

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

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12 **Abstract**

13 **Word count: 180**

14 **Objective:** To understand COVID-19 vaccine hesitancy.

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

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

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

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

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31 **Main Text Word Count: 3486**

32 **Introduction**

33 The first COVID-19 vaccination was administered in the US on December 14, 2020¹, 3 days
34 following the Federal Drug Administration (FDA)'s first Emergency Use Authorization of a
35 COVID-19 vaccine². By March 2021, 3 COVID-19 vaccines had been authorized in the US³, and
36 the president announced procurement of enough doses for every adult to be vaccinated by the
37 end of May 2021⁴. By May 2021, vaccine eligibility was expanded to everyone covered under
38 the FDA authorizations (initially ≥ 16 years old, expanded to ≥ 12 years old on May 10⁵), and
39 efforts to increase vaccine access to underserved populations (e.g., rural communities,
40 homebound individuals) were underway^{6,7}. However, vaccine hesitancy (i.e., a refusal or
41 reluctance to be vaccinated) slowed vaccination uptake, potentially prolonging the pandemic³.

42 A longitudinal study of US adults (N=7,420) by Daly et al. reported an overall decrease in COVID-
43 19 vaccine hesitancy from 46.0% in October 2020 to 35.2% in March 2021, with larger
44 decreases in Black and Hispanic versus White race/ethnicity⁸, thereby reducing the racial
45 disparity in COVID-19 vaccine hesitancy. However, if and how vaccine hesitancy has changed
46 during the first five months of the US COVID-19 vaccine rollout, overall and among subgroups,
47 is largely unstudied.

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

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

55 **Methods**

56 This analysis used the COVID Trends and Impact Survey (CTIS)⁹, created by the Delphi Group at
57 Carnegie Mellon University (CMU) and conducted in collaboration with Facebook Data for
58 Good. Survey sampling is described in the **eMethods**. Survey weights accounting for the
59 sampling design and non-response are post-stratified to match the US general population by
60 age, gender, and state¹⁰. The study design ensures CMU researchers do not see usernames or
61 profile information and Facebook does not see survey microdata.

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

68 *Measures.*

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

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

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

82 *Statistical analysis.* Weighted percentages of COVID-19 vaccine receipt and intent were
83 calculated by month for the full sample and by categories of race/ethnicity, education, US
84 Census region, and county Trump to Biden vote share. Percentages were plotted by month and
85 first-last month differences were calculated. The race/ethnicity comparison was limited to
86 adults 18-34 years due to an interaction between race/ethnicity and age in relation to COVID-
87 19 vaccine hesitancy (reported below with May data), and because hesitancy is higher among
88 younger versus older adults.

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

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

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

101 **Results**

102 *Participant characteristics.* May participants (N= 529,658) had a median age range of 55-64
103 years, 45.0% identified as male, 52.6% female, 1.1% nonbinary, and 1.4% self-described gender;
104 16.7% were Hispanic, 68.7 % White, 6.5% Black, 3.6% Asian, 0.9% Native American, 0.2% Pacific
105 Islander, and 3.4% were multi-racial; 22.5% had ≤high school education; 41.2% a four-year
106 college degree or higher. Over half (55.7%) worked for pay; 43.2% worked outside the home.
107 Demographics were similar in January through April (data not shown).

108 *COVID-19 vaccine receipt and intent over time.* Hesitancy decreased each month, with a one-
109 third decrease from 25.7% (95%CI 25.6-25.8) in January to 17.1% (95% CI, 17.0-17.2) in May,
110 2021 (**eFigure 1**). There was a bigger decrease in the response “probably not” (-7.0 percentage
111 points (%) [95% CI -7.1, -6.9]) versus “definitely not” (-1.6 % [95% CI -1.7, -1.4]) (**eTable 2**).

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

115 two of the three most hesitant race/ethnicity groups (e.g., Black and Pacific Islanders but not
116 Native American) and the two most hesitant education groups (\leq high school and some college
117 education) in January. There was not a decrease in hesitancy among those with a professional
118 degree or PhD. Changes in percent hesitant over time were fairly similar across US Census
119 regions (panel C); however, there was less of a decrease in the Midwest and Mountain regions
120 versus the South, Pacific and Northeast. The gap in percent hesitant by county Trump vote
121 share increased slightly from January to May, with the highest quartile, which was the most
122 hesitant group, having the smallest decrease (panel D). Supporting data is provided in **eTable 3.**
123 *Factors related to COVID-19 vaccine hesitancy.* Hesitancy in May, 2021 is reported by
124 participant demographics and geographic factors in **Table 1**. Although hesitancy was lower in
125 females versus males (RR=0.79, 95% CI 0.78, 0.81), with adjustment for covariates (i.e.,
126 variables reported in **Tables 1 and 2**), female versus male gender was associated with higher
127 hesitancy (aRR=1.12, 95%CI 1.10-1.14). In contrast, non-binary adults had similar hesitancy to
128 males (RR=1.10, 95%CI, 0.97-1.22; aRR=0.99, 95%CI 0.88-1.10).

129 In general, younger age and non-Asian race (particularly Multi-racial and Native American),
130 were related to greater hesitancy. However, an interaction was observed between age and
131 race/ethnicity categories (**Figure 2**). Differences in hesitancy by age (e.g., 18-24 year-olds versus
132 65-74 year-olds) were more pronounced in Blacks (RR=7.23 [95%CI, 5.89-8.57]) and less
133 pronounced in Asians (RR=2.39 [95%CI 1.01-3.76]; although hesitancy <5% in all Asian age
134 groups) compared to Whites (RR=2.94 [95%CI 2.79-3.09]). Differences in hesitancy by
135 race/ethnicity were more pronounced in younger adults and adults \geq 75 years. Furthermore, for
136 some comparisons, the direction of the difference in hesitancy by race/ethnicity differed by

137 age. For example, for Blacks versus Whites the RR of hesitancy was 1.28 (95%CI, 1.09-1.47) in
138 18-24 year olds, and 0.52 (95%CI 0.46-0.59) in 64-75 year olds. RRs for age groups stratified by
139 race/ethnicity groups and for race/ethnicity groups stratified by age groups, with and without
140 adjustment for all covariates, are provided in **eTable 4** and **5**. In general, age and race/ethnicity
141 differences were attenuated in the full multivariable model, but still present.

142 The association between hesitancy and education level followed a U-shaped curve with the
143 lowest hesitancy among those with a master's degree (RR=0.75 [95% CI 0.72-0.78]) and the
144 highest hesitancy among those with a PhD (RR=2.16 [95%CI 2.05-2.28]) or ≤high school
145 education (RR=1.88 [95%CI 1.83-1.93]) versus a bachelor's degree. Additional demographic risk
146 factors for hesitancy included working outside the home (RR=2.48 [95%CI 2.39-2.57]) or not
147 working for pay (RR=1.49 [95% CI: 1.43-1.54]) versus working at home, living in the South
148 (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
149 1.43-1.55]) versus the Pacific US region, and in a less urban county (e.g., RR=2.34 [95 CI, 2.27-
150 2.41] for non-core versus large central metro). Associations were attenuated with adjustment,
151 but remained (**Table 1**).

152 COVID-19 vaccine hesitancy is reported by indicators of political/COVID-19 environment, health
153 status, beliefs and behaviors in **Table 2**. Risk factors for hesitancy were living in a state with
154 Republican versus Democratic governor (RR= 1.33 [95%CI 1.31-1.36]), living in a county with a
155 relatively higher Trump vote share (e.g., RR= 2.55 [95%CI 2.48-2.62] for highest versus lowest
156 quartile), living in a county with a relatively lower April COVID-19 death rate (e.g. RR=0.70
157 [95%CI 0.68-0.73] for highest versus lowest quartile), history versus no history of a positive
158 COVID-19 test (RR= 1.24 (95%CI 1.22-1.27)), not having versus having a high-risk health

159 condition (RR=1.41 [95%CI 1.39-1.43]), being less worried about self or immediate family
160 becoming seriously ill from COVID-19 (e.g., RR=3.82 [3.74-3.91] for not worried at all versus
161 worried), not having had versus having had a past-year flu vaccination (RR=5.06 [95%CI 4.94-
162 5.18]), and not avoiding versus avoiding contact with others (e.g., RR=4.03 [95%CI 3.92-4.15] for
163 none versus all of the time). Political affiliation of state governor was excluded from the
164 multivariable model due to collinearity with county Trump vote share. The adjusted
165 associations were attenuated but in the same direction, except for April 2021 COVID-19 death
166 rate, which was not independently related to hesitancy.

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

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

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

185 Reasons for COVID-19 vaccine hesitancy among hesitant US adults by race/ethnicity are
186 provided in **eTable 7**. Concern about side effects, followed by not trusting the COVID-19
187 vaccine, were the most common concerns in all race/ethnicity groups, with the ranking
188 reversed among Native Americans. Both were chosen by >40% of each group except Asians
189 (39.3% [95%CI, 32.3, 46.3]) reported not trusting the COVID-19 vaccine). There was more
190 racial/ethnicity variability in not trusting the government, which was highest among Multiracial
191 adults (52.4% [95%CI, 50.2-54.5]), followed by Native Americans (44.0% [95%CI, 39.5-48.5]),
192 Whites (43.7% [95%CI, 43.2-44.3], and Hispanics (41.0% [95%CI, 39.5-42.6]); in waiting to see if
193 safe, which was highest in Hispanics (41.6%, 95%CI, 40.1-43.2), followed by Asians (40.8%
194 [95%CI, 33.8-47.7]) and Blacks (40.7% [95%CI, 38.6-42.8]); and in do not need, which was
195 highest in Multiracial (48.5% [95%CI, 46.3-50.7]), and Whites (42.1% [95%CI, 41.5-42.7]). Other
196 reasons were chosen by <40% of hesitant adults in each race/ethnicity group.

197 **Discussion**

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

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

212 Large decreases January-May in COVID-19 vaccine hesitancy among Blacks and Pacific Islanders
213 led to these groups joining Asian and Hispanics as having a lower prevalence of hesitancy than
214 Whites (all age groups combined) in May 2021. Racial/ethnic disparities have been observed in
215 all aspects of the COVID-19 pandemic, with communities of color experiencing higher rates of
216 SARS-CoV-2 infection (despite higher positivity rates indicative of lower access to testing¹¹),
217 COVID-19-related hospitalizations and mortality¹¹. Racial/ethnic disparities in COVID-19 vaccine
218 acceptance at the start of the vaccine rollout threatened to continue this trend. However, many
219 groups from at-risk communities initiated targeted outreach campaigns¹². Our finding that
220 racial/ethnic disparities in COVID-19 hesitancy are decreasing suggests that messaging and
221 outreach campaigns, combined with the opportunity to observe initial months of the rollout,
222 have had positive effects. However, vaccination rates for Black and Hispanics continued to lag

223 through July 6, 2021¹³, 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

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

245 Adults who were “not worried at all” about themselves or someone in their family becoming
246 seriously ill from COVID-19 or who were not intentionally avoiding contact with others had
247 much higher likelihood of COVID-19 vaccine hesitancy, as did those working outside the home.
248 These latter two findings are particularly concerning as they indicate non-vaccinated (versus
249 vaccinated) individuals may be more likely to engage in activities in which transmission can
250 occur. While prior studies have linked history of past-year flu vaccine with hypothetical COVID-
251 19 vaccine acceptance^{14,16}, our finding that those who had not received a flu vaccine were 224%
252 more likely to be COVID-19 vaccine hesitant, after controlling for such a wide array of
253 covariates, is striking.

254 Even prior to COVID-19, vaccine hesitancy was identified as one of the top ten global health
255 threats by the World Health Organization (WHO)¹⁸. This is because incomplete vaccine coverage
256 increases the risk of disease for the entire population¹⁹. This study’s county-level variables raise
257 concerns, as high hesitancy areas could provide reservoirs for the Sars-CoV2 virus, even if
258 national or state level vaccination rates increase.

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

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

267 *Limitations and Strengths.* The study employs a novel sampling method with a soft ask and low
268 response rate, the effect of which has not yet been fully studied. Survey weights adjust for non-
269 response and coverage bias (i.e., matching the sample to gender, age, and geographic profile of
270 the US). However, a comparison with the American Community Survey²⁰ shows our sample is
271 more educated with higher vaccine uptake than general population, indicating that vaccine
272 hesitancy is underestimated in this sample. Importantly, these characteristics have been
273 consistent over time. CTIS results follow similar patterns observed by others,⁸ and have been
274 helpful for tracking trends, understanding associations and informing policies^{21,22}. Demographic
275 questions were asked at the end of the survey and had high unit non-response (e.g., 12% for
276 age), which was treated as a category in analysis. Additionally, we assume the survey was
277 completed in good faith. However, a review of fill-in responses for self-described gender
278 suggest a small percentage of participants used that category to make political statements (e.g.,
279 trans-phobic comments). A sensitivity analysis eliminating respondents with self-described
280 gender produced very similar results, though the increase in hesitancy for those age ≥ 75 years
281 was attenuated (data not shown). A strength of our novel sampling method is that it yielded a
282 large sample with diverse characteristics that enabled detailed subgroup analyses that
283 identified new findings (e.g., non-binary and male genders had similar hesitancy prevalence).
284 Additionally, while a previous study evaluated changes in hesitancy by age, sex, education, or
285 income level, October 2020 through March 2021⁸, estimated change by these categories had

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

289 In the US, the COVID-19 vaccination campaign has moved from an initial phase of scarcity,
290 where equity concerns guided access, to a phase of abundance, where messaging and attention
291 to barriers to access is essential to equity, and where increasing vaccine acceptance is critical to
292 achieving herd immunity. Better understanding of reasons for hesitancy among subgroups,
293 combined with up-to-date information on hesitancy by demographics, political environment,
294 and individual health, behaviors and beliefs can help policy makers achieve these goals.

295 Particularly hesitant subgroups include Native American and Multi-racial groups of all ages, and
296 White and Blacks adults <35 years; adults with \leq high school education or PhDs; adults living in
297 small metro, micropolitan or non-core urban (rural) counties or counties with high Trump
298 support; adults with a history of a positive COVID-19 test; not worried about serious illness
299 from COVID-19; working outside the home; never intentionally avoiding contact with others;
300 and adults who did not receive a past-year flu vaccination. Among participants who said they
301 probably would not get vaccinated today, messaging about safety and policy interventions to
302 address downstream impacts of vaccine side effects, such as potential lost work, could be
303 impactful. However, among those who definitely would not get vaccinated today, results
304 suggest the existence of a subgroup with entrenched hesitancy and high distrust of government
305 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)	1.0 (NA) ^c
Yes	47859	9.0	18.0 (17.5, 18.5)	2.07 (2.00, 2.14)	
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 \leq 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 \geq 75 years.

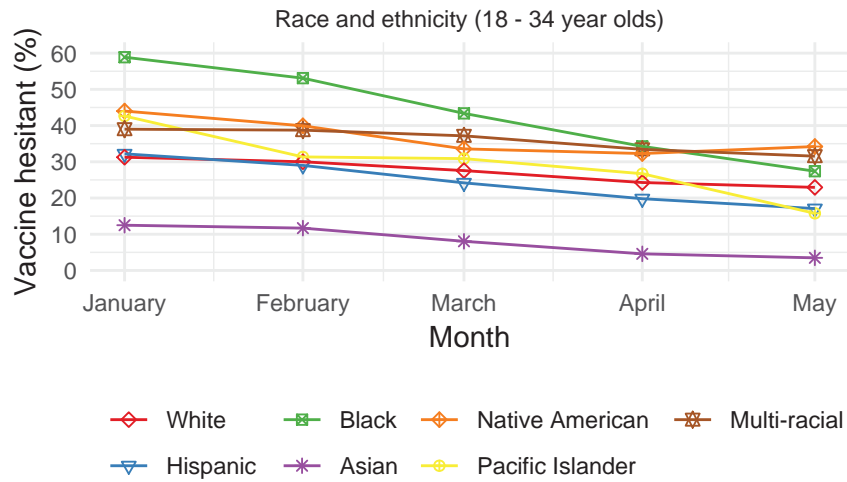
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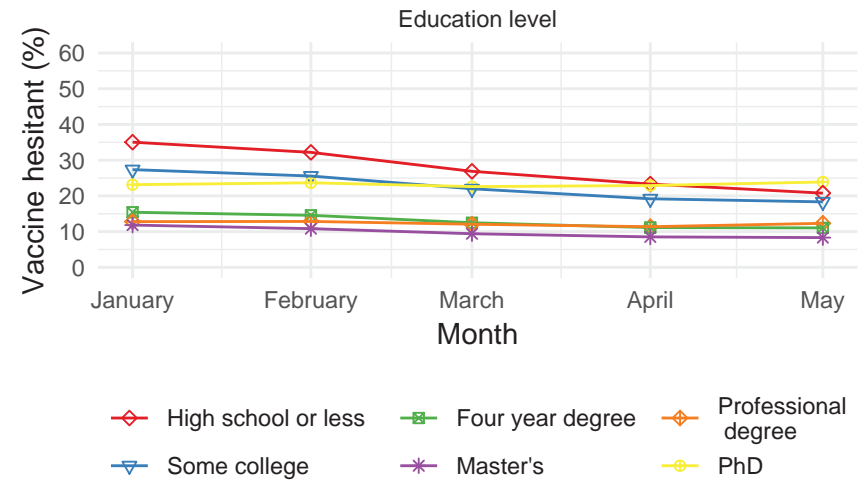
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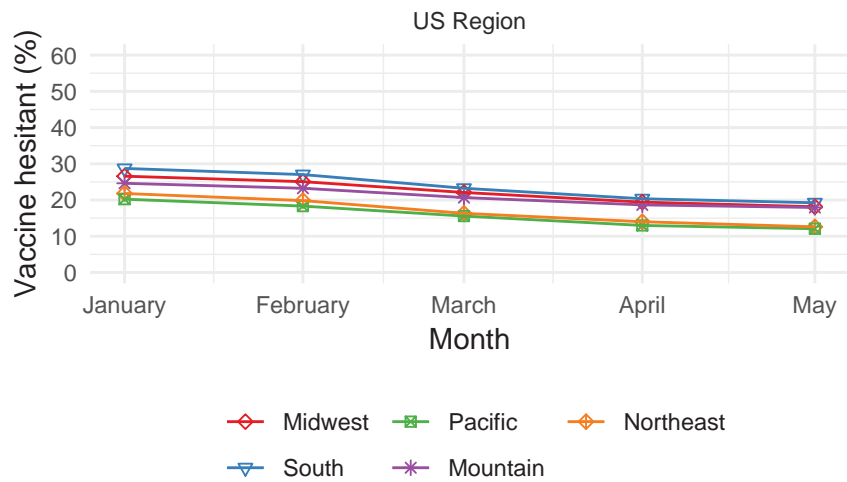
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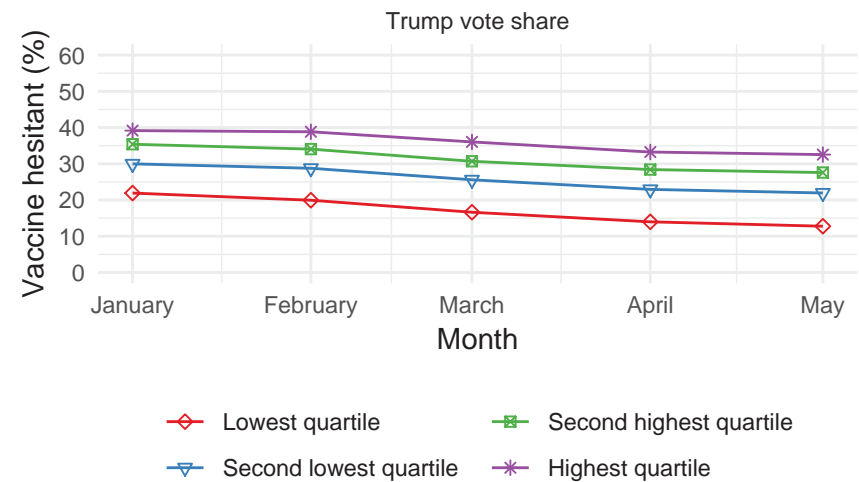
B



C



D



Race/ethnicity

White

Hispanic

Black

Asian

Native American

Pacific Islander

75 or more years
65-74 years
55-64 years
45-54 years
35-44 years
25-34 years
18-24 years

75 or more years
65-74 years
55-64 years
45-54 years
35-44 years
25-34 years
18-24 years

