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ARTICLE

Perceived threat of COVID-19, attitudes towards vaccination, and vaccine hesitancy: A prospective longitudinal study in the UK

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Abstract

Objectives: Using the Health Belief Model as a conceptual framework, we investigated the association between attitudes towards COVID-19, COVID-19 vaccinations, and vaccine hesitancy and change in these variables over a 9-month period in a UK cohort.

Methods: The COPE study cohort (n = 11,113) was recruited via an online survey at enrolment in March/April 2020. The study was advertised via the HealthWise Wales research registry and social media. Follow-up data were available for 6942 people at 3 months (June/July 2020) and 5037 at 12 months (March/April 2021) post-enrolment. Measures included demographics, perceived threat of COVID-19, perceived control, intention to accept or decline a COVID-19 vaccination, and attitudes towards vaccination. Logistic regression models were fitted cross-sectionally at 3 and 12 months to assess the association between motivational factors and vaccine hesitancy. Longitudinal changes in motivational variables for vaccine-hesitant and non-hesitant groups were examined using mixed-effect analysis of variance models.

COVID-19 grant (Project number WG 90) was awarded to cover our follow-up data collection, analysis, and dissemination activities for the period between 1 August 2020 to 31 March 2021.

Results: Fear of COVID-19, perceived susceptibility to COVID-19, and perceived personal control over COVID-19 infection transmission decreased between the 3- and 12-month surveys. Vaccine hesitancy at 12 months was independently associated with low fear of the disease and more negative attitudes towards COVID-19 vaccination. Specific barriers to COVID-19 vaccine uptake included concerns about safety and efficacy in light of its rapid development, mistrust of government and pharmaceutical companies, dislike of coercive policies, and perceived lack of relaxation in COVID-19-related restrictions as the vaccination programme progressed.
Conclusions: Decreasing fear of COVID-19, perceived susceptibility to the disease, and perceptions of personal control over reducing infection-transmission may impact future COVID-19 vaccination uptake.

KEYWORDS
behaviour change, COVID-19, risk perception, SARS CoV2, vaccine hesitancy

Statement of contribution

What is already known about this subject?

- Understanding the potentially modifiable determinants of vaccine hesitancy is essential in informing public health policy and communications to promote vaccination uptake.
- Motivational factors, including the perceived health threat from infections, perceived risks and benefits of vaccination, and self-efficacy can contribute to vaccine uptake and vaccine hesitancy.
- Research carried out during the early stages of the COVID-19 pandemic identified general anti-vaccination attitudes, perception of COVID-19 as harmless and therefore vaccination unnecessary, safety concerns regarding a perceived rushed development process, lack of trust, and wanting more information before making a decision may act as potential barriers to vaccination uptake.

What does this study add?

- While COVID-19 vaccines were being widely rolled out in the United Kingdom, vaccine hesitancy was independently associated with low fear of the disease and more negative attitudes towards COVID-19 vaccination, including concerns about profiteering, preference for natural immunity, mistrust of vaccine benefits, and worries about unforeseen future effects.
- Specific barriers to COVID-19 vaccine uptake included concerns about safety and efficacy in light of its rapid development, mistrust of government and pharmaceutical companies, dislike of coercive policies, and perceived lack of relaxation in COVID-19-related restrictions as the vaccination programme progressed.
- Fear of COVID-19 and perceived personal control over COVID-19 infection transmission decreased between the 3- and 12-month surveys. This could impact on future uptake of COVID-19 vaccines and should be monitored to inform communication and policy strategies as the vaccination programme continues to be rolled out.

BACKGROUND

The COVID-19 pandemic has led to high levels of mortality, morbidity, and economic and social disruption, with national lockdowns, border closures, and pressure on healthcare services worldwide (McBride et al., 2021; McKibbin & Fernando, 2020; UK Government, 2020; World Health Organization, 2020c; World Health Organization, 2020d). The only safe and ethical method of achieving herd immunity for COVID-19, where a significant proportion of the population has acquired immunity through vaccination or infection and recovery, is via mass vaccination (World Health Organisation, 2020a). "Vaccine hesitancy," the reluctance or refusal to accept a vaccination despite its availability, is a major barrier to the success of mass vaccination programmes and was identified as one of the top public health threats by the WHO in 2019 (World Health Organisation, 2019). An evidence-based approach is needed to inform policy and communication strategies to support COVID-19 vaccine uptake (COCONEL Group, 2020; Pappas, 2021; World Health Organisation, 2019; World Health Organisation, 2020b).

Motivational factors such as attitudes, perceived control, and emotions are potentially modifiable and can have a significant influence on vaccination attitudes and behaviour (COCONEL Group, 2020; Dyer, 2020; Enria et al., 2021; Fisher et al., 2020; Loomba et al., 2021; Neumann-Böhme et al., 2020; Parsons & Wiggins, 2020; Ward et al., 2020; Woolf et al., 2021), including in the context of COVID-19 vaccination (Butter et al., 2021; Freeman et al., 2020; Kreps et al., 2020; Lazarus et al., 2020; Lazarus et al., 2021; Li et al., 2021; Lindholt et al., 2021; Sethi et al., 2021; Tao et al., 2021; Woolf et al., 2021). The Health Belief Model (Rosenstock et al., 1988; Strecher & Rosenstock, 1997) postulates that intention to engage in health behaviour in response to a health threat is influenced by people's beliefs about the seriousness of the threat, susceptibility to the threat, ability to perform behaviours that reduce harm from the threat, and the potential costs and benefits of engaging in an action that will reduce the threat. The Health Belief Model has been applied to understanding intentions to receive a vaccination for influenza and COVID-19 (Bechard et al., 2021; Rabin & Dutra, 2021; Scherr et al., 2017; Shmueli, 2021; Wong et al., 2020; Zampetakis & Melas, 2021).

COVID-19 specific vaccine hesitancy has been found to be associated with female sex, younger age, lower household income, and educational attainment, as well as lower levels of annual seasonal influenza vaccination (COCONEL Group, 2020; Fisher et al., 2020; Neumann-Böhme et al., 2020; Sallam, 2021; Sherman et al., 2021; Ward et al., 2020). Emerging research into the reasons for refusing a COVID-19 vaccination includes general anti-vaccination attitudes, perception of COVID-19 as harmless and therefore vaccination unnecessary, safety concerns regarding a perceived rushed development process, lack of trust, and wanting more information before making a decision (COCONEL Group, 2020; Fisher et al., 2020; Neumann-Böhme et al., 2020; Ward et al., 2020). The perceived threat from COVID-19 is likely to shift over time (Schneider et al., 2021) and attitudes towards vaccination may shift as new evidence on safety and efficacy becomes available, which may have an impact on the uptake of initial and "booster" vaccinations.

Here, we report on vaccine hesitancy in a large UK community-based longitudinal cohort as part of the UK COVID-19 Public Experiences (COPE) Study (Hallingberg et al., 2021; Phillips et al., 2021). The proportion of the population needed to be vaccinated against COVID-19 to achieve herd immunity, the "herd immunity threshold," is difficult to assess for COVID-19 (Rubin, 2020). Typically for infectious diseases such as smallpox and rubella, the herd immunity threshold is estimated to be between 70% and 90% (GOA, 2020; Rubin, 2020). In the United Kingdom, vaccination against COVID-19 began in December 2020, initially limited to those over 80 years of age and healthcare workers, and later rolled out to all adults (UK Government, 2021). In England, 91.8% of people aged 12 years or over had received at least one dose of a vaccine, 85.9% had received two doses, and 66.2% had received a third or "booster" dose by the end of March 2022 (NHS England, 2021). In Wales, 92% of adults had received the first dose, 87.3% had a second dose, and 72.8% had received a third or "booster" by this time (Welsh Government, 2021). While the high level of COVID-19 vaccination uptake in the United Kingdom has been encouraging, there remains a sizeable minority who are not fully vaccinated (UK Government, 2020). It is likely that further booster vaccinations will be required to maintain immunity

(Mahase, 2021a) and maintaining good uptake will be an important part of the ongoing public health response to COVID-19.

Using the Health Belief Model as the conceptual framework, we investigated the association between vaccine hesitancy and the perceived threat of COVID-19, perceived control for reducing COVID-19 infection-transmission, and attitudes towards COVID-19 vaccination. Further, we examined how these motivational variables and vaccine hesitancy changed during the first year of the COVID-19 pandemic in the United Kingdom. This will provide an understanding of the determinants of vaccine hesitancy, which can inform public health policy and communication strategies to support people with making informed choices around COVID-19 vaccination uptake.

METHOD

UK COVID-19 Public Experiences (COPE) study design

In this study, we focus on analysing closed-response and open-text data on vaccination hesitancy from the COPE study, a longitudinal mixed-methods study of the experiences of the UK public over the course of the COVID-19 pandemic (Hallingberg et al., 2021; Phillips et al., 2021). Surveys were conducted using online platforms onlinesurveys.ac.uk (survey 1) and qualtrics.com (surveys 2 and 3) (Hallingberg et al., 2021).

Study population and recruitment

The COPE study participants were 11,113 adults living in the United Kingdom at the time of enrolment (13 March 2020 to 13 April 2020) (Phillips et al., 2021). Participants were recruited via social media adverts (Facebook®, Twitter® and Instagram®) and advertisements to the HealthWise Wales (HWW) research registry (Hurt et al., 2019). Details of recruitment and sampling are provided in full elsewhere (Hallingberg et al., 2021; Phillips et al., 2021). Figure 1 provides an overview of the data collection points for this study.

The COPE baseline survey took place at enrolment, as the United Kingdom was entering its first national lockdown (Phillips et al., 2021). Follow-up surveys took place at 3 months (20 June 2020 to 20 July 2020) and 12 months (12 March 2021 to 13 April 2021) post-enrolment. The 3-month survey took place before a COVID-19 vaccine was available to members of the public in the United Kingdom (UK Government, 2020). During the 12-month survey data collection period, COVID-19 vaccinations were being widely rolled out across the United Kingdom on the basis of clinical vulnerability via the National Health Service (NHS), free at the point of vaccination (UK Government, 2020; UK Government, 2021). By 13 April 2021, 56.2% of adults in the United Kingdom had received the first dose of a COVID-19 vaccine and 14.2% had received a second dose (UK Government, 2020).

Measures

Demographics and self-reported health and well-being

Data on age, gender, the highest level of education, ethnic group, children aged <18 living in the household, pre-existing medical conditions, and seasonal flu vaccination uptake in the last 12 months were collected at enrolment. General psychological distress was assessed using the 4-item version of the Patient Health Questionnaire (PHQ-4) (Kroenke et al., 2009) at 3 and 12 months. The PHQ-4 includes two items relating to anxiety and two relating to depression, rated as 0 ("not at all"), 1 ("several days"), 2 ("more than half the days"), or 3 ("nearly every day"). Scores from the four items can be summed

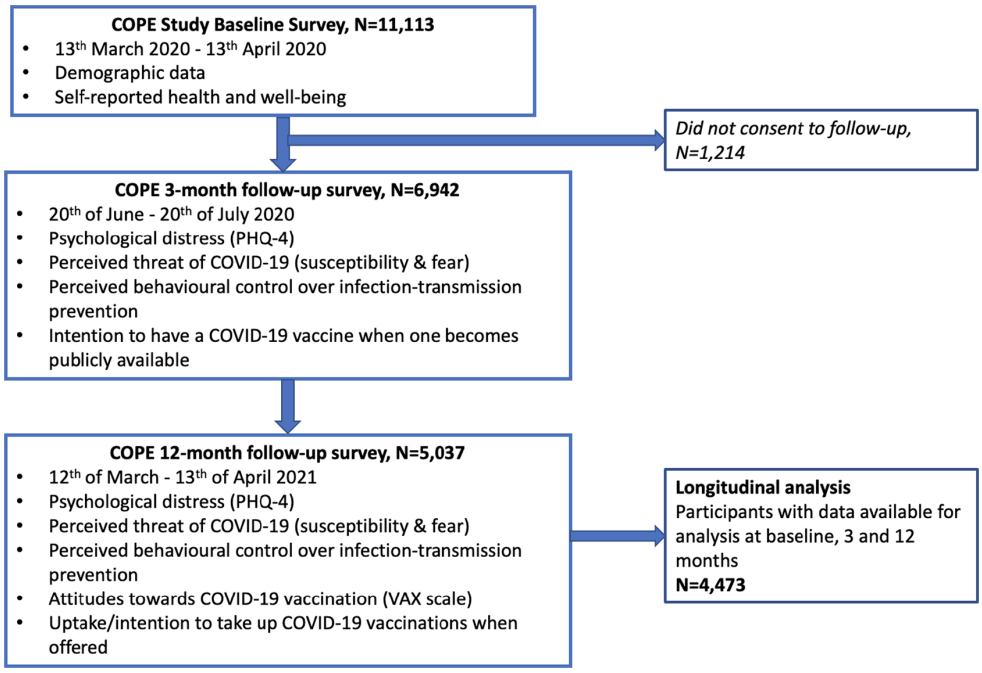

FIGURE 1 Flow diagram of data collection points

to provide a total score ranging from 0 to 12, which correspond with normal (0–2), mild (McBride et al., 2021; UK Government, 2020; World Health Organization, 2020d), moderate (Pappas, 2021; World Health Organisation, 2019; World Health Organisation, 2020a), and severe (COCONEL Group, 2020; Enria et al., 2021; Parsons & Wiggins, 2020; World Health Organisation, 2020b) elevations in psychological distress (Kroenke et al., 2009; Löwe et al., 2010). People who think they have had prior exposure to COVID-19 are more likely to believe that they have acquired some immunity and are less likely to adhere to lockdown measures (Smith et al., 2020). Therefore, participants were asked whether they had or thought they may have had COVID-19, and whether this had been confirmed by a polymerase chain reaction (PCR) laboratory test at each survey time point.

COVID-19 vaccination uptake

Three months post-enrolment: Participants were asked to what extent they agreed with the statement "If there was a vaccination available for COVID-19 right now, I would get vaccinated" using a five-point Likert scale (strongly disagree to strongly agree).

12-month post-enrolment: Participants were asked whether they had been offered a COVID-19 vaccine, whether they had accepted or intended to accept the vaccination, were unsure, had declined, or intended to decline it. Those who were unsure or had declined the vaccine were asked "What are the main reasons that you have decided not to have the vaccine or are not sure about whether or not to have it?" to which there was a free-text response.

Motivational factors

Attitudes towards vaccines against COVID-19 were assessed at 12 months using a modified version of the Vaccination Attitudes Examination (VAX) Scale (Martin & Petrie, 2017). The VAX scale has four

sub-scales; concerns about profiteering, preference for natural immunity, mistrust of vaccine benefits, and worries about unforeseen future effects (Martin & Petrie, 2017). The modified scale asked about COVID-19 vaccination specifically. It included three additional items that had been identified as being potentially important through the qualitative component of the COPE study: "If I get vaccinated against COVID-19, it will help protect my family and friends," "The more people that get vaccinated against COVID-19, the quicker we can return to normal," "Getting vaccinated against COVID-19 will help reduce pressure on the NHS." Responses were rated on a 5-point Likert-type scale from "strongly agree" to "strongly disagree." Relevant items were reversed so that higher scores indicated stronger anti-vaccination attitudes.

Questions relating to the perceived threat to health from COVID-19 were included at all survey time points and had been adapted from studies during previous viral pandemics (Brug et al., 2004; Bults et al., 2011; de Zwart et al., 2007). Using four-point Likert scales, participants were asked to rate the perceived harmfulness of COVID-19 in the next 12 months (not harmful at all to very harmful), how scared they were of COVID-19 (not at all scared to very scared), and how worried they were (not at all worried to very worried) about COVID-19, and how likely they thought they were to get COVID-19 in the next 12 months (very unlikely to very likely). We asked how often people thought about COVID-19 on a 5-point Likert scale (never to all the time) to assess attention to the COVID-19 threat. Exploratory Principal Components Analysis indicated that all five items loaded into a single component, but the susceptibility item did not load as strongly as the other four items (Supplementary File 3). Reliability analysis indicated that Cronbach's alpha improved when the susceptibility item was removed from the scale (Supplementary File 3). Further, there is an important conceptual distinction to be made between susceptibility and perceptions of harm of COVID-19, that is, people may believe that they are very susceptible to COVID-19 but perceived the disease to be mild (and vice versa). Therefore, the harmful, scared, worried, and attention items were summed to provide a total "fear of COVID-19" score, with good internal reliability (Cronbach's alpha = .81). Susceptibility was retained as a separate single-item measure. Both "fear of COVID-19" score and susceptibility were required to understand people's appraisals of the threat of COVID-19.

Perceived behavioural control is a concept that includes self-efficacy (beliefs about the ability to exercise control over events) and the controllability of an event or action (Ajzen, 2002). This study was assessed using two items rated on a five-point scale (no control to complete control): perceived control over protecting themselves and members of their household from being infected by COVID-19, and perceived control over helping to prevent the spread of COVID-19 in their community. The two perceived control items were moderately correlated and were retained as separate items during analysis ($r[7006] = .36, p < .001$).

Analysis

Analyses were carried out using IBM® SPSS® Statistics version 27. Descriptive analysis was carried out on the demographic characteristics and self-reported health for the samples available for cross-sectional analysis at 3- and 12-month follow-up, and for longitudinal analysis across the two survey time points.

Cross-sectional analysis

Multi-variable binary logistic regression models were produced to assess which variables had an independent association with vaccine hesitancy at each time point when key demographic variables had been taken into account. The dependent variable, "Vaccination Hesitancy," was coded as accepted/intend to accept the offer of a COVID-19 vaccination vs. declined/intend to decline/unsure whether to have a COVID-19 vaccination at each time point. Self-reported vaccine uptake and intended uptake were

combined at a 12-month follow-up as the vaccine roll-out was still underway and not all respondents had yet been offered a vaccination.

We fitted a multivariable logistic regression model, with vaccine hesitancy at 3 months post-enrolment as the outcome and the following predictors: fear of COVID at 3 months; susceptibility to COVID at 3 months; perceived exposure to COVID at any point prior to 3-month follow-up; PHQ 4 total score at 3 months; gender; education status; age group; ethnicity; the presence of a pre-existing medical condition; two perceived control items. Fear of COVID and PHQ-4 were fitted as linear predictors, following inspection of model fit statistics when including them as linear predictors and restricted cubic splines with three, four, or five knots. All other predictors were fitted as categorical variables. The logistic regression model for the 12-month data included the same predictor variables as the 3-month model, with the addition of the VAX subscales.

At the 3-month follow-up, the multivariable model comprised a total sample size of 6600 participants, with 5386 events (agree or strongly agree that they would have a COVID-19 vaccination if one was available) and 1214 non-events (unsure, disagree, or strongly disagree that they would accept a COVID-19 vaccine if one were available). With 25 parameters to be estimated, this resulted in an "events per variable" (EPV = min[events, non-events]/parameters) of 49. For the 12-month cross-sectional multivariable analysis, there was a total sample size of 4846 participants, with 4647 events (vaccine uptake or intention to take up) and 199 non-events (vaccine refusal or intention to refuse). With 26 parameters to be estimated, this resulted in an EPV of 8.

Longitudinal analyses

The longitudinal analysis included only those participants for whom vaccination hesitancy data were available at both 3- and 12-month follow-ups (n = 4473). Mixed analysis of variance (ANOVA) models were used to assess *within-person differences* in fear of COVID-19, perceived susceptibility, perceived control over infection-transmission, and psychological distress (PHQ-4) from 3 to 12 months, and *between-person differences* in these variables according to vaccination hesitancy status, that is, (World Health Organization, 2020c) vaccine-hesitant at 3 and 12 months, (McKibbin & Fernando, 2020) vaccine-hesitant at 3 but not 12 months, (McBride et al., 2021) vaccine-hesitant at 12 but not 3 months, and (World Health Organization, 2020d) vaccine-hesitant and both 3 and 12 months). Interactions between the within and between-person factors were also examined. Bonferroni *post-hoc* tests and estimated marginal means were used to examine between-person main effects in all models.

Free-text data analysis

Content analysis was performed on free-text responses relating to the main reasons participants had declined or were unsure whether to accept a COVID-19 vaccination to identify the most common reasons for hesitancy (Hsieh & Shannon, 2005). Common themes were identified and then responses were coded, such that each response might relate to a number of different codes, and the frequency of codes assigned to each theme was counted (Hsieh & Shannon, 2005). Comments were coded in Excel. Comments written in Welsh were translated into English before coding.

RESULTS

Demographic characteristics of the participants were included in the cross-sectional analyses at 3 months, 12 months, and those were included in the longitudinal analysis (data available at both time points) and are summarized in Table 1.

Vaccine hesitancy

At 3 months post-enrolment, 81.4% (5649/6942) agreed or strongly agreed that they would accept a COVID-19 vaccine when one became available, while 1293 (18.6%) did not agree. At 12 months post-enrolment, 95.9% (4830/5037) had either accepted or intended to accept a COVID-19 vaccination and 4.1% (207) did not intend to have the vaccine or were undecided (vaccine-hesitant). This was consistent with data from Public Health Wales published in April 2021 that indicated that uptake was very high, at around 95%, at that time (Public Health Wales, 2021). At 12 months, 85.2% (4289/5037) reported that they had been offered a COVID-19 vaccination, 59.3% (2989/5037) had received a first COVID-19 vaccine and 17.6% (885/5037) had received two doses of a COVID-19 vaccine. For those included in the longitudinal analysis, 81% (3622/4473) were not COVID-19 vaccine-hesitant at either 3 or 12 months, 15.2% (n = 681) were hesitant at 3 months but not at 12 months, 1.4% (n = 62) were not hesitant at 3 months but were hesitant at 12 months, and 2.4% (n = 108) were hesitant at both time points.

The perceived threat of COVID-19, perceived control, and psychological distress by vaccine hesitancy status at 3 and 12 months post-enrolment are shown in Tables 2 and 3, respectively. Those who were vaccine-hesitant at 3 months reported lower perceived susceptibility to COVID-19 and lower perceived control over protecting themselves and members of their household against COVID-19 infection, but these differences were not observed at 12 months.

The three new items added to the VAX modified scale is used in this study loaded onto the "concerns about profiteering" subscale of the original VAX scale, with the other items loading onto their original VAX scale components (Supplementary file 1). Cronbach's alpha for the four subscales in the modified measure ranged from .788 to .859. Cronbach's alpha for the whole scale was .879 indicating good internal consistency (Supplementary file 2). Those who were vaccine-hesitant had more negative attitudes towards COVID-19 vaccination on all the modified COVID-19 VAX scale subscales and total scores, lower fear of COVID-19, and higher levels of psychological distress (PHQ-4) at 12 months.

Multivariable regression: Vaccine hesitancy at 3 months post-enrolment (hypothetical vaccine)

Predictors of vaccine hesitancy at 3 months post-enrolment are shown in Table 4. The model accounted for between 6.1% (Cox and Snell R square) and 9.9% (Nagelkerke R square) of variance in vaccine hesitancy. The model correctly predicted 81.6% of cases overall, correctly predicting 99.5% of non-vaccine-hesitant cases (true positive), but only 3.05% (true negative) of vaccine-hesitant cases.

Predictors of vaccine hesitancy at 12 months post-enrolment are shown in Table 5. At 12 months post-enrolment, the model accounted for between 15% (Cox and Snell R square) and 51.6% (Nagelkerke R square) of variance in vaccine hesitancy. The model correctly predicted 97.3% of cases overall, correctly predicting 99.6% of non-vaccine-hesitant cases (true positives) and 44.2% of vaccine-hesitant cases (true negatives).

Longitudinal analysis

Mixed-effect ANOVA models were produced for continuous variables to assess change between the 3- and 12-months post-enrolment assessments and differences in these variables by vaccine hesitancy status (Table 6). Means and standard deviations for the psychological variables of interest by vaccine hesitancy status are provided in Supplementary File 4.

Fear of COVID-19, perceived susceptibility to COVID-19, and perceived control over preventing the transmission of COVID-19 for themselves or household members and in the community all decreased from 3 to 12 months post-enrolment. There was no change in general psychological distress. Examination

TABLE 1 Characteristics of COPE cohort participants with vaccine hesitancy data available for analysis at 3-month follow-up, 12-month follow-up, and at all time points

Characteristic	Category	3-month cross-sectional analysis ($n = 6942$)	12-month cross-sectional analysis ($n = 5037$)	Longitudinal analysis: all time points ($n = 4473$)
		N (%)	*N* (%)	*N* (%)
Gender	Male	2206 (31.8)	1657 (32.9)	1497 (33.5)
	Female	4704 (67.8)	3358 (66.7)	2955 (66.1)
	Other	13 (.2)	9 (.2)	9 (.2)
	Missing	19 (.2)	13 (.3)	12 (.3)
Age category	18–30 years	339 (4.9)	200 (4.0)	142 (3.2)
	31–40 years	650 (9.4)	408 (8.1)	320 (7.2)
	41–50 years	855 (12.3)	576 (11.4)	498 (11.1)
	51–60 years	1463 (21.1)	963 (19.1)	859 (19.2)
	61–70 years	2225 (32.1)	1748 (34.7)	1598 (35.7)
	71–80 years	1260 (18.2)	1023 (20.3)	947 (21.2)
	81+ years	145 (2.1)	114 (2.3)	105 (2.3)
	Missing	5 (.1)	5 (.1)	4 (0)
Ethnicity	White	6803 (98)	4942 (98.1)	4394 (98.2)
	Ethnic minority communities	80 (1.2)	55 (1.0)	47 (1.1)
	Missing	59 (.8)	40 (.8)	32 (.7)
Marital status	Married, civil partnered, or cohabiting	4841 (69.7)	3480 (69.1)	3119 (70.0)
	Other	2077 (29.9)	1534 (30.5)	1322 (29.6)
	Missing	24 (.3)	23 (.5)	32 (.7)
Caring responsibilities for children	Had children under 18 years living in the household	1181 (17)	748 (14.9)	619 (13.8)
	No children under 18 years in the household	5725 (82.5)	4265 (84.7)	3832 (85.7)
	Missing	36 (.5)	24 (.4)	22 (.5)

(Continues)

TABLE 1 (Continued)

Characteristic	Category	3-month cross-sectional analysis ($n = 6942$)	12-month cross-sectional analysis ($n = 5037$)	Longitudinal analysis: all time points ($n = 4473$)
Highest level of education	College education	4843 (69.8)	3481 (69.1)	3122 (69.8)
	No college education	1998 (28.8)	1485 (29.5)	1289 (28.8)
	Missing	101 (1.5)	71 (1.4)	62 (1.4)
Pre-existing medical conditions	Any pre-existing medical condition(s)	3571 (51.4)	2662 (52.8)	2371 (53.0)
	No pre-existing medical conditions reported	3371 (48.6)	2375 (47.2)	2102 (47.0)
Flu vaccination in the last 12 months	Yes	4023 (58.0)	3057 (60.7)	2749 (61.5)
	No	2891 (41.6)	1959 (38.9)	1707 (38.2)
	Missing	28 (.4)	21 (.4)	17 (.4)
COVID-19 disease	Have had or may have had COVID-19 (perceived exposure) at 3 months	1599 (23.1)	920 (20.5)	912 (20.4)
	Laboratory confirmed cases of COVID-19 at 3 months	47 (.7)	26 (.5)	25 (.6)
	Have had or may have had COVID-19 (perceived exposure) at 12 months	N/A	996 (19.8)	772 (17.3)
	Laboratory PCR confirmed cases of COVID-19 at 12 months	N/A	236 (4.7)	179 (4.0)

TABLE 2 The perceived threat of COVID-19, perceived control, and psychological distress for those who were vs. those who were not vaccine-hesitant at 3-month follow-up

Variables assessed at 3-month follow-up	Not vaccine-hesitant at 3-month follow-up (n = 5649)		Vaccine-hesitant at 3-month follow-up (n = 1293)		95% CI for vaccine-hesitant vs. not vaccine-hesitant means	p
	Mean	SD	Mean	SD		
Fear of COVID-19 total (higher scores = more fearful)	7.01	2.76	6.05	2.94	.79, 1.13	<.001
Perceived susceptibility to COVID-19: likelihood of getting COVID-19 in the next 12 months (higher scores = more susceptible)	1.24	.66	1.18	.75	.02, .11	.006
Perceived control for COVID-19 infection transmission prevention (higher scores = higher perceived control)						
Perceived control over preventing themselves or household members from becoming infected with COVID-19	3.31	.81	3.23	.92	.02, .12	.009
Perceived control over preventing the spread of COVID-19 in their community	3.10	.97	3.10	1.03	−.06, .06	.953
General anxiety and depression: PHQ-4 total score (higher scores = more anxious & depressed)	2.48	2.98	2.96	3.19	−.67, −.29	<.001

of the interaction between time and vaccine hesitancy status indicated that there was less of a reduction in perceived susceptibility over time for those who were vaccine-hesitant at 3 months but not at 12 months.

Bonferroni *post-hoc* tests indicated that those who were consistently not vaccine-hesitant were more fearful of COVID-19 than those who were consistently vaccine-hesitant (mean difference = 2.98, 95% CI 2.31, 3.65), were vaccine-hesitant at 3 months but not at 12 months (mean difference = .72, 95% CI .43, 1.00), or were vaccine-hesitant at 12 months but not at 3 months (mean difference = 1.32, 95%CI .45, 2.20). Those who were consistently vaccine-hesitant were less fearful of COVID-19 than those who changed vaccine hesitancy status between surveys (hesitant at 3 but not 12 months, mean difference = −2.26, 95% CI −2.97, −1.55, hesitant at 12 but not 3 months, mean difference = −1.66, 95% CI -2.75, −.57).

Bonferroni *post-hoc* tests indicated that those who were consistently not vaccine-hesitant had lower levels of psychological distress than those who were only hesitant at 3 months (mean difference = −.38, 95% CI −.68, −.07) and those who were only hesitant at 12 months (mean difference −1.06, 95% CI −1.99, −.12).

Perceived barriers to COVID-19 vaccine uptake at 12 months

The qualitative data gathered relating to reasons people were vaccine-hesitant were used to understand the what was underlying people's responses to the quantitative component of the survey and to identify

TABLE 3 Attitudes towards COVID-19 vaccination, perceived risk of COVID-19, perceived control, and psychological distress for those who were vs. those who were not vaccine-hesitant at 12-month follow-up

	Not vaccine-hesitant at 12-month follow-up (n = 4830)		Vaccine-hesitant at 12-month follow-up (n = 207)		95% CI vaccine-hesitant vs. not vaccine-hesitant groups	p
Variables assessed at 12-month follow-up	**Mean**	**SD**	**Mean**	**SD**		
COVID-19 vaccination hesitancy: Modified VAX scale (higher scores = more negative attitudes towards vaccination)						
Concerns about profiteering (modified to include the three new items)	3.44	3.27	11.97	6.63	−9.45, −7.61	<.001
Preference for natural immunity	2.90	2.55	6.48	3.37	−4.42, −3.48	<.001
Mistrust of vaccine benefits	2.78	2.20	7.19	3.60	−4.91, −3.91	<.001
Worries about unforeseen future effects	5.67	2.48	9.10	2.66	−3.78, −3.08	<.001
VAX scale total (modified to include the three new items)	14.79	7.41	35.04	13.56	−22.13, −18.36	<.001
Perceived severity of COVID-19 threat: Fear of COVID-19 total (higher scores = more fearful)	6.81	2.80	4.61	3.20	1.81, 2.59	<.001
Perceived susceptibility to COVID-19: likelihood of getting COVID-19 in the next 12 months (higher scores = more susceptible)	.89	.65	.83	.79	−.05, .17	.315
Perceived control for COVID-19 infection transmission prevention (higher scores = higher perceived control)						
Perceived control over preventing themselves or household members from becoming infected with COVID-19 at 12-month follow-up	2.51	.81	2.41	1.03	−.02, 2.10	.187
Perceived control over preventing the spread of COVID-19 in their community at 12-month follow-up	2.34	.99	2.18	1.16	−.01, .31	.065
General anxiety and depression: PHQ-4 total score (higher scores = more anxious & depressed)	2.48	3.08	3.37	3.64	−1.41, −.39	<.001

any specific concerns relating to the COVID-19 vaccines, vaccination programme, and wider socio-political context. There were 171 free-text comments. Major themes identified included: perceived risks of COVID-19 vaccines; low perceived severity of COVID-19; preference for natural immunity, and mistrust of COVID-19 vaccine benefits.

Perceived risks of COVID-19 vaccines

Concerns about side-effects of COVID-19 vaccines (n = 58 comments)

When discussing short-term side effects, specific symptoms (e.g., fatigue, tenderness at the injection site) were not mentioned, but rather concerns were expressed about the unpleasantness and inconvenience of being unwell for a few days, including the need to take time off work:

TABLE 4 Predictors of in the logistic regression model for vaccine hesitancy in relation to a hypothetical COVID-19 at 3-month follow-up (n = 6600, number of parameters = 25)

Predictor variable		OR	Lower 95% CI	Upper 95% CI	p	Overall p-value (for categorical variables with >2 categories)
Fear of COVID-19 (higher scores = more fearful)		**.871**	**.848**	**.894**	**<.001**	
Susceptibility: Likelihood of getting COVID-19 in the next 12 months	Very unlikely	1.000				<.001
	Fairly unlikely	.572	.469	.696	<.001	
	Fairly likely	.594	.476	.742	<.001	
	Very likely	.746	.488	1.141	.176	
Self-reported prior exposure to COVID-19 infection	Does not think they have had COVID-19	.787	.678	.912	.001	
	Believes they have had or may have had COVID-19	1.000				
Psychological distress: PHQ-4 total score (higher scores = more distress)		1.051	1.027	1.076	<.001	
Gender	Male	.517	.441	.607	<.001	
	Female	1.000				
Highest level of education	Not college educated	1.401	1.215	1.615	<.001	
	College educated	1.000				
Age	18–30 years	1.000				<.001
	31–40 years	1.614	1.145	2.277	.006	
	41–50 years	1.662	1.191	2.320	.003	
	51–60 years	1.588	1.151	2.191	.005	
	61–70 years	1.210	.873	1.678	.251	
	71–80 years	.910	.633	1.309	.612	
	81+ years	.750	.377	1.489	.410	

(Continues)

TABLE 4 (Continued)

Predictor variable		OR	Lower 95% CI	Upper 95% CI	*p*	Overall *p*-value (for categorical variables with >2 categories)
Ethnicity	Ethnic minority communities	.864	.481	1.554	.627	
	White	1.000				
Pre-existing medical conditions	None	1.112	.970	1.274	.128	
	One or more conditions	1.000				
Perceived control over preventing COVID-19: self and household members	No control	1.000				<.001
	A little control	.515	.346	.768	.001	
	Some control	.460	.315	.673	<.001	
	A lot of control	.455	.308	.672	<.001	
	Complete control	.694	.427	1.128	.141	
Perceived control over preventing community transmission of COVID-19	No control	1.000				.292
	A little control	.924	.702	1.218	.576	
	Some control	.837	.655	1.071	.158	
	A lot of control	.994	.774	1.276	.960	
	Complete control	.854	.562	1.297	.458	
	Constant	1.622	.933	2.819	.086	

> Too busy with work cannot take time off if it makes me ill
>
> (Female, aged 41–50).

> I am at little risk from COVID, I don't want to get bad side effects and be off work
>
> (Male, age 31–40).

There were also a few comments relating specifically to serious short-term side-effects such as blood clots and anaphylactic reactions ($n = 5$).

> Recent news stories about blood clots and other countries halting the vaccine
>
> (Female, age 18–30).

Concerns about long-term side effects were common in the data. Again, there were few specific concerns mentioned and most concerns related to unspecified long-term side effects. Several comments related to both concerns about side effects and concerns about the rapid development, testing, and approval of COVID-19 vaccines ($n = 15$).

> Not too happy about an experimental vaccine and the unknown long-term effects from having it
>
> (Female, age 41–50).

> The new generation of high-tech vaccines are untried, untested, unproven and the medium to long term effects on the human body are unknown. Clinical trials do not conclude until 2023. Governments have indemnified Big Pharma for emergency use of an experimental vaccine. The negative effects of theses vaccines are irreversible once injected
>
> (Female, age 61–70).

There were also concerns about insufficient adverse event reporting ($n = 3$). Some participants reported that their concerns about vaccine safety was resulting in them delaying, rather than refusing, the vaccine ($n = 3$).

> Not anti-vaccination, but waiting to see if there are any significant side effects
>
> (Male, age 61–70).

> I'm terrified it might have an adverse effect on my health, as I had pneumonia after a flu vaccine when I was healthy, it's frightening. As they tell you they're safe, but is it really for everyone? I would be happier waiting until I know it's safe and has been tested more
>
> (Female, age 41–50).

Others reported that the confusion over public health mixed messages around side-effects, dosing regimens, and efficacy had resulted in them opting not to have the vaccine ($n = 9$).

> A huge amount of conflicting claims and informati
>
> on (Female, age 71–80).

> It won't be a one-off vaccine. It will probably have to be administered annually like the flu vaccine
>
> (Female, age 41–50).

TABLE 5 Predictor variables in logistic regression model for COVID-19 vaccine hesitancy during the roll-out of effective vaccines at 12-month follow-up (n = 4846, number of parameters = 26)

Predictor variables		OR	Lower 95% CI	Upper 95% CI	p	Overall p-value (for categorical variables with >2 categories)
Modified COVID-19 VAX scale total score (higher scores = more negative attitudes towards COVID-19 vaccination)		1.212	1.186	1.239	<.001	
Fear of COVID-19 (higher scores = more fearful)		.899	.835	.968	.005	
Age	18–30 years	1.000				<.001
	31–40 years	.527	.238	1.166	.114	
	41–50 years	.309	.139	.687	.004	
	51–60 years	.199	.091	.436	<.001	
	61–70 years	.128	.057	.287	<.001	
	71–80 years	.117	.045	.303	<.001	
	81+ years	.045	.003	.638	.022	
Highest level of education	Not college educated	.590	.381	.913	.018	
	College educated	1.000				
Pre-existing medical conditions	None	1.532	1.023	2.294	.038	
	One or more conditions	1.000				
Psychological distress: PHQ-4 (higher scores = more distress)		.943	.886	1.004	.066	
Gender	Male	.857	.536	1.369	.518	
	Female	1.000				
Ethnicity	Ethnic minority communities	.324	.029	3.597	.359	
	White	1.000				
Susceptibility: Perceived likelihood of getting COVID-19 in the next 12months	Very unlikely	1.000				.983
	Fairly unlikely	.956	.593	1.542	.854	
	Fairly likely	1.034	.542	1.971	.919	
	Very likely	.830	.208	3.309	.792	

TABLE 5 (Continued)

Predictor variables		OR	Lower 95% CI	Upper 95% CI	*p*	Overall *p*-value (for categorical variables with >2 categories)
Self-reported prior exposure to COVID-19 infection	Does not think they have had COVID-19	.806	.528	1.230	.318	
	Believe they have had or may have had COVID-19	1.000				
Perceived control over preventing COVID-19 transmission: self and household members	No control	1.000				.345
	A little control	.609	.193	1.915	.396	
	Some control	1.056	.359	3.108	.921	
	A lot of control	1.347	.450	4.034	.594	
	Complete control	1.069	.264	4.324	.926	
Perceived control over preventing community transmission of COVID-19	No control	1.000				.649
	A little control	1.604	.704	3.656	.261	
	Some control	1.081	.498	2.348	.844	
	A lot of control	1.005	.463	2.182	.989	
	Complete control	1.103	.342	3.561	.870	

TABLE 6 Mixed ANOVA models for continuous variables at 3 and 12 months post-enrolment and by vaccination status

Variable	Within-person main effect: Time point	Between-person main effect: Vaccine hesitancy status	Interaction: Time*Vaccine hesitancy status
Fear of COVID-19	$F(1,4468) = 6.82, p = .009$	$F(3,4468) = 61.73, p < .001$	$F(3,4468) = 1.50, p = .212$
Perceived susceptibility to COVID-19	$F(1,4435) = 88.49, p < .001$	$F(3,4435) = 2.56, p = .53$	$F(3,4435) = 2.81, p = .038$
Perceived control over COVID-19 transmission: self and household	$F(1,4465) = 530.07, p < .001$	$F(3,4465) = 1.92, p = .12$	$F(3,4465) = 1.07, p = .36$
Perceived control over COVID-19 transmission: community	$F(1,4446) = 274.79, p < .001$	$F(3,4446) = .96, p = .41$	$F(3,4446) = .05, p = .99$
General distress: PHQ-4	$F(1,4407) = .006, p = .94$	$F(3,4407) = 7.92, p < .001$	$F(1,4407) = .240, p = .87$

> I am not confident in the evidence and don't agree with the government waiting longer than was trialled to give a second dose
>
> (Female, age 61–70).

Concerns about rapid development, testing, and approval of the COVID-19 vaccines ($n = 41$ comments)

Concerns about rapid development, testing, and approval of the vaccine were common. A number of participants declared their general distrust in all vaccines ($n = 10$), but there was also concern about new technologies (platforms) that were used for COVID-19 vaccines. Some described the COVID-19 vaccines as experimental ($n = 6$), with some citing that the trials would not be properly concluded until 2023 ($n = 2$).

> Because it's still classed as an experimental vaccine, it does not stop you catching or transmitting the virus and it cannot possibly have been fully tested for safety as this takes time and no amount of research or money can buy the time needed to fully test for safety and possible side effects it may cause
>
> (Female, age 61–70).

> It is a novel vaccine - injection of RNA to enter the nucleus of my body's cells to provoke a reaction - compared with traditional ones. The vaccine has been rushed through by emergency powers without sufficient testing or any knowledge of long, or medium, term harmful consequences
>
> (Male, age 71–80).

Lack of trust in the pharmaceutical industry, government, and scientists ($n = 22$ comments)

Lack of trust was primarily directed towards the pharmaceutical industry and the UK Government, with only a couple of comments relating to distrust in scientists.

> No thinking person is going to take the word of politicians and experts that something is safe! Clinical staff are not allowed to speak out, which is very alarming. Curbs on free speech now extend to COVID, the virus and vaccine. The MSM [main stream media?] is the last source to consult for reliable information
>
> (Female, age 61–70).

Concerns were expressed about the financial motives of pharmaceutical companies, indemnity provided to pharmaceutical companies, and data sharing between the pharmaceutical industry and regulators ($n = 12$).

> The GP surgery is offering the Pfizer vaccine and I do not believe that it is safe in light of Pfizer's insistence on total legal protection and the fact they haven't released all the data. I would consider the AstraZeneca/Oxford but they have just had to stop trialling it because problems have arisen
>
> (Male, age 61–70).

The UK government was criticized for covering up safety concerns, changing the timing of the second dose, being motivated by political/economic priorities, and their general handling of COVID-19 ($n = 20$).

> I'm in good health and disagree with the view that everyone should be vaccinated, especially as the govt. has not handled the crisis at all well since it began. The mass vaccination is a desperate response to other failed measures they didn't take
>
> (Male, age 51–60).

Some participants reported they felt coerced into having the vaccine and this was enough to refuse it ($n = 9$).

> I was absolutely intending to have the vaccine, but all the coercive tactics such as vaccine passports or making civil liberties contingent on vaccine status have now made me very suspicious and distrustful, so I am now far more reluctant to get the vaccine
>
> (Male, age 31–40).

Concerns about allergies/medical history ($n = 18$ comments)

Concerns related to the short-term effects of the vaccine. Concerns about having allergies were common although specific allergies were not mentioned.

> Got a lot of allergies so I declined the vaccine as to me there's less risk not having it
>
> (Female, age 61–70).

> I've already had COVID, possibly twice. I have food allergies and don't want to risk having it
>
> (Male, age 41–50).

Medical conditions were occasionally cited as a reason not to have the vaccine, such as eczema, arthritis, and myalgic encephalomyelitis ($n = 4$). Other given reasons for refusing the vaccine included pregnancy and breastfeeding ($n = 10$), as available vaccines had not yet been approved for use during pregnancy and breastfeeding at the time of the survey.

> Because I am pregnant. I am unsure on the guidance on the vaccine and its use in pregnancy. There seems to be conflicting information out there on it at the moment. I will research it more and make an informed choice if I am offered it before I give birth. I will definitely have it afterwards if offered it at that point
>
> (Female, age 31–41).

Low perceived severity of COVID-19 ($n = 36$ comments)

Respondents' perceptions of their own low risk of poor health outcomes with COVID-19 was a common reason to refuse vaccination. Specifically, participants mentioned risk factors that put them at low risk of serious complications due to being young, fit and healthy, not being overweight, having a strong immune system, and genetic factors.

> I am not elderly, I do not have any health problems, I am slim and I have a functioning immune system. I do not believe a vaccine is necessary for me
>
> (Female, age 41–50).

> I believe my immune system is good enough for protection plus I most probably carry the gene CCR5-Delta 32 giving me added protection
>
> (Male, age 71–80).

Other comments reflected a more nuanced weighing up of the risks and benefits, but ultimately deciding that the risks of the vaccine were not worth taking.

> We have immune systems and I'm of the age that isn't classed as at risk, I'm fit and healthy too apart from my mental health. I believe that the immune system is designed to fight of viruses and I think that I have had COVID-19. I understand that some people need to have the jab as they are high risk and that's their choice
>
> (Female, age 18–30).

Preference for natural immunity ($n = 18$ comments)

There were comments which related to participants' beliefs that they already had sufficient immunity to COVID-19 due to prior infection and therefore vaccination was not needed, and beliefs that vaccination was not as effective in providing future protection as being naturally exposed to the virus. There were a couple of participants ($n = 2$) who expressed more social-Darwinist views around the survival of the fittest.

> I would much prefer to acquire natural immunity and feel that it is better in evolutionary terms for humans to adapt. It's what survival is all about unfortunately
>
> (Female, age 41–50).

For many of these participants, herd immunity by COVID-19 infection rather than vaccination was perceived to be the most effective way out of the pandemic.

> A healthy immune system does not need boosting. Vaccination is not the way to achieve herd immunity
>
> (Male, age 61–70).

Mistrust of COVID-19 vaccine benefits ($n = 26$ comments)

There were a number of comments ($n = 14$) that related to doubts about the efficacy of the vaccine, both in terms of reducing morbidity and preventing transmission.

> Effectiveness of vaccine is questionable
>
> (Female, aged 51–60).

> It's not very clear how infectious someone who has been vaccinated can be a carrier or for how long
>
> (Female, aged 41–50).

Seven respondents cited the need to have repeat vaccines as a reason not to engage with the vaccination programme, implying that the personal and societal costs of including the vaccine within the national vaccine programme were not worth the effort.

> We've been told that we would get back to normal life when the vulnerable have been vaccinated. The vast majority have, but they now will not commit to that promise. They now tell us over-50s all have to have the jab. Then it will be the variants stopping us going back to normal life. And after that it will be forcing young people and children to get it before we have a normal life. I feel I'm about to be blackmailed, and sometimes I feel like a child who's always being let down by his parents after they promised something. It's really doing my head in now. I've had enough of this
>
> (Female, age 51 to 60).

Some felt the vaccine was pointless as it did not seem to affect relaxations in restrictions, and four people said they would only have the vaccine if it were mandated for travel reasons.

> I do not see any interest in our politicians and scientists in removing restrictions and COVID regulations even though the vaccine is being rolled out at great speed. We can't wait forever until the last person has had it
>
> (Male, age 41-50)

> I don't really want to have it but if it means I can only travel abroad if I've got the vaccine then I'll have it
>
> (Male, age 41–50).

Other reasons for vaccine hesitancy ($n = 25$)

A variety of miscellaneous reasons for refusing the vaccine were given, including wanting a choice of vaccine ($n = 8$), the convenience of appointments (travel and choice of time) ($n = 3$), general vaccine hesitancy ($n = 10$), needle phobia ($n = 2$), and ethical issues relating to testing of the vaccines on animals ($n = 1$).

DISCUSSION

Using the Health Belief Model (Rosenstock et al., 1988; Strecher & Rosenstock, 1997) as a conceptual framework, we investigated the association between the perceived threat of COVID-19, attitudes

towards vaccination, and COVID-19 vaccine hesitancy. We examined how these factors changed between the early stages of the COVID-19 pandemic in relation to a hypothetical vaccine (June/July 2020) and 9 months later (March/April 2021) when effective COVID-19 vaccines were being rolled out in the United Kingdom. We found that vaccine hesitancy at 12 months was independently associated with low fear of the disease and more negative attitudes towards COVID-19 vaccination, including concerns about profiteering, preference for natural immunity, mistrust of vaccine benefits, and worries about unforeseen future effects. Specific barriers to COVID-19 vaccine uptake included concerns about safety and efficacy in light of its rapid development, mistrust of government and pharmaceutical companies, dislike of coercive policies, and perceived lack of relaxation in COVID-19-related restrictions as the vaccination programme progressed. Fear of COVID-19, perceived susceptibility to COVID-19, and perceived personal control over COVID-19 infection transmission decreased between the 3- and 12-month surveys.

Psychological factors can be more predictive of risk perception than an objective measure of situational severity, including pro-social tendencies, trust in government, scientists, and health professionals, as well as collective and individual efficacy (Schneider et al., 2021). Low trust in government, vaccine hesitancy in general, and specific concerns and misinformation about the COVID-19 vaccine were all identified as potential contributors to vaccine hesitancy in our study, which is consistent with previous research (Woolf et al., 2021; Dyer, 2020; Enria et al., 2021; Loomba et al., 2021; Parsons & Wiggins, 2020). The perceived threat of COVID-19 has a strong influence on vaccine hesitancy across cultures (Sallam, 2021). Self-efficacy, an important aspect of perceived behavioural control, has been found to be important in determining behaviour and well-being in the context of the COVID-19 pandemic (Scholz & Freund, 2021; Zheng et al., 2020). Our data indicated that fear of COVID-19, perceived susceptibility to the disease, and perceptions of personal control over the prevention of infection transmission all decreased between our 3- and 12-month surveys. There may be a number of reasons for these changes, including a natural attenuation in perceived threat over time as people adjust to the pandemic context, the protection the population has acquired through the mass population and natural exposure to COVID-19, and diminished perceptions of personal control following lockdowns which transfer control from the individual to the state (Hargreaves & Logie, 2020). Nonetheless, reduced perceived threat from COVID-19 coupled with reduced perceived control over reducing the transmission of COVID-19 may impact future COVID-19 uptake.

There are differences between countries in the role of demographic factors in determining vaccine hesitancy (Lazarus et al., 2020; Lin et al., 2020). Our data indicated that women were more likely to be vaccine-hesitant in the early stages of the pandemic, but not at the 12-month follow-up. Those with lower educational attainment were more vaccine-hesitant at both time points. Younger age groups in our cohort were more vaccine-hesitant at both time points, which has been observed in several other countries, although this relationship is not universal (Lazarus et al., 2020). Rare side effects associated with the Oxford/Astra-Zeneca vaccine, particularly in younger age groups, were being reported at the time that our 12-month survey took place, which may have contributed to hesitancy in this group in our study (Medicines and Healthcare products Regulatory Agency, 2021; Wise, 2021). It has since been recommended that adults aged <40 years in the United Kingdom with no underlying health conditions be offered an alternative to the Oxford/Astra-Zeneca vaccine (Mahase, 2021b).

Strengths and limitations

The COPE study has provided prospective longitudinal data on the perception of the risk of COVID-19 and attitudes towards COVID-19 vaccinations in a large community-based sample in the United Kingdom. The COPE cohort is a non-random community-based sample, with a higher proportion of older age groups, women, those with complex health needs, college-educated individuals, and people from white ethnic groups compared with the Welsh and UK general population (Phillips et al., 2021).

As such, our cohort would be expected to be less vaccine-hesitant than other demographic groups that are at lower risk of severe harm from COVID-19 disease and/or have more negative attitudes towards vaccination (COCONEL Group, 2020; Fisher et al., 2020; Mueller et al., 2020; Neumann-Böhme et al., 2020; Sallam, 2021; Ward et al., 2020; Woolf et al., 2021). Other factors, such as trust in government and officials can contribute strongly to vaccine hesitancy in under-served communities (Chaudhuri et al., 2022; Doherty et al., 2021) and so the findings of this study should not be generalized to the general population as a whole.

Our regression models were designed to test for association between variables and are not intended as prediction models for vaccine hesitancy. In both the 3-month and 12-month analysis, the models were better at predicting "true positives," that is, those who had accepted/intended to accept the vaccine than "true negatives," that is, those who had not/did not intend to/were unsure about accepting the vaccine. As such, these models should not be used as risk prediction tools for vaccination uptake.

In this study, we included a brief and broad assessment of general perceived behavioural control over COVID-19 infection transmission. A more detailed investigation of perceptions of self-efficacy and controllability in relation to infection-transmission and specifically relating to vaccination uptake could provide valuable additional information on the motivational factors underlying vaccine hesitancy.

Implications

Twenty percent of respondents were vaccine-hesitant during the early stages of the pandemic, but only 6% were vaccine-hesitant when effective vaccines had become available. A similar pattern of increasing acceptance of the COVID-19 vaccination was observed in an Italian longitudinal study (Caserotti et al., 2021), indicating that uptake of the initial dose(s) of the vaccine is likely to be higher than initially anticipated. However, declining perceptions of COVID-19 threat, susceptibility, and personal control, coupled with concerns about vaccination safety and efficacy and mistrust of government and pharmaceutical companies may impact uptake during the ongoing vaccination programme. Amidst the easing of lockdown and increasing rates of infection at this time in the United Kingdom amongst a partially vaccinated population, it is essential that efforts to encourage uptake of initial and booster vaccinations continue (Dolgin, 2021; Mahase, 2021a; Senedd Research, 2021; UK Government, 2020). Indeed, the latest UK data on COVID-19 vaccination indicates that uptake is declining as booster vaccinations are being rolled out and younger age groups are included in the vaccination programme, with 67.5% of people aged 12 and over having received a third or booster dose as of 31 March 2022 (UK Government, 2020). Changes in attitudes towards COVID-19 disease, COVID-19 vaccines, and vaccination uptake need to be investigated over the longer term as the pandemic context shifts and more evidence on the safety and efficacy of COVID-19 vaccines becomes available.

As COVID-19 vaccines continue to be developed, evaluated, and improved, honest and up-to-date information about COVID-19 vaccination effectiveness, side effects, and safety needs to be made available to the public (Karlsson et al., 2021). However, providing information alone does not change vaccination uptake intention (Kerr et al., 2021). Building trust is critical in increasing engagement with vaccination programmes; government representatives and authority figures need to be mindful of this, particularly in marginalized groups, and need to communicate information about vaccines clearly and honestly (Enria et al., 2021; Fancourt et al., 2020; OECD, 2021; Parsons & Wiggins, 2020; Paul et al., 2021; Reid & Mabhala, 2021).

The increasing perceived threat of COVID-19 is ethically problematic and may have paradoxical effects of increasing distrust of government (Jørgensen et al., 2021; Karlsson et al., 2021). Interventions that involve enforcement of vaccination, for example, vaccine passports as a requirement to access social liberties, can potentially be effective if implemented well but also carry the risks of increasing health inequalities and being viewed as coercive (Brown et al., 2020; Waller et al., 2020). In contrast, interventions that focus on addressing vaccine hesitancy through increasing intrinsic motivation, encouraging

pro-social behaviour, and increasing empathy are likely to be useful and acceptable in the longer term (Chou & Budenz, 2020; Freeman et al., 2020; Pfattheicher et al., 2020; Spisak & McNulty, 2021). The personal risk of harm from COVID-19 to most individuals is low and people's actions are likely to be influenced by perceived risk to others (Faasse & Newby, 2020). This was apparent in our data on the modified VAX scale that was used in this study, with pro-social motivations relating to protecting family and friends, vaccinations facilitating a return to "normal life," and helping to reduce pressure on the NHS being strongly inversely correlated with the concerns about profiteering subscale items of the VAX scale.

This large-scale prospective longitudinal study indicated that low fear of COVID-19 and negative attitudes towards COVID-19 vaccinations were associated with vaccine hesitancy. Although initial COVID-19 uptake in the United Kingdom has been high, decreasing fear of COVID-19, perceived susceptibility to the disease, and perceptions of personal control over reducing infection transmission may impact future vaccination uptake. Understanding the beliefs and attitudes underlying vaccine hesitancy and investigating how these change over time is essential in informing the ongoing public health response to COVID-19 and associated communication strategies.

AUTHOR CONTRIBUTIONS

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CONFLICT OF INTEREST

All authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Individual-level data from our COPE online survey and qualitative data will not be made publicly available due to data security and ethical considerations. The data provided are of a detailed and sensitive

nature. Our public contributors expressed concerns about privacy and security during the development and recruitment stages of this research and did not feel that it was appropriate for individual-level data to be made publicly available. Anonymized data from the COPE study can be made available by the authors on reasonable request, subject to approval from the COPE Study Management Group and Cardiff Metropolitan University Applied Psychology Ethics Panel.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

Supplementary File 1 Modified COVID-19 VAX scale factor loadings

Supplementary File 2 Alpha reliabilities, means, and standard deviations for the modified COVID-19 VAX subscales

Supplementary File 3 Factor structure and internal reliability of the COVID-19 threat items

Supplementary File 4 COVID-19 fear, susceptibility, perceived control, and psychological distress in the cohort overall and stratified by vaccine hesitancy status at 3 and 12 months

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