- 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
- 3 Author names and affiliations:
- 4 Wendy C King, PhD, Associate Professor, Department of Epidemiology, Graduate School of
- 5 Public Health University of Pittsburgh, Pittsburgh, PA, <u>kingw@edc.pitt.edu</u>
- 6 Max Rubinstein, MPP, PhD Student, Heinz College and Department of Statistics & Data Science,
- 7 Carnegie Mellon University, Pittsburgh, PA, <u>mrubinst@andrew.cmu.edu</u>
- 8 Alex Reinhart, PhD, Assistant Teaching Professor, Department of Statistics & Data Science,
- 9 Carnegie Mellon University, Pittsburgh, PA, <u>areinhar@stat.cmu.edu</u>
- 10 Robin J. Mejia, MPH, PhD, Special Faculty, Department of Statistics & Data Science, Carnegie
- 11 Mellon University, Pittsburgh, PA, <u>rmejia@andrew.cmu.edu</u>
- 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
- 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 ≤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
- 23 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.
- 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.
- 30

31 Main Text Word Count: 3486

32 Introduction

33	The first COVID-19 vaccination was administered in the US on December 14, 2020 ¹ , 3 days
34	following the Federal Drug Administration (FDA)'s first Emergency Use Authorization of a
35	COVID-19 vaccine ² . By March 2021, 3 COVID-19 vaccines had been authorized in the US ³ , and
36	the president announced procurement of enough doses for every adult to be vaccinated by the
37	end of May 2021 ⁴ . By May 2021, vaccine eligibility was expanded to everyone covered under
38	the FDA authorizations (initially \geq 16 years old, expanded to \geq 12 years old on May 10 ⁵), 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 pandemic ³ .
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/ethnicity ⁸ , 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

and behaviors, and associations between each potential risk factor with hesitancy is estimated 52 53 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. 54 Methods 55 This analysis used the COVID Trends and Impact Survey (CTIS)⁹, created by the Delphi Group at 56 Carnegie Mellon University (CMU) and conducted in collaboration with Facebook Data for 57 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 age, gender, and state¹⁰. The study design ensures CMU researchers do not see usernames or 60 profile information and Facebook does not see survey microdata. 61 Study sample. The analysis sample includes 5,121,436 survey responses from participants who 62 63 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 64 vaccine receipt and intent. To inform policy and public health efforts we used the most recent 65 month's data (May 2021) to assess how demographics, geographic factors, political/COVID-19 66 environment, health status, beliefs and behaviors relate to COVID-19 vaccine hesitancy. 67 Measures. 68 Participants were asked if they had received the COVID-19 vaccine, and if not, "If a vaccine to 69 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
- 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-
- third decrease from 25.7% (95%Cl 25.6-25.8) in January to 17.1% (95% Cl, 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
- 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

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 (≤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%Cl, 0.97-1.22; aRR=0.99, 95%Cl 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%Cl, 5.89-8.57]) and less
133	pronounced in Asians (RR=2.39 [95%Cl 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%Cl 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%Cl 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%Cl 1.55-1.64]), Midwest (RR=1.50 [95%Cl 1.46-1.55]) or Mountain (RR=1.49 [95%Cl
149	1.43-1.55]) versus the Pacific US region, and in a less urban county (e.g., RR=2.34 [95 Cl, 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%Cl 1.31-1.36]), living in a county with a 155 relatively higher Trump vote share (e.g., RR= 2.55 [95%Cl 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%Cl 0.68-0.73] for highest versus lowest quartile), history versus no history of a positive 158 COVID-19 test (RR= 1.24 (95%Cl 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%C 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	<i>Reasons for COVID-19 vaccine hesitancy</i> . 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

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).

- 185 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
- 187 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%Cl, 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
- adults (52.4% [95%Cl, 50.2-54.5]), followed by Native Americans (44.0% [95%Cl, 39.5-48.5]),
- 192 Whites (43.7% [95%Cl, 43.2-44.3], and Hispanics (41.0% [95%Cl, 39.5-42.6]); in waiting to see if
- safe, which was highest in Hispanics (41.6%, 95%Cl, 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%Cl, 46.3-50.7]), and Whites (42.1% [95%Cl, 41.5-42.7]). Other
- reasons were chosen by <40% of hesitant adults in each race/ethnicity group.

197 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

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 testing ¹¹),
217	COVID-19-related hospitalizations and mortality ¹¹ . 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 campaigns ¹² . 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

through July 6, 2021¹³, indicating that further efforts are needed to overcome barriers to access
for at-risk communities.

225 Most previous studies of COVID-19 vaccine hesitancy grouped Asians with American Indian/Alaska Native, Native Hawaiian or other Pacific Islanders^{8,14–16} However, our study, 226 227 which included 12,012 Asian participants, identified a remarkably lower prevalence of hesitancy in this race/ethnicity group versus all others. This study also identified a race/ethnicity by age 228 229 interaction, yielding greater insight into the gross patterns of each factor, which had previously been identified as key predictors of vaccine hesitancy^{8,17}. For example, Blacks have relatively 230 high hesitancy among adults under 35 years while Whites have relatively high hesitancy among 231 232 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 high hesitancy prevalence. Those with professional degrees (e.g., JD, MBA) and PhDs were the 236 only education groups without a decrease in hesitancy, and by May, those with PhDs had the 237 highest hesitancy. To our knowledge, no other study has evaluated education with this level of 238

granularity, which was possible due to our unusually large sample size (>10,000 participants

with PhDs). Further investigation into hesitancy among those with a PhD is warranted.

January-May, there was a dose-response relationship between relative degree of local Trump 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.

245	Adults who were "not worried at all" about themself 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.

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.

267 *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-268 response and coverage bias (i.e., matching the sample to gender, age, and geographic profile of 269 the US). However, a comparison with the American Community Survey²⁰ shows our sample is 270 271 more educated with higher vaccine uptake than general population, indicating that vaccine hesitancy is underestimated in this sample. Importantly, these characteristics have been 272 consistent over time. CTIS results follow similar patterns observed by others,⁸ and have been 273 helpful for tracking trends, understanding associations and informing policies^{21,22}. Demographic 274 questions were asked at the end of the survey and had high unit non-response (e.g., 12% for 275 276 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 277 suggest a small percentage of participants used that category to make political statements (e.g., 278 279 trans-phobic comments). A sensitivity analysis eliminating respondents with self-described gender produced very similar results, though the increase in hesitancy for those age \geq 75 years 280 was attenuated (data not shown). A strength of our novel sampling method is that it yielded a 281 282 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). 283 Additionally, while a previous study evaluated changes in hesitancy by age, sex, education, or 284 income level, October 2020 through March 2021⁸, estimated change by these categories had 285

large overlapping 95% CI, likely in part reflecting the much smaller sample size. Further, the 286 287 racial and education categories (White, Hispanic, Black, Other; and Yes/No College Degree) collapsed groups in which we have identified meaningful differences. 288 289 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 to barriers to access is essential to equity, and where increasing vaccine acceptance is critical to 291 292 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 ≤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 from COVID-19; working outside the home; never intentionally avoiding contact with others; 299 300 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.

	San	nple		COVID-19 vaccine hesitant			
Candar	n	%	% (95% Cl)	RR (95% CI)	Adj. RR (95% Cl)		
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)			

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

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)	С

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		COV	tant	
	Ν	%	% (95% Cl)	RR (95% CI)	Adj. RR (95% Cl)
State governor's political party					
Democratic	282446	53.3	14.4 (14.2, 14.6)	1.0 (NA)	а
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 vot	e total i	n 2020 presidential el	ection	
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 co	unty deatl	h 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)	

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									
ls ≥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 son	neone in in	nmedia [.]	te family might becom	e 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 c	ontact witl	n others	5						
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									

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 Hesitant (Definitely/ probably not)	accepting the COV Definitely not	/ID-19 vaccine if of Probably not	fered it today Probably yes
	N = 75792	N = 48674 % (95	N = 27118 5% Cl)	N = 14718
Concerned about possible side	49.2 (48.8, 49.7)	49.1 (48.6, 49.7)	49.3 (48.6, 50.1)	49.3 (48.3, 50.3)
effects				
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	24.2 (23.8, 24.6)	23.4 (22.9, 23.9)	25.7 (25.0, 26.3)	28.5 (27.6, 29.4)
reaction				
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	12.6 (12.3, 12.9)	12.2 (11.8, 12.5)	13.3 (12.9, 13.8)	13.4 (12.8, 14.1)
health condition				
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	7.2 (7.0, 7.5)	7.3 (7.0, 7.6)	7.2 (6.8, 7.5)	4.9 (4.5, 5.3)
pregnant/breastfeeding				
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

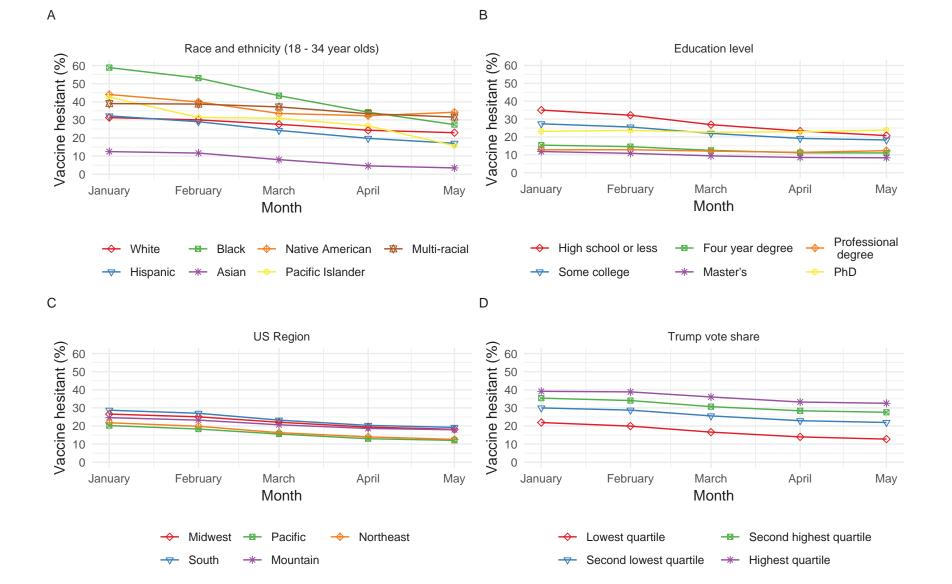
Differences in hesitancy by age (e.g., 18-24 year-olds versus 65-74 year-olds) were most pronounced in Blacks (RR=7.23 [95%Cl, 5.89, 8.57]) and less pronounced in Asians (RR=2.39 [95% Cl 1.01, 3.76]; hesitancy <5% in all age groups) versus Whites (RR=2.94 [95% Cl 2.79, 3.09]). Differences in hesitancy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

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Race/ethnicity

