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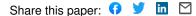
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Racial and ethnic differences in COVID-19 vaccine hesitancy and uptake

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Background: Racial and ethnic minorities have been disproportionately impacted by COVID-19. In the initial phase of population-based vaccination in the United States (U.S.) and United Kingdom (U.K.), vaccine hesitancy and limited access may result in disparities in uptake.

Methods: We performed a cohort study among U.S. and U.K. participants in the smartphone-based COVID Symptom Study (March 24, 2020-February 16, 2021). We used logistic regression to estimate odds ratios (ORs) of COVID-19 vaccine hesitancy (unsure/not willing) and receipt.

Results: In the U.S. (n=87,388), compared to White non-Hispanic participants, the multivariable ORs of vaccine hesitancy were 3.15 (95% CI: 2.86 to 3.47) for Black participants, 1.42 (1.28 to 1.58) for Hispanic participants, 1.34 (1.18 to 1.52) for Asian participants, and 2.02 (1.70 to 2.39) for participants reporting more than one race/other. In the U.K. (n=1,254,294), racial and ethnic minorities had similarly elevated hesitancy: compared to White participants, their corresponding ORs were 2.84 (95% CI: 2.69 to 2.99) for Black participants, 1.66 (1.57 to 1.76) for South Asian participants, 1.84 (1.70 to 1.98) for Middle East/East Asian participants, and 1.48 (1.39 to 1.57) for participants reporting more than one race/other. Among U.S. participants, the OR of vaccine receipt was 0.71 (0.64 to 0.79) for Black participants, a disparity that persisted among individuals who specifically endorsed a willingness to obtain a vaccine. In contrast, disparities in uptake were not observed in the U.K.

Conclusions: COVID-19 vaccine hesitancy was greater among racial and ethnic minorities, and Black participants living in the U.S. were less likely to receive a vaccine than White participants. Lower uptake among Black participants in the U.S. during the initial vaccine rollout is attributable to both hesitancy and disparities in access.

Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the COVID-19 pandemic have claimed 2.4 million lives among nearly 110 million confirmed cases worldwide.[1] The speed and urgency with which multiple vaccines have been authorized for use in the United States (U.S.),[2,3] the United Kingdom (U.K.),[4–6] and elsewhere[7] represent an unrivaled scientific achievement. However, there is a critical need for effective vaccine delivery to realize the promise of ending the pandemic. Logistical hurdles and supply chain difficulties have plagued the early phase of a massive global vaccination campaign, particularly in the U.S.[8] As of February 17, 2021, only 17 doses of vaccine per 100 individuals have been administered in the U.S. compared with 24 per 100 in the U.K.[9]

Racial and ethnic minorities are at particularly increased risk of COVID-19, its related complications, and death.[10–12] Nonetheless, eligibility for most vaccine programs have prioritized health care workers (HCW), older adults and those with comorbidities, but have not considered race or ethnicity.[13] In addition to concerns over fairness and availability, a substantial barrier to uptake in minority communities is vaccine hesitancy, rooted in ongoing discrimination and prior injustices that have resulted in deeply seated mistrust of the medical system.[14,15]

The U.S. and U.K. have diverse populations that have been comparably stricken by the COVID-19 pandemic. In contrast to the U.K., which has centralized vaccine delivery through the National Health Service, U.S. efforts have been led by fragmented state and local health authorities that have not routinely collected information on race, ethnicity, or hesitancy.[16] In both countries, there have been reports of racial/ethnic disparities in vaccine uptake, but specific data across a broad community-based sample, particularly in the U.S., are lacking. To assess the real-world impact of the initial phase of these vaccination programs, we used an established

smartphone-based data collection tool[17] to conduct a comparative population-based cohort study to examine country-specific variation in racial and ethnic disparities in vaccine willingness and receipt.

Methods

Study design and participants

We performed a cohort study in the U.S. and U.K. using the COVID Symptom Study (CSS) smartphone application developed by Zoe Global Ltd. in collaboration with researchers at the Massachusetts General Hospital, King's College London, Lund University, and Uppsala University.[17] This research study was approved by the Mass General Brigham Human Research Committee (Institutional Review Board Protocol 2020P000909) and King's College London Ethics Committee (REMAS ID 18210).

Beginning December 10, 2020–two days after the first authorized vaccine administration to a member of the U.K. public,[19] we introduced a questionnaire to U.K. participants assessing whether they received a vaccine dose. Starting January 7, 2021 in the U.S. and U.K. (study baseline), we collected information on participant willingness to obtain a COVID-19 vaccine (yes/no/unsure) if it was offered to them and any suspected vaccine-related symptoms. For those unsure about or unwilling to receive a vaccine, we queried their underlying reasons (**Table S1**).

Ascertainment of racial/ethnic identity

Information collected using the CSS application has previously been provided.[17] Briefly, at download and study enrollment, participants were asked to provide baseline demographic

information, as well as details on suspected risk factors or relevant comorbidities (**Table 1**).

They were asked with which race and/or ethnicity they self-identified based on standardized

categories from the National Institutes of Health (NIH) in the U.S.[21] and the Office for National

Statistics in the U.K. (**Table S2**).[22] In the U.S., Hispanic classification was defined as any race of

Hispanic or Latino ancestry. Non-Hispanic categories were defined as each respective race not

of Hispanic or Latino ancestry. Individuals who identified their race or ethnicity as "Other" were

offered an opportunity to provide a free-text entry. Those who identified as "Mixed Race" or

selected more than one race were categorized as "More than one race". "Native Hawaiian and

Pacific Islanders" were classified as Asian. Due to limited sample sizes, "American Indian or

Alaskan Natives" were categorized as "Other", and "Other" and "More than one race" were

combined. In the U.K., individuals were asked whether they identified as "Chinese" or

"Asian/British Asian", which offered the following examples, but did not specifically ask about

other racial identities from the Asian continent: "Indian, Pakistani, Bangladeshi, Other".

Responses were then aggregated in a manner consistent with prior analyses.[23] We excluded

individuals who selected "Prefer not to say" as their response or did not answer these questions.

Community-level sociodemographic factors

Participants who elected to share information on their zip code (U.S./U.K.) or Lower Layer

Super Output Area (LSOA, U.K.) of residence were assigned community-level socioeconomic

measures. Socioeconomic measures were generated using established metrics derived from

aggregated census data: proportion of individuals aged ≥25 years old with a Bachelor's degree

and median annual income (U.S.)[24] and the education and income measures from the U.K.'s

Indices of Multiple Deprivation (deciles, IMD),[25] respectively. U.S. zip codes were further

categorized into broader regions using U.S. Census Bureau criteria[26–28] (American Northeast,

Midwest, South, and West) and LSOAs were linked to one of four countries in the U.K. (England, Scotland, Northern Ireland, and Wales).[24]

Ascertainment of other covariates and exposures

We collected information on age (years), sex at birth (male, female, or other), weight (kg) and height (meters) were used to calculate body mass index (BMI, <18.5, 18.5-24.9, 25-29.9, and ≥30 kg/m^2), prior history of diabetes, heart disease, lung disease, kidney disease, or active malignancy (each yes/no), smoking history (current/prior vs. never), and frontline HCW status (yes/no). We longitudinally ascertained whether they had ever tested positive for COVID-19 (yes/no). To ascertain the validity of self-reported COVID Symptom Study information, we performed a validation study among a random subset of 235 users who reported a COVID-19 test from whom we requested photographs of their COVID-19 test reports. Study staff blinded to participant-provided information found excellent agreement between self-report and test reports with 88% sensitivity and 94% specificity.

Statistical analysis

For missing data, imputation replaced no more than 5% of missing values for a given metadatum with numeric values replaced with the median and categorical variables imputed using the mode. Complete case analyses without imputation were performed to ensure robustness of findings and to ensure correction of missingness did not materially alter risk estimates (data not shown). LHN, ADJ, DAD, and ATC had access to raw data. LHN performed data analysis, and the corresponding author had full access to data and the final responsibility to submit for publication. Based on the size of the assembled study population and the empirically observed vaccine hesitancy of 6%, we had 80% power to detect a minimum OR of

1.12 and 1.07, respectively, in the U.S. and the U.K. for risk of (or protection from) reporting vaccine hesitancy among non-White compared to White participants.

To investigate determinants of COVID-19 vaccine hesitancy and uptake, we performed multivariable logistic regression to estimate odds ratios (OR) and their 95% confidence intervals (CIs) conditioned upon age, sex, and date of study entry adjusting for history of diabetes, heart disease, lung disease, kidney disease, cancer, current/prior smoking status, BMI, prior history of COVID-19 infection, occupation as frontline HCW, geographic region (U.S.)/country (U.K.), and sociodemographic factors based on community-level measures of educational and financial deprivation. We performed stratified analyses among frontline HCWs and the general community, and both lower and higher community-level educational attainment and financial deprivation, respectively. Formal tests for interaction were assessed using the Wald test in models with country-by-race/ethnicity interaction terms. Finally, we reported the prevalence of localized injection-site symptoms among vaccinated participants. Two-sided *p*-values were considered statistically significant. All statistical analyses were performed using R 4.0.3 (Vienna, Austria) and packages from the Bioconductor 3.12 release.

Results

Study population

From March 24, 2020 to February 16, 2021, we enrolled a total of 4,797,306 individuals (*n*=370,282 U.S. participants and *n*=4,427,024 U.K participants), of whom 1,894,940 individuals were active (logged at least one entry) as of Dec 24, 2020 (i.e., two weeks prior to the initial vaccine questionnaire). After excluding participants who did not provide their racial/ethnic information and restricting to those who responded to at least one vaccine questionnaires, a final analytic cohort of 1,341,682 individuals remained; **Fig S1**).

In the U.S., White participants tended to be older and reside in communities with higher income and educational attainment compared to Black or Hispanic individuals (**Table 1**). Black and Hispanic individuals more frequently reported being a frontline HCW and having previously been infected with SARS-CoV-2. Similar trends were observed in the U.K.

Vaccine hesitancy among racial/ethnic minorities

Among 1,228,638 individuals who reported vaccine willingness, 91% of the 73,650 U.S. participants and 95% of the 1,154,988 U.K. participants were willing to accept a COVID-19 vaccine if offered (**Table S3**). In the U.S., those who were hesitant (unwilling/unsure) tended to be younger, female, less likely to have had heart disease or cancer, and more likely to live in communities with lower educational attainment and median incomes. Among frontline HCWs, 6% were unwilling to pursue vaccination and 11% were unsure, compared to 2% and 7% across the entire U.S. study population. Similar (younger) age distributions, burden of chronic disease, proportion of frontline HCWs, and rates of prior SARS-CoV-2 infection were observed among U.K. participants, though U.K. HCWs generally reported greater vaccine willingness.

In the U.S. and U.K., racial/ethnic minorities were more likely to report being unsure or unwilling to undergo vaccination. In the U.S., compared to White, the age-adjusted ORs for vaccine hesitancy were 3.84 (95% CI: 3.51 to 4.21) for Black, 1.69 (95% CI: 1.53 to 1.86) for Hispanic, and 1.22 (95% CI: 1.03 to 1.38) for Asian individuals, and 2.14 (95% CI: 1.82 to 2.52) for those who reported other or more than one race (**Table 2**). Additional adjustment for relevant covariates did not materially alter these risk estimates. Similar degrees of hesitancy were observed among racial and ethnic minorities in the U.K., which was most striking among Black and Hispanic individuals (**Table 2**).

In the U.S., we observed regional differences in willingness to be vaccinated with greater hesitancy in the South (**Table S4**). In the U.K., compared to participants in England, the age-adjusted ORs for vaccine hesitancy were 1.38 (1.25 to 1.51) for participants from Northern Ireland and 1.10 (1.06 to 1.15) for Wales. These were not substantially altered after additional adjustment.

When exploring the specific reasons for reluctance, the most frequently indicated concerns among all race and ethnicities related to long-term side effects (50-57%) and adverse reactions (45-54%). Additionally, Black and Hispanic individuals cited a lack of knowledge about the vaccine (45-51%) at a higher rate than White individuals (37-42%; **Table S5**).

Racial/ethnic disparities in COVID-19 vaccine uptake

Based on eligibility in the initial phase of mass vaccinations, as expected, vaccinated participants through February 1, 2021 tended to be older, had greater comorbidities, and were considerably more likely to be frontline HCWs (**Table S6**). In the U.S., Black individuals were less likely to be vaccinated than White participants (OR 0.71, 95% CI: 0.64 to 0.79), even after adjusting for age, region, comorbidities, and occupation as a HCW (**Table 3A**). In a subgroup analysis, these associations persisted even when we limited analysis to individuals who reported vaccine-willingness (**Table 3B**). In contrast, in the U.K, non-White participants reported higher vaccination rates than White individuals, including Black, South Asian, and Middle East/East Asian persons, though adjustment for personal and community risk factors attenuated these results.

The disparity in vaccine uptake among Black individuals compared with White individuals differed significantly by country ($P_{heterogeneity}<0.001$). When compared to White individuals within their respective countries, Black individuals were considerably less likely to be vaccinated in the

U.S. (**Fig. 1**). Compared to the Northeast, vaccine uptake was comparatively greater in other parts of the U.S. In the U.K., England appeared to have greater vaccine uptake compared to other countries where increased vaccine hesitancy has been documented (**Table S7**).[30,31]

Lower vaccine uptake among Black persons in the U.S. were comparable among specific sociodemographic groups, including frontline HCWs (**Table 4A**) and individuals living in communities with lower educational attainment (**Table 4C**). Notably, in the U.K., Black frontline HCWs had lower vaccine uptake than their White counterparts (**Table 4B**). Finally, no consistent differences were observed in local vaccine reactions according to race and ethnicity (**Table S8**).

Discussion

Among 1,341,682 participants in the U.S. and U.K., we observed increased COVID-19 vaccine hesitancy among racial/ethnic minority participants largely driven by concerns about long-term safety and fear of adverse reactions. Through the early phase of the vaccination campaign (February 1, 2021), we revealed significant racial and ethnic disparities in uptake in the U.S., but not the U.K., even among those willing to receive a vaccine, suggesting issues related to access in the U.S. Interestingly, we observed a higher than anticipated rate of vaccine hesitancy among frontline HCWs, perhaps due to their substantially higher rate of prior COVID-19 infection and heightened concern about the relative lack of initial safety data.

Our findings of greater vaccine hesitancy among minority populations has been previously shown in smaller, more limited investigations.[32] Deep-rooted and ongoing mistrust of the medical system among people of color[33] and a lack of diverse representation in clinical trials[34] likely play a substantial role in explaining this hesitancy. The speed with which vaccines were

approved has raised suspicions over whether regulatory standards meant to protect vulnerable populations were relaxed for expediency.[35] Moreover, racial and ethnic minorities who have already borne the disproportionate brunt of the pandemic[36] may be taking a more cautious approach to new vaccines, particularly with our current incomplete understanding of post-infectious immunity and potential adverse effects. Reassuringly, our data did not reveal significant differences in localized injection-site reactions by race/ethnicity. Prior work specifically examining attitudes toward COVID-19 vaccines further support our findings. A recent randomized controlled trial demonstrated that COVID-19 vaccine misinformation significantly reduced vaccination intent in the U.K. and U.S.[33] Notably, differences in susceptibility and receptiveness were observed across sociodemographic groups.

Our findings demonstrating lower vaccine uptake among communities of color have been shown in other studies. A recent study of U.K. HCWs showed substantially lower vaccine uptake among racial and ethnic minorities.[34] Our results significantly extend these data by concurrently examining vaccine hesitancy and receipt within the same participants from sizable community-based samples in two countries. Importantly, we found that even among the U.S. vaccine-willing population, Black individuals were less likely to receive a vaccine, whereas in the U.K., no consistent disparities in vaccine uptake were observed.

The strengths of our study include the prospective population-scale enrollment of a diverse group of participants from two comparably afflicted nations using a common data collection instrument. With disparate approaches to COVID-19 vaccination campaigns and healthcare delivery in the U.S. and U.K., our multinational study design provided a unique opportunity to consider the degree to which structural inequities, public mistrust, and unequal care access could result in differences in vaccine willingness and uptake. Our use of a digital platform to rapidly collect this information on vaccine skepticism and usage provides real-time actionable

insights to inform the public health response to an ongoing pandemic. Finally, extensive demographic information is generally not available in registry-level data or large-scale surveillance efforts, and we had an opportunity of uncommon breadth and depth to evaluate whether these established risk factors could influence vaccine attitudes and uptake.

We acknowledge several limitations. We relied primarily on volunteered information which may be subject to measurement and reporting bias. However, our validation study (**Methods**) demonstrates that self-reported information from the general population was accurately and faithfully reported. While our study had comparatively lower proportions of minorities, we enrolled relatively high absolute numbers for most groups. To maximize participation, greater detail on racial/ethnic self-identity could not be obtained, and our current categorizations may oversimplify or incompletely characterize the different lived experiences of minority participants navigating the healthcare system. Despite more than 80% of U.S. adults adopting smartphones,[35] we acknowledge that our data collection may have comparatively lower penetrance among certain socioeconomic/age groups, though under-recruitment of more deprived or less technologically literate participants would likely have attenuated observed differences. In fact, the use of a mobile app for data collection allowed us to highlight racial/ethnic disparities in uptake that persisted despite access to technology. Finally, our cohort of study volunteers willing to share information about COVID-19 does not represent a random sampling of the U.S. and U.K. population and are likely enriched for individuals that are generally more accepting of vaccinations. Nonetheless, the significant differences we observed in vaccine hesitancy and uptake between racial groups remain internally valid and likely underestimate broader disparities within population samples that do not use a common data collection instrument.

In conclusion, we found significantly higher likelihood of COVID-19 vaccine hesitancy among racial and ethnic minority groups in the U.S. and the U.K., particularly among Black and Hispanic individuals, driven by concerns about adverse effects, supporting the need for targeted vaccine education from trusted messengers. Furthermore, in the U.S., a striking disparity in vaccination uptake among Black Americans was observed even among vaccine-willing individuals with similar access to mobile technology to White Americans. This difference, not found in the U.K., suggests that early disparities in U.S. vaccine uptake have been exacerbated by inequities in the fairness of prioritization and distribution of vaccines to minority communities. Given the relative lack of a national public health infrastructure in the U.S., our data highlight the potential value of a more centralized system of vaccine delivery to ensure equitable vaccine uptake. Taken together, these findings support the need to address long-standing systemic disparities to achieve the health equity required for population-scale immunity.

Data Sharing

Data collected using the COVID Symptom Study smartphone application are being shared with other health researchers through the U.K. National Health Service-funded Health Data Research UK (HDRUK) and Secure Anonymised Information Linkage consortium, housed in the U.K. Secure Research Platform (Swansea, UK). Anonymized data are available to be shared with researchers according to their protocols in the public interest (https://web.www.healthdatagateway.org/dataset/fddcb382-3051-4394-8436-b92295f14259).

U.S. investigators are encouraged to coordinate data requests through the Coronavirus Pandemic Epidemiology (COPE) Consortium (https://www.monganinstitute.org/cope-consortium).

Declaration of Interests

LP, CH, SS, RD, and JW are employees of Zoe Global Ltd. TDS is a consultant to Zoe Global Ltd. DAD and ATC previously served as investigators on a clinical trial of diet and lifestyle using a separate smartphone application that was supported by Zoe Global Ltd.

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Table 1. Baseline characteristics of study participants by race and ethnicity according to country of enrollment

	United States				
	White (*n*=76286)	**Black (*n*=2468)**	**Hispanic (*n*=3838)**	**Asian (*n*=3602)**	**Other/More than one (*n*=1194)**
Age (years)	60.9 (15.0)	58.5 (16.0)	50.5 (18.1)	55.8 (20.3)	56.9 (17.1)
<25	1804 (2.4)	110 (4.5)	341 (8.9)	370 (10.3)	58 (4.9)
25-34	4035 (5.3)	149 (6.0)	563 (14.7)	376 (10.4)	106 (8.9)
35-44	6603 (8.7)	210 (8.5)	597 (15.6)	409 (11.4)	136 (11.4)
45-54	8716 (11.4)	341 (13.8)	646 (16.8)	445 (12.4)	163 (13.7)
55-64	15970 (20.9)	635 (25.7)	664 (17.3)	434 (12.0)	237 (19.8)
≥65	39158 (51.3)	1023 (41.5)	1027 (26.8)	1568 (43.5)	494 (41.4)
Female sex	50523 (66.2)	1825 (73.9)	2421 (63.1)	2193 (60.9)	773 (64.7)
BMI (kg/m^2)	27.0 (6.0)	30.0 (7.0)	27.9 (6.4)	25.1 (5.1)	28. (6.7)
<18.5	31208 (40.9)	582 (23.6)	1337 (34.8)	1900 (52.7)	404 (33.8)
18.5-24.9	1480 (1.9)	32 (1.3)	91 (2.4)	139 (3.9)	18 (1.5)
25-29.9	25206 (33.0)	815 (33.0)	1261 (32.9)	1085 (30.1)	419 (35.1)
≥30	18392 (24.1)	1039 (42.1)	1149 (29.9)	478 (13.3)	353 (29.6)
Comorbidities					
Diabetes	3770 (4.9)	274 (11.1)	215 (5.6)	272 (7.6)	74 (6.2)
Heart Disease	5988 (7.8)	165 (6.7)	219 (5.7)	263 (7.3)	102 (8.5)
Lung Disease	2261 (3.0)	76 (3.1)	59 (1.5)	68 (1.9)	46 (3.9)
Kidney Disease	1392 (1.8)	63 (2.6)	65 (1.7)	79 (2.2)	37 (3.1)

Table 1. Baseline characteristics of study participants by race and ethnicity according to country of enrollment

	United States				
	White (*n*=76286)	**Black** (*n*=2468)	**Hispanic** (*n*=3838)	**Asian** (*n*=3602)	**Other/More than one** (*n*=1194)
Cancer	2202 (2.9)	55 (2.2)	80 (2.1)	79 (2.2)	27 (2.3)
Education	45.5 (18.4)	36.5 (17.5)	38.9 (18.9)	47.0 (17.7)	43.1 (19.1)
Income	81106 (31527)	68086 (28329)	74883 (30427)	89684 (31559)	78042 (30526)
Current/prior smoking	22254 (29.2)	723 (29.3)	992 (25.8)	838 (23.3)	392 (32.8)
Healthcare worker	5985 (7.8)	226 (9.2)	346 (9.0)	273 (7.6)	105 (8.8)
Prior COVID-19	4542 (6.0)	204 (8.3)	514 (13.4)	192 (5.3)	89 (7.5)

All racial categories were defined as each respective race not of Hispanic or Latino ancestry. Census-level data on education assessed the proportion of the general population above age 25 years with a Bachelor's degree and income using median annual household income (U.S. dollars/year). N (percentages) presented for categorical variables. Values are means (SD) for continuous variables. Values of polytomous variables may not sum to 100% due to rounding
Abbreviations: BMI (body mass index), m (meter), kg (kilogram).

	United Kingdom				
	White (*n*=1204721)	**Black** (*n*=9615)	**South Asian** (*n*=17628)	**Middle East/East Asian** (*n*=7689)	**More than one/other** (*n*=14641)
Age (years)	55.0 (15.4)	47.4 (15.6)	49.6 (15.1)	49.3 (15.4)	46.7 (15.7)
<25	46399 (3.9)	920 (9.6)	816 (4.6)	369 (4.8)	1462 (10.0)
25-34	92413 (7.7)	1312 (13.6)	2021 (11.5)	1055 (13.7)	2022 (13.8)
35-44	159125 (13.2)	1676 (17.4)	4063 (23.0)	1710 (22.2)	3122 (21.3)
45-54	238482 (19.8)	2186 (22.7)	4391 (24.9)	1668 (21.7)	3172 (21.7)
55-64	306131 (25.4)	2323 (24.2)	3145 (17.8)	1404 (18.3)	2811 (19.2)
≥65	362171 (30.1)	1198 (12.5)	3192 (18.1)	1483 (19.3)	2052 (14.0)
Female sex	711693 (59.1)	5642 (58.7)	9883 (56.1)	4438 (57.7)	9016 (61.6)
BMI (kg/m^2)	26.6 (6.0)	27.7 (7.2)	25.5 (5.7)	25.3 (6.0)	26.2 (6.7)
<18.5	517674 (43.0)	3477 (36.2)	8779 (49.8)	4119 (53.6)	7033 (48.0)
18.5-24.9	31567 (2.6)	376 (3.9)	796 (4.5)	334 (4.3)	590 (4.0)
25-29.9	404507 (33.6)	3087 (32.1)	5422 (30.8)	2131 (27.7)	4265 (29.1)
≥30	250973 (20.8)	2675 (27.8)	2631 (14.9)	1105 (14.4)	2753 (18.8)
Comorbidities					
Diabetes	39168 (3.3)	429 (4.5)	1233 (7.0)	275 (3.6)	461 (3.1)
Heart Disease	48828 (4.1)	258 (2.7)	832 (4.7)	300 (3.9)	440 (3.0)
Lung Disease	25971 (2.2)	155 (1.6)	294 (1.7)	118 (1.5)	226 (1.5)
Kidney Disease	11089 (0.9)	112 (1.2)	206 (1.2)	69 (0.9)	128 (0.9)
Cancer	17046 (2.1)	121 (1.8)	151 (1.3)	71 (1.4)	129 (1.4)

	United Kingdom				
	White (*n*=1204721)	Black (*n*=9615)	South Asian (*n*=17628)	Middle East/East Asian (*n*=7689)	More than one/other (*n*=14641)
Education	7.1 (2.5)	6.5 (2.6)	7.24 (2.50)	7.5 (2.4)	7.4 (2.5)
Income	7.0 (2.5)	5.7 (2.7)	6.41 (2.65)	6.6 (2.6)	6.5 (2.6)
Current/prior smoking	272021 (22.6)	2210 (23.0)	2711 (15.4)	1533 (19.9)	3110 (21.2)
Healthcare worker	47300 (3.9)	636 (6.6)	1365 (7.7)	404 (5.3)	611 (4.2)
Prior COVID-19	72555 (6.0)	1020 (10.6)	1762 (10.0)	625 (8.1)	1242 (8.5)

Census-level data on education used the education score and income score for the Index of Multiple Deprivation, respectively. N (percentages) presented for categorical variables. Values are means (SD) for continuous variables. Values of polytomous variables may not sum to 100% due to rounding
Abbreviations: BMI (body mass index), m (meter), kg (kilogram)

Table 2. Vaccine hesitancy by race and ethnicity according to country of enrollment

	United States				
	White	**Black**	**Hispanic**	**Asian**	**More than one/other**
Number hesitant or unsure / total	4715/64144	611/2179	505/3235	309/3089	166/1003
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	3.84 (3.51 to 4.21)	1.69 (1.53 to 1.86)	1.22 (1.03 to 1.38)	2.14 (1.82 to 2.52)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	3.68 (3.35 to 4.05)	1.66 (1.50 to 1.84)	1.33 (1.17 to 1.50)	2.13 (1.80 to 2.52)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	3.15 (2.86 to 3.47)	1.42 (1.28 to 1.58)	1.34 (1.18 to 1.52)	2.02 (1.70 to 2.39)

	United Kingdom				
	White	**Black**	**South Asian**	**Middle East/East Asian**	**More than one/other**
Number hesitant or unsure / total	567734/1110544	1616/8787	1487/15199	771/6946	1270/13512
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	3.00 (2.86 to 3.16)	1.59 (1.51 to 1.67)	1.83 (1.70 to 1.97)	1.43 (1.36 to 1.52)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	2.96 (2.82 to 3.12)	1.65 (1.56 to 1.73)	1.84 (1.71 to 1.97)	1.42 (1.34 to 1.50)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	2.84 (2.69 to 2.99)	1.66 (1.57 to 1.76)	1.84 (1.7 to 1.98)	1.48 (1.39 to 1.57)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status, region, and education and income at the community level
Abbreviations: CI (confidence interval), OR (odds ratio)

Table 3. Vaccine uptake by race and ethnicity according to country of enrollment

A. Vaccine uptake among all participants

	United States				
	White	**Black**	**Hispanic**	**Asian**	**More than one/other**
Number receiving a vaccine / total	15341/64144	362/2179	519/3235	716/3089	202/1003
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	0.76 (0.68 to 0.84)	1.00 (0.92 to 1.10)	1.10 (1.02 to 1.19)	0.97 (0.84 to 1.11)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	0.76 (0.68 to 0.85)	1.01 (0.93 to 1.11)	1.07 (0.99 to 1.15)	0.96 (0.83 to 1.10)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.71 (0.64 to 0.79)	0.93 (0.84 to 1.02)	1.00 (0.93 to 1.09)	0.94 (0.81 to 1.08)

	United Kingdom				
	White	**Black**	**South Asian**	**Middle East/East Asian**	**More than one/other**
Number receiving a vaccine / total	171453/1110544	1022/8787	2339/15199	922/6946	1506/13512
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	1.13 (1.06 to 1.20)	1.34 (1.29 to 1.40)	1.10 (1.03 to 1.18)	1.05 (1.00 to 1.11)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	1.12 (1.06 to 1.19)	1.31 (1.25 to 1.36)	1.09 (1.02 to 1.16)	1.04 (0.98 to 1.09)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.98 (0.92 to 1.04)	1.18 (1.13 to 1.23)	1.01 (0.94 to 1.08)	0.99 (0.93 to 1.04)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status, region, and education and income at the community level
Abbreviations: CI (confidence interval), OR (odds ratio). Data shown through February 1, 2021.

B. Vaccine uptake among vaccine willing

	United States				
	White	**Black**	**Hispanic**	**Asian**	**More than one/other**
Number receiving a vaccine / total	15062/59429	328/1568	499/2730	681/2780	192/837
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	0.88 (0.78 to 0.98)	1.04 (0.95 to 1.14)	1.11 (1.03 to 1.20)	1.03 (0.89 to 1.19)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	0.88 (0.78 to 0.98)	1.05 (0.96 to 1.15)	1.08 (1.00 to 1.17)	1.02 (0.88 to 1.17)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.82 (0.73 to 0.92)	0.95 (0.86 to 1.04)	1.01 (0.93 to 1.09)	1.00 (0.86 to 1.16)

	United Kingdom				
	White	**Black**	**South Asian**	**Middle East/East Asian**	**More than one/other**
Number receiving a vaccine / total	168369/1053810	951/7171	2255/13712	884/6175	1469/12242
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	1.22 (1.14 to 1.30)	1.37 (1.31 to 1.42)	1.13 (1.06 to 1.21)	1.09 (1.03 to 1.15)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	1.22 (1.14 to 1.30)	1.33 (1.28 to 1.39)	1.12 (1.05 to 1.20)	1.07 (1.01 to 1.13)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	1.07 (1.00 to 1.14)	1.21 (1.16 to 1.26)	1.04 (0.97 to 1.11)	1.02 (0.97 to 1.08)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status, region, and education and income at the community level
Abbreviations: CI (confidence interval), OR (odds ratio). Data shown through February 1, 2021.

Table 4. Vaccine uptake by race and ethnicity according to country of enrollment by participant subgroup

A. Vaccine uptake among frontline healthcare workers and the general community

	United States				
	White	**Black**	**Hispanic**	**Asian**	**More than one/other**
Frontline healthcare workers					
Number receiving a vaccine / total	827/1906	28/112	41/136	41/89	18/44
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	0.59 (0.38 to 0.92)	0.85 (0.57 to 1.27)	1.00 (0.64 to 1.55)	1.01 (0.54 to 1.90)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	0.63 (0.39 to 1.03)	0.81 (0.52 to 1.25)	1.11 (0.68 to 1.80)	1.02 (0.50 to 2.06)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.67 (0.40 to 1.11)	0.84 (0.53 to 1.33)	1.01 (0.62 to 1.66)	1.04 (0.51 to 2.10)
General community					
Number receiving a vaccine / total	14514/62238	334/2067	478/3099	675/3000	184/959
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	0.75 (0.68 to 0.84)	1.01 (0.92 to 1.11)	1.10 (1.01 to 1.18)	0.95 (0.82 to 1.10)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	0.76 (0.68 to 0.85)	1.02 (0.93 to 1.12)	1.07 (0.98 to 1.15)	0.94 (0.81 to 1.09)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.73 (0.65 to 0.82)	0.93 (0.85 to 1.03)	0.99 (0.91 to 1.08)	0.91 (0.79 to 1.06)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status, region, and education and income at the community level (except in models for a given strata)
Abbreviations: CI (confidence interval), OR (odds ratio). Data shown through February 1, 2021.

	United Kingdom				
	White	**Black**	**South Asian**	**Middle East/East Asian**	**More than one/other**
Frontline healthcare workers					
Number receiving a vaccine / total	14955/25449	158/373	313/579	106/204	152/320
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	0.70 (0.59 to 0.82)	0.94 (0.84 to 1.06)	0.87 (0.72 to 1.06)	0.79 (0.67 to 0.93)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	0.71 (0.6 to 0.84)	0.97 (0.86 to 1.10)	0.85 (0.70 to 1.05)	0.81 (0.68 to 0.96)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.71 (0.6 to 0.85)	0.95 (0.84 to 1.09)	0.85 (0.68 to 1.05)	0.78 (0.65 to 0.94)
General community					
Number receiving a vaccine / total	156498/1085095	864/8414	2026/14620	816/6742	1354/13192
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	1.13 (1.06 to 1.21)	1.34 (1.28 to 1.4)	1.11 (1.04 to 1.19)	1.10 (1.04 to 1.16)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	1.13 (1.05 to 1.21)	1.30 (1.24 to 1.36)	1.10 (1.02 to 1.18)	1.08 (1.02 to 1.14)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	1.05 (0.98 to 1.13)	1.22 (1.17 to 1.28)	1.05 (0.98 to 1.13)	1.02 (0.97 to 1.08)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status, region, and education and income at the community level (except in models for a given strata)
Abbreviations: CI (confidence interval), OR (odds ratio). Data shown through February 1, 2021.

B. Vaccine uptake by economic deprivation

	United States				
	White	**Black**	**Hispanic**	**Asian**	**More than one/other**
Lower income (Quartile 1)					
Number receiving a vaccine / total	3660/15207	156/937	152/1033	71/421	55/267
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	0.73 (0.62 to 0.86)	0.99 (0.84 to 1.18)	0.90 (0.71 to 1.15)	1.13 (0.85 to 1.49)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	0.75 (0.63 to 0.89)	0.99 (0.83 to 1.19)	0.89 (0.69 to 1.14)	1.07 (0.80 to 1.43)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.73 (0.61 to 0.86)	0.94 (0.79 to 1.14)	0.90 (0.70 to 1.16)	1.08 (0.81 to 1.44)
Higher income (Quartile 4)					
Number receiving a vaccine / total	3645/15599	54/302	115/630	244/1089	53/225
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	0.86 (0.65 to 1.13)	1.13 (0.93 to 1.36)	1.09 (0.95 to 1.24)	1.13 (0.85 to 1.50)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	0.85 (0.64 to 1.13)	1.15 (0.94 to 1.39)	1.08 (0.94 to 1.24)	1.12 (0.84 to 1.49)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.83 (0.62 to 1.11)	1.05 (0.86 to 1.28)	0.97 (0.84 to 1.12)	1.09 (0.81 to 1.45)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status, region, and education and income at the community level (except in models for a given strata)
Abbreviations: CI (confidence interval), OR (odds ratio). Data shown through February 1, 2021.

	United Kingdom				
	White	**Black**	**South Asian**	**Middle East/East Asian**	**More than one/other**
Lower income (Quartile 1)					
Number receiving a vaccine / total	41761/283212	455/3904	745/5377	289/2260	459/4524
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	1.12 (1.02 to 1.23)	1.24 (1.15 to 1.33)	1.15 (1.02 to 1.29)	0.97 (0.88 to 1.06)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	1.11 (1.01 to 1.22)	1.21 (1.12 to 1.30)	1.15 (1.02 to 1.29)	0.95 (0.87 to 1.04)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.97 (0.89 to 1.07)	1.12 (1.04 to 1.21)	1.05 (0.94 to 1.18)	0.90 (0.82 to 0.99)
Higher income (Quartile 4)					
Number receiving a vaccine / total	29993/192710	111/863	345/2250	136/1063	224/2018
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	1.18 (0.98 to 1.42)	1.32 (1.19 to 1.47)	0.99 (0.83 to 1.17)	1.04 (0.91 to 1.19)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	1.20 (1.00 to 1.45)	1.29 (1.16 to 1.43)	0.97 (0.81 to 1.14)	1.03 (0.90 to 1.18)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	1.08 (0.90 to 1.31)	1.19 (1.07 to 1.33)	0.91 (0.77 to 1.08)	1.01 (0.88 to 1.15)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status, region, and education and income at the community level (except in models for a given strata)
Abbreviations: CI (confidence interval), OR (odds ratio). Data shown through February 1, 2021.

C. Vaccine uptake by educational attainment

	United States				
	White	**Black**	**Hispanic**	**Asian**	**More than one/other**
Lower educational attainment (Quartile 1)					
Number receiving a vaccine / total	3441/14875	141/926	189/1221	165/610	55/304
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	0.69 (0.58 to 0.82)	1.11 (0.95 to 1.30)	1.18 (1.01 to 1.39)	0.91 (0.69 to 1.21)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	0.70 (0.58 to 0.83)	1.15 (0.98 to 1.36)	1.14 (0.96 to 1.35)	0.87 (0.66 to 1.16)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.65 (0.54 to 0.78)	1.06 (0.90 to 1.26)	1.10 (0.92 to 1.31)	0.86 (0.64 to 1.14)
Higher educational attainment (Quartile 4)					
Number receiving a vaccine / total	3808/16031	56/278	88/528	155/800	46/214
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	0.96 (0.73 to 1.26)	1.03 (0.83 to 1.28)	1.27 (1.07 to 1.50)	1.06 (0.78 to 1.44)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	0.97 (0.73 to 1.28)	1.05 (0.84 to 1.32)	1.28 (1.08 to 1.52)	1.06 (0.78 to 1.45)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.93 (0.70 to 1.24)	0.95 (0.75 to 1.19)	1.19 (1.00 to 1.42)	1.09 (0.80 to 1.50)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status, region, and education and income at the community level (except in models for a given strata)
Abbreviations: CI (confidence interval), OR (odds ratio). Data shown through February 1, 2021.

	United Kingdom				
	White	**Black**	**South Asian**	**Middle East/East Asian**	**More than one/other**
Lower educational attainment (Quartile 1)					
Number receiving a vaccine / total	39534/273555	354/2822	439/3422	178/1324	289/2881
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	1.22 (1.10 to 1.36)	1.14 (1.03 to 1.25)	1.16 (1.00 to 1.35)	0.94 (0.84 to 1.05)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	1.21 (1.09 to 1.34)	1.13 (1.03 to 1.24)	1.18 (1.02 to 1.37)	0.93 (0.83 to 1.04)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	1.08 (0.97 to 1.20)	1.06 (0.97 to 1.17)	1.09 (0.94 to 1.27)	0.94 (0.83 to 1.05)
Higher educational attainment (Quartile 4)					
Number receiving a vaccine / total	35969/217167	153/1259	503/3215	220/1632	346/3110
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	1.07 (0.91 to 1.25)	1.30 (1.19 to 1.43)	1.05 (0.92 to 1.20)	1.03 (0.93 to 1.14)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	1.06 (0.90 to 1.24)	1.27 (1.16 to 1.39)	1.02 (0.89 to 1.17)	1.01 (0.91 to 1.13)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.96 (0.81 to 1.12)	1.13 (1.03 to 1.23)	0.93 (0.81 to 1.06)	0.96 (0.86 to 1.07)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status, region, and education and income at the community level (except in models for a given strata)
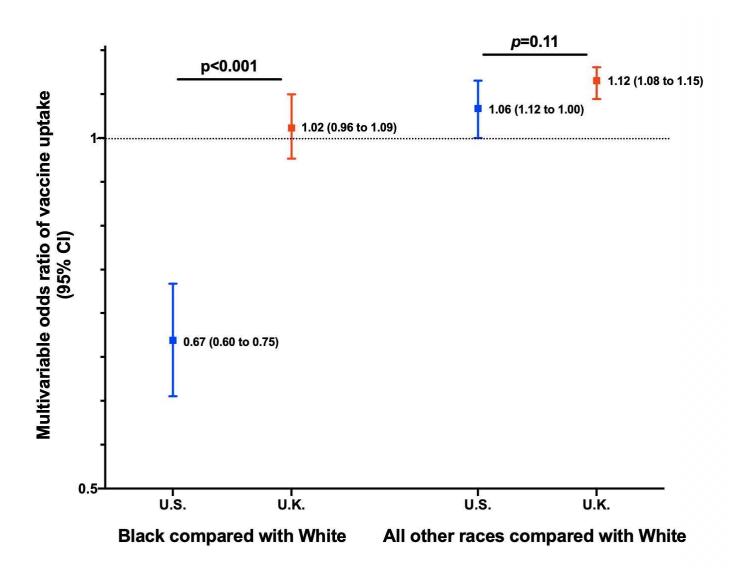Abbreviations: CI (confidence interval), OR (odds ratio). Data shown through February 1, 2021.

Figure 1. Disparity in vaccine uptake by race and ethnicity according to country of enrollment

Risk estimates of receiving a vaccine through February 1, 2021 calculated within country using multivariable logistic regression conditioned upon age, sex, and date of study entry and adjusted for personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, prior reported history of COVID-19 infection, frontline healthcare worker status, and education and income at the community level.
Abbreviations: CI (confidence interval), OR (odds ratio).

Figure S1. Study diagram

Table S1. Vaccine-related questions through February 1, 2021

Would you accept a COVID-19 vaccine if offered?

1. Yes

2. No

3. Unsure

If No or Unsure, tell us why. (Tick all that apply)

1. I took part in a vaccine trial

2. Religious reasons

3. Personal belief/philosophical reasons

4. Pregnancy/breastfeeding

5. Concerned about the long-term side effects

6. Do not know enough about it

7. Illness/Medication

8. Do not think it will be available to me

9. Do not think it is necessary

10. Do not think it will work

11. Concerned about adverse reaction

12. Prefer not to say

13. Other (free text)

Vaccine Uptake

Vaccine brand

Dose number

Date received

Batch (U.S.)/Lot (U.K.) number

Vaccine-related Symptoms

Are you experiencing any symptoms near the injection site? (Check all that apply)

1. Pain

2. Redness

3. Swelling

4. Swollen glands in the armpit

5. Warmth

6. Itch

7. Tenderness

8. Bruising

9. Other (free text)

Table S2. Race and ethnicity categories by country of enrollment

United States	
Responses	**Categories**
Non-Hispanic White	White, non-Hispanic
Black or African-American	Black
Hispanic/LatinX	Hispanic
Asian	Asian
Native Hawaiian or other Pacific Islander	Asian
American Indian or Alaska Native	More than one/other
Other non-Hispanic racial group, other racial or ethnic group, multiple race/ethnicity groups identified	More than one/other

United Kingdom	
Responses	**Categories**
White- British, Irish, or other	White
Black/Black British - Caribbean, African, or other	Black
Asian/Asian British - Indian, Pakistani, Bangladeshi, or other	Middle East/East Asian
Chinese/Chinese British	Chinese
Middle Eastern/Middle Eastern British - Arab, Turkish, other	Middle East/East Asian
East/Southeast Asian, other, or mixed/multiple race - White and Black/Black British, other	More than one/other

Table S3. Baseline characteristics of study participants by vaccine willingness and country of enrollment

	United States		
	Willing (*n*=67344)	**Unsure** (*n*=4943)	**Unwilling** (*n*=1363)
Age (years)	60.8 (15.5)	54.7 (17.2)	54.1 (16.8)
<25	2090 (3.1)	317 (6.4)	82 (6.0)
25-34	3681 (5.5)	486 (9.8)	145 (10.6)
35-44	5615 (8.3)	582 (11.8)	165 (12.1)
45-54	7548 (11.2)	783 (15.8)	217 (15.9)
55-64	13584 (20.2)	1063 (21.5)	320 (23.5)
≥65	34826 (51.7)	1712 (34.6)	434 (31.8)
Female sex	43181 (64.1)	3597 (72.8)	971 (71.2)
Race/ethnicity			
White	59429 (88.2)	3708 (75.0)	1007 (73.9)
Black	1568 (2.3)	468 (9.5)	143 (10.5)
Hispanic	2730 (4.1)	385 (7.8)	120 (8.8)
Asian	2780 (4.1)	262 (5.3)	47 (3.4)
More than one / other	837 (1.2)	120 (2.4)	46 (3.4)
BMI (kg/m^2)	27.0 (6.0)	28.0 (6.8)	27.9 (6.8)
<18.5	27477 (40.8)	1792 (36.3)	502 (36.8)
18.5-24.9	1372 (2.0)	121 (2.4)	36 (2.6)
25-29·9	22390 (33.2)	1493 (30.2)	405 (29.7)

Table S3. Baseline characteristics of study participants by vaccine willingness and country of enrollment

	United States		
	Willing (*n*=67344)	**Unsure** (*n*=4943)	**Unwilling** (*n*=1363)
≥30	16105 (23.9)	1537 (31.1)	420 (30.8)
Comorbidities			
Diabetes	3626 (5.4)	240 (4.9)	76 (5.6)
Heart Disease	5296 (7.9)	318 (6.4)	92 (6.7)
Lung Disease	1907 (2.8)	168 (3.4)	43 (3.2)
Kidney Disease	1290 (1.9)	97 (2.0)	34 (2.5)
Cancer	1955 (2.9)	113 (2.3)	19 (1.4)
Education	45.9 (18.4)	37.5 (17.5)	34.4 (16.3)
Income	81764 (31778)	73783 (28354)	70161 (25705)
Current/prior smoking	19582 (29.1)	1542 (31.2)	411 (30.2)
Healthcare worker	1833 (2.7)	301 (6.1)	153 (11.2)
Prior COVID-19	3734 (5.5)	702 (14.2)	263 (19.3)

All racial categories were defined as each respective race not of Hispanic or Latino ancestry. Census-level data on education assessed the proportion of the general population above age 25 years with a Bachelor's degree and income using median annual household income. N (percentages) presented for categorical variables. Values are means (SD) for continuous variables. Values of polytomous variables may not sum to 100% due to rounding
Abbreviations: BMI (body mass index), m (meter), kg (kilogram)

	United Kingdom		
	Willing (*n*=1093110)	**Unsure** (*n*=52021)	**Unwilling** (*n*=9857)
Age (years)	54.9 (15.0)	46.1 (14.7)	45.0 (15.3)
<25	42646 (3.9)	4609 (8.9)	855 (8.7)
25-34	81363 (7.4)	7383 (14.2)	1907 (19.3)
35-44	142917 (13.1)	11521 (22.1)	2320 (23.5)
45-54	218009 (19.9)	12823 (24.6)	1979 (20.1)
55-64	285250 (26.1)	10027 (19.3)	1702 (17.3)
≥65	322925 (29.5)	5658 (10.9)	1094 (11.1)
Female sex	631477 (57.8)	35134 (67.5)	6467 (65.6)
Race/ethnicity			
White	1053810 (96.4)	47663 (91.6)	9071 (92.0)
Black	7171 (0.7)	1340 (2.6)	276 (2.8)
South Asian	13712 (1.3)	1258 (2.4)	229 (2.3)
Middle East/East Asian	6175 (0.6)	677 (1.3)	94 (1.0)
More than one/other	12242 (1.1)	1083 (2.1)	187 (1.9)
BMI (kg/m^2)	26.6 (6.0)	26.4 (6.4)	26.1 (6.4)
<18.5	470397 (43.0)	23423 (45.0)	4452 (45.2)
18.5-24.9	28162 (2.6)	2122 (4.1)	478 (4.8)
25-29·9	368595 (33.7)	15604 (30.0)	2972 (30.2)
≥30	225956 (20.7)	10872 (20.9)	1955 (19.8)

	United Kingdom		
	Willing (*n*=1093110)	**Unsure** (*n*=52021)	**Unwilling** (*n*=9857)
Comorbidities			
Diabetes	36909 (3.4)	1004 (1.9)	198 (2.0)
Heart Disease	42258 (3.9)	979 (1.9)	191 (1.9)
Lung Disease	22022 (2.0)	672 (1.3)	127 (1.3)
Kidney Disease	9459 (0.9)	315 (0.6)	61 (0.6)
Cancer	14540 (1.9)	311 (0.9)	88 (1.3)
Index of multiple deprivation, education score	7.1 (2.5)	6.5 (2.7)	6.4 (2.7)
Index of multiple deprivation, income score	7.0 (2.5)	6.4 (2.7)	6.3 (2.7)
Current/prior smoking	242643 (22.2)	12671 (24.4)	2404 (24.4)
Healthcare worker	24300 (2.2)	1972 (3.8)	653 (6.6)
Prior COVID-19	62681 (5.7)	4583 (8.8)	1034 (10.5)

All racial categories were defined as each respective race not of Hispanic or Latino ancestry. Census-level data on education used the education score and income score for the Index of Multiple Deprivation, respectively. N (percentages) presented for categorical variables. Values are means (SD) for continuous variables. Values of polytomous variables may not sum to 100% due to rounding
Abbreviations: BMI (body mass index), m (meter), kg (kilogram)

Table S4. Vaccine hesitancy by geographical region according to country of enrollment

	United States			
	Northeast	**Midwest**	**South**	**West**
Number of individuals hesitant or unsure / total	1174/16365	1133/13093	1931/17633	1969/24474
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	1.16 (1.06 to 1.26)	1.43 (1.33 to 1.54)	1.16 (1.08 to 1.25)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	1.12 (1.03 to 1.23)	1.31 (1.21 to 1.41)	1.13 (1.05 to 1.23)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	1.03 (0.94 to 1.12)	1.24 (1.14 to 1.34)	1.04 (0.96 to 1.12)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for race/ethnicity, personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status and education and income at the community level

Regions defined by the U.S. Census Bureau guidelines. The Northeast included the states of Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The Midwest included the states of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. The South included Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia. The West included Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming.

Abbreviations: CI (confidence interval), OR (odds ratio)

	United Kingdom			
	England	**Northern Ireland**	**Scotland**	**Wales**
Number of individuals hesitant or unsure / total	50580/952267	434/5994	2744/56232	2581/49811
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	1.38 (1.25 to 1.51)	0.96 (0.93 to 1.00)	1.10 (1.06 to 1.15)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	1.44 (1.31 to 1.58)	1.00 (0.96 to 1.04)	1.13 (1.08 to 1.18)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	1.42 (1.30 to 1.57)	1.00 (0.96 to 1.04)	1.11 (1.07 to 1.16)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for race/ethnicity, personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status and education and income at the community level

Abbreviations: CI (confidence interval), OR (odds ratio)

Table S5. Reasons for vaccine hesitancy by race and ethnicity according to country of enrollment

Reason Cited (%)	United States				
	White (*n*=4715)	Black (*n*=611)	Hispanic (*n*=505)	Asian (*n*=309)	More than one/other (*n*=166)
Concerned about the long-term side effects	51.8	57.3	54.9	49.5	47.0
Concerned about adverse reaction	44.7	54.2	51.9	47.2	45.8
Do not know enough about it	41.7	50.6	50.9	42.4	41.6
Personal belief/philosophical reasons	8.8	14.1	13.1	7.8	10.8
Illness/Medication	8.3	8.7	7.5	7.1	12.1
Do not think it is necessary	6.7	2.5	4.2	3.9	10.8
Do not think it will be available to me	5.0	4.6	6.5	7.1	6.0
Prefer not to say	4.3	6.2	4.2	4.2	4.2
Do not think it will work	3.9	3.8	4.6	2.9	7.2
Pregnancy/breastfeeding	2.4	0.7	2.8	4.5	1.2
Religious reasons	1.9	1.3	3.6	2.6	2.4
I took part in a vaccine trial	0.3	0.3	0.4	0.3	0.6
Other	9.8	9.8	6.1	9.4	13.9

Proportions are calculated within racial and ethnic categories among individuals expressing vaccine unwillingness or unsure if they will obtain one. Participants were allowed to check more than one reason.

Reason Cited (%)	United Kingdom				
	White (*n*=56775)	Black (*n*=1617)	South Asian (*n*=1487)	Middle East/East Asian (*n*=771)	More than one/other (*n*=1270)
Concerned about the long-term side effects	49.9	52.9	50.9	55.6	51.3
Concerned about adverse reaction	30.2	39.3	36.5	37.2	34.4
Do not know enough about it	36.7	45.0	41.9	39.8	36.0
Personal belief/philosophical reasons	5.4	7.3	6.3	4.0	5.0
Illness/Medication	5.8	5.9	5.5	5.3	4.9
Do not think it is necessary	7.5	5.6	5.9	5.1	7.6
Do not think it will be available to me	9.0	7.2	9.8	8.4	10.9
Prefer not to say	5.8	8.0	8.3	6.2	5.5
Do not think it will work	3.0	2.8	4.7	3.4	3.7
Pregnancy/breastfeeding	7.6	4.8	5.9	6.0	6.3
Religious reasons	0.5	1.9	1.8	1.0	1.0
I took part in a vaccine trial	0.4	0.1	0.4	0.4	0.3
Other	8.2	6.2	5.1	7.4	9.0

Proportions are calculated within racial and ethnic categories among individuals expressing vaccine unwillingness or unsure if they will obtain one. Participants were allowed to check more than one reason.

Table S6. Baseline characteristics of study participants by vaccination status and country of enrollment

	United States	
	Vaccinated (*n*=26854)	**Unvaccinated** (*n*=46796)
Age (years)	69.1 (11.3)	55.2 (15.7)
<25	118 (0.4)	2371 (5.1)
25-34	495 (1.8)	3817 (8.2)
35-44	852 (3.2)	5510 (11.8)
45-54	1170 (4.4)	7378 (15.8)
55-64	2474 (9.2)	12493 (26.7)
≥65	21745 (81.0)	15227 (32.5)
Female sex	17652 (65.7)	30097 (64.3)
Race/ethnicity		
White	24138 (89.9)	40006 (85.5)
Black	615 (2.3)	1564 (3.3)
Hispanic	801 (3.0)	2434 (5.2)
Asian	990 (3.7)	2099 (4.5)
More than one / other	310 (1.2)	693 (1.5)
BMI (kg/m^2)	26.7 (5.6)	27.3 (6.3)
<18.5	11237 (41.8)	18534 (39.6)
18.5-24.9	535 (2.0)	994 (2.1)
25-29·9	9295 (34.6)	14993 (32.0)
≥30	5787 (21.5)	12275 (26.2)

Table S6. Baseline characteristics of study participants by vaccination status and country of enrollment

	United States	
	Vaccinated (*n*=26854)	**Unvaccinated** (*n*=46796)
Comorbidities		
Diabetes	1857 (6.9)	2085 (4.5)
Heart Disease	3118 (11.6)	2588 (5.5)
Lung Disease	1030 (3.8)	1088 (2.3)
Kidney Disease	702 (2.6)	719 (1.5)
Cancer	1122 (4.2)	965 (2.1)
Education	45.2 (18.2)	45.0 (18.7)
Income	81071 (31280)	80969 (31710)
Current/prior smoking	8999 (33.5)	12536 (26.8)
Healthcare worker	1145 (4.3)	1142 (2.4)
Prior COVID-19	751 (2.8)	3948 (8.4)

All racial categories categories were defined as each respective race not of Hispanic or Latino ancestry. Census-level data on education assessed the proportion of the general population above age 25 years with a Bachelor's degree and income using median annual household income. N (percentages) presented for categorical variables. Values are means (SD) for continuous variables. Values of polytomous variables may not sum to 100% due to rounding
Abbreviations: BMI (body mass index), m (meter), kg (kilogram)

	United Kingdom	
	Vaccinated (*n*=357358)	**Unvaccinated** (*n*=797630)
Age (years)	66.0 (12.3)	49.2 (13.3)
<25	2491 (0.7)	45619 (5.7)
25-34	8613 (2.4)	82040 (10.3)
35-44	16294 (4.6)	140464 (17.6)
45-54	29815 (8.3)	202996 (25.4)
55-64	51303 (14.4)	245676 (30.8)
≥65	248842 (69.6)	80835 (10.1)
Female sex	209567 (58.6)	463511 (58.1)
Race/ethnicity		
White	347170 (97.1)	763374 (95.7)
Black	1810 (0.5)	6977 (0.9)
South Asian	3931 (1.1)	11268 (1.4)
Middle East/East Asian	1649 (0.5)	5297 (0.7)
More than one/other	2798 (0.8)	10714 (1.3)
BMI (kg/m^2)	26.6 (5.9)	26.6 (6.1)
<18.5	151913 (42.5)	346359 (43.4)
18.5-24.9	9040 (2.5)	21722 (2.7)
25-29·9	126016 (35.3)	261155 (32.7)
≥30	70389 (19.7)	168394 (21.1)
Comorbidities		

	United Kingdom	
	Vaccinated (*n*=357358)	**Unvaccinated** (*n*=797630)
Diabetes	19317 (5.4)	18794 (2.4)
Heart Disease	27921 (7.8)	15507 (1.9)
Lung Disease	16295 (4.6)	6526 (0.8)
Kidney Disease	5947 (1.7)	3888 (0.5)
Cancer	11194 (4.2)	3745 (0.7)
Education	7.2 (2.5)	7.0 (2.5)
Income	7.1 (2.4)	6.9 (2.5)
Current/prior smoking	92163 (25.8)	165555 (20.8)
Healthcare worker	18249 (5.1)	8676 (1.1)
Prior COVID-19	15265 (4.3)	53033 (6.6)

All racial categories were defined as each respective race not of Hispanic or Latino ancestry. Census-level data on education used the education score and income score for the Index of Multiple Deprivation ,respectively. N (percentages) presented for categorical variables. Values are means (SD) for continuous variables. Values of polytomous variables may not sum to 100% due to rounding
Abbreviations: BMI (body mass index), m (meter), kg (kilogram)

Table S7. Vaccine uptake by geographical region according to country of enrollment

	United States			
	Northeast	**Midwest**	**South**	**West**
Number of individuals receiving a vaccine / total	2942/16365	2569/13093	4541/17633	6748/24474
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	1.13 (1.07 to 1.19)	1.69 (1.61 to 1.77)	1.52 (1.46 to 1.59)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	1.14 (1.08 to 1.21)	1.70 (1.62 to 1.79)	1.52 (1.45 to 1.59)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	1.14 (1.08 to 1.21)	1.73 (1.65 to 1.82)	1.55 (1.48 to 1.62)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for race/ethnicity, personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status and education and income at the community level

Regions defined by the U.S. Census Bureau guidelines. The Northeast included the states of Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The Midwest included the states of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. The South included Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia. The West included Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming.

Abbreviations: CI (confidence interval), OR (odds ratio). Data shown through February 1, 2021.

	United Kingdom			
	England	**Northern Ireland**	**Scotland**	**Wales**
Number of individuals receiving a vaccine / total	151200/952267	884/5994	4290/56232	6770/49811
Age-adjusted OR (95% CI)[1]	1.0 (ref.)	0.92 (0.86 to 0.98)	0.42 (0.40 to 0.43)	0.72 (0.70 to 0.74)
Multivariable-adjusted OR (95% CI)[2]	1.0 (ref.)	0.91 (0.85 to 0.97)	0.42 (0.40 to 0.42)	0.72 (0.70 to 0.73)
Multivariable-adjusted OR (95% CI)[3]	1.0 (ref.)	0.89 (0.83 to 0.95)	0.41 (0.40 to 0.42)	0.71 (0.70 to 0.73)

[1]Conditioned upon age and date of study entry
[2]Additional conditioning upon sex and adjustment for race/ethnicity, personal history of diabetes, heart disease, lung disease, kidney disease, current smoking status, body mass index, and prior reported history of COVID-19 infection
[3]Additional adjustment for frontline healthcare worker status and education and income at the community level

Abbreviations: CI (confidence interval), OR (odds ratio). Data shown through February 1, 2021.

Table S8. Localized symptoms among vaccinated participants according to country of enrollment

	United States				
	White (*n*=32316)	Black (*n*=811)	Hispanic (*n*=1198)	Asian (*n*=1328)	More than one/other (*n*=431)
Pain	9115 (28.2)	228 (28.1)	400 (33.4)	492 (37.0)	134 (31.1)
Redness	708 (2.2)	19 (2.3)	36 (3.0)	30 (2.3)	12 (2.8)
Swelling	1427 (4.4)	73 (9.0)	78 (6.5)	98 (7.4)	27 (6.3)
Swollen lymph nodes	159 (0.5)	11 (1.4)	13 (1.1)	6 (0.5)	4 (0.9)
Warmth	1463 (4.5)	46 (5.7)	94 (7.8)	76 (5.7)	38 (8.8)
Bruising	78 (1.1)	1 (0.5)	10 (4.6)	3 (1.4)	2 (2.1)
Itchiness	457 (1.4)	27 (3.3)	22 (1.8)	29 (2.2)	4 (0.9)
Tenderness	11950 (37.0)	281 (34.6)	466 (38.9)	528 (39.8)	157 (36.4)

	United Kingdom				
	White (*n*=393456)	Black (*n*=2218)	South Asian (*n*=5092)	Middle East/East Asian (*n*=2051)	More than one/other (*n*=3378)
Pain	53666 (13.6)	594 (26.8)	1662 (32.6)	514 (25.1)	800 (23.7)
Redness	6387 (1.6)	56 (2.5)	131 (2.6)	45 (2.2)	82 (2.4)
Swelling	10144 (2.6)	158 (7.1)	302 (5.9)	81 (3.9)	160 (4.7)
Swollen lymph nodes	1558 (0.4)	23 (1.0)	46 (0.9)	11 (0.5)	22 (0.7)
Warmth	15787 (4.0)	164 (7.4)	300 (5.9)	119 (5.8)	171 (5.1)
Bruising	2095 (1.7)	12 (2.0)	18 (1.5)	12 (2.2)	25 (2.6)
Itchiness	4029 (1.0)	38 (1.7)	78 (1.5)	29 (1.4)	58 (1.7)
Tenderness	111833 (28.4)	760 (34.3)	1559 (30.6)	592 (28.9)	1101 (32.6)

Proportions are calculated within racial and ethnic categories among individuals expressing vaccine unwillingness or unsure if they will obtain one. Participants were allowed to check more than one reason.