sample		COVID-19 vaccine hesitant		
	n	%	% (95% CI)	RR (95% CI)	Adj. RR (95% CI)
Gender					
Male	159427	30.1	16.6 (16.4, 16.9)	1.0 (NA)	1.0 (NA)
Female	294983	55.7	13.2 (13.1, 13.4)	0.79 (0.78, 0.81)	1.12 (1.10, 1.14)
Non-binary	3232	0.6	18.2 (16.1, 20.3)	1.10 (0.97, 1.22)	0.99 (0.88, 1.10)
Self-described	4014	0.8	64.2 (62.3, 66.1)	3.86 (3.73, 3.99)	1.42 (1.37, 1.47)
Missing	68002	12.8	26.3 (25.8, 26.7)	1.58 (1.54, 1.61)	1.39 (1.34, 1.44)
Age group					
18-24 years	15678	3.0	22.9 (22.1, 23.7)	2.79 (2.67, 2.91)	[b]
25-34 years	52640	9.9	21.3 (20.8, 21.7)	2.60 (2.52, 2.68)	
35-44 years	73245	13.8	18.4 (18.1, 18.8)	2.25 (2.18, 2.32)	
45-54 years	81578	15.4	17.0 (16.7, 17.3)	2.07 (2.01, 2.13)	
55-64 years	103380	19.5	12.9 (12.7, 13.1)	1.57 (1.53, 1.62)	
65-74 years	95964	18.1	8.2 (8.0, 8.4)	1.0 (NA)	
≥ 75 years	42657	8.1	9.8 (9.4, 10.2)	1.20 (1.14, 1.25)	
Missing	64516	12.2	24.6 (24.1, 25.0)	3.00 (2.91, 3.09)	
Race/ethnicity					
White	338578	63.9	15.8 (15.6, 16.0)	1.0 (NA)	[b]
Hispanic	57608	10.9	13.4 (13.0, 13.7)	0.85 (0.82, 0.87)	
Black	28625	5.4	13.0 (12.5, 13.5)	0.82 (0.79, 0.86)	
Asian	12012	2.3	3.2 (2.8, 3.6)	0.20 (0.17, 0.23)	
Native American	3993	0.8	25.3 (23.4, 27.2)	1.60 (1.48, 1.72)	
Pacific Islander	1002	0.2	13.9 (11.3, 16.5)	0.88 (0.71, 1.04)	

Multi-racial	13433	2.5	29.2 (28.2, 30.2)	1.85 (1.78, 1.92)	
Missing	74407	14.0	26.5 (26.1, 27.0)	1.68 (1.65, 1.71)	
Education level					
≤ High school	92557	17.5	20.8 (20.4, 21.1)	1.88 (1.83, 1.93)	1.56 (1.52, 1.60)
Some college	167096	31.5	18.3 (18.1, 18.6)	1.66 (1.62, 1.70)	1.37 (1.34, 1.40)
Bachelor's	110944	20.9	11.0 (10.8, 11.3)	1.0 (NA)	1.0 (NA)
Master's	62862	11.9	8.3 (8.1, 8.6)	0.75 (0.72, 0.78)	0.90 (0.87, 0.92)
Professional (e.g., JD)	14970	2.8	12.3 (11.6, 13.0)	1.12 (1.05, 1.18)	1.09 (1.04, 1.15)
PhD	10969	2.1	23.9 (22.7, 25.1)	2.16 (2.05, 2.28)	1.20 (1.14, 1.25)
Missing	70260	13.3	23.9 (23.5, 24.3)	2.16 (2.10, 2.22)	1.18 (1.10, 1.25)
Employment status					
Work outside home	176197	33.3	21.2 (20.9, 21.4)	2.48 (2.39, 2.57)	1.33 (1.28, 1.37)
Work at home	57246	10.8	8.5 (8.2, 8.8)	1.0 (NA)	1.0 (NA)
Does not work for pay	223071	42.1	12.7 (12.5, 12.9)	1.49 (1.43, 1.54)	1.34 (1.29, 1.38)
Missing	73144	13.8	23.9 (23.5, 24.3)	2.80 (2.69, 2.91)	1.33 (1.25, 1.41)
US Region					
Midwest	126686	23.9	18.1 (17.9, 18.4)	1.50 (1.46, 1.55)	1.10 (1.07, 1.13)
South	182852	34.5	19.2 (19.0, 19.5)	1.59 (1.55, 1.64)	1.13 (1.10, 1.16)
Pacific	73521	13.9	12.1 (11.7, 12.4)	1.0 (NA)	1.0 (NA)
Mountain	42261	8.0	17.9 (17.4, 18.5)	1.49 (1.43, 1.55)	1.11 (1.07, 1.15)
Northeast	88229	16.7	12.6 (12.3, 12.9)	1.04 (1.01, 1.08)	0.96 (0.93, 0.99)
Territories	191	<0.05	12.0 (6.3, 17.8)	1.00 (0.52, 1.48)	0.64 (0.44, 0.84)
Missing	15918	3.0	33.3 (32.3, 34.3)	2.76 (2.64, 2.87)	[c]
County urban classification					

Large central metro	120722	22.8	11.7 (11.5, 12.0)	1.0 (NA)	1.0 (NA)
Large fringe metro	115854	21.9	14.3 (14.0, 14.5)	1.22 (1.18, 1.25)	1.03 (1.01, 1.06)
Medium metro	138457	26.1	16.8 (16.5, 17.1)	1.43 (1.39, 1.47)	1.13 (1.10, 1.16)
Small metro	57778	10.9	21.0 (20.6, 21.5)	1.79 (1.74, 1.85)	1.18 (1.15, 1.22)
Micropolitan	49266	9.3	24.2 (23.7, 24.7)	2.06 (2.00, 2.12)	1.19 (1.15, 1.23)
Non-core	31472	5.9	27.4 (26.8, 28.1)	2.34 (2.27, 2.41)	1.23 (1.19, 1.27)
Missing	16109	3.0	33.0 (32.0, 34.0)	2.82 (2.71, 2.92)	[c]

Juris Doctorate= JD; NA=not applicable, NH=Non-Hispanic

[a] Race/ethnicity groups other than the group labeled "Hispanic" are non-Hispanic.

[b] Due to an interaction between age group and race/ethnicity, adjusted relative risks from the multivariable model are reported in supplemental digital content (age group stratified by race/ethnicity in eTable 4; race/ethnicity by age group in eTable 5).

[c] Reliable estimates could not be calculated for the missing category for variables based on participants' zip code, due to collinearity.

Table 2. COVID-19 vaccine hesitancy in May 2021 political/by COVID-19 environment, health status, beliefs and behaviors among US adults (N=529,658)

	Sample		COVID-19 vaccine hesitant		
	N	%	% (95% CI)	RR (95% CI)	Adj. RR (95% CI)
State governor's political party					
Democratic	282446	53.3	14.4 (14.2, 14.6)	1.0 (NA)	[a]
Republican	230264	43.5	19.2 (19.0, 19.4)	1.33 (1.31, 1.36)	
Missing	16948	3.2	31.8 (30.8, 32.7)	2.21 (2.13, 2.28)	
County Trump vote total minus Biden vote total in 2020 presidential election					
Lowest quartile	343255	64.8	12.8 (12.6, 12.9)	1.0 (NA)	1.0 (NA)
Second lowest quartile	101627	19.2	21.9 (21.6, 22.3)	1.72 (1.69, 1.75)	1.27 (1.25, 1.30)
Second highest quartile	47422	9.0	27.6 (27.0, 28.1)	2.16 (2.11, 2.21)	1.34 (1.30, 1.37)
Highest quartile	19712	3.7	32.5 (31.7, 33.4)	2.55 (2.48, 2.62)	1.42 (1.38, 1.47)
Missing	17642	3.3	32.4 (31.5, 33.4)	2.54 (2.46, 2.62)	[b]
County COVID-19 April 2021 county death rate					
Lowest quartile	26160	4.9	24.3 (23.7, 25.0)	1.0 (NA)	1.0 (NA)
Second lowest quartile	168948	31.9	16.2 (15.9, 16.4)	0.66 (0.64, 0.69)	0.97 (0.94, 1.00)
Second highest quartile	214630	40.5	15.7 (15.5, 15.9)	0.65 (0.63, 0.67)	1.00 (0.97, 1.03)
Highest quartile	103804	19.6	17.1 (16.8, 17.4)	0.70 (0.68, 0.73)	1.01 (0.98, 1.04)
Missing	16116	3.0	33.0 (32.0, 34.0)	1.36 (1.30, 1.41)	[b]
Ever tested positive for COVID-19					
Yes	55851	10.5	20.7 (20.2, 21.1)	1.24 (1.22, 1.27)	1.10 (1.08, 1.13)
No or unsure	470576	88.8	16.6 (16.5, 16.8)	1.0 (NA)	1.0 (NA)
Missing	3231	0.6	19.6 (17.8, 21.4)	1.18 (1.07, 1.29)	0.94 (0.86, 1.01)
Ever diagnosed with high-risk medical condition					

One or more conditions	324323	61.2	13.8 (13.6, 13.9)	1.0 (NA)	1.0 (NA)
No condition	184503	34.8	19.4 (19.2, 19.7)	1.41 (1.39, 1.43)	1.01 (0.99, 1.02)
Missing	20832	3.9	35.9 (35.0, 36.8)	2.60 (2.53, 2.67)	1.70 (1.65, 1.75)
Someone 65 years or older in the home					
Is ≥65 years	138621	26.2	8.7 (8.5, 8.9)	1.0 (NA)	
Yes	47859	9.0	18.0 (17.5, 18.5)	2.07 (2.00, 2.14)	1.0 (NA) [c]
No	204999	38.7	18.1 (17.9, 18.3)	2.08 (2.03, 2.13)	1.07 (1.04, 1.09)
Missing	138179	26.1	20.9 (20.7, 21.2)	2.41 (2.35, 2.47)	1.11 (1.08, 1.13)
Extent worried that you or someone in immediate family might become seriously ill from COVID-19					
Worried	209897	39.6	8.8 (8.6, 9.0)	1.0 (NA)	1.0 (NA)
Not too worried	164794	31.1	13.7 (13.5, 13.9)	1.55 (1.52, 1.59)	1.31 (1.28, 1.35)
Not worried at all	98919	18.7	33.7 (33.3, 34.1)	3.82 (3.74, 3.91)	1.78 (1.74, 1.83)
Missing	56048	10.6	24.8 (24.3, 25.3)	2.81 (2.74, 2.89)	1.30 (1.11, 1.49)
Past-year flu vaccine					
Yes	280787	53.0	5.6 (5.5, 5.7)	1.0 (NA)	1.0 (NA)
No or unsure	193242	36.5	28.3 (28.0, 28.5)	5.06 (4.94, 5.18)	3.24 (3.16, 3.32)
Missing	55629	10.5	24.9 (24.4, 25.4)	4.46 (4.33, 4.59)	2.12 (1.79, 2.45)
Extent intentionally avoiding contact with others					
All of the time	67156	12.7	11.0 (10.7, 11.3)	1.0 (NA)	1.0 (NA)
Most of the time	142287	26.9	8.4 (8.2, 8.6)	0.76 (0.73, 0.79)	0.87 (0.84, 0.90)
Some of the time	187201	35.3	9.0 (8.8, 9.1)	0.81 (0.78, 0.84)	0.88 (0.86, 0.91)
None of the time	85930	16.2	44.5 (44.1, 45.0)	4.03 (3.92, 4.15)	2.43 (2.35, 2.50)
Missing	47084	8.9	26.2 (25.6, 26.7)	2.37 (2.29, 2.45)	1.46 (1.37, 1.54)

NA=not applicable

[a] State governor's political party was excluded from the multivariable model due to collinearity with county Trump vote share.

[b] Reliable estimates could not be calculated for the missing category for variables based on participants' zip code, due to collinearity.

[c] "Someone 65 years or older in the home" was evaluated as a binary variable in multivariable analysis, which controlled for participant's age.

Table 3. Reasons for not getting the COVID-19 vaccine in May, 2021, by vaccine intent level among US adults (N=90,510)[a]

	Likelihood of accepting the COVID-19 vaccine if offered it today			
	Hesitant (Definitely/ probably not)	**Definitely not**	**Probably not**	**Probably yes**
	N = 75792	**N = 48674**	**N = 27118**	**N = 14718**
	% (95% CI)			
Concerned about possible side effects	49.2 (48.8, 49.7)	49.1 (48.6, 49.7)	49.3 (48.6, 50.1)	49.3 (48.3, 50.3)
Don't trust COVID-19 vaccines	49.1 (48.6, 49.5)	59.6 (59.0, 60.1)	29.6 (28.9, 30.3)	13.1 (12.4, 13.8)
Don't trust the government	42.7 (42.2, 43.1)	52.3 (51.7, 52.8)	24.8 (24.2, 25.5)	14.2 (13.4, 14.9)
Don't believe I need it	39.0 (38.5, 39.4)	47.4 (46.9, 48.0)	23.3 (22.6, 23.9)	7.6 (7.0, 8.2)
Plan to wait and to see if safe	34.0 (33.6, 34.5)	24.2 (23.7, 24.8)	52.2 (51.5, 53.0)	46.9 (45.9, 47.9)
Concerned about an allergic reaction	24.2 (23.8, 24.6)	23.4 (22.9, 23.9)	25.7 (25.0, 26.3)	28.5 (27.6, 29.4)
Don't know if it will work	22.5 (22.1, 22.9)	24.0 (23.5, 24.5)	19.6 (19.0, 20.2)	17.1 (16.3, 17.9)
Don't like vaccines	15.5 (15.1, 15.8)	18.5 (18.0, 19.0)	9.9 (9.4, 10.4)	7.7 (7.1, 8.3)
Other people need it more	13.0 (12.7, 13.4)	9.7 (9.3, 10.1)	19.2 (18.5, 19.8)	25.2 (24.2, 26.1)
Safety concern because of my health condition	12.6 (12.3, 12.9)	12.2 (11.8, 12.5)	13.3 (12.9, 13.8)	13.4 (12.8, 14.1)
Doctor has not recommended	10.0 (9.7, 10.3)	10.9 (10.5, 11.3)	8.4 (8.0, 8.8)	6.9 (6.4, 7.4)
Against religious beliefs	9.3 (9.0, 9.5)	12.5 (12.1, 12.9)	3.3 (3.0, 3.5)	1.2 (1.0, 1.5)
Currently/planning to be pregnant/breastfeeding	7.2 (7.0, 7.5)	7.3 (7.0, 7.6)	7.2 (6.8, 7.5)	4.9 (4.5, 5.3)
Concerned about cost	3.9 (3.7, 4.2)	4.1 (3.8, 4.4)	3.7 (3.3, 4.0)	8.0 (7.3, 8.6)
Other	17.6 (17.3, 18.0)	20.5 (20.0, 20.9)	12.4 (11.9, 12.8)	11.8 (11.2, 12.5)

[a] Excludes adults who already were vaccinated or reported “definitely yes” to intent question.

Figure Legends

Figure 1. COVID-19 vaccine hesitancy by race/ethnicity (ages 18-34 years[a]), education level, US region and county Trump vote share in 2020 presidential election among US adults by month (January-May, 2021)

Between January and May the gap in percent hesitant between race/ethnicity groups among adults 18-34 years (panel A) and education levels among all ages (panel B) decreased, with the biggest decreases among the most hesitant groups (e.g., Black race and ≤high school education, respectively). Changes in percent hesitant over time were fairly similar across US regions (panel C); however, there was a slightly smaller decrease in the Mountain region and slightly larger decrease in the South versus other regions. The gap in percent hesitant by county political environment, quantified in quartiles of percent Trump vote share in the 2020 presidential election, increased slightly between January and May, with the most hesitant group (highest quartile) having the smallest decrease (panel D).

Figure 2. COVID-19 vaccine hesitancy by age group, stratified by race/ethnicity, among US adults, May 2021

Differences in hesitancy by age (e.g., 18-24 year-olds versus 65-74 year-olds) were most pronounced in Blacks (RR=7.23 [95%CI, 5.89, 8.57]) and less pronounced in Asians (RR=2.39 [95% CI 1.01, 3.76]; hesitancy <5% in all age groups) versus Whites (RR=2.94 [95% CI 2.79, 3.09]). Differences in hesitancy by race/ethnicity were more pronounced in younger adults and adults ≥ 75 years.

References

1. Loftus P, West MG, Hopkins JS. First Covid-19 Vaccine Given to U.S. Public. MSN. Accessed May 26, 2021. https://www.msn.com/en-us/news/us/first-covid-19-vaccine-given-to-us-public/ar-BB1bUDkJ

2. Hinton RDM. Pfizer-BioNTech COVID-19 Vaccine EUA Letter of Authorization reissued. Published online May 10, 2021. Accessed May 26, 2021. https://www.fda.gov/media/144412/download

3. Centers for Disease Control and Prevention. COVID Data Tracker. Centers for Disease Control and Prevention. Published March 28, 2020. Accessed May 26, 2021. https://covid.cdc.gov/covid-data-tracker

4. Liptak K, Zeleny J, Harwood J. Biden now says US will have enough vaccine for every adult by the end of May. CNN. Accessed May 26, 2021. https://www.cnn.com/2021/03/02/politics/biden-merck-johnson--johnson-vaccine/index.html

5. Office of the Commissioner. Pfizer-BioNTech COVID-19 Vaccine. *FDA*. Published online June 11, 2021. Accessed June 25, 2021. https://www.fda.gov/emergency-preparedness-and-response/coronavirus-disease-2019-covid-19/pfizer-biontech-covid-19-vaccine

6. Rearden C. Gov. Wolf announces effort to get COVID-19 vaccines to homebound individuals. WFMZ.com. Accessed May 26, 2021. https://www.wfmz.com/health/coronavirus/gov-wolf-announces-effort-to-get-covid-19-vaccines-to-homebound-individuals/article_f13537dc-a6d6-11eb-a00c-5f21dab164af.html

7. Pietsch B. Dracula's Castle Is Now a Vaccination Site - The New York Times. Published May 12, 2021. Accessed June 25, 2021. https://www.nytimes.com/2021/05/12/us/covid-vaccine-unusual-location.html

8. Daly M, Jones A, Robinson E. Public Trust and Willingness to Vaccinate Against COVID-19 in the US From October 14, 2020, to March 29, 2021. *JAMA*. 2021;325(23):2397. doi:10.1001/jama.2021.8246

9. Delphi Group. COVID Symptom Survey. Delphi Epidata API. Accessed July 9, 2021. https://cmu-delphi.github.io/delphi-epidata/symptom-survey/

10. Barkay N, Cobb C, Eilat R, et al. Weights and Methodology Brief for the COVID-19 Symptom Survey by University of Maryland and Carnegie Mellon University, in Partnership with Facebook. *arXiv:200914675 [cs]*. Published online October 6, 2020. Accessed May 26, 2021. http://arxiv.org/abs/2009.14675

11. Rentsch CT, Kidwai-Khan F, Tate JP, et al. Patterns of COVID-19 testing and mortality by race and ethnicity among United States veterans: A nationwide cohort study. *PLoS Med*. 2020;17(9):e1003379. doi:10.1371/journal.pmed.1003379

12. Lopez-Villafana A. Black nurses bring vaccine to community centers, churches to target under-served people. San Diego Union-Tribune. Published March 17, 2021. Accessed June 25, 2021.

https://www.sandiegouniontribune.com/communities/san-diego/story/2021-03-17/san-diegos-black-nurses-focus-on-vaccinating-black-residents-in-southeastern-san-diego

13. Pham O, Jul 08 NPP, 2021. Latest Data on COVID-19 Vaccinations by Race/Ethnicity. KFF. Published July 8, 2021. Accessed July 9, 2021. https://www.kff.org/coronavirus-covid-19/issue-brief/latest-data-on-covid-19-vaccinations-race-ethnicity/

14. Fisher KA, Bloomstone SJ, Walder J, Crawford S, Fouayzi H, Mazor KM. Attitudes Toward a Potential SARS-CoV-2 Vaccine: A Survey of U.S. Adults. *Ann Intern Med*. 2020;173(12):964-973. doi:10.7326/M20-3569

15. Reiter PL, Pennell ML, Katz ML. Acceptability of a COVID-19 vaccine among adults in the United States: How many people would get vaccinated? *Vaccine*. 2020;38(42):6500-6507. doi:10.1016/j.vaccine.2020.08.043

16. 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. *Science Communication*. 2020;42(5):698-723. doi:10.1177/1075547020960463

17. Szilagyi PG, Thomas K, Shah MD, et al. National Trends in the US Public's Likelihood of Getting a COVID-19 Vaccine—April 1 to December 8, 2020. *JAMA*. 2021;325(4):396. doi:10.1001/jama.2020.26419

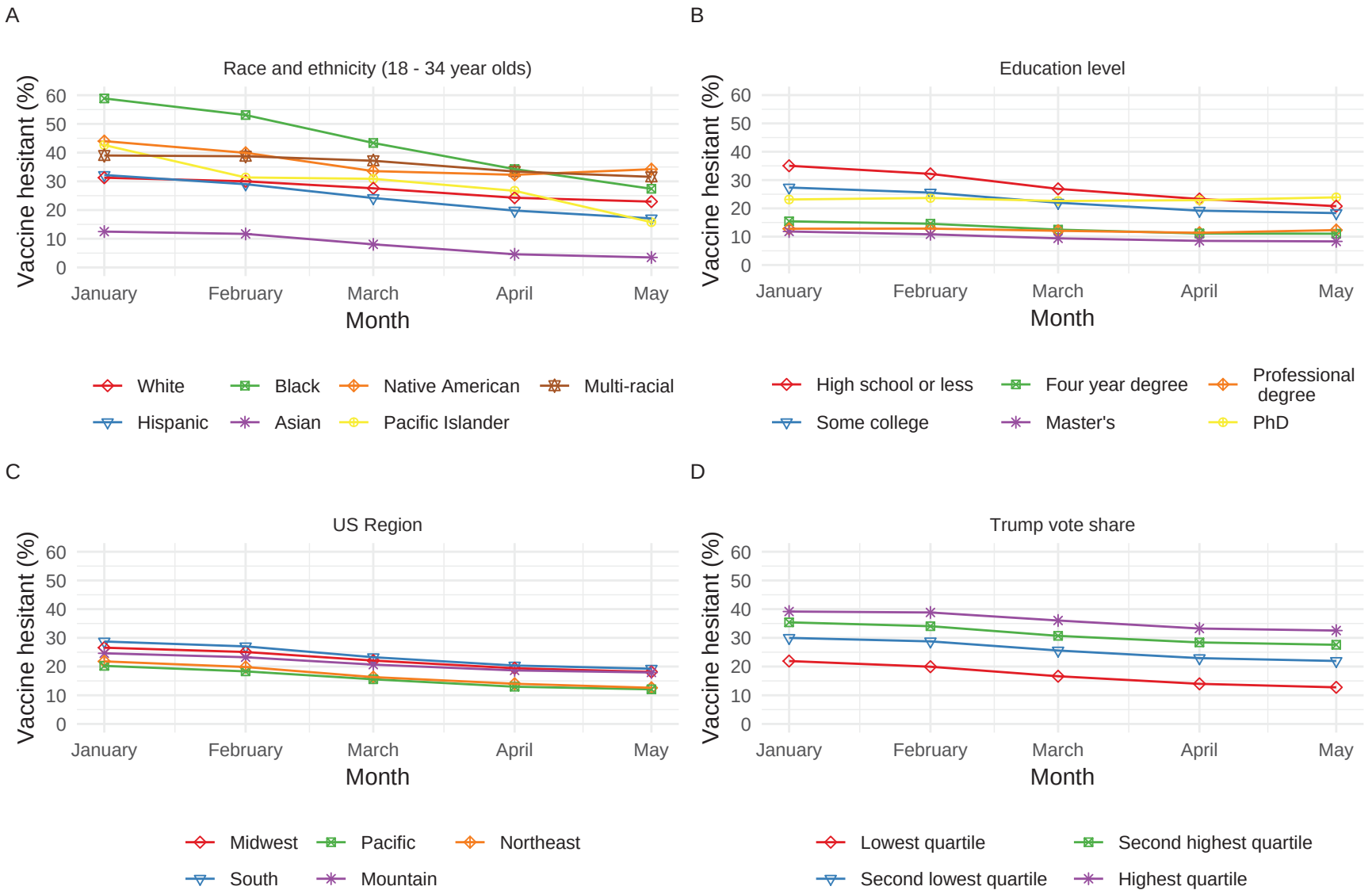
18. Ten health issues WHO will tackle this year. World Health Organization. Accessed June 25, 2021. https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019

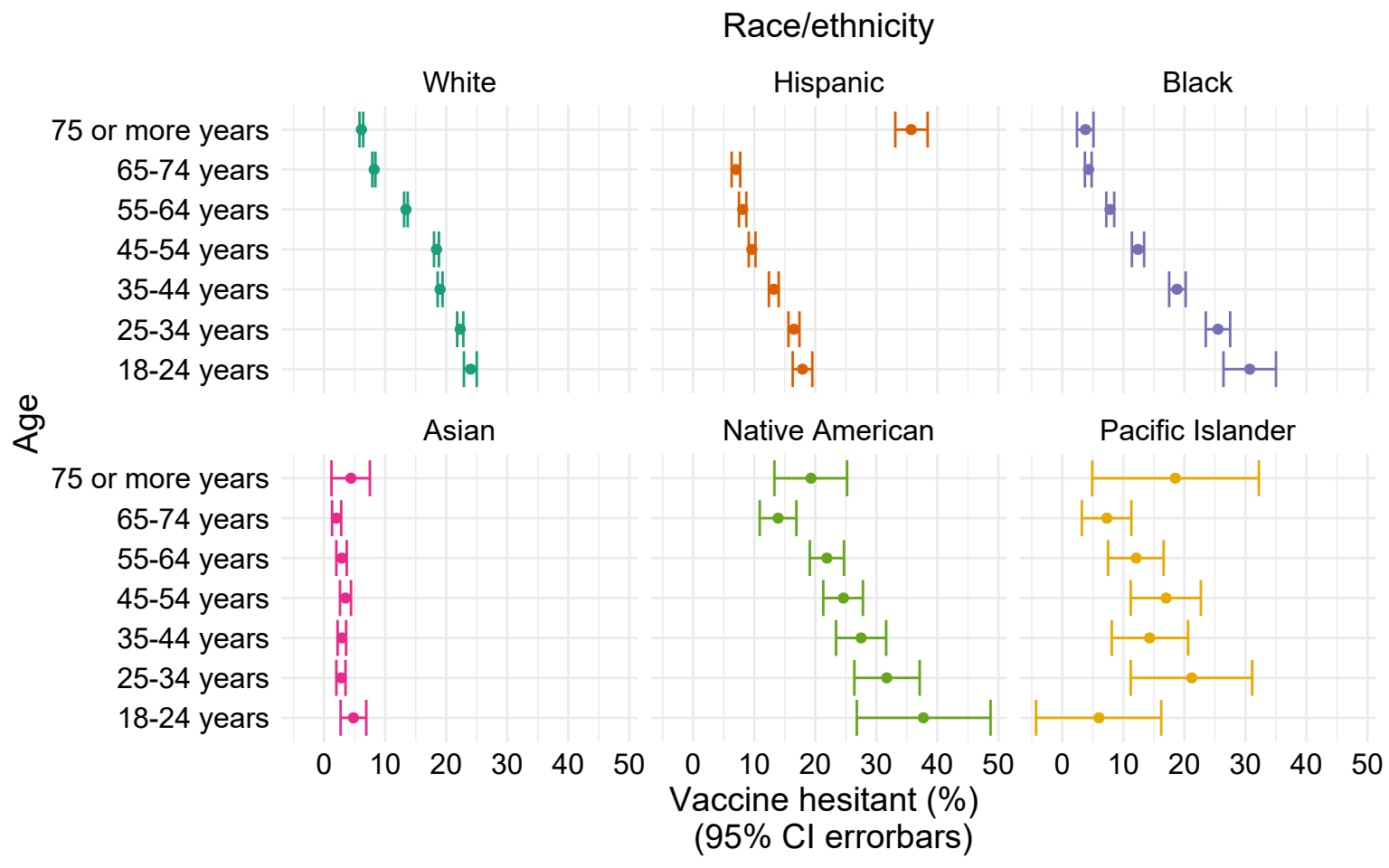
19. Wallace A. An Epidemic of Fear: How Panicked Parents Skipping Shots Endanger Us All. *Wired*. 2009;17(11). Accessed June 25, 2021. https://www.wired.com/2009/10/ff-waronscience/

20. US Census Bureau. American Community Survey 5-Year Data (2009-2019). The United States Census Bureau. Accessed June 27, 2021. https://www.census.gov/data/developers/data-sets/acs-5year.html

21. Lessler J, Grabowski MK, Grantz KH, et al. Household COVID-19 risk and in-person schooling. *Science*. 2021;372(6546):1092-1097. doi:10.1126/science.abh2939

22. Institute for Health Metrics and Evaluation. IHME | COVID-19 Projections. Institute for Health Metrics and Evaluation. Accessed July 9, 2021. https://covid19.healthdata.org/




Race/ethnicity
White
Hispanic
Black
Asian
Native American
Pacific Islander
Age
75 or more years
65-74 years
55-64 years
45-54 years
35-44 years
25-34 years
18-24 years
0
10
20
30
40
50
Vaccine hesitant (%)
(95% CI errorbars)