



Profiling vaccine attitudes and subsequent uptake in 1.1 million people in England: a nationwide cohort study

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Summary

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Background Despite highly effective vaccines against SARS-CoV-2, COVID-19 vaccine hesitancy persisted in some populations in England during the pandemic, with rates and motivations for hesitancy varying by demographic group. Addressing the drivers of vaccine hesitancy through targeted interventions in hesitant groups is a public health priority for better and more rapid control of disease spread. We aimed to characterise the determinants and subtypes of vaccine hesitancy and identify more persistent forms of hesitancy via analysis of vaccine uptake in a large cross-sectional cohort with linked National Health Service (NHS) data.

Methods We conducted an initial cross-sectional analysis of vaccine hesitancy at baseline, followed by a longitudinal analysis of vaccine uptake in the hesitant cohort. We analysed survey data from the Real-time Assessment of Community Transmission (REACT) studies, which monitored the prevalence of SARS-CoV-2 in England during the COVID-19 pandemic at regular intervals from May 1, 2020, to March 31, 2022, in random samples of the population. Participants self-reported detailed sociodemographic information, vaccination status, and attitudes towards vaccination. Participants were classified as hesitant if they reported that they had refused, planned to refuse, or had not yet decided whether to receive the COVID-19 vaccine. Participants who said they were unvaccinated when NHS records showed that they had been vaccinated were excluded from further analysis. The primary outcome of the cross-sectional analysis was vaccine hesitancy. Longitudinal analysis of vaccine uptake was done in participants in the hesitant cohort who consented to the use of linked NHS vaccination records to track their vaccination history after the survey, with post-survey vaccination as the outcome. Consensus clustering was used to categorise reasons for vaccine hesitancy, and cross-sectional and longitudinal analyses used logistic regression models to identify demographic predictors of vaccine hesitancy and subsequent vaccination.

Findings Our analyses included 1137927 adults (aged 18 years and older) surveyed between Jan 6, 2021, and March 31, 2022. Across the whole study period, 37982 (3.3%) participants indicated some form of vaccine hesitancy. Hesitancy rates peaked at 8.0% in early 2021, subsequently decreasing to a low of 1.1% at the start of 2022, and increasing to 2.2% in early 2022. Of the 24229 participants who indicated hesitancy and consented to NHS data linkage, 15744 (65.0%) went on to receive one or more vaccinations. Cluster analysis identified eight stable categories of vaccine hesitancy, including concerns about effectiveness and side-effects, perception of low risk from COVID-19 and mistrust of vaccine developers, and fear of vaccines and reactions. The most prevalent categories of hesitancy, related to effectiveness and health concerns, declined substantially over the roll-out period and were not strongly associated with the likelihood of later vaccination. Some forms of hesitancy, primarily related to low trust, low risk perception, and general anti-vaccine sentiment, were more resistant, rebounded in 2022, and were strongly associated with a lower likelihood of subsequent vaccination.

Interpretation Our findings suggest that most COVID-19 vaccine hesitancy was rooted in concrete concerns that can be addressed and successfully overcome with time and increasing availability of information. These findings should help future vaccination roll-outs to encourage vaccine acceptance.

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Introduction

Vaccine hesitancy—a reluctance or refusal to take a vaccine when offered—is a major public health challenge with complex determinants. Before the COVID-19 pandemic, vaccine hesitancy was already a growing public health issue, stimulated in particular by misinformation regarding risks of childhood vaccination.¹

Tangible effects of vaccine hesitancy have included a global resurgence of measles mortality, in part due to reduced rates of vaccination.² Against this background, the COVID-19 pandemic and vaccine roll-out put vaccine attitudes at the centre of political and social discourse.

Rapid and widespread vaccine roll-outs were essential to reducing the spread of SARS-CoV-2 virus and risk of

Research in context

Evidence before this study

A PubMed search for ("vaccine"[Title] OR "vaccination"[Title]) AND ("hesitancy"[Title] OR "attitude"[Title]) OR "Vaccine hesitancy"[MeSH Terms] OR "Vaccine acceptance"[MeSH Terms] from database inception to June 16, 2025, without language restrictions, returned 3689 papers. Of these, 2044 mentioned COVID-19 or SARS-CoV-2 in the title. Estimates showed that the prevalence of COVID-19 vaccine hesitancy in the UK changed over time from as high as 31% in March, 2020, to as low as 4% in early 2022. Established psychological predicates of COVID-19 vaccine hesitancy include low trust in institutions and experts, concerns over side-effects, perception of COVID-19 as being low risk, and lack of information.

Added value of this study

To the best of our knowledge, no previous research has linked COVID-19 vaccine attitudes before vaccination with

subsequent vaccination behaviour. Our analyses leveraged longitudinal survey data from participants in the Real-time Assessment of Community Transmission studies, in whom vaccine sentiment at enrolment could be compared with subsequent vaccination history from linkage data. Our results show that specific types of hesitancy, generally relating to concerns over vaccine effectiveness and health consequences, were more prevalent in the early phase of the vaccine roll-out. Individuals expressing these types of hesitancy were more likely to go on to be vaccinated than those expressing hesitancy stemming from low trust, perception of COVID-19 as being low risk, or general anti-vaccine sentiment.

Implications of all the available evidence

Our results provide a data-driven characterisation of the main types of vaccine hesitancy and a first quantitative exploration of their potential for reversibility. The findings will help inform the targeting and messaging for future vaccination roll-outs.

severe disease from COVID-19 (the disease caused by the virus), thereby allowing the easing of lockdowns and other restrictions during the pandemic's first year.³ The vaccination roll-out began in the UK on Dec 8, 2020, with a phased strategy that prioritised population cohorts on the basis of age and clinical risk.⁴ Eligible cohorts were notified by SMS and by post, with follow-up reminders. Despite the availability of highly effective vaccines⁵⁻⁷ with relatively low levels of adverse events,⁸ vaccine hesitancy persisted in many populations.⁹ A US-based study estimated that 45 deaths per million people could have been averted for every 1% decrease in baseline vaccine hesitancy during the COVID-19 pandemic.¹⁰ Addressing vaccine hesitancy was, therefore, a primary public health concern worldwide and was the focus of large-scale public awareness and information campaigns during the pandemic.¹¹

Sociodemographic determinants of COVID-19 vaccine hesitancy have been well characterised in the UK. Rates of COVID-19 vaccine hesitancy were higher in individuals who were not of White ethnicity^{12,13} and in less-educated, economically disadvantaged individuals versus those in individuals of White ethnicity and more-educated, less economically disadvantaged individuals, respectively.¹³⁻¹⁵ Some campaigns, therefore, targeted specific sociodemographic groups¹⁶ to improve rates of vaccine uptake.

Variation in hesitancy rates by demographic groups might, however, only be indicators of different underlying attitudinal drivers of hesitancy, which vary between demographic and cultural groups. Understanding these drivers is paramount for successful public health campaigns¹⁷ and for preparedness for future health crises. Previous studies have proposed categories of psychological disposition towards vaccination,¹⁸ the better to understand

and explain hesitancy. Betsch and colleagues¹⁸ proposed the 5 Cs model to describe the psychological antecedents of vaccination: confidence, complacency, convenience (or constraints), risk calculation, and collective responsibility. Doglioni and colleagues¹⁹ extended this model to 7 Cs in the aftermath of the COVID-19 pandemic, adding social conformism and confidence in the system and showing that these antecedents improved the fit of models of vaccine intentionality.

Other studies have applied these existing categorical frameworks of vaccine hesitancy to COVID-19 vaccines²⁰ and investigated changing attitudes to vaccination during the pandemic.²¹⁻²⁴ To our knowledge, however, none have investigated relationships between vaccine attitudes and subsequent independently recorded vaccination behaviour, and none have used data-driven approaches to identify categories of vaccine hesitancy. Here, we used vaccine attitude survey data from 1·1 million participants at the time of the COVID-19 vaccine roll-out in England alongside linked, prospective National Health Service (NHS) vaccination data to characterise the determinants of vaccine hesitancy, classify subtypes of hesitancy, and identify so-called harder and softer categories of hesitancy as defined by those going on to refuse or accept actual COVID-19 vaccination.

Methods

Study design and participants

The Real-time Assessment of Community Transmission (REACT) studies monitored the community prevalence of SARS-CoV-2 virus positivity (REACT-1)²⁵ and anti-spike protein antibody positivity (REACT-2)²⁶ in England during the COVID-19 pandemic. The protocols and sampling methods have been described elsewhere.^{25,26} Briefly, random population samples (from the NHS list

of patients registered with a general practitioner in England) were invited to participate in the study every 4–6 weeks between May 1, 2020, and March 31, 2022 (REACT-1) or every 2–4 months between June 20, 2020, and May 25, 2021 (REACT-2). Participants completed an extensive survey (either online or by post) with sections on demographics (age, sex, education level, and ethnicity), comorbidities (including depression, anxiety, and other psychiatric disorders), behaviour (smoking, shielding, and face covering), and history of COVID-19 (appendix pp 3–5). REACT-1 participants supplied a nose or throat swab sample for PCR testing for SARS-CoV-2 virus and REACT-2 participants conducted an at-home fingerprick lateral flow immunoassay test for SARS-CoV-2 antibodies. All participants gave written consent for their data to be used for research purposes; we also sought consent for linkage to participants' NHS records. We obtained research ethics approval from the South Central-Berkshire B Research

Ethics Committee (Integrated Research Application System ID: 283787).

Vaccine hesitancy, vaccine refusal, and subsequent vaccination status

From Jan 6, 2021 onwards, surveys included questions about participants' vaccination status and attitudes. Participants were asked whether they had been, or intended to get, vaccinated. Those who had refused the vaccine or who were not certain that they intended to get vaccinated were asked about their motivations for hesitancy or refusal (from a checklist of 23 options [appendix p 3], with the additional option to write in free text). Participants were classified as hesitant if they reported that they had refused, planned to refuse, or had not yet decided whether to receive the COVID-19 vaccine.

Most participants consented to linkage to their NHS records (appendix p 15). We obtained individual incident vaccination status from (consented) linkage to NHS

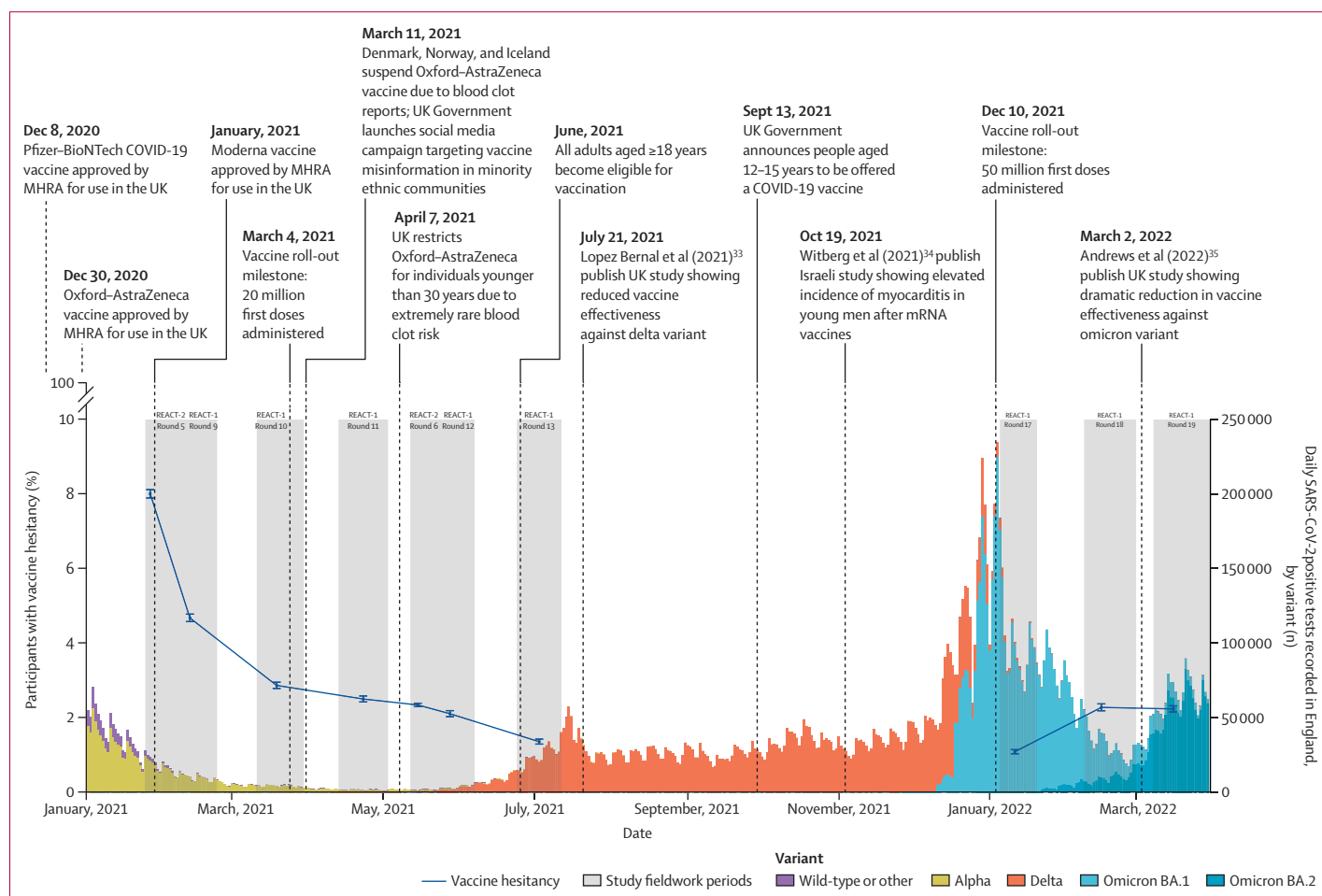


Figure 1: Daily SARS-CoV-2 positive tests recorded in England from Jan 1, 2021, to March 31, 2022, and percentage of study population reporting vaccine hesitancy
The plot shows the numbers of SARS-CoV-2 positive tests by variant (right-hand y-axis; shaded and colour-coded plot area; data from the UK Health Security Agency³¹ and GISAID via covariants.org.³² with major processing by Our World in Data) and percentage of study participants reporting hesitancy (left y-axis; black error bars and dotted joining lines); error bars denote 95% CIs. REACT-1²⁵ and REACT-2²⁶ fieldwork periods are denoted by shaded grey areas. Milestones in the UK vaccine roll-out and notable publications and events relating to vaccine safety and effectiveness are shown in annotations.^{33–35} MHRA=UK Medicines and Healthcare products Regulatory Agency.

records of COVID-19 vaccinations to May 7, 2024,²⁷ and compared NHS vaccination records with self-reported vaccination histories to examine data validity. Participants who said they were unvaccinated when NHS records showed that they had been vaccinated were excluded from further analysis (appendix p 5). Those who said they had been vaccinated but had no NHS record were not excluded, as non-NHS vaccination (eg, overseas or through clinical trials) could not be ruled out.

Statistical analysis

We conducted an initial cross-sectional analysis of reported vaccine hesitancy at baseline, followed by a longitudinal analysis of vaccine uptake in the hesitant cohort who consented to linkage. Outcomes were vaccine hesitancy and subsequent vaccination, respectively.

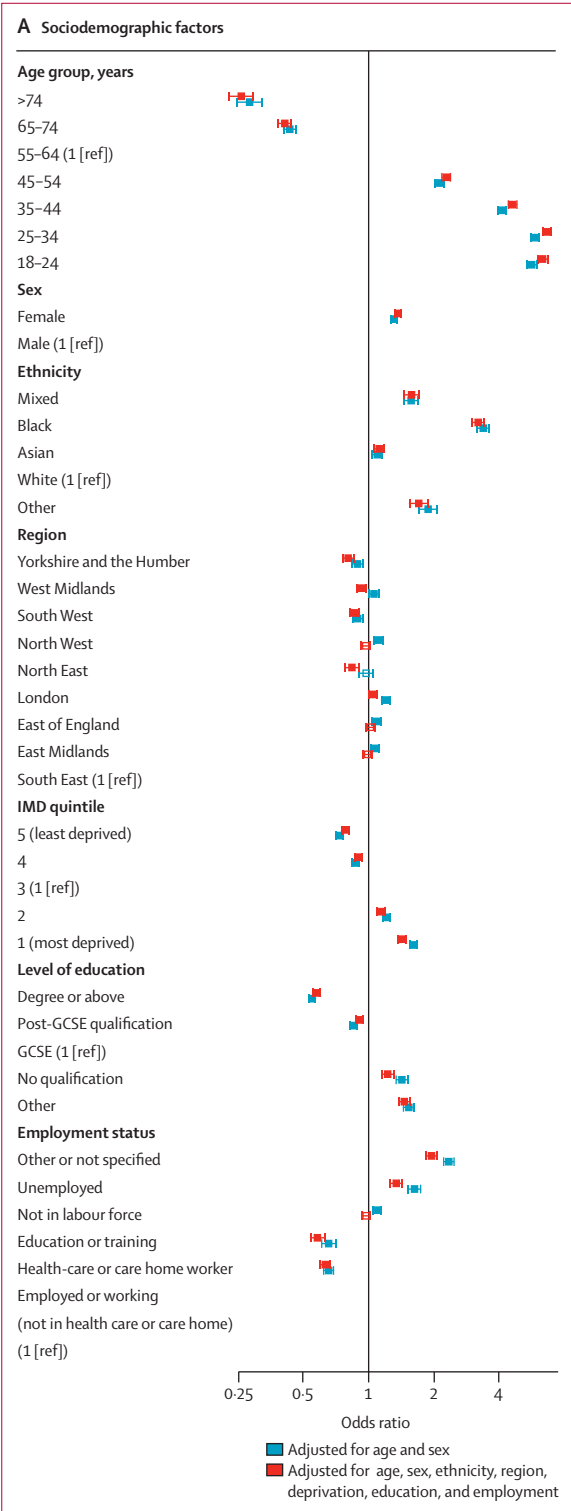
Descriptive analyses were conducted to visualise changing rates of hesitancy over time and show the variation in motivations for hesitancy across demographic groups. Multivariable logistic regression was used to identify sociodemographic characteristics associated with vaccine hesitancy or refusal and to estimate their mutually adjusted effects. Odds ratios (ORs) are reported, with adjusted risk differences also computed with the mean predicted probability under the reference versus non-reference categories. We report 95% CIs for all parameter estimates; 95% CIs obtained for prevalence estimates were derived from the Wilson score interval.

Among those indicating hesitancy, we applied hierarchical consensus clustering²⁸ using Ward’s method²⁹ and used the Jaccard distance metric to partition the hesitancy reasons into groups (appendix pp 5–6). The optimal number of clusters was ascertained with the consensus score. Alternative clustering algorithms and metrics were implemented as sensitivity analyses.

Reason-specific temporal trends in vaccine hesitancy were analysed by calculating the number and proportion of respondents reporting each reason by week and fitting weighted generalised additive models to the proportions, with weights determined by the total number reporting the reason. More detailed model specifications are included in the appendix (p 6).

The longitudinal analysis in the hesitant cohort used logistic regression models with post-survey vaccination as the outcome to identify demographic characteristics and specify hesitancy reasons associated with the likelihood of subsequent vaccination. The models were also used to investigate specific reasons for vaccine hesitancy to identify the reasons that were indicative of persistent hesitancy (ie, a lower likelihood of subsequently receiving a vaccination).

All models, with the exception of those modelling relationships between reasons for hesitancy and subsequent vaccination, were adjusted for age, sex, ethnicity, region, area-level deprivation (measured as Index of Multiple Deprivation quintiles),³⁰ education (degree or



(Figure 2 continues in next page)

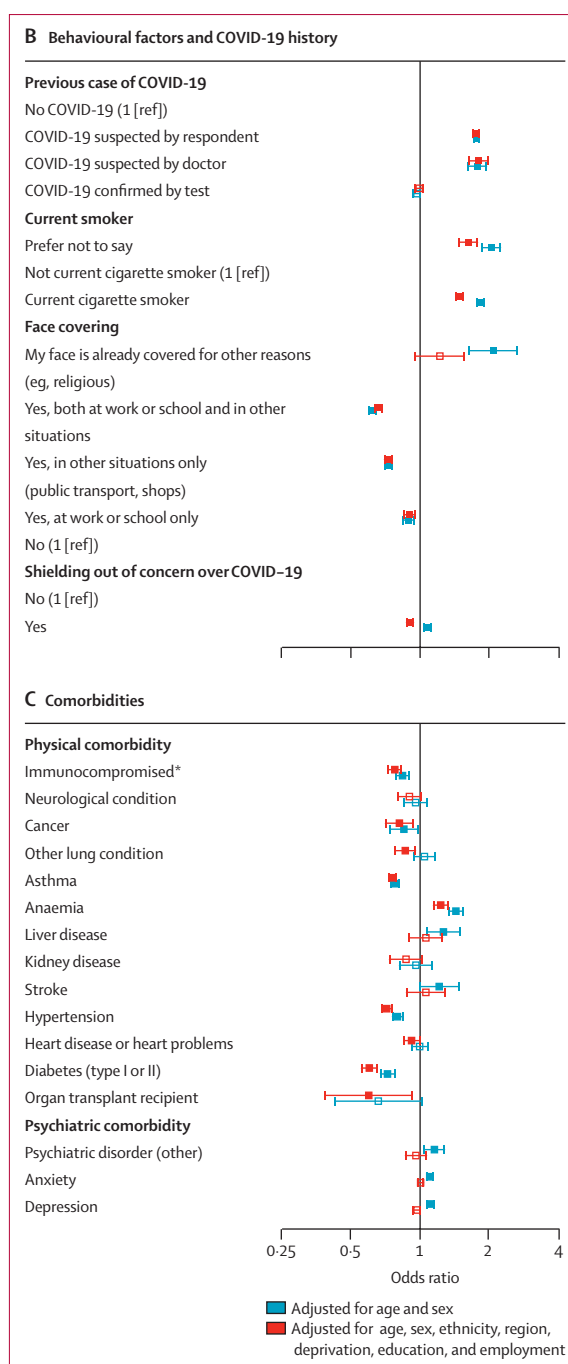


Figure 2: Odds ratios for vaccine hesitancy or refusal versus intention to vaccinate or previous vaccination in 1137 927 participants in the REACT study

Odds ratios are reported for models adjusted for age and sex or for age, sex, ethnicity, region, deprivation, education, and employment and subdivided by sociodemographic factors (A), behavioural factors and COVID-19 history (B), and comorbidities (C; reference categories for all comorbidities are those without the specific comorbidity). Solid boxes indicate significant odds ratios; hollow boxes indicate non-significant odds ratios. Whiskers indicate 95% CIs. GCSE=General Certificate of Secondary Education. IMD=Index of Multiple Deprivation. *Weakened immune system or reduced ability to deal with infections.

higher qualification; post-General Certificate of Secondary Education [GCSE] qualification; GCSE; no qualification; or other) and employment status (employed—health-care or care home worker; employed—not health-care or care home worker; in education or training; not in labour force; unemployed; or other). Models of relationships between reasons for hesitancy and subsequent vaccination were adjusted for age and sex only. As a sensitivity analysis, we further adjusted all models for survey round (to account for changing vaccine availability, COVID-19 prevalence, variant, and information environment across the study period). All analyses were done with R statistical software (version 4.4.3).

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Of the 4354480 participants from REACT-1²⁵ and REACT-2²⁶ who registered for this study, our analyses included 1137927 adults (aged 18 years and older) surveyed between Jan 6, 2021, and March 31, 2022 (rounds 9–13 and 17–19 of REACT-1 and rounds 4–6 of REACT-2). Data on vaccine hesitancy were not collected in rounds 14–16 of REACT-1, and these rounds were, therefore, excluded.

318729 (28.0%) of 1137927 participants were unvaccinated at the time of their survey. Over the whole study period, 37982 respondents (3.3% of the study population) indicated some degree of vaccine hesitancy, of whom 10316 (0.9% of the study population) reported that they had either refused the COVID-19 vaccine or were planning to refuse it (appendix p 8). A further 27666 (2.4%) respondents reported they had not yet decided whether to take the vaccine or would prefer not to answer (appendix pp 17–20).

Rates of vaccine hesitancy declined over time, from an initial high of 7.9% (11945 of 151608) in those surveyed in January, 2021, to a low of 1.1% (937 of 85564) at the start of 2022, before increasing again to 2.3% (2003 of 88801) in February and March, 2022 (figure 1).

Higher risk of vaccine hesitancy was associated with younger age (adjusted OR 6.41 [95% CI 6.11–6.73] for ages 18–24 years vs 55–64 years), female sex (1.37 [1.34–1.40] for female vs male), ethnicity other than White (with the largest OR of 3.22 [3.04–3.42] for Black ethnicity vs White ethnicity), deprivation (1.43 [1.38–1.48] for the most deprived quintile vs the third quintile), low educational attainment (1.23 [1.16–1.29] for no qualification vs GCSE), employment status (1.37 [1.30–1.46] for unemployed vs employed), previous suspected (but not test-confirmed) COVID-19 (1.75 [1.71–1.80] for respondent-suspected COVID-19 vs no COVID-19), and smoking (1.48 [1.43–1.53] for being a current smoker vs not being a current smoker; figure 2; appendix pp 25–26). We found a negative

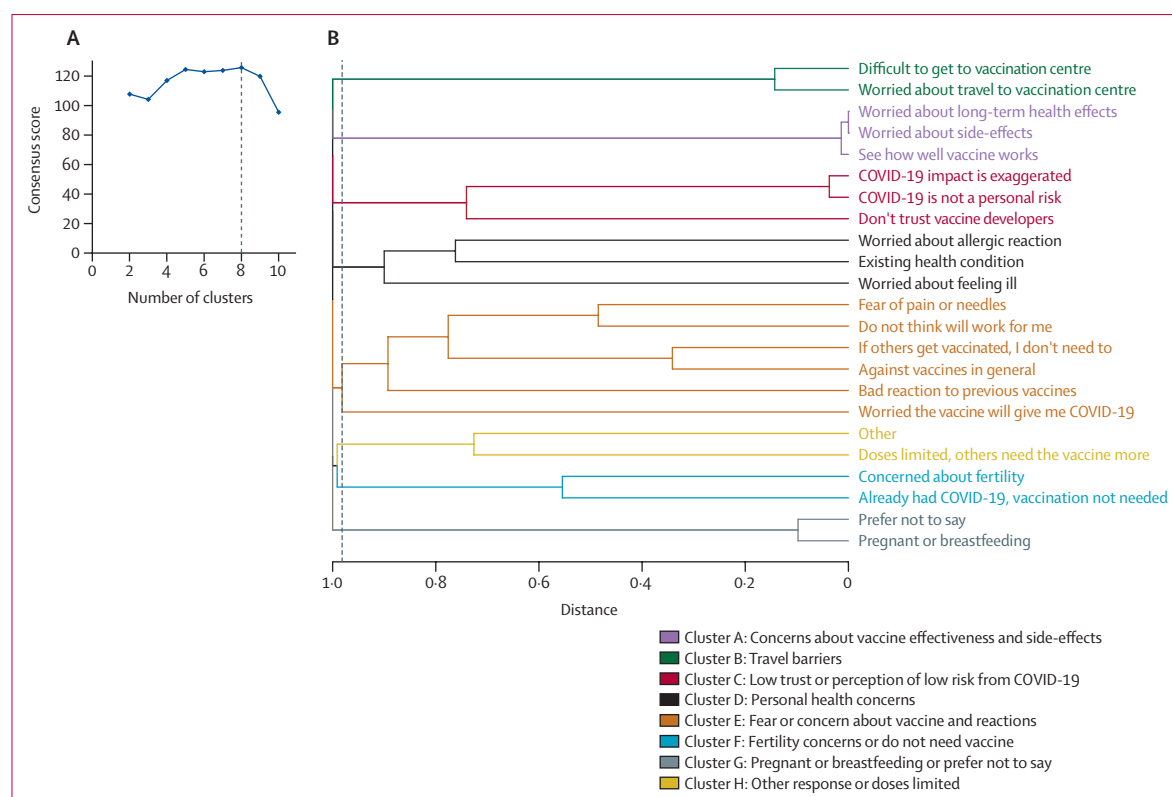


Figure 3: Consensus clustering of vaccine hesitancy reasons in 30 701 participants

(A) Optimisation plot with consensus clustering as a function of the number of clusters, showing that eight clusters optimised the consensus score. (B) Dendrogram showing the clustering of hesitancy reasons. Dashed line on dendrogram indicates optimal split point according to the consensus score.

association (less hesitancy) among those masking for non-religious reasons (0.66 [0.64–0.69] for those masking at work or school and elsewhere vs not masking) and shielding (0.91 [0.88–0.94]). Many physical (but not psychological) comorbidities were also associated with hesitancy, both negatively (eg, diabetes: 0.60 [0.56–0.65]) and positively (eg, anaemia: 1.23 [1.15–1.32]). Results expressed as adjusted risk differences are reported in the appendix (pp 27–28).

Consensus clustering grouped the vaccine hesitancy reasons into eight stable categories (figure 3A). Cluster A included concerns about vaccine effectiveness and general concerns about short-term and long-term side-effects; cluster B included concerns about travel to the vaccination centre; cluster C included perception of low risk from COVID-19 and mistrust of vaccine developers; cluster D included personal health concerns; cluster E included fear of vaccines, previous adverse reactions, and generalised anti-vaccine sentiment; cluster F included fertility and perceived lack of need because of having had COVID-19 previously; cluster G included concerns over pregnancy or breastfeeding and the response “Prefer not to say”; and cluster H included the response “Other” and concern over doses being limited (figure 3B). Differing clustering metrics and algorithms mostly identified similar groupings (appendix p 9).

The most prevalent reasons for hesitancy were all from cluster A (vaccine effectiveness and side-effects). Of 30 701 participants who were given the option of reporting prespecified reasons for hesitancy, 12 498 (40.7%) reported that they were worried about long-term health effects; 11 953 (38.9%) reported that they wanted to wait and see how well the vaccine worked; and 11 287 (36.8%) reported that they were worried about side-effects (appendix p 10). Analysis of correlations between hesitancy reasons showed high within-cluster levels of correlation for clusters A, C, and D (appendix pp 11–12).

Reasons for hesitancy varied across demographic groups. Men were more likely than women to report hesitancy reasons from cluster C (low trust and risk perception): for example, 1924 (17.9% [95% CI 17.2–18.6]) of 10 744 men said that they did not feel that COVID-19 was a personal risk, compared with 2036 (10.2% [9.8–10.6]) of 19 956 women (appendix pp 13, 30–31). Women, by contrast, were more likely to be concerned about fertility: 1696 (21.2% [20.4–22.1]) of 7988 women versus 349 (8.4% [7.6–9.3]) of 4134 men. By age, fear of pain or needles was largely confined to younger age groups: 332 (8.3% [7.5–9.2]) of 3989 participants aged 18–24 years versus three (1.5% [0.5–4.2]) of 204 participants aged 74 years or older (figure 4; appendix

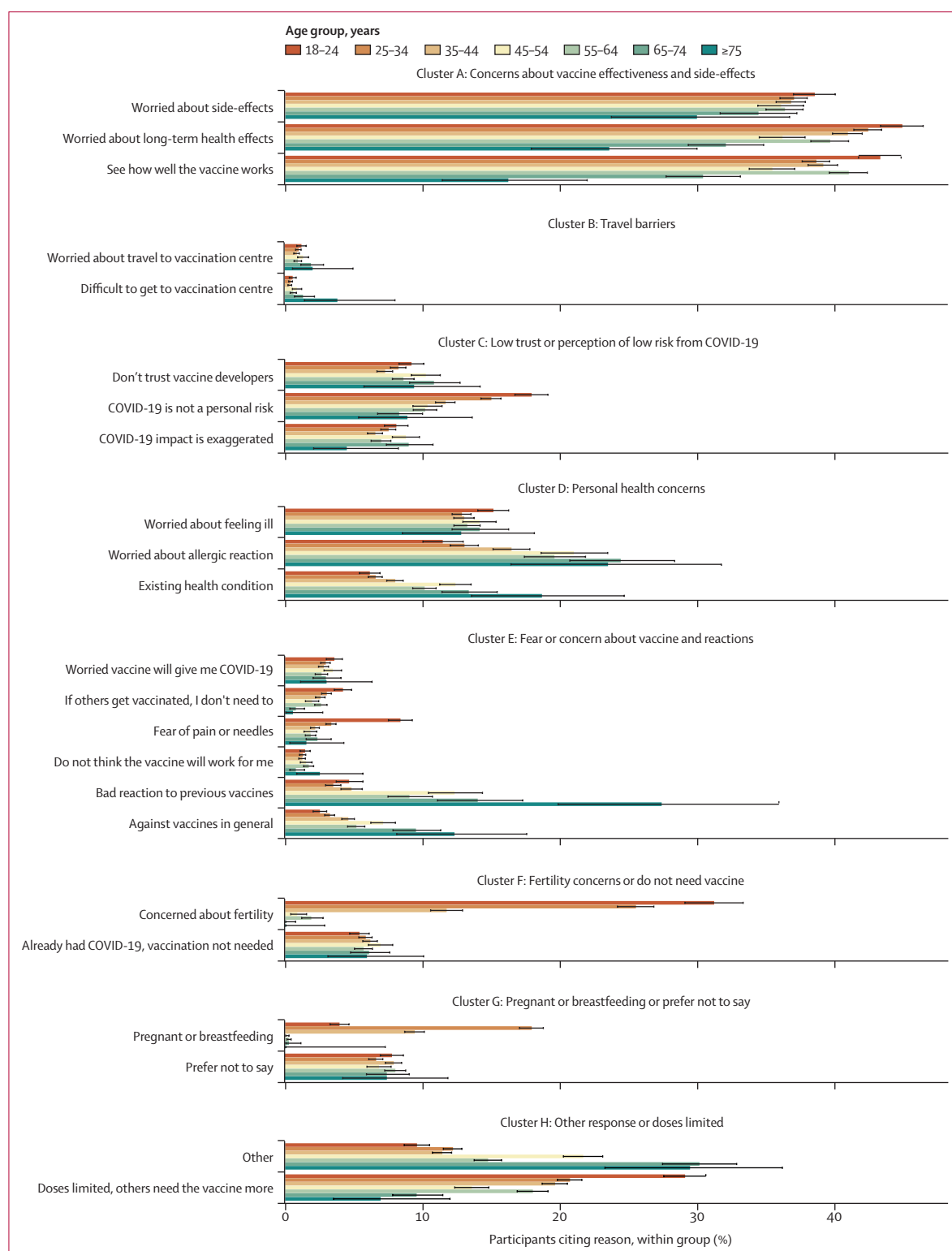


Figure 4: Prevalence of reasons for vaccine hesitancy in 30 701 participants, by age group

The percentages of respondents with hesitancy were calculated using the numbers of individuals who selected a particular reason for hesitancy divided by the number of those who were given this reason as an option (further details are in the appendix [p 5]). Whiskers indicate 95% CIs.

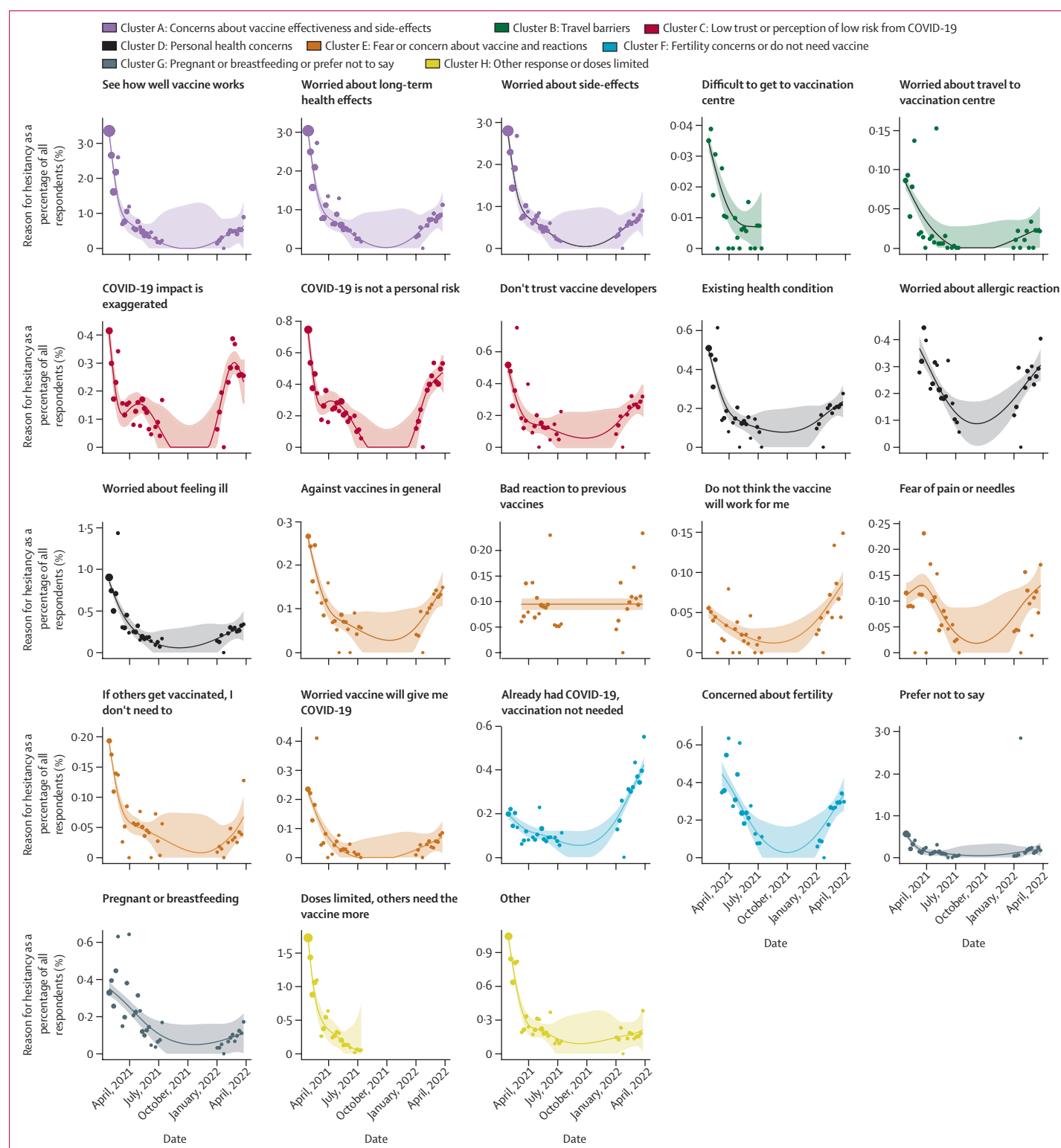
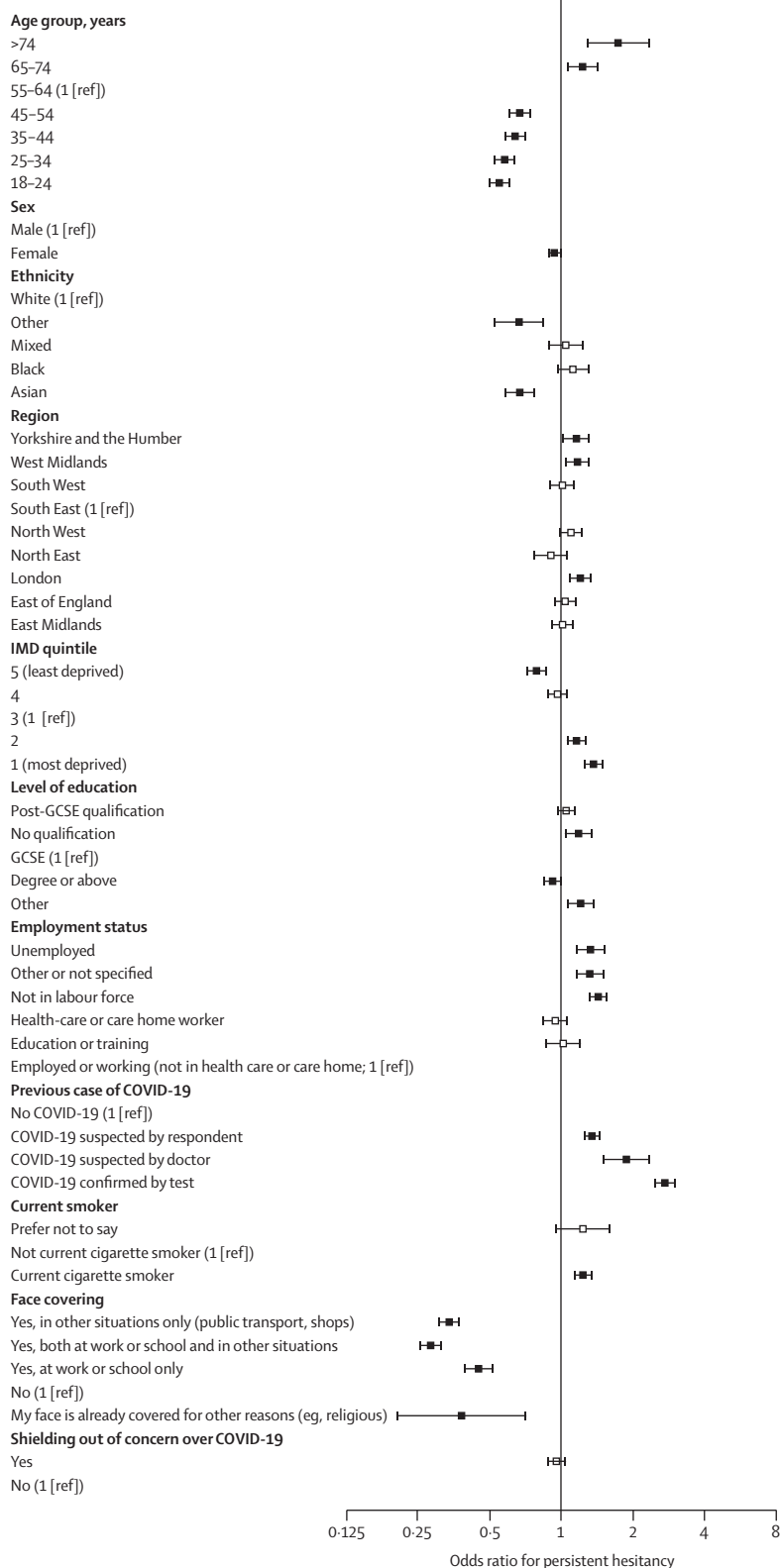


Figure 5: Change in prevalence of reasons for hesitancy over time in all 1137 927 participants

Reported reasons for hesitancy are shown as a percentage of all respondents, by survey week, grouped by hesitancy reason cluster. Weighted generalised additive models were fitted to show trends (model specifications are provided in the appendix [p 6]). Shaded areas show 95% CIs. Point size indicates the number of people reporting each reason for hesitancy each week (from 0 to 5072). Variable scales have been used in the y-axes to facilitate visualisation of trajectories at different hesitancy prevalences.

A Sociodemographic and behavioural factors and COVID-19



(Figure 6 continues on next page)

pp 32–36). Older age groups were more likely to be against vaccines in general: 25 (12.3% [8.4–17.5]) of 204 individuals aged 74 years or older versus 98 (2.5% [2.0–3.0]) of 3989 participants aged 18–24 years.

Most of the reported reasons for hesitancy followed a similar trajectory: higher prevalence in early 2021, decreasing to a low by the start of 2022 and subsequently increasing again in February–March, 2022 (figure 5). Cluster C reasons (low trust and risk perception) showed a large spike in 2022, returning to nearly the same levels as at the start of the study. The reason “I do not think I need the vaccine as I have already had the coronavirus (COVID-19)” (cluster F) showed the largest increase, with prevalence of this attitude more than twice as high in early 2022 as it was in early 2021. By contrast, cluster A reasons, relating to vaccine effectiveness and health concerns, saw only a modest increase in 2022 relative to levels at the start of 2021.

For longitudinal analysis of subsequent vaccination, we followed up 847914 (74.5% of the full study population) participants who consented to linkage (appendix pp 15–16) until May, 2024. Mean follow-up was 1076 days, with a total follow-up time of 2498569 years. Of 37982 participants who indicated hesitancy, 24229 (63.8%) provided consent for linkage to NHS data. Of these 24229 participants, 15744 (65.0%) had received one or more vaccinations as of May 7, 2024 (appendix pp 17–20).

Among participants with NHS linkage who indicated hesitancy, rates of subsequent vaccination varied by demographic group (appendix pp 17–20). In adjusted logistic regression models, the likelihood of remaining unvaccinated was lower for younger age groups versus older age groups (adjusted OR 0.55 [95% CI 0.49–0.62] for the 18–24 years age group vs the 55–64 years age group), participants of Asian or Other ethnicity versus those of White ethnicity (0.67 [0.58–0.77] and 0.66 [0.52–0.84], respectively), and participants classed as less deprived according to the Index of Multiple Deprivation (0.78 [0.72–0.86] for the least deprived quintile vs the third quintile; figure 6). In contrast, the likelihood of remaining unvaccinated was higher for participants with no qualification or other educational qualification versus those with GCSE-level education (1.18 [1.03–1.34] and 1.20 [1.07–1.36], respectively); participants who were unemployed, not in the labour force, or in other employment versus the reference employed group (not health-care or care home worker; 1.32 [1.15–1.52], 1.43 [1.31–1.55], and 1.31 [1.16–1.49], respectively); participants with a history of COVID-19 infection versus those with no history of COVID-19 (1.34 [1.25–1.44] for respondent-suspected COVID-19, 1.87 [1.50–2.33] for doctor-suspected COVID-19, and 2.72 [2.48–2.99] for test-confirmed COVID-19); and for current cigarette smokers versus non-smokers (1.18 [1.06–1.31]). Participants with depression (1.11 [1.02–1.21]) or anxiety (1.11 [1.03–1.19]) were also more likely to remain unvaccinated than those without

these conditions. Effects were robust to further adjustment for study round (appendix pp 37–39), with some attenuation (eg, the OR for test-confirmed previous COVID-19 was decreased to 1.20 [1.06–1.36]—an expected finding, given the expansion of asymptomatic mass-testing in mid-2021 in England). Results expressed as adjusted risk differences are reported in the appendix (pp 40–42).

In adjusted models, the hesitancy reason associated with the highest likelihood of remaining unvaccinated was being against vaccines in general (cluster E), with an adjusted OR of 3.10 (95% CI 2.70–3.56; figure 6C; appendix p 39). Reasons related to trust and risk perception (cluster C) were all strongly positively associated with remaining unvaccinated (3.21 [2.87–3.60] for “The impact of COVID-19 is being greatly exaggerated”; 2.63 [2.37–2.93] for “I don’t trust the people who have developed the vaccine”; and 2.19 [2.01–2.39] for “I do not feel the coronavirus [COVID-19] is a personal risk”).

Reasons related to vaccine effectiveness or health concerns (cluster A) were either negatively associated with remaining unvaccinated (OR 0.94 [0.88–0.99] for “I want to wait and see how well the vaccine works”), or had ORs close to 1.00 (1.24 [1.17–1.32] for “I am worried about the side-effects” and 1.35 [1.26–1.45] for “I am worried about the long-term effects on my health”; figure 6; appendix p 39). Further adjustment for study round increased the OR to 1.13 (1.05–1.21) for “I want to wait and see how well the vaccine works”.

Lower risks for remaining unvaccinated were observed for those who reported in the survey that they were pregnant or breastfeeding (OR 0.64 [95% 0.56–0.73]) and for those who said that doses were limited and others needed them more (0.76 [0.70–0.83]; appendix p 39).

Discussion

In this study of more than 1.1 million people in England across 15 months of the COVID-19 pandemic, we observed a general decline in vaccine hesitancy, mainly due to decreased concerns over side-effects, vaccine effectiveness, and long-term health effects, but noted a slight increase in hesitancy in early 2022. These three concerns were the most common reasons for hesitancy, particularly in the early phase of the vaccine roll-out, and people who expressed hesitancy for these reasons were more likely to subsequently accept vaccination than those hesitant for other reasons. Those who were hesitant because of a generalised anti-vaccine sentiment, low trust in vaccine developers, or low perception of risk from COVID-19 were particularly unlikely to change their minds and get vaccinated.

Our analyses of the prevalence, trajectory, and sociodemographic correlates of vaccine hesitancy are similar to other findings from the UK: the Office for National Statistics reported a hesitancy rate of 7% in January–February, 2021,³⁶ decreasing to 4% in August, 2021.³⁷ The increase in hesitancy in 2022 has

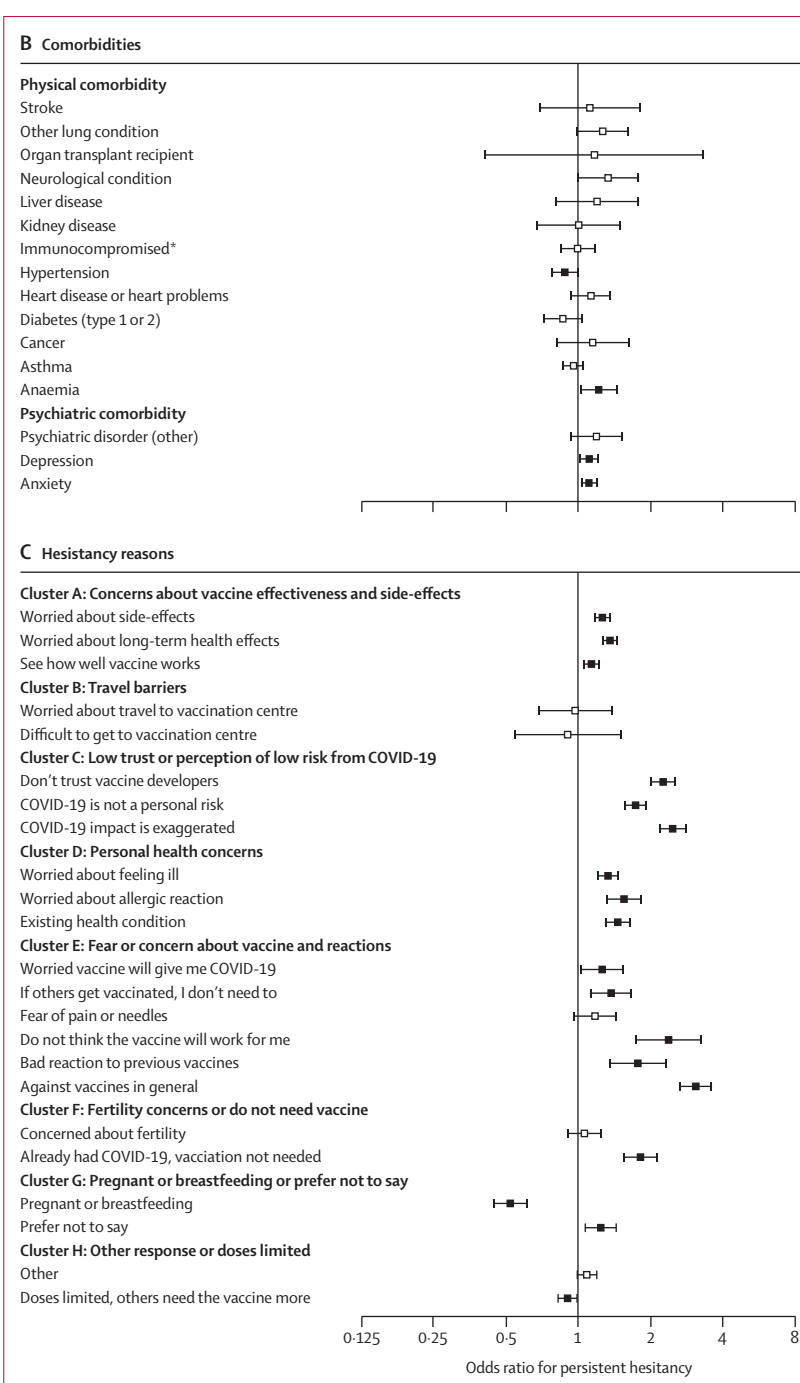


Figure 6: Odds ratios for persistent hesitancy (ie, no subsequent vaccination recorded) in 24 229 vaccine-hesitant participants who consented to UK National Health Service data linkage
Logistic regression modelling was done against demographic covariates (A), comorbidities (B), and reasons for hesitancy (C). In models (A) and (B), odds ratios were adjusted for age, sex, ethnicity, region, deprivation, education, and employment; in model (C), odds ratios were adjusted for age and sex. Solid boxes indicate significant odds ratios; hollow boxes indicate non-significant odds ratios. Whiskers indicate 95% CIs. GCSE=General Certificate of Secondary Education. IMD=Index of Multiple Deprivation. *Weakened immune system or reduced ability to deal with infections.

been shown elsewhere, with Sabat and colleagues³⁸ describing a similar trajectory of decreasing hesitancy throughout 2021 followed by a small uptick in early 2022

in the UK (and other European countries). Lazarus and colleagues⁹ also showed a 4% increase in COVID-19 vaccine hesitancy between 2021 and 2022 in the UK.

The increase in hesitancy in early 2022 came after the highly transmissible omicron wave caused a surge in COVID-19 prevalence in England from December, 2021, to March, 2022, although with a reduced risk of hospitalisation compared with previous variants.^{39,40} In the survey rounds after this surge, there was an increase in the proportion of people reporting their reasons for hesitancy as feeling that the impact of COVID-19 was being exaggerated, not needing the vaccine as they had already had COVID-19, or not feeling that COVID-19 was a personal risk. This finding might reflect the modification of personal risk perception, with reports in early 2022⁴¹ showing that previous infection provided similar⁴² if not better⁴³ protection against re-infection and future severe COVID-19. The increase in hesitancy might also have been a product of pandemic fatigue⁴⁴—two previous studies found associations between pandemic fatigue and (lowered) intention to vaccinate^{45,46}—and a more general rejection of COVID-19-induced disruption; for example, Phillips and colleagues²³ showed an association between vaccine hesitancy in the UK and a dislike of coercive policies and perceived lack of relaxation of COVID-19 restrictions.

Our analysis of subsequent vaccination behaviour showed that some determinants of hesitancy (previous COVID-19, lower level of education, and deprivation) were also risk factors for remaining unvaccinated, conditional on hesitancy. By contrast, the age gradient was reversed—ie, older respondents were less likely to express hesitancy initially but were more likely to remain unvaccinated after initially expressing hesitancy. Similarly, women were more likely than men to be hesitant, but less likely to remain unvaccinated after initially expressing hesitancy. Both inversions could be explained by age and sex differences in the underlying motivations for hesitancy. For example, some women might have been hesitant because of being pregnant or breastfeeding, which are time-limited motivations for hesitancy. Conversely, many older people reported hesitancy because of bad reactions to previous vaccines (in England, seasonal vaccines are only offered to those aged 65 years and older or the clinically vulnerable) or because of existing health conditions; both of these motivations are likely to be persistent. In keeping with existing research,⁴⁷ we found that younger people were also more likely than older people to report feeling that COVID-19 was not a personal risk. This perception aligned with early guidance from the Joint Committee on Vaccination and Immunisation, whereby older adults were prioritised for vaccination according to their increased risk of morbidity and mortality. Previous research has also indicated that susceptibility to attitude change decreases in older age⁴⁸ and that women are more open than men to changes of attitude in relation to

vaccination.⁴⁹ Santos-Requejo and Torres-González²⁴ describe the same paradox of women declaring less of an intention to vaccinate but subsequently self-reporting higher rates of vaccination, noting that the psychological factors underpinning changes of mind differ between men and women in the study.

A reversal in subsequent vaccine sentiment was also observed among individuals who were not of White ethnicity: those of Asian, Black, or Other ethnicities were all more likely than those of White ethnicity to be vaccine hesitant, with Black participants three times as likely to be hesitant as White participants. However, initially hesitant participants of non-White ethnicities were more likely (in the case of participants of Asian and Other ethnicities) or no less likely (in the case of participants of Black ethnicities) than White participants to be vaccinated at a later date. Other studies have found similar trends. Byrne and colleagues⁵⁰ found that initial disparities in rates of reported hesitancy between minority ethnic groups and White individuals declined over time. Some of the subgroup-specific reversals in hesitancy observed in our data might reflect the substantial public health efforts made in the UK to address vaccine hesitancy among individuals of minority ethnic groups through community outreach, tailored communication, and targeted delivery,⁵¹ although little evaluative analysis of these schemes has been done. One analysis from the UK Government found that a community outreach scheme targeting minority religious and ethnic groups improved booster uptake in minority religious groups but did not improve overall levels of vaccine trust.⁵² Our findings suggest, at least, that vaccine-hesitant communities, who might be at risk of severe COVID-19, can be flexible in their vaccine sentiment. Further longitudinal analysis is required to assess the specific effect of targeted approaches.

There is clear evidence from the analysis of rates of subsequent COVID-19 vaccination that some types of vaccine hesitancy are highly context-specific—and might, therefore, be more readily addressed—whereas others are more resistant. Among hesitant participants, those citing hesitancy reasons from cluster A (general concerns about vaccine effectiveness or side-effects) were the most likely to get vaccinated subsequently. This cluster was also the largest source of hesitancy and showed the most substantial and sustained decline throughout the pandemic, relative to other drivers of hesitancy (except for the hesitancy reason “Doses of the vaccine are limited and other people need it more than me”). Collectively, these findings indicate the success of the vaccines themselves, the vaccine roll-out, and public health communications. Most hesitancy was concentrated in the early roll-out phase, when information was scarce—crucially, this hesitancy was not persistent.

This study had some limitations. NHS vaccine records and self-report vaccine status showed some discordance.

Discrepancies likely reflect both imperfect recall and imperfect coverage in the NHS data. Self-reporting might involve systematic bias—eg, particularly for weight and psychiatric conditions versus symptom-based diagnosis.⁵³ Hesitancy reasons varied between rounds, resulting in incomplete data capture. Follow-up required consent to linkage, and vaccine-hesitant respondents were less likely to consent, introducing selection bias. Similarly, our analysis did not extend to the timing of the eventual vaccination in those vaccinated, relative to eligibility or COVID-19 history, both of which are highly relevant factors. People's circumstances and positions evolve, and hesitancy reasons provided at survey could differ from those influencing eventual vaccine behaviour; follow-up surveys of hesitant unvaccinated individuals would provide valuable additional data.

In conclusion, we identified multiple categories of vaccine hesitancy with differing levels of persistence. Reassuringly, most hesitancy reverted over time since vaccine roll-out. The most prevalent forms of COVID-19 vaccine hesitancy were context-specific and, accordingly, there was an uptick in hesitancy in 2022 driven by a perception of lowered risk from COVID-19. To our knowledge, this study is the first to compare vaccine attitudes with objective, longitudinal data on vaccine acceptance. Our findings will help future vaccination roll-outs to successfully target awareness campaigns and expedite vaccine acceptance.

Contributors

MW: conceptualisation, data curation, formal analysis, methodology, visualisation, writing (original draft), and writing (review and editing). JE: conceptualisation, methodology, writing (original draft), and writing (review and editing). IG-U: formal analysis, methodology, and writing (review and editing). CAD: conceptualisation, methodology, writing (review and editing), and supervision. GSC: conceptualisation and writing (review and editing). HW: conceptualisation, writing (review and editing), and supervision. PE: funding acquisition, investigation, project administration, writing (review and editing), and supervision. MC-H: conceptualisation, methodology, investigation, project administration, writing (original draft), writing (review and editing), and supervision. MW, PE, and MC-H verified the data. All authors had access to the data. All authors were responsible for the decision to submit the manuscript.

Declaration of interests

MC-H holds shares of the O-SMOSE consulting company. All other authors declare no competing interests.

Data sharing

Summary tables included in this report are available at https://figshare.com/projects/Profiling_vaccine_attitudes_and_subsequent_uptake_in_a_nationwide_cohort_study_of_1.1_million_people_in_England/253865. The study materials and questionnaires used in this study can be found at <https://www.imperial.ac.uk/medicine/research-and-impact/groups/react-study/studies/the-react-1-programme/react-1-study-materials/>. For access to individual-level data for further analyses, a data access request can be made at <https://www.imperial.ac.uk/medicine/research-and-impact/groups/react-study/data-access-requests/>.

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References

- Thompson S, Meyer JC, Burnett RJ, Campbell SM. Mitigating vaccine hesitancy and building trust to prevent future measles outbreaks in England. *Vaccines* 2023; **11**: 288.
- Motta M, Stecula D. Quantifying the effect of Wakefield et al. (1998) on skepticism about MMR vaccine safety in the U.S. *PLoS One* 2021; **16**: e0256395.
- Watson OJ, Barnsley G, Toor J, Hogan AB, Winskill P, Ghani AC. Global impact of the first year of COVID-19 vaccination: a mathematical modelling study. *Lancet Infect Dis* 2022; **22**: 1293–302.
- National Audit Office. The rollout of the COVID-19 vaccination programme in England. Feb 25, 2022. <https://www.nao.org.uk/reports/the-roll-out-of-the-covid-19-vaccine-in-england/> (accessed Aug 1, 2025).
- Polack FP, Thomas SJ, Kitchin N, et al, and the C4591001 Clinical Trial Group. Safety and efficacy of the BNT162b2 mRNA Covid-19 vaccine. *N Engl J Med* 2020; **383**: 2603–15.
- Baden LR, El Sahly HM, Essink B, et al, and the COVE Study Group. Efficacy and safety of the mRNA-1273 SARS-CoV-2 vaccine. *N Engl J Med* 2021; **384**: 403–16.
- Voysey M, Clemens SAC, Madhi SA, et al, and the Oxford COVID Vaccine Trial Group. Safety and efficacy of the ChAdOx1 nCoV-19 vaccine (AZD1222) against SARS-CoV-2: an interim analysis of four randomised controlled trials in Brazil, South Africa, and the UK. *Lancet* 2021; **397**: 99–111.
- Faksova K, Walsh D, Jiang Y, et al. COVID-19 vaccines and adverse events of special interest: a multinational Global Vaccine Data Network (GVDN) cohort study of 99 million vaccinated individuals. *Vaccine* 2024; **42**: 2200–11.
- Lazarus JV, Wyka K, White TM, et al. A survey of COVID-19 vaccine acceptance across 23 countries in 2022. *Nat Med* 2023; **29**: 366–75.
- de Miguel-Arribas A, Aleta A, Moreno Y. Impact of vaccine hesitancy on secondary COVID-19 outbreaks in the US: an age-structured SIR model. *BMC Infect Dis* 2022; **22**: 511.
- UK Government. New campaign to support vaccine roll-out backed by social media companies and British institutions. Feb 19, 2021. <https://www.gov.uk/government/news/new-campaign-to-support-vaccine-roll-out-backed-by-social-media-companies-and-british-institutions> (accessed Dec 2, 2024).
- UK Government. Third quarterly report on progress to address COVID-19 health inequalities. <https://www.gov.uk/government/publications/third-quarterly-report-on-progress-to-address-covid-19-health-inequalities/third-quarterly-report-on-progress-to-address-covid-19-health-inequalities> (accessed Dec 2, 2024).
- Allington D, McAndrew S, Moxham-Hall V, Duffy B. Coronavirus conspiracy suspicions, general vaccine attitudes, trust and coronavirus information source as predictors of vaccine hesitancy among UK residents during the COVID-19 pandemic. *Psychol Med* 2023; **53**: 236–47.
- Robertson E, Reeve KS, Niedzwiedz CL, et al. Predictors of COVID-19 vaccine hesitancy in the UK household longitudinal study. *Brain Behav Immun* 2021; **94**: 41–50.
- Murphy J, Vallières F, Bentall RP, et al. Psychological characteristics associated with COVID-19 vaccine hesitancy and resistance in Ireland and the United Kingdom. *Nat Commun* 2021; **12**: 29.
- NHS England. Bake Off star Nadiya backs NHS COVID vaccine drive. Match 6, 2021. <https://www.england.nhs.uk/2021/03/bake-off-star-nadiya-backs-nhs-covid-vaccine-drive/> (accessed Dec 2, 2024).
- Tuckerman J, Kaufman J, Danchin M. Effective approaches to combat vaccine hesitancy. *Pediatr Infect Dis J* 2022; **41**: e243–45.
- Betsch C, Schmid P, Heinemeier D, Korn L, Holtmann C, Böhm R. Beyond confidence: development of a measure assessing the 5C psychological antecedents of vaccination. *PLoS One* 2018; **13**: e0208601.

- 19 Doglioni DO, Gagneux-Brunon A, Gauchet A, et al. Psychometric validation of a 7C-model of antecedents of vaccine acceptance among healthcare workers, parents and adolescents in France. *Sci Rep* 2023; **13**: 19895.
- 20 Rancher C, Moreland AD, Smith DW, et al. Using the 5C model to understand COVID-19 vaccine hesitancy across a national and South Carolina sample. *J Psychiatr Res* 2023; **160**: 180–86.
- 21 Gallant AJ, Nicholls LAB, Rasmussen S, Cogan N, Young D, Williams L. Changes in attitudes to vaccination as a result of the COVID-19 pandemic: a longitudinal study of older adults in the UK. *PLoS One* 2021; **16**: e0261844.
- 22 Fridman A, Gershon R, Gneezy A. COVID-19 and vaccine hesitancy: a longitudinal study. *PLoS One* 2021; **16**: e0250123.
- 23 Phillips R, Gillespie D, Hallingberg B, et al. Perceived threat of COVID-19, attitudes towards vaccination, and vaccine hesitancy: a prospective longitudinal study in the UK. *Br J Health Psychol* 2022; **27**: 1354–81.
- 24 Santos-Requejo L, Torres-González OM. Between intention and action: the paradoxes of female vaccination. *Arch Public Health* 2025; **83**: 53.
- 25 Elliott P, Whitaker M, Tang D, et al. Design and implementation of a national SARS-CoV-2 monitoring program in England: REACT-1 study. *Am J Public Health* 2023; **113**: 545–54.
- 26 Ward H, Atchison C, Whitaker M, et al. Design and implementation of a national program to monitor the prevalence of SARS-CoV-2 IgG antibodies in England using self-testing: the REACT-2 study. *Am J Public Health* 2023; **113**: 1201–09.
- 27 NHS England Digital. COVID-19 vaccine data. <https://digital.nhs.uk/about-nhs-digital/corporate-information-and-documents/directions-and-data-provision-notice/data-provision-notice-dpns/covid-19-vaccine-data> (accessed Dec 3, 2024).
- 28 Bodinier B, Rodrigues S, Karimi M, Filippi S, Chiquet J, Chadeau-Hyam M. Stability selection and consensus clustering in R: the R package sharp. *J Stat Softw* 2025; **112**: 1–27.
- 29 Murtagh F, Legendre P. Ward's hierarchical agglomerative clustering method: which algorithms implement ward's criterion? *J Classif* 2014; **31**: 274–95.
- 30 McLennan D, Noble S, Noble M, Plunkett E, Wright GN. The English indices of deprivation 2019. September, 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/833951/IOD2019_Technical_Report.pdf (accessed June 19, 2025).
- 31 UK Government. COVID-19 Archive data download. May 1, 2025. <https://ukhsa-dashboards.data.gov.uk/covid-19-archive-data-download> (accessed July 31, 2025).
- 32 Hodcroft EB. CoVariants: SARS-CoV-2 mutations and variants of interest. 2021. <https://covariants.org/> (accessed July 30, 2025).
- 33 Lopez Bernal J, Andrews N, Gower C, et al. Effectiveness of Covid-19 vaccines against the B.1.617.2 (delta) variant. *N Engl J Med* 2021; **385**: 585–94.
- 34 Witberg G, Barda N, Hoss S, et al. Myocarditis after Covid-19 vaccination in a large health care organization. *N Engl J Med* 2021; **385**: 2132–39.
- 35 Andrews N, Stowe J, Kirsebom F, et al. Covid-19 vaccine effectiveness against the omicron (B.1.1.529) variant. *N Engl J Med* 2022; **386**: 1532–46.
- 36 Office for National Statistics. Coronavirus and vaccine hesitancy, Great Britain: 13 January to 7 February 2021. March 8, 2021. <https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandwellbeing/bulletins/coronavirusandvaccinehesitancygreatbritain/13januaryto7february2021> (accessed Dec 4, 2024).
- 37 Office for National Statistics. Coronavirus and vaccine hesitancy, Great Britain: 9 August 2021. <https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandwellbeing/bulletins/coronavirusandvaccinehesitancygreatbritain/9august2021> (accessed Dec 4, 2024).
- 38 Sabat I, Neumann-Böhme S, Barros PP, et al. Vaccine hesitancy comes in waves: longitudinal evidence on willingness to vaccinate against COVID-19 from seven European countries. *Vaccine* 2023; **41**: 5304–12.
- 39 Elliott P, Bodinier B, Eales O, et al. Rapid increase in omicron infections in England during December 2021: REACT-1 study. *Science* 2022; **375**: 1406–11.
- 40 Elliott P, Eales O, Steyn N, et al. Twin peaks: The omicron SARS-CoV-2 BA.1 and BA.2 epidemics in England. *Science* 2022; **376**: eabq4411.
- 41 León TM, Dorabawila V, Nelson L, et al. COVID-19 cases and hospitalizations by COVID-19 vaccination status and previous COVID-19 diagnosis—California and New York, May–November 2021. *MMWR Morb Mortal Wkly Rep* 2022; **71**: 125–31.
- 42 Rick A-M, Laurens MB, Huang Y, et al, and the NIAID-funded COVID-19 Prevention Network (CoVPN). Risk of COVID-19 after natural infection or vaccination. *EBioMedicine* 2023; **96**: 104799.
- 43 Bobrovitz N, Ware H, Ma X, et al. Protective effectiveness of previous SARS-CoV-2 infection and hybrid immunity against the omicron variant and severe disease: a systematic review and meta-regression. *Lancet Infect Dis* 2023; **23**: 556–67.
- 44 Petherick A, Goldszmidt R, Andrade EB, et al. A worldwide assessment of changes in adherence to COVID-19 protective behaviours and hypothesized pandemic fatigue. *Nat Hum Behav* 2021; **5**: 1145–60.
- 45 Alie MS, Abebe GF, Negesse Y, Girma D, Adugna A. Pandemic fatigue, behavioral intention and predictors of COVID-19 vaccination among individuals living with HIV in Bench Sheko Zone, in Southern Ethiopia, application of TBP: a facility based cross sectional study. *Front Public Health* 2024; **12**: 1305777.
- 46 Wong LP, Alias H, Siaw Y-L, et al. Intention to receive a COVID-19 vaccine booster dose and associated factors in Malaysia. *Hum Vaccin Immunother* 2022; **18**: 2078634.
- 47 Cascini F, Pantovic A, Al-Ajlouni Y, Failla G, Ricciardi W. Attitudes, acceptance and hesitancy among the general population worldwide to receive the COVID-19 vaccines and their contributing factors: a systematic review. *EClinicalMedicine* 2021; **40**: 101113.
- 48 Krosnick JA, Alwin DF. Aging and susceptibility to attitude change. *J Pers Soc Psychol* 1989; **57**: 416–25.
- 49 Okuno H, Satoh H, Arai S, Suzuki M, Kikkawa T. Gender differences in responses to an altruistic message regarding rubella vaccination. *Front Public Health* 2024; **12**: 1353091.
- 50 Byrne T, Patel P, Shrotri M, et al, and the Virus Watch Collaborative. Trends, patterns and psychological influences on COVID-19 vaccination intention: findings from a large prospective community cohort study in England and Wales (Virus Watch). *Vaccine* 2021; **39**: 7108–16.
- 51 Bradley F, Nelson PA, Dumville J. Implementing targeted vaccination activities to address inequalities in vaccination: a qualitative study. *J Public Health (Oxf)* 2025; **47**: 258–67.
- 52 UK Government. Community Champions research and evaluation reports. July 3, 2023. <https://www.gov.uk/government/publications/community-champions-research-and-evaluation-reports> (accessed Aug 2, 2025).
- 53 Davies MR, Buckman JEJ, Adey BN, et al. Comparison of symptom-based versus self-reported diagnostic measures of anxiety and depression disorders in the GLAD and COPING cohorts. *J Anxiety Disord* 2022; **85**: 102491.